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RTO TECHNICAL REPORT **TR-AVT-115**

Environmental Impact of Munition and Propellant Disposal

(Impact environnemental de l'élimination des munitions et des combustibles)

Final Report of Task Group AVT-115.

Published February 2010

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Glossary

AAP	Army Ammunition Plant
AOP	Allied Operating Procedure
AP	Ammonium Perchlorate
ARW	NATO Advanced Research Workshop
AVT	Applied Vehicle Technology
BASF	Company name
BATNEEC	Best Available Technology Not Entailing Excessive Costs
BOFORS	Company name
CASG	NATO CNAD Ammunition Safety Group
CATNAP	Cheapest Available Technology Narrowly Avoiding Prosecution
CFB	Canadian Forces Base
CNAD	Conference of National Armaments Directors
CRREL	Cold Regions Research and Engineering Laboratory
DAT	Defence Against Terrorism
DDR	Former East Germany
demil	Demilitarisation
DGE	Director General Environment
DGM	Director General Munitions
DLE	Director Land Environment
DND	Department of National Defence (CAN)
DNT	Dinitrotoluene
DoD	Department of Defense (USA)
DRDC	Defence Research and Development Canada
EL	Environmental Laboratory
EM	Energetic Materials
EOD	Explosives Ordnance Disposal
EODIS	EOD Information System
ERDC	Engineer Research and Development Center (USA)
EU	European Union
EUCLID	European Cooperation for the Long Term in Defence
FBI	Fluidised Bed Incinerator
FSU	Former Soviet Union
GATES	German Army Training Exchange Shilo
HE	High Explosives
HMS	Her Majesty's Ship
HMX	Octogen – explosive substance
HTBP	Hydroxy Terminated PolyButadiene
IM	Insensitive Munitions
IPT	Integrated Project Team
KTA	Key Technical Area

LN	Lead Nation
MLRS	Multi-Launch Rocket System
MMR	Massachusetts Military Reservation
MoD	Ministry of Defence
MSIAC	Munition Safety Information and Advice Center
NAAG	NATO Army Armament Group
NAMSA	NATO Maintenance and Supply Agency
NATO	North Atlantic Treaty Organisation
NG	Nitroglycerine
NSA	NATO Standardisation Agency
OB	Open Burning
OD	Open Detonation
OSCE	Organization for Security and Co-operation in Europe
PBX	Polymer Bonded Explosive
PfP	Partnership for Peace
PoC	Point of Contact
PoW	Programme of Work
R&D	Research and Development
RDX	Hexogen – explosive substance
RTO	Research and Technology Organisation
SEESAC	South Eastern European Clearinghouse for the Control of Small Arms and Light Weapons
SERDP	Strategic Environmental R&D Program
STANAG	Standardised Agreement
SWOT	Strengths, Weaknesses, Opportunities and Threats
TATP	Triacetone, tri-peroxide explosive
TNT	Trinitrotoluene
TTCP	The Technical Cooperation Program
UCTM	University of Chemical Technology and Metallurgy
UDMH	Unsymmetrical dimethylhydrazine
UN	United Nations
UNDP	United Nations Development Programme
UWA	Unwarranted Ammunition
UXO	Unexploded Ordnances
WEAG	Western European Armaments Group
WP	White Phosphorus
Wpn	Weapon

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Environmental Impact of Munition and Propellant Disposal

(RTO-TR-AVT-115)

Executive Summary

Introduction

The armed forces of NATO and the PfP countries possess large quantities of munitions that are surplus to requirement or have exceeded their design life. Disposal of the energetic materials requires great care and considerable cost. The environmental impact of the processes must be acceptable to an increasingly critical general population to avoid anti-military backlash. Past practices of dumping at sea or into land-fill sites are no longer generally acceptable and long-term storage is neither safe nor cost effective. Weapons must be dismantled and the energetic materials destroyed in a manner that does not harm the environment.

Within NATO there exists a wealth of information on disposal and a wide range of experience. Currently this information is scattered and poorly co-ordinated. A Task Group was established within AVT to attempt to identify the critical issues faced by the NATO nations, seek out the best current practices, identify statutory constraints and make recommendations on future actions required to meet environmental requirements.

Approach

The available technologies were reviewed and it became clear that the capabilities did exist to deal with most existing materials.

It became clear that while much capability did exist there was still a need to understand the management of land contamination; the management of material dumped or lost underwater, and the effects of continually strengthening environmental legislation.

In order to discuss the issues more completely, exchange expertise between nations and present the state of the art in a few relevant related topics, the Technical Team held a Workshop in Sofia in September 2007 to discuss the topic.

The attendance included scientists, engineers and military personnel with responsibility for the disposal of munitions and the management of the effects of that disposal on the environment. The meeting included attendees from across NATO and partners including Russia and Georgia.

Sessions were designed to include both presentations and discussions, with sufficient time to properly discuss the critical topics. The presence of both research scientists and military personnel generated a very satisfying debate from very different backgrounds.

The conclusions from the study supported the view that the technology and expertise existed to deal with immediate problems and to deal with the current generation of munitions. However, the expertise and technology was lodged in countries where there was no significant problem, and that a mechanism was required to assist in the transfer of both to the places where it was needed. Proper application will have an impact on Defence Against Terrorism (DAT) through the effective disposal of material.

There remains a need to manage environmental damage either from training, or from sea dumping of old munitions and this will require attention in the future as problems continue to develop and as legislation increasingly limit the acceptable options.

Finally, there is a need to develop greener technology to assist in the NATO aim of ‘design for disposal’ for munitions, in order to meet present and future needs in NATO.

Impact environnemental de l'élimination des munitions et des combustibles

(RTO-TR-AVT-115)

Synthèse

Introduction

Les forces armées des pays de l'OTAN et du PpP possèdent de grandes quantités de munitions qui dépassent leurs besoins ou qui ont atteint leur limite de vie. L'élimination des matériaux énergétiques nécessite un grand soin et représente un coût considérable. L'incidence des processus sur l'environnement doit sembler acceptable à une population dans son ensemble de plus en plus critique afin d'éviter une réaction antimilitariste. Les pratiques passées de largage en mer ou de dépôt dans des décharges terrestres ne sont plus acceptables et un stockage à long terme n'est ni sûr ni économique. Les armes doivent être démantelées et les matériaux énergétiques être détruits de telle manière que cela ne nuise pas à l'environnement.

Il existe au sein de l'OTAN une information riche en ce qui concerne l'élimination ainsi qu'une grande variété d'expériences. Actuellement cette information est dispersée et mal coordonnée. Un groupe de travail a été créé au sein d'AVT pour essayer d'identifier les questions critiques auxquelles les nations de l'OTAN sont confrontés, pour rechercher les meilleures pratiques actuelles et identifier les contraintes statutaires et établir des recommandations sur les actions futures nécessaires pour satisfaire aux exigences environnementales.

Approche

Les technologies disponibles ont été passées en revue et il est apparu clairement que des possibilités existaient pour traiter la plupart des matériaux existants.

Il est apparu clairement que tandis que de nombreuses possibilités existaient déjà, le besoin perdurait de comprendre la gestion de la contamination des sols, la gestion des matériaux jetés ou perdus sous l'eau et les effets d'une législation environnementale continuellement renforcée.

Afin de discuter plus complètement de ces problèmes, d'échanger le savoir-faire entre nations et de présenter la situation actuelle dans quelques domaines connexes concernés, l'équipe technique a tenu un atelier à Sofia en septembre 2007 pour discuter du sujet.

L'assistance comprenait des scientifiques, des ingénieurs et des personnels militaires ayant pour responsabilité l'élimination des munitions et la gestion des effets de cette élimination sur l'environnement. La réunion a inclus des participants provenant de l'OTAN et des partenaires dont la Russie et la Géorgie.

Les sessions étaient conçues de manière à inclure à la fois les présentations et des discussions, avec suffisamment de temps pour permettre des discussions convenables sur les sujets critiques. La présence de scientifiques du domaine de la recherche et de personnels militaires à généré des débats très satisfaisants à partir de cultures différentes.

Les conclusions de l'étude indiquent que technologies et expertises existent déjà pour faire face aux problèmes immédiats et traiter la génération actuelle des munitions. Cependant, l'expertise et la technologie sont localisées dans des pays qui ne font pas face à des problèmes importants et il faut mettre en place un mécanisme d'aide au transfert de ces deux éléments là où ils sont nécessaires. Sa bonne application aura un impact sur la défense contre le terrorisme (*Defence Against Terrorism (DAT)*) par une élimination effective des matériels.

Reste la nécessité de gérer les dommages environnementaux dus soit à l'entrainement, soit au largage en mer des vieilles munitions et ceci nécessitera une attention particulière dans le futur car les problèmes continueront à se développer au fur et à mesure que la législation limitera de manière croissante les options acceptables.

Enfin, il est nécessaire de développer une technologie plus verte pour aider l'OTAN dans son objectif d'un ‹ concept d'élimination › des munitions, de manière à satisfaire les besoins présents et futurs en son sein.

Chapter 1 – INTRODUCTION

1.1 BACKGROUND

The armed forces of the North Atlantic Treaty Organisation (NATO) and the Partnership for Peace (PfP) countries possess large quantities of munitions that are surplus to requirement or have exceeded their design life. Disposal of the energetic materials requires great care and considerable cost. The environmental impact of the processes must be acceptable to an increasingly critical general population to avoid anti-military backlash. Past practices of dumping at sea or into land-fill sites are no longer generally acceptable and long-term storage is neither safe nor cost effective. Weapons must be dismantled and the energetic materials destroyed or recycled/reused in a manner that does not harm the environment.

Governments have a duty of care to the members of their armed forces and all reasonable precautions must be exercised to ensure safe disposal of munitions. Simple burning methods are not acceptable. For example, red phosphorus from incendiary devices can be destroyed by atmospheric combustion, but large quantities of toxic gases are evolved. New disposal techniques are required that convert the energetic materials to harmless bi-products and do not pollute the environment. In some instances it is possible to reprocess materials for installation in new weapons or for alternative civil use. From a sustainability perspective, this is to be welcomed, but processes must still meet stringent environmental requirements. The safety and cost effectiveness of the recycling process needs to be assured.

Environmental control legislation is becoming tougher on emissions and disposal of residues. The design of new weapons must include disposal procedures and an environmental impact statement. The understanding of munition disposal is lagging behind this design requirement. It is important to fully understand the environmental issues so that they do not place undue constraints on the design of weapons. Within NATO there exists a wealth of information on disposal and a wide range of experience. Currently this information is scattered and poorly co-ordinated. A Task Group was established within the Applied Vehicle Technology (AVT) Panel to attempt to identify the critical issues faced by the NATO nations, seek out the best current practices, identify statutory constraints and make recommendations on the future actions required to meet environmental requirement.

NATO RTO is uniquely well placed to undertake this form of study, with not only the involvement of NATO nations, but also through Partners for Peace and others links to many of the areas where problems exist. It is also uniquely placed to develop processes based on techniques for future management of munitions and to support their development throughout the Alliance and Partners.

1.2 APPROACH

The first problem was to understand what the current position was and where capability gaps existed. The available technologies were reviewed and it became clear that the capabilities did exist to deal with most existing materials. Some of the types of capabilities are illustrated below.

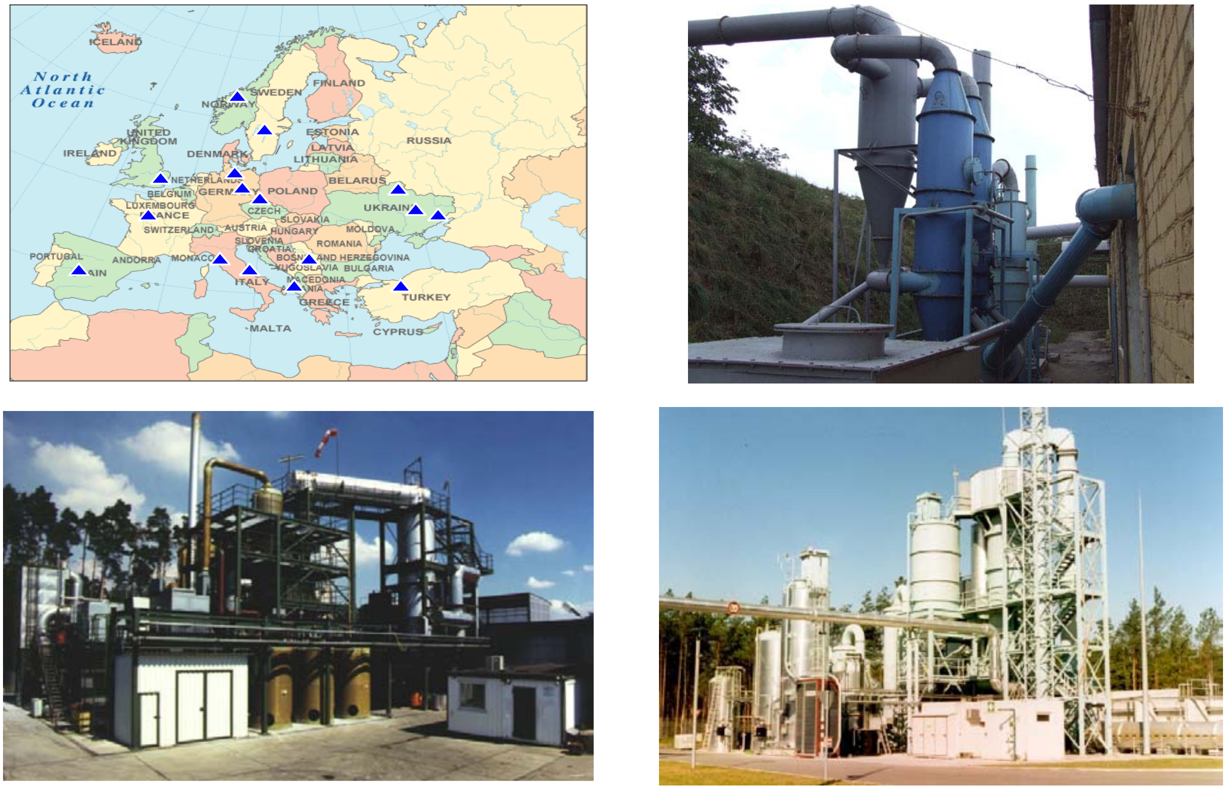

Figure 1-1: Industrial Demilitarisation Capability Examples.

Unfortunately such processes cost money and while organisations such as NATO Maintenance and Supply Agency (NAMSA) do assist in the development of capability where it is needed, there is still a need for transfer of knowledge to the places where it needs to be applied. In addition, it became clear that while much did exist, there was still a need to understand the management of land contamination, the management of material dumped or lost underwater, and the effects of continually strengthening environmental legislation.

In order to discuss the issues more completely, the Technical Team held a Workshop in Sofia in September 2007. The aims of the Workshop were to discuss the topic of:

"Environmental and Security Impact of Munition and Propellant Disposal"

This included sessions covering:

- Policy and problems:
  - Overview of policy development; and
  - Outline of critical problem areas.
- Ways of dealing with problems.
- Underwater munition management and clearance.
- Blow in place for unexploded ordnances (UXO).
- Management of contaminated land.
- Available demilitarisation technologies.
- What must be done now and in the future?
  - Greener munitions and design for disposal.
- Counter-terrorism.

The attendance included scientists, engineers and military personnel who are responsible for the disposal of munitions and the management of the effects of that disposal on the environment. The meeting included attendees from across NATO and Partners including Russia and Georgia.

Sessions were designed to include both presentations and discussion, with sufficient time allocated to properly discuss the critical topics. With both research scientists and military present, there was often very satisfying debate drawing on experience from very different backgrounds.

This report is based on the discussions prior to the meeting in Sofia, but contains the totality of that meeting, including the discussion sessions and questions and answers. In addition, three annexes have been prepared that provide links to a number of relevant documents:

- Annex A – Presentations and Documents Supporting Capability Assessments
- Annex B – Presentations, Paper/Posters and Videos from the Sofia Meeting
- Annex C – Supporting Material and Reference Resources

Chapter 2 – REVIEW OF CAPABILITIES AND NEEDS

2.1 INTRODUCTION

An important part of the study was to establish two base line factors:

- What was the requirement and where was it focussed? and
- What capability existed to deal with it?

The Team were fortunate in having a range of participants, including those from newer members of NATO, and also from NAMSA, who have significant experience in supporting the needs of many PfP nations. Presentations and documents were provided by members to assist in understanding what had been done and where there were still matters to be resolved. Links to all supporting documents and presentations have been provided in Annex A.

During the discussion meetings we also had presentations on industrial capability, both from NAMSA and also from the major industrial contractors in Europe, and these presentations are also attached for reference. A separate presentation was provided by the Czech Republic covering their experience in dealing with surplus munitions, including those inherited from former Soviet Union (FSU). This too is included.

The next sections cover the input from the participants.

2.2 UTILIZATION PROCESS STATE OF AMMUNITION WITH EXPIRED STORAGE TERM IN REPUBLIC OF BULGARIA TO 2005

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2.2.1 Introduction

The store of unwarranted ammunition is kept in units of the Ministry of Defence, Ministry of Interior and in the Republic of Bulgaria. The concept **'The Unwarranted Ammunition'** (UWA), in accordance with **'The Programme for Utilization and Destruction of an Unwarranted Ammunition in the Territory of the Republic Bulgaria'** (the Programme) means an ammunition which has had more than 30 years service life, while not employed in military business, resulting in irreversible physical and chemical changes.

Utilization is a process, where in specific conditions with specific equipment and with trained engineers and technicians, the UWA is rendered safe, their dismounting, disassembly and recovering of useful products as explosives, pyrotechnics and propellants and their reuse in other items or readiness for use in products. All explosive elements, assemblies and other items which could not be dismounted are destroyed by explosion or burning using specific technologies with the help of special equipment and in strict conformity with norms for environmental protection.

The UWA are dangerous and economically unprofitable for the following reasons:

1) The UWA are unpredictable as a result of irreversible processes within them, which can result in ignition and explosion of the main charge and environmental damage in the storage area.
2) The storage area for UWA is in roofed premises and in field conditions which are close to populated areas and this raises the probability of a human injury;
3) The storage of the UWA in field conditions increases the probability of the non-authorized access to ammunition and their use for terrorist purposes.

4) The UWA needs storage and preservation under the same conditions, as service ammunition – storage areas and trained technicians. This leads to significant financial expenses, approximately € 2.5 – 3 million for one year.
5) In spite of the charge for materials and the financial assets that are UWA, the costs of utilization can not be recovered from marketing of the extracted materials, the as the cost of utilization and the storage charges, the recovery of materials and of managing the risks associated with potential losses in incidents with ammunition many times exceed the revenue.

Therefore, the delay in UWA utilization:

1) Is economically disadvantageous;
2) Threatens the safety populated areas safety near storage sites; and
3) Produces environmental risk.

The process of utilization has to have the following basic requirements: safety of all activities and nature preservation in accordance with accepted norms and of the laws in the Republic of Bulgaria and of the European Union.

2.2.2 Programme for Utilization and Destruction of Unwarranted Ammunition in the Territory of Republic of Bulgaria

The Republic of Bulgaria is a member of organizations which deal with utilization questions for ammunition: Vasenaar's Agreement, the Disarmament Conference in Geneva, the Organization on the Chemical Weapon Prohibition, the Organization of Safety and Co-operation in Europe and also it is party to international agreements on the control of arms: the Agreement covering Conventional Arms, the Vienna Document, Resolution 46/36 L of the United Nations for the Register of Conventional Arms, the Protocol 2 on the Prohibition of the Use of Specific Mines in accordance with the Convention for Especially Inhumane Arms, the Ottawa Convention for Complete Prohibition Anti-Personnel Mines, the Convention for Prohibition of the Chemical and Biological Weapon.

The term 'small arms' is used in all international documents. These ammunitions are a part of these arms. According to the report by the General Secretary of the United Nations on small arms, this term includes 'ammunition and explosives', which consists of: bullets and ammunition for infantry weapons, ammunition and rockets for small arms, carried containers with anti-aircraft and anti-tank rockets or expendable projectiles, anti-personnel and anti-tank light weapon, anti-personnel mines and explosives.

On the basis of these documents and according to the laws of the Republic of Bulgaria, it is necessary to observe the following process:

1) The representatives from the Ministry of Environment and Water are obliged to observe what technologies and process equipment correspond to the Bulgarian and European ecological norms for preservation of an environment;
2) The representatives from the Ministry of Justice are obliged to harmonize the whole programme with the Bulgarian and European normative documents; and
3) The experts from the Ministry of Foreign Affairs are obliged to represent the programme to the international organizations and institutions and to help in the maintenance of financial resources for its performance.

The programme purpose is the creation of the basic document for application and demonstration of the use of modern technologies and process equipment, as well as to provide for necessary financial resources for UWA utilization and destruction, within the territory of Bulgaria and the subsequent use of recovered materials.

In this document, the following tasks are listed:

1) Analysis and estimation of modern methods and technologies for utilization and destruction of ammunition;
2) Analysis and assessment of the process equipment, which corresponds to new methods and technologies for utilization and destruction;
3) Estimation of methods, technologies and process equipment within Bulgarian military industry;
4) Definition of UWA type, quantity and the condition, which are to be subject to utilization and destruction both now and in the longer term;
5) Forecast of the results and possibilities for use of the recovered materials;
6) Definition of the necessary capacity for carrying out of the programme and its validation; and
7) Development of the economic base to provide the necessary financial support for the programme.

This has produced a programme which meets the requirements of both the international forums and the law of Bulgaria. The analysis of the unwarranted ammunition is made as a kind, quantity, constituents, years since their manufacture and duration of storage (age), and an analysis of their technical condition is also made. Basic attention is given to explosive substances and propellants. This analysis has established the UWA volume.

The modern methods for utilization and destruction UWA have been considered and the environmental problems are determined for the utilization activity. The opportunities for participation of Military industrial units in Bulgaria and units of the Ministry of Defence are established.

The UWA utilization is one approach to a problem. The period of the UWA utilization programme is approximately 10 years and it is necessary to have sufficient financial resources – about € 30 million to pursue it. These resources would otherwise have to be spent over the same period for UWA storage, and the problems of their safety and their harmful influence on the environment will increase.

2.2.3 Quantity of Conventional Ammunition in the Expired Term

Long experience from laboratory and range tests on ammunition has established that after 30 years of storage, they are not suitable for battle usage. On this basis, all unwarranted ammunition is divided into two groups – prior to 1975 and post 1975.

The quantity of UWA is determined based on years since manufacture. Oldest UWA have a much reduced reserve of chemical stability and considerable deviation from the expected functional characteristics. It is assumed that there will be no opportunity for future use.

By 01.01.2005 the total quantity was approximately:

1) UWA – 76,100 tones.
2) Explosives and propellants in various forms – 12,400 tones and of that Propellants (7 400 tones) and Explosives (5,000 tones).
3) Metal from shells and cases – 23,682 tones.
4) UWA packing material – 1,556,045 in number and by weight – 23,387 tones.

The bullets for small arms (machine guns, assault rifles and pistols) have the greatest volume in the UWA – more than 98%; the next largest classes being anti-aircraft ammunition, light anti-tank ammunition and others. The quantitative analysis is shown as a percentage for each kind of UWA, based on the total ammunition weight:

- Bullets – 13.4%;
- Light anti-tank weapons – 7.1%;
- Anti-tank ammunition – 5.9%;
- Tank ammunition – 17.7%;
- Artillery ammunition – 16.7%; and
- Anti-aircraft ammunition – 24.1%.

The tank, artillery and anti-aircraft ammunition have the largest volume for utilization – 58.5% total.

Ammunition for common army purposes produces the largest share – 92.3% from total volume.

The general UWA weight for utilization is:

1) Approximately 69,700 tones by 01.01.2003; and
2) Approximately 76,100 tones by 01.01.2005.

For two years, UWA weight has increased by 6,400 tones, from 2003 this being considered the reference year weight, a rise is of 9.2%. This rise is as a result of reform of the Bulgarian Armed Forces and the aging of ammunition, which are now transferred to the UWA group.

In the last two years there are has been no work on UWA utilization, in spite of the steady rise in the UWA quantity. In recent years, UWA utilization must result in a steady reduction in total UWA weight. Delay has a financial impact.

2.2.4 Technological Possibilities for Utilization of Life Expired Conventional Ammunition

Technological capabilities for UWA utilization within military factories are as follows:

2.2.4.1 'VMZ' Co., Sopot

The factory specializes in the manufacture of anti-tank and high explosives (HE) ammunition for anti-tank light weapons, guided and non guided rockets, and HE ammunition for air and field artillery with calibre up to 152 mm, together with fuzes, portable and mobile anti-tank and anti-aircraft systems.

The necessary capability for special manufacture is built and functioning. The factory has plant for chemical and technological processing, a station for waste water clearing and a test range. The well qualified experts work here in the field of special manufacture.

In recent years, the factory has successful utilized anti-tank mines and the extracted trinitrotoluene (TNT) has been used in the manufacture of industrial explosives.

In the factory it is possible to utilize all products which the factory has made as well as similar products. There are storage areas and specialized equipment, installations for disassembling of the ammunition shells containing TNT by melting, as well as machines for crushing TNT.

The utilization process consists of mechanical disassembly and explosives removal. If it is impossible to extract the explosives, the explosive assembly is destroyed on the range.

The propellants are given to specialized firms for utilization or they are destroyed on the range by chemical decomposition.

The metal, non-metal parts and electronic components from UWA are removed and sorted, being sent to separate plants and melted in a foundry works.

The capabilities of the factory meet the requirements of the requirements for work with dangerous materials and classified information.

2.2.4.2 'Trema' Co., Tryavna

The factory has capabilities for the manufacture of ammunition with calibres from 85 mm to 125 mm and mines from 82 mm up to 120 mm. The capabilities include the equipment for disposal of defective filled shells. The specialized capabilities of the factory are equipped with the necessary structures for protection, according to the requirement of the regulations for work with explosive substances, arms and ammunition.

The factory can convert the metal parts to scrap, but there is not the capability and technology for processing or destruction of explosives. The factory has a separate water drain and facilities for waste water clearing, which meet the requirements of the regulations for permissible pollution.

'Trema' Co can disassemble ammunition and deal with materials from ammunition with calibre from 85 mm up to 125 mm, but can not rework explosives and propellants.

2.2.4.3 'Arcus' Co., Lyaskovetz

The factory has the technological equipment for utilization of all fuzes, which are in the factory product list and others of similar type and applicability. The existing technologies allow mechanical disassembly, separation of pyrotechnical components, metal or non-metal parts. It can also handle fuzes from ammunition with calibres up to 40 mm.

The factory has produced a process capability for the industrial disposal of small calibre ammunition utilization. The capability has a basic form, to which can be added further processes. The factory has developed the project proposal for a centre for disposal of ammunition.

2.2.4.4 'Videx' Co., Sofia

The factory carries out disposal of anti-tank mines and various forms of charges.

2.2.4.5 'Dunarit' Co., Russe

The factory specializes in the development of equipment for TNT ammunition with high-viscosity mixes. The factory has unique technologies in Bulgaria for the manufacture of ammunition for air forces.

'Dunarit' makes more than 15 kinds of ammunition, including anti-tank and anti-vehicle mines, their fuzes, charges, as well as more than 10 kinds of basic artillery ammunition with calibres from 57 mm up to 122 mm. The equipment has low productivity, but it can rapidly increase its capacity up to a set limit for specific ammunition disposal requirements. This has been proven in practice with the disposal of more than half of the anti-personnel mines in Bulgaria within half a year.

The factory has recently invested in the development of projects for UWA utilization. The projects started through the disposal of defective production from the factory, and after that in the destruction of anti-personnel mines.

'Dunarit' has a protected storage base in accordance with all regulations and requirements for the preservation of the environment together with well qualified experts. It enables 'Dunarit' Co. to solve the questions connected with disposal of large quantities of ammunition.

2.2.4.6 'Elovitza' Co., Gabrovo

'Elovitza' Co. has technological processes and installation for:

- TNT ammunition disassembly;
- Reworking TNT to allow it to be reused;
- Manufacturing of powder, particulate and plastic explosive substances with industrial applicability; and
- Manufacturing cast and pressing charges from recovered TNT with industrial applicability.

The factory can utilize the following ammunition:

- Anti-tank mines;
- Charges; and
- Pressed TNT and other compositions.

The factory can utilize artillery projectiles and large calibre ammunition when in possession of the documentation for design and handling.

2.2.4.7 'Arsenal' Co., Kazanlak

'Arsenal' has technologies and process equipment for utilization and destruction of the following kinds of ammunition:

- Bullets for machine guns, rifles and pistols;
- Small calibre artillery ammunition;
- Mortar ammunition;
- Middle calibre artillery ammunition;
- Light anti-tank ammunition;
- Non-guided rockets;
- Modular ammunition;
- Fuzes;
- Primers;
- Pyrotechnical compositions and products; and
- Propellants.

The factory has a protected storage base, which is in accordance with the regulations for safety and ecological norms and well qualified experts in UWA utilization.

2.2.4.8 'Terem' Co., Unit Kostenetz

The factory is specialized in the repair of ammunition and focussed on artillery ammunition. There is based the necessary process equipment and repair technologies are also developed.

This last factory has collected significant experience in the UWA utilization of all calibres of ammunition. Here Bulgarian anti-personnel mines were demilitarised. The specialized equipment is in this area for utilization ammunition, but it does not meet modern requirements for safety and preservation of the environmental. On the other hand, the factory has the trained specialists for UWA utilization and a good infrastructure, as well as a large free storage base, which can serve as the main basis for modernizing and increasing the volume of utilization.

2.2.4.9 University of Chemical Technology and Metallurgy (UCTM), Sofia

The UCTM works actively in the last years in the field of UWA utilization and develops relevant new technologies.

The university has provided advice and experts in the process of utilization of anti-personnel mines.

The Ministry of Defence financed the UCTM for the development of technology and an installation for processing propellants from dismounted UWA and conversion to liquid fertilizers for agriculture.

By the end of 2005 the UCTM has to produce an experimental installation for processing of propellants into liquid fertilizers. The UCTM reported in August 2005 on the project developed design capacities for processing 1 tonne propellants into liquid fertilizer in one day.

2.2.4.10 General Estimation of Methods, Technology and Process Equipment

Military factories have industrial and personnel potential, which is capable of solving the large volume of specific tasks on disassembling, explosive and propellants processing and UWA utilization. The experts in facilities have experience in the same explosive technology and mixes within their base technology. They have technologies for production of industrial explosives and explosives with special applicability (shaped charges for splitting mountain rocks, punchers for oil-boring).

The choice of the technological process for UWA utilization depends on the property of the explosives and propellants and the requirement for safety during their extraction. In accordance with these conditions, the ammunition is classified as:

1) Ammunition, where explosives are in the form of grain or blasting cartridge. These are HE middle calibre ammunition, non-guided rockets and others;
2) Ammunition with an explosive charge based on TNT, which can be melted. This ammunition group consists of most HE ammunition: the sea mines, missile warheads, artillery ammunition warheads, etc.;
3) Ammunition with mixed explosive charge, which consists of a filled TNT component (not less than 20%) with metal. This includes artillery mines, rocket warheads, torpedo, sea mines and air bombs of a various type, anti-tank and anti-personnel weapon;
4) Ammunition with mixed explosive charge, which consists of a filled TNT component (not less than 20%). In this group is HE ammunition – warhead for non-guided ammunition for example;
5) Ammunition with liquid, plastic and elastic explosives – different systems for mine field clearance, for example; and
6) Clustered ammunition.

In general the procedure for dismantling starts with the removal of the fuze from the shell and continues with providing access to the explosives and its removal. The fuzes are dismantled too in a similar way. The explosive disposal also includes both the body of the projectiles and fuzes. The removal of the inside of fuzes (in cases of shaped charge warheads) is done by ultrasonic-cutting, water jet-cutting or mechanical cutting with special devices and procedures.

Of the two methods – physical and chemical, physical with thermal or mechanical procedures are preferred – with explosive crushing after strong cooling and vibration, or explosive melting (for TNT-based most often). The available chemical methods are being modernised through use of the recovered materials for the manufacture of liquid fertilizers for agriculture, for example.

It is possible to draw the following conclusions:

- The factories have specific capabilities with the necessary production capacities and technologies, which can be used for UWA utilization. Some factories use old technologies, but modernization is possible;
- The available capabilities and production areas of the factories meet the requirements for work in explosive and fire risk areas, but not all works and factories comply with environmental requirements.
- The factories have the necessary storage base for of ammunition and their components after disassembly;
- The qualified workers in the factories have experience in development, manufacture and range-test of ammunition, and in recent years they have got experience in UWA disposal of anti-personnel mines, engineering and artillery mines, and ammunition and other large calibre munitions. This experience could be applied successful to the UWA utilization;
- UWA utilization could be concentrated at one or several centres, on the basis of already existing capabilities, where it is possible to modernize the old and to introduce modern methods and technologies for demilitarisation, This would focus on where it is possible to use the existing equipment, and to ensure high productivity, safety and environment protection; and
- The programme for UWA utilization needs urgent financing of approximately € 30 million. Bulgaria cannot itself provide such a large sum. The technical and economic assessment has shown that UWA utilization will pay for itself in approximately 10 years, if the programme could be financed now.

2.2.5 Acts on Environment Preservation in Utilization of Conventional Ammunition in the Expired Term

The estimation of environmental impact is necessary for the utilization and destruction of ammunition, because Bulgaria has natural, geographical, territorial and sites of major importance. Other important reasons are:

- The major part of UWA contains dangerous substances and components with hazardous properties, such as explosion, fire risk, toxicity;
- Large quantities of UWA are stored posing a significant environmental risk;
- Installations with a large capacity or specialised factories for processing of dangerous products are not produced in Bulgaria, and those which are do not often meet environmental requirements; and
- Bulgaria is country with a high population density and there is nowhere where it is possible to carry out UWA utilization free from environmental impact.

The explosives are divided into two groups:

- Containing heavy metals; and
- Free of heavy metals.

The biosphere can be actively protected against explosives from the second group. For example there are micro organisms which eat TNT.

It is necessary to protect the biosphere from heavy metals (lead for example) by removing the lead chemistry, which locks the lead in anions or complexes. However, lead is widely dispersed during unconfined explosion and this limits the use of this method. Therefore explosive of ammunition is carried out in hermetically closed areas, where it is possible to neutralize toxic gases and heavy metals.

During burning of explosives a quantity of dirty particles is thrown into the air producing approximately 100 times more than during an explosion. Environmental damage in this case is large and producing large economic losses. In such cases the process is carried out in closed chambers with various filters. In some cases alkali water solution is sprayed into the chamber. In this case (e.g., destruction of rocket composite propellants) the utilization operation is ecologically clean.

The cleaning of waste water during UWA utilization is done through the combined action of filters, which have mechanical, chemical and biological action.

The assessment criteria for the quality of individual environmental aspects such as water, ground, biological variety and atmospheric air are made in accordance with the requirements of Bulgarian and European laws:

- Law for preservation of an environment – Official Procedure 91/2002;
- Law for limitation of the harmful waste on environments – Official Procedure 86/1997, in addition Official Procedure 91/2002;
- Law for water purity – Official Procedure 67/1999, in addition Official Procedure 42/2003;
- Law for purity of the atmospheric air – Official Procedure 45/1996, in addition Official Procedure 102/2001;
- Law for protection against harmful influence of chemical substances, preparations and products – Official Procedure 10/2000, in addition Official Procedure 91/2002;
- Regulation № 2/1998 about norms for allowable limits (concentration in waste gases) harmful exhausted substances in the atmospheric air from motionless sources;
- Regulation № 2 about protection against failures in working with dangerous chemical substances – Official Procedure 51/1998, in addition Official Procedure 73/1999;
- Regulation № 6 about covering of the level of harmful and dangerous substances in waste water, which are let out in water objects – Official Procedure 97/2000;
- Regulation № 9 about limits for sulphuric dioxide, nitrogen dioxide, fine dust particles and lead in the atmospheric air – Official Procedure 46/1999;
- Regulation № 14 about limits for extreme allowed concentration of harmful substances in the atmospheric air in the populated places – Official Procedure 88/1999;
- The decree of ministry council № 153/1999 about remaking and transportation of the industrial and harmful waste;
- 96/61/EEC the complex prevention directive and pollution control; and
- 78/319/EEC the directive about toxically and dangerous waste.

Independent experts carry out an ecological estimation. They are licensed for this activity by the Ministry of Environment and Water, on the basis of their competence in the appropriate lawful procedure. The ecological estimation method is based on the documents listed.

2.2.6 Conclusions

The amount of conventional ammunition with expired life up to 01.01.2005 is approximately 76,100 tonnes on the territory of the Republic of Bulgaria. The volume has increased by 6,400 tonnes in the last two years. Up to 2003 the increase is 9.2%. This tendency is a result of the structural reform in Bulgarian Army Forces and constant aging of service ammunition, which move to the UWA group. The UWA are obsolete and in their constituents have undergone irreversible physical and chemical changes. It has affected their tactical and technical characteristics and has transformed UWA to a threat and real danger for workers, for civilians and for the environment in the storage areas.

The military factories In the Republic of Bulgaria and the units in the Ministry of Defence have identified options and the necessary production capacity and technology, which can be used for UWA utilization. The available industrial capability meets the requirements for work in explosive conditions, but not all of the factories meet the requirements for preservation of the environment. The factories have the necessary storage base for the preservation of sufficient quantities of UWA and their components. The factories have qualified personnel and in some of the factories there is experience in the utilization of ammunition through disposal work on anti-personnel mines, engineering and artillery ammunition. Therefore the UWA process needs decisions on the options, looking at the possibilities of separate military factories or a centre to create on the basis of an already existing powerful industrial capability. There is a need to monitor options for the modernization of technologies and changing requirements for safety and environmental preservation.

The UWA utilization has not started, in spite of the UWA quantity rising to 76,100 tones. The reasons are financial. The programme for UWA utilization requires urgent financing in order to start the programme, with an amount of approximately € 30 million being needed. Bulgaria alone can not cope with such a large challenge. The technical and economic assessment has shown that the UWA utilization costs will be repaid in approximately 10 years, if the programme could be financed now. In the near term it is necessary to make a steady reduction in total volume of the UWA if it is not possible to dispose of the whole amount. The delay in starting this process of utilization will mean that it will be necessary to spend the financial resources available on UWA storage and preservation. However, the problem of their safety and the harmful influence on the environment will continue to rise, and the risk of accidents will remain high with probable human cost, together with risk of environmental pollution, as well as an increase in the probability criminal access to UWA and their use for terrorist acts.

Literature

1) The Ministry of Defence. The programme for utilization and destruction of unwarranted ammunition in the territory of the Republic of Bulgaria.

2) Bulgarian regulatory documents.

2.3 CZECH DEMILITARIZATION TECHNOLOGIES FOR RDX CONTAINING MUNITIONS

Excess stockpiles of obsolete or unserviceable munitions have in many countries reached a level requiring their industrial-scale demilitarization. There is a wealth of relatively cheap, highly productive and reasonably safe technologies available for demilitarization of TNT filled ammunition. Some technology gaps however remains for industrial-scale demilitarization of RDX based high explosives, either pressed or melt-cast within large calibre projectiles and warheads. The problem is actual and critical especially in the countries of the former Soviet Union. Well characterized industrial-scale technologies are needed for removal of the high explosives from the projectiles (e.g., using high-pressure water jet wash-out or cutting, cryogenic wash-out, mechanical sawing or drilling) with following safe processing of the explosive wastes into commercial blasting agents or their environmentally friendly disposal. The session would be dedicated to presentations and discussions on the best available technologies to deal with this problem (see Annex A).

2.4 INDUSTRIAL AND OTHER CAPABILITIES

During the review of capabilities, the Team was briefed by the major industrial companies in Europe, Rheinmetall, ISL-Luebben and Nammo Buck as well as by Frauenhofer ICT, and given a preliminary presentation by NAMSA (see Annex A).

Other information on disposal of pyrotechnics and view of open burning and demolition was provided and discussed at the Budapest Team meeting.

2.4.1 Disposal of Pyrotechnics

Today and in the future we are going to have problems with pyrotechnics. The disposal of them is often complicated due to the small amount in each round, but also due to the complexity of the pyrotechnic composition.

Pyrotechnic compositions are in many cases based or mixed with different metals such as lead, strontium, etc.

As it is today, only small amount of pyrotechnics are reused and the problem is going to grow.

This topic should be about how to dismantle and treating the pyrotechnics so either a reuse could be possible or to use an environmentally sound disposal technology. Participants should include members of the demil, environmental and pyrotechnic communities.

2.4.2 Open Detonation of Large Stockpiles of Unexploded Munitions

Large stockpiles of unexpended munitions that are unsafe to remove for disposal await open detonation to render safe. These repositories are often weathered shells whose content and sensitivity are not easily determined. The potential for spontaneous detonations in some environments makes early disposal critical. Achieving effective high order detonations to assure maximum consumption of energetic material is desirable to protect the environment. However, balancing the risk associated with delayed action with the risk associated with the environmental consequences of open detonation is a significant challenge. This session will focus on developing approaches that minimize environmental residues while achieving effective disposal. Participants should include members of the demil and environmental communities. Recommended practices and considerations should form the products of the discussion.

2.4.3 WEAG EUCLID JP 14.6 on Demilitarisation and the Environment

A European study was carried out by the UK and Denmark, during the 1990s, under the Western European Armaments Group (WEAG) umbrella, and provides a technical base for advancing the study (see Annex A).

2.4.4 UK Assessment of the Environmental Impact of Sea Dumping

A UK MoD commissioned study, while focussing on chemical agents contained information of relevance to munitions management and disposal. This is included in Annex A.

2.4.5 TTCP Weapon Study on Land Contamination

Within The Technical Co-operation Program (TTCP) Weapon Area there had been an in depth study of land contamination by munitions and a protocol for management of this proposed. The study is available and further information is included in Annex A.

2.5 ENVIRONMENTAL ASPECTS OF ENERGETIC MATERIALS IN NORTH AMERICA

During the review of existing capabilities, the Team were briefed in many occasions by the Canadian and United States members on their respective programmes related to environmental aspects of energetic materials. Canada and United States have been collaborating for more than ten years to understand the fate and behaviour of energetic materials in their training ranges. These programmes were initiated because of concern over the international context of demilitarization, the closure of military bases and increasingly stringent aspects of environmental laws. This context has led to the establishment of new areas for research and development.

Many activities of the Canadian and the United States Forces such as the firing of ammunition, demolition, and the destruction of obsolete ammunition by open burning and open detonation may lead to the dispersion of energetic compounds and other munitions-related contaminants in the environment. Most of the Canadian weapons are fired in our homeland within our training areas. The United States also practice extensively in their ranges and this raises questions about the potential impact of military exercises within training areas.

It is within this context that Defence Research and Development Canada – Valcartier (DRDC Valcartier) and the US Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL) and the ERDC Environmental Laboratory (EL) initiated research programmes to study the environmental impact of energetic materials that are found in the Department of National Defence (DND) and in the US Department of Defence (DoD) ammunition stockpiles. The programmes of site characterisation allowed the development of a unique expertise and positioned our departments to better understand the impact of live fire training and to be in a readiness state to answer any inquiries and take corrective actions if needed. The first training areas to be characterized within the programme were mainly army bases such as CFB Chilliwack, Shilo, Valcartier, Gagetown in Canada and, Fort Bliss, Fort Lewis, Yakima, MMR and many others in the United States. The list of ranges that were visited and characterised in North America is now very extensive. All the military bases in Canada have been characterised and instrumented with observation wells. Canada is the only country in the world that extensively studied the hydrogeological aspects of energetic materials and for this has developed a unique expertise in that area. The Canadian programme was sponsored by DRDC internal thrusts (sustain thrust), Director General Environment (DGE) Director Land Environment (DLE) and by a major US DoD funding programme, the Strategic Environmental R&D Program (SERDP).

Energetic materials and metals are amongst the major components of munitions and weapons which can be found in war zones, training ranges and on production sites. During the last decade, R&D projects were carried out to understand different aspects of explosive contamination and to develop tools to understand and analyse these unique contaminants. Explosives are crystalline compounds that are spread by the use of munitions in specific conditions. Since crystals are dispersed in heterogeneous conditions in soils, sampling techniques were studied and developed to obtain representative samples during the collection of samples for characterisation studies. Sample treatment and analytical chemistry methods were also developed to allow the understanding of the dispersion of energetic materials in our ranges. To understand the fate and behaviour, much effort was also put in biotechnology, ecotoxicology and hydrogeology. Research and development (R&D) projects were also designed to develop bioremediation technology to deal with contamination should it occur. Management of the training areas was also studied including methods for the destruction of unexploded ordnances (UXOs), the most important problem resulting from the use of munitions. Finally, based on this expertise, both Canada and United States are looking the design of new ranges to counteract the negative aspects of training and to sustain the operational activities. All these aspects and topics were discussed during the meetings and presentations were made by Canada and United States to illustrate the progress in these new areas of research. Metals are intrinsic parts of the munitions and metallic debris represents an important issue for our departments since live firing of munitions is spreading significant quantities of metals which are strictly regulated by law. R&D projects were dedicated to these aspects especially for small arms.

2.5.1 Canadian Programme

2.5.1.1 Characterisation of Canadian Bases

Many Canadian Forces sites used as impact areas, training ranges, demolition and open burning / open detonation (OB/OD) ranges, and which have been used to destroy out-of- specification materials, were suspected of being contaminated with energetic substances. To evaluate the contamination of DND sites, sampling and characterisation of various ranges took place over the last fifteen years. Presentations by Dr. Ampleman and Dr. Thiboutot were given that explained the results of these many studies. Most of the Canadian studies were first aimed at target areas that were suspected to be the most contaminated but, following an American study which showed that firing positions were contaminated by propellant residues. Many of the studies are now dedicated to investigation of that specific aspect. It was determined that nitroglycerine (NG) and/or 2,4-dinitrotoluene (2,4-DNT) embedded in nitrocellulose fibres are deposited in front and around firing positions.

Under the auspices of "The Technical Co-operation Program" (TTCP), it was decided to characterise an international site to demonstrate and validate the sampling and analytical chemistry techniques. Following that demonstration, a protocol describing the different methods of sampling and the analytical chemistry was developed and later updated in collaboration with the US Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL). Finally, it was reviewed by the member nations (Canada, the US, the UK, Australia and New Zealand) in a Key Technical Area (KTA 4-28) and has been made available to the NATO members. The last version of this protocol can be found on the web at: http://www.em-guidelines.org/ener.htm. To date, research has demonstrated that explosives are not common contaminants, since they exhibit limited aqueous solubility and are dispersed in a heterogeneous pattern of contamination and because of that, specific sampling, sample treatment and analytical chemistry are needed to evaluate contamination by energetic materials.

To better assess the contamination and characterise an area, an appropriate definition and understanding of the hydrogeological context of the site is required. Characterising the groundwater quality, especially on large ranges, is critical because metals and energetic materials are mobile in sandy environments and may migrate in groundwater, presenting a threat to human health and to the environment. Large sites can be seen as big filters for the contamination and managers or site owners must ensure that no contamination migrates off site. Soil surface sampling may point out specific areas where the contamination occurs, but the final answers will be obtained following the hydrogeological study. Groundwater flow has to be carefully assessed by determining its velocity and direction. The quality of the groundwater also has to be evaluated since it is often used for irrigation purposes, as a drinking water source by the base and to sustain aquatic ecosystems. Hydrogeological studies were completed in all Canadian bases and the expertise developed was presented to the members of the AVT group and also at the Sofia Workshop. Canada is now developing modelling, vulnerability and risk maps to help in the effective management of the major Canadian training areas.

2.5.1.2 Unexploded Ordnance

One of the most problematic issues encountered by all countries in the world is the presence of unexploded ordnance (UXO). Canada did not invest R&D in developing UXO detection technologies since a lot of efforts in this area is done worldwide. Since UXOs still represent a threat to the training area users, Canada devoted some of its efforts to understanding this problem. When munitions are fired, it is known that some of these munitions do not function properly and as a result, a UXO is created in the field. The dud rate is the percentage of munitions that do not function and is specific to each munitions system and may vary from 1 to 40% (in some rare cases). UXO represent a threat and when they are found, they are destroyed in place using a block of C4 to detonate them, thus getting rid of the safety and security issue. When the UXO are not found, in the long run, they will corrode, eventually perforate and their explosive content will leach into the environment resulting into an environmental issue. Moreover, in some occasions, blow in place procedure results in incomplete detonation, often described as low order detonation, that spreads significant quantities of explosives around the items.

Our studies demonstrated that the blow-in-place of UXO using C4 often leads to the dispersion of explosives into the environment, especially RDX which is expelled from the unconfined C-4 Blocks. Moreover, detonation of munitions is designed to explode shells from the inside out where the pressure and detonation have a chance to build up quickly, completely destroying the explosives content of the munitions. In the blow in place procedure, the application of an unconfined C-4 block on the outside of a UXO sometimes leads to incomplete detonation, with lower pressure and temperature and as a result, a low order detonation spreads the explosives. This practice is used on a regular basis on training areas to eliminate the risk associated with the presence of UXOs and often sampling in the vicinity of a past blow in place event revealed significant RDX concentrations. Canada is trying to develop a clean blow in place procedure using modified shape charges specifically designed to get temperature and pressure high enough to completely detonate the explosives. This work was discussed and presented during the meetings.

Moreover, Canada also performed many experiments to understand the impact of cracked shells on the environment. It was found that UXO that lies at the surface of training areas can be cut open by incoming flying shrapnel exposing their content to the environment. These flying shrapnel fragments are the result of incoming munitions that explode over the area during training. Studies of cracked shells exposed to different weather conditions were carried out in large columns at DRDC Valcartier to understand the impacts of these cracked shells. It was demonstrated that these cracked shells are probably the source of contamination of the Massachusetts Military Reservation (MMR) training area in the US which was closed because of the RDX presence in its groundwater. These topics were discussed during the meetings of the AVT.

Furthermore, corrosion of the munitions is an important aspect of the UXO problem since it is difficult to know when environmental impact will appear resulting from the perforation of the UXOs. Most of the studies on corrosion have used the models developed from the petroleum industries related to the corrosion of the pipelines. Canadian studies looked at the corrosivity of the soils instead of looking at the corrosion of the items itself. Munitions were instrumented and buried in different type of soils to evaluate the corrosivity of the soils. Knowing the corrosivity of a soil would influence and help to choose the right range for the right weapon. These studies were also discussed during the meetings and the Workshop.

Finally, the Canadian government has recently been concerned by the presence of underwater unexploded ordnances (UXO) coming from a large number of shipwrecks and ammunition that are present in its territorial waters. Underwater UXOs also represent a worldwide problem. The munitions come from two main sources, shipwrecks and sea dumping. Underwater UXOs do not only represent an environmental risk but are also a security and safety risk since population can eventually get in contact with these UXOs. Furthermore, UXOs may be retrieved for improper use such as terrorism.

In Canada, the first incident took place when a citizen picked up a 155 mm shell lying on a beach close to Lac St-Pierre and put it in a fire. This resulted in his death and the injury of others. A second incident took place in the mid-nineties in Point Amour, Labrador, when local residents discovered ammunition shells rolling on the beach. With further inspection, it was discovered that the shells were in fact UXOs, and that the safety of local residents could be endangered by the close presence of these objects. The UXOs came from the wreck of HMS Raleigh, a Royal Navy cruiser that ran aground in 1922. In addition, Halifax harbour contains many sunken ships which are still full of munitions and which are slowly corroding as are the remaining parts of the ships.

Sea dumping was practiced by many countries including Canada but is now banned. As a result, in many parts of the world, sea dumps are found and can contain very large quantities of unfired items sitting at the bottom of the ocean. In these sea dump areas, where sediments often cover the areas as a result of particle movement and sedimentation in water, the items are slowly corroding. These munitions contain explosives such as TNT, picric acid, RDX and HMX, which will eventually leak in the ocean following perforation by corrosion, and increase risks of contaminating sea life involved in the food chain. Furthermore, the shells and the ignition systems contain metals that are slowly dissolved in sea water. This can result in an important adverse impact to the marine environment.

For these reasons, the interest regarding underwater UXOs is constantly growing but research in this domain is still very recent. The total amount of ammunition dumped in this area is still unknown but extremely large quantities of munitions were dumped after World War II. The best solution to this problem would be the removal and destruction of the items but the costs are prohibitive. There are no easy ways to deal with this important problem and interesting discussions took place between participants of the Workshop.

2.5.1.3 Fate and Behaviour of Energetic Materials

The bioavailability of munitions-related contaminants is closely related to their environmental fate. It is therefore critical to improve our knowledge of the fate of the various munitions-related residues, including explosives, propellants and heavy metals. Our programme has discovered that firing positions are impacted with high levels of gun powder residues. Numerical simulation and column studies of the fate and behaviour of gun powder residues were conducted. Also, live fire testing of weapons was conducted and samples collected in the field to assess the environmental depositions of propellant residues and supply the columns with residues.

In addition to this, many studies were done to understand the degradation pathways of the energetic materials and numerous radio-labelled, isotopic or metabolites of energetic materials were synthesised and used as tracers or standards in analytical chemistry to understand how they biodegrade into the environment. Moreover, bioremediation technologies were developed to clean contaminated soils. Furthermore, nothing was known on “how clean is clean” and threshold criteria needed to be developed to understand the toxicity of energetic materials. Since Human Health Risk threshold criteria were too severe, it was decided to develop environmental threshold criteria based on ecotoxicology. Under the auspices of the TTCP, a group of researchers was formed to develop such criteria and is now working in a KTA 4-32. Their work was reported to the AVT.

2.5.1.4 Demilitarisation in Canada

In Canada, open detonation of obsolete items is still allowed. A study performed at the OB/OD site in Dundurn Saskatchewan demonstrated that the open detonation results in clean and complete combustion of energetic materials in the specific instances where detonation is high order and performed according to a precise procedure. Another study demonstrated that incineration of small arms is a dirty process which has now been banned. Canada is in the process of identifying a technology that will fit our specific needs for the demilitarisation of the obsolete stockpile.

One of the issues encountered by range managers is the range scrap that requires disposal. Technologies are being sought to safely get rid of the range scrap as this represents a more important problem than demilitarisation in Canada. The AVT group discussed this subject and concluded that eventually a solution will be identified.

2.5.1.5 Future Projects

Based on the expertise developed during the last decade, Canada is now looking at the next generation of training areas. In this aspect, designing and building of new ranges are of great interest especially for small arms which are now constructed of sand butts. It was found that high contamination by metals especially lead, copper and antimony is observed in most of the small arm ranges across Canada. Furthermore, these sand butts are difficult to manage and clean and it is expensive to treat the soils after disposal. The most important driver for the contamination movement into the environment is that water (rain, snow) is allowed to percolate through the soils containing the metals in small arms range allowing the contaminants to be dissolved or simply dragged into the groundwater. This is also true for explosives as contaminants as they too can move through groundwater in other ranges such as grenade range. Range managers will soon have to decide what mitigation technique or what type of ranges should be constructed or acquired in order to lower the environmental impacts of the training. Canada is now working on a solution to the small arm ranges. DRDC Valcartier is developing a bullet catcher that will stop water percolating through soils. When possible, a small arm range will be constructed with these bullet catchers. Discussions among NATO members on this topic are very beneficial since it is a problem common to all participating nations.

Another aspect that is now arising from our studies is the impact of air emissions on users. It was found recently that air emissions can contain harmful particles (based on size). More work is needed in this area and Canada is now initiating many projects to look at this particular aspect.

Finally, based on existing knowledge, one of the best solutions to mitigate the environmental impacts of training would be the development of greener munitions that contain a double fuzing system allowing a zero dud rate. Such munitions would give no UXO eliminating most of the environmental impacts. Canada is now developing such munitions and this project was presented to the AVT members and also at the Workshop in Bulgaria.

2.5.2 United States Program

As mentioned earlier, the US Army Corps of Engineers collaborates with DRDC Valcartier in assessing contamination in both US ranges and Canadian ranges. In contrast to the Canadian approach, the US scientists were more interested in sampling efficiency and the analytical chemistry than in assessing the overall contamination of the entire base. Therefore, their studies were more oriented towards the goal of developing that chemistry. Over the years, their expertise in the analytical chemistry of explosives became among the best worldwide and they are now concentrating on teaching these techniques of sampling and analyses to their own agencies and also to other countries. Dr. Pennington has presented their work in many occasions.

The US scientists have also focussed much effort on understanding the deposition of energetic materials following open detonation of different munitions such as: 105 mm, 155 mm artillery shells and 81 mm, etc., mortar artillery firings. They examined the live firing of these systems and realised that the firing positions were contaminated with propellant residues. Their approach to the collection of residues was different than the one used by Canada. They first used large tarpaulins to collect the residues but later used pristine snow cover as the receptor and upon snow collection, melting and analyses obtained results from the deposition of different firing systems. Presentations were made during the meetings and at the Workshop by Mrs. and Mr. Walsh to explain the results obtained. In contrast, Canada used witness plates at the beginning of their studies but later they used collection traps wet with ethanol to collect the residues from different systems. Comparison of methods and results confirmed the results obtained by the American studies. Dr. Pennington from USA studied the environmental impacts of low order detonation and the set-up they used and results were presented to the AVT group.

The United States also intensively studied the fate and behaviour of explosives and at developing remediation tools. Many columns and phytoremediation studies were performed to determine dissolution factors, migration capacity, phyto-absorption, etc. Dr. Pennington was responsible for these studies at the Environmental Laboratory in Vicksburg and has presented her studies on numerous occasions. She was also responsible for the natural attenuation study of a TNT contaminated lagoon in Mississippi and she has presented this work.

2.5.3 Conclusions

The United States and Canada have complementary expertises and an outstanding collaboration in their environmental programmes. Canadian expertise in land contamination and hydrogeology was based on the analytical chemistry developed by CRREL in the United States. Both countries have combined efforts at understanding the fate and behaviour of energetic materials and other munition related contaminants in the environment and as a result the North American knowledge in this area of expertise is extensive. Both countries are keen to share this expertise with other NATO countries and especially with PfP Nations in the hope of igniting the interest of these countries in the protection of their environment and the sustainability of their military training areas.

These discussions formed the basis of the Sofia meeting and provided background information. The interim conclusions were that much of the technology required was available, but that there were gaps that needed consideration. The major gaps identified at this stage were dealing with pyrotechnics; issues with dealing with munitions dumped at sea, and the ability to deal with next generation explosives. Additionally, there was agreed to be a requirement to refine and develop techniques for land contamination avoidance and management, as well as reviewing the positions held, sometime strongly, on open burning and open detonation.

The discussions and presentations formed the basis for the extending meeting in Sofia, where these were discussed and developed further in larger, broad based community.

Chapter 3 – EXTENDED MEETING IN SOFIA

3.1 INTRODUCTION

RTO – NATO 'Environmental Impact of Munitions and Propellant Disposal'

This meeting, to discuss common problems and potential solutions in the above area, was held at the Ministry of Defence (MoD) Information Centre, Sofia, Bulgaria, between 12 and 14 September 2007.

The meeting was attended by:

Guy Ampleman	DRDC Valcartier, Canada
Gudrun Bunte	Fraunhofer Institut – ICT, Germany
José Campos	University of Coimbra, Portugal
Jim Carr	United Nations Development Programme (UNDP), UN
Narimantas Cenas	Institute of Biochemistry, Lithuania
Peter Courtney-Green	NATO Maintenance and Supply Agency (NAMSA),
Adam Cumming	Dstl, UK
Avtandil Dolidze	P. Melikishvili Institute, Georgia
Ilona Ekmane	Ministry of Defence, Latvia
Jean-Claude Fabrello	DGA, France
Drahoslav Hagara	MoD, Slovakia
Joakim Hagvall	FOI, Sweden
Nico van Ham	TNO, Netherlands
Hristo Hristov	Rakovski Defence and Staff College, Bulgaria
Michael Huggins (13^{th}, 14^{th} only)	AFRL, USA (AVT Chair)
Zinfer Ismagilov	Boreskov Institute of Catalysis, Russia
Tom Jenkins	US Army CRREL, USA
Arnt Johnsen	FFI, Norway
Christophe Joy	DGA, France
Michel Lefebvre	RMA, Belgium
Richard Martel	Québec University, Canada
Barry McConnell	Dstl, UK
Larry Nortunen	Defense Ammunition Center, USA
Traian Rotariu	Military Technical Academy, Romania
Jonas Sarlauskas	Institute of Biochemistry, Lithuania
Hiltmar Schubert	Fraunhofer Institut – ICT, Germany
Serge Secco	DGA, France
Nadir Serin	Defence Industries Research and Development Institute, Turkey
Sonia Thiboutot	DRDC Valcartier, Canada

David Towndrow	MoD, UK
Øyvind Voie	FFI, Norway
Marianne Walsh	ERDC, USA
Michael Walsh	ERDC, USA
Adrian Wilkinson	South Eastern European Clearinghouse for the Control of Small Arms and Light Weapons (SEESAC), UN

Links to all supporting documents and presentations have been provided in Annex B.

3.2 DAY 1

The meeting was officially opened by Major General Evgeni Manev of Bulgaria. The General welcomed all the countries to the meeting. He noted the importance of discussing these issues. Hristo Hristov also offered his greetings as the host of the meeting, welcoming everyone to Sofia.

Adam Cumming gave a short presentation (see Annex B) offering some background and an overview of the meeting. He noted that its inception could be traced back to a NATO advanced Workshop held in Porto, 2001. Here it was decided that discussions between NATO and PfP nations on capabilities and capability gaps were essential in this complex area of shifting legislation and public opinion. As well as the presentations themselves, the discussions around the table are seen as an important part of the final AVT-115 report. These will help shape the final recommendations given to NATO.

3.2.1 Policy and Problems – *Moderator Dr. Adam S. Cumming (Dstl, UK)*

All disposal and contamination work is subject to external influences. These include legislation, public perception and opinion, as well as the needs of the field operator. As technical capability increases, for example in the development of new understanding of biological impact or the development of new methods of detection, these affect the options available to technicians and lead to policy modifications. It is important to be able to affect these policy and legislative developments through cogent and well developed science.

If the relevant questions are to be asked, then an understanding of the pressures on policy makers is essential as it is important to be able to hold an effective dialogue. For example, explaining that because a particular substance can now be detected does not necessarily mean that it is present at a dangerous level.

During the meetings of AVT-115 it had become clear that the problems faced across the broader NATO community could not be generalised. However, certain themes did emerge:

- The existence of substantial contamination and surplus munitions in newer NATO countries and PfP nations.
- The greater concentration on contamination and management in older nations where other issues were perceived to be manageable.
- The changing legislation, which differed from country to country and group to group – the US legislation priorities differing in some ways from those of the EU.
- The need to manage the impact of munitions dumped underwater.
- The need to develop greener munitions with clear disposal routes.

The Moderator pointed out that this part of the meeting was to set the scene, providing a basis for future discussions.

3.2.1.1 UK MoD Munitions Disposal
Maj. David Towndrow, Environment, Safety and Disposals Manager DGM IPT

Abstract

- *Defence General Munitions Integrated Project Team (DGM IPT) has policy co-ordination role for UK MoD for munitions disposal.*
- *The Aim of Paper is to provide an overview of how MoD:*
  - *Is currently managing the process of disposing of Munitions.*
  - *The types and quantities of munitions requiring disposal.*
  - *Aspects of environmental, safety and security legislation that currently drive the policy.*
  - *Our view of future legislation and future capability.*
- *The general conclusions are:*
  - *That we are free to move munitions to specialist contractors (within Europe) for disposal where they are fully competent, provide a high degree of recovery of materials, and are commercially sustainable.*
  - *We need to maintain a minimal capability in UK for processing routine arisings, emergency arisings and for certain specialist processing.*
  - *We need to ensure we retain the capability to dispose of munitions by a variety of techniques and protect our ability to use OB and OD where appropriate. This includes ensuring that appropriate legislation is adopted at a European and National level.*
  - *We need to continue to invest in an appropriate level of research to ensure we can dispose of the quantities likely to arise into the future*.

David Towndrow is part of a MoD team who deal with the logistics of UK munitions. DGM IPT is responsible for over 1,700 types of munitions. These require appropriate disposal, both in small ‘housekeeping’ amounts and also larger logistic operations. There are a number of options when deciding on how best to dispose of munitions:

1) Sell surplus;
2) Use them in training;
3) Refurbishment; and
4) Demilitarisation ~ £ 1000 per ton.

The surplus must not be allowed to exceed certain limits. It is UK policy to return everything from theatre, except what is unsafe to move. During the general planning process, safety security and munition legislation takes precedent, with environmental issues a close second.

Under the correct circumstances, OB/OD (Open Burning / Open Detonation) can be an environmentally responsible method of disposal. The example given is the planned open burning of 170,000 Barmines, 20 miles outside of London. This was considered the best option due to industries lack of interest in buying the RDX/TNT, and also the cost in sending the mines to Europe for processing (£ 13 compared with £1 each for burning in the UK). The proposal is currently waiting for the green light from Government ministers.

The presentation also discussed the UK’s own incinerator facility at Shoeburyness, run by QinetiQ on behalf of the MoD. This is clean, but can be an expensive option. It also has an environmental cost in terms of the amount of oil it uses. For large amounts of ammunition, open burning is a better process.

OB/OD may contaminate the ground it's carried out on. However, it is important to remember that the ground on these ranges is already contaminated after years of use. They will eventually be cleaned by MoD, certainly if they have to be released back to public use.

When considering the effects disposal can have on the environment, you have to consider what comes off *after* burning of the munition (quite often benign chemicals) and then apply this information to any site specific issues. The presentation expressed a concern that any new methods of disposal (such as cryofracture, electrolysis, bio-remediation) require commercial and scale-up potential.

There are a lot of good facilities across Europe for use for disposal when *appropriate*. However, problems with legislation associated with the moving of ammunition and waste across borders requires the UK to maintain its own capability.

Questions and Discussion

Larry Nortunen: Are there any specific munitions you are not allowed to dispose off?

> **Answer:** Nothing specifically, but we are not allowed to dispose of anything which is known to cause environmental damage (e.g., Uranium).

Sonia Thiboutot: Sometimes disturbances on ranges can actually increase biodiversity (i.e., a positive impact!). Why not detonate the Barmines instead of burning them? Burning processes generally lead to the emission of higher levels of contaminants in the environment when compared with detonations.

> **Answer:** We don't have the available space to dispose of Barmines in that way (although some are used to detonate other munitions).

Zinfer Ismagilov: Is jet cutting (e.g., on motor charges) still R&D, or an industrial process?

> **Answer:** It is now an industrial process.

3.2.1.2 Presentation on NATO DAT Activities
Major Drahoslav Hagara, Armaments Division, MoD, Slovakia

Abstract

Topic: CNAD POW DAT Item 8 – Explosives Ordnance Disposal (EOD) and Consequence Management – Lead Nation: Slovakia

1) *Introduction.*
2) *NATO Overview regarding EOD: NATO bodies, guidance; areas of responsibility.*
3) *Evaluation of EOD Lead Nation (LN) business: Requirements and Projects Status; Way ahead.*
4) *Munition Bulk Disposal project: Scope of the project; Request for Study regarding Bulk Disposal needs; expected outcomes.*
5) *Conclusion.*

Major Drahoslav Hagara works for the Armaments Division of the Slovak MoD, subordinated to National Armament Director as EOD Lead Nations Section Chief. His presentation consisted of an introduction to the tasks of Slovakia as a NATO lead nation in EOD, and consequence management realized within the Conference of National Armaments Directors (CNAD) Programme of Work (PoW) DAT.

In July 2004 NATO held a summit in Istanbul, on Countering Global Terrorism. EOD and consequence management formed part of the programme. As the lead nation in this area, the initiative's aims are:

- To prevent existing stockpiles of munitions from falling into the hands of terrorists and increase NATO's ability to dispose of these stockpiles.
- To improve the capabilities of EOD specialists in neutralizing improvised explosive devices and to establish a common database on existing ordnance and developing new technologies for detection and ordnance disposal.

This involved tasks such as: organising STANAGs, training and interoperability, encouraging new EOD technologies, etc. A website containing EOD information has been activated: www.mosr.sk/eod. This is a secure site which can be accessed by contacting national points of contact.

A short analysis of existing relevant NATO, UN and EU expert groups was undertaken and asked to participate in future events. This list included:

1) CNAD Ammunition Safety Group – AC/326;
2) NATO Standardisation Agency (NSA) – Explosives Ordnance Working Group;
3) NSA – Interservice Ammo Working Group;
4) NATO Army Armament Group (NAAG) Land Capability Group 7 (LCG-7);
5) RTO AVT-115 – Task Group on Environmental Impact of Munitions and propellant disposal;
6) Organisation for Security and Co-operation in Europe;
7) UN Mine Action Service;
8) Geneva International Centre for Humanitarian Demining; and
9) International Bans and Conventions.

Questions and Discussion

After the presentation Adam Cumming noted that the information was stimulating and also new to a lot of us. This exchange of information is seen as one of the main aims of the meeting. We need to form closer links.

Hiltmar Schubert noted that there may be some overlapping between the various groups. There are many activities within the NATO Science Programme closely linked to this subject, especially in Russia. They have a Workshop on liquid explosive detection in St Petersburg this autumn for example. He also agreed with the need to form links.

Larry Nortunen: What exactly is the EOD Information System (EODIS) mentioned? Is it a field destruction tool, database for planning, or a field detection tool?

> **Answer:** It is an operational tool (database), on a secure webpage. It contains research procedures, EOD analysis tool, library of scenarios, mapping and documentation tools.

Adam Cumming: What is the availability of the website?

> **Answer:** EOD LN website is a secured, password protected website based on EOD community requirements. It will contain important information regarding: training facilities, international courses offered, forum for discussions about new EOD technologies, equipment database and events calendar.
>
> Access is divided:
>
> - Open space (registered users), limited access.
> - Companies space (verified by Point of Contact (PoC)), limited access.
> - Non open space (specially registered users approved by PoC).

It will have links with companies' websites and selected NATO websites. In order to achieve access, each participant needs to register via his countries PoC. A list of PoCs is held by EOD LN team (SVK). Contact me on my email address if you need more details. The website requires active contribution by nations and organisations for its development and actualization.

Jim Carr: Does the database contain authorised AEPPP (EOD disposal procedures)?

Answer: No. Each nation includes its own procedures and authorisation.

Adam Cumming: Are the Allied Operating Procedures (AOP) there?

Answer: No.

3.2.2 Critical Problems of Utilization – *Moderator Dr. Adam S. Cumming (Dstl, UK)*

One of the major problems facing broader NATO and partners is the difficulty in dealing with surplus munitions, often with indeterminate fillings and of uncertain age. These problems are faced by former Warsaw Pact nations as well as others outside NATO links. Often there is neither the expertise and facilities nor the finance to address the problem, and this session is intended to illustrate and discuss the issues to enable them to be addressed properly. It is not intended to be exhaustive, and indeed it cannot, but will describe how the problems are being approached, and how reuse is being addressed where possible.

3.2.2.1 The State of Bulgarian Utilization Process in 2007
Prof. Hristo Hristov, Rakovski Defence and Staff College, Bulgaria

Abstract

The analysis of utilization problem in Bulgaria was made. It is shown that the utilization of surplus ammunition is current event and makes decision for one of main problems of the reform in Bulgaria Army forces and Military works. This is difficult activity with needs of modern technologies and technical equipment and trained specialists and considerable financing. The utilization process was started and quantity of 60 kt surplus ammo has continued to utilize but there must have capacity to rise of temps of utilization from approximately 6 kt 10 kt for next 7 – 8 years.

Bulgaria owns large stockpiles of surplus ammunition which are dangerous and economically unprofitable for a number of reasons. A survey on the best way forward was carried out, using 16 Bulgarian experts on ammunition utilization. Strengths, weaknesses, opportunities and threats (SWOT) analysis of the ammunition utilization process was used. The prevailing position of the experts was that the programme for utilization, *not destruction* of the redundant ammunitions should be given priority. Those who think that the programme should be nationally controlled are in the majority.

Questions and Discussion

David Towndrow: Where does the majority of this ammunition come from? It is left over from a previous era, or is it mainly out of life and demil stock?

Answer: It has spent many years in storage. It also contains civilian as well as military ammunition.

Hiltmar Schubert commented that Germany has a lot of useful experience obtained from demilitarisation of the Eastern Army 15 years ago. There is a huge problem of communication. We need better channels of communication between countries.

Jim Carr noted that the problem is a conceptual one for the people in charge. They need to understand that if a munition is old enough, it will eventually explode.

Adam Cumming suggested that it is not a matter of risk avoidance, but rather risk management.

To highlight the depth of the problem, Jim Carr and Adrian Wilkinson noted that since 1997, there have been at least 20 major accidental munitions explosions per year.

Ilona Ekmane made a comment on Hiltmar Schubert's suggestion: For PfP nations it is not simply a case of being able to exactly copy across German experiences. The information must be adapted. Latvia has heard of many ways to potentially solve problems, but the administrative structure is not the same as in Germany.

Adam Cumming noted that we need something as a starting position, whilst still being aware that there are differences between available technologies, and even more importantly: legislation.

Traian Rotariu commented that for Romania the problem of demil is the same as with the other countries. However, they now have industrial partners in place to help with disposal, as well as MoD having its own facilities. So the problem is under control. The issue now for Romania is the environmental dimension.

Adam Cumming asked Traian Rotariu if Romania has access to best practices for adoption. The answer was No.

Latvia, Lithuania and Slovakia have similar problems. Drahoslav Hagara said that Slovakia have companies to deal with demil. However, there is an issue over what they do with the munitions, i.e., renew, reuse or just detonate. Usually the economics decide. Also, the best technology is not always available.

Adam Cumming commented that if NATO (AC326) functions correctly, there should be NATO standards produced in this field so that the knowledge can be shared. A cost benefit analysis for any process will usually be required. Although the whole issue needs to be driven by what's affordable, what might seem to be unaffordable may turn out to be the only truly cost effective answer (due to legislation, etc.).

3.2.2.2 Priorities and Experiences in Disposal of Surplus Munition Materials in Georgia

Prof. Avtandil Dolidze, P. Melikishvili Institute of Physical and Organic Chemistry, Georgia

Abstract

Dangerous wastes were left on former military bases in Georgia. STC "Delta" safely recycled munitions, while NGO "Monitoring" utilized liquid wastes. The corresponding works were proceeded: Neutralization of "Melange" (700 tones) and "Samin" (350 tones) – 2001-2002; liquidation 170,000 pieces obsolete munitions – 2003-2006; utilization in useful products of non-conditioned Napalm (~60 tones), liquid decontaminating agent РД-2, imitating mixture ИВ-2 (~10 tones) and smoke-screen containers (~63 tones) – 2003-2006; rehabilitation of 10 former military installations of Akhaltsikhe region – 2005-2006; construction of special plant for smelting of TNT from munitions – 2007, and utilization of dangerous chemicals from air forces storage (30 tones), liquidation of highly toxic substances and army poison-gas, beginning of inspection at Kopitnari former military airfield – 2007.

The other priority is to inspect the pollution rate of Akhalkalaki military base (military town, Abuli and Kvarsha shooting grounds, former military airfields, etc.). This base should be passed to Georgian State during this year and according to the available data there are lots of useless military wastes and polluted areas on the base territory. In the future similar inspections should be carried in Adjaria, as well.

For Georgia is very important to investigate the waste produced from recycling of arsenic (main component of the former soviet chemical weapon – lewisite) mine and discover effective and safe methodology of its utilization (in total up to 80,000 tones).

The presentation highlighted the many and varied problems of dumped munitions in Georgia, left over from the Soviet era. It also highlighted some of the unique ways that Georgia has dealt with the problem –

for example, disposing of degraded napalm by mixing with road bitumen. However, some major problems still exist, with proper funding also an obstacle. It is hoped that international organisations, together with Georgian specialists will help to promote a reduction in environmental impact.

Questions and Discussion

Hiltmar Schubert noted that NATO has offered to hold a Workshop in Georgia to discuss German experiences. This has not happened yet (due to political issues), but hopefully will soon.

Avtandil Dolidze agreed this would be very useful. He also noted that last September they held a meeting with American representatives in Europe, discussing issues of soil contamination.

Narimantas Cenas: How did you determine the fuel distribution in the soil?

> **Answer:** Gas chromatography / mass spectroscopy (with samples taken at quite large intervals).

Adrian Wilkinson offered to discuss the realities of international donor support for ammunition demilitarisation: His organisation SEESAC, advices countries on demil disposal, including costs, etc. It is important to realise that all the major international organisations (NAMSA, SEESAC, OSCE, EU) are involved in a variety of projects. Each has its advantages. Donors will fund demil from a variety of sources. It is important when you ask for international support to target a specific organisation, don't shop around. Donors want transparency. Some form of independent technical assistance is required, otherwise the proposal is unlikely to be funded.

3.2.2.3 Development of Physicochemical Principles and Technology for Utilization of Large-Scale Composite Solid Rocket Propellant Charges
Prof. Zinfer Ismagilov, Boreskov Institute of Catalysis, Russia

The presentation covered disposal of rockets in Russia. This was initiated by the START-2 Treaty, which stipulated destruction of 410 missiles and 1230 solid propellant charges. This totalled 22,850 tonnes of material. Dismantling and disposal requires a systematic approach. There were three possible solutions to the problem:

- Burn the propellant inside the motor.
- Mechanical destruction and burning or reprocessing of solid propellants to commercial explosives.
- Chemical disruption of the propellant's binder (in a safe and environmentally acceptable process), followed by extraction and recycling into commercial products.

The rest of the presentation dealt mainly with analysis and techniques to carry out the latter approach, as well as assembly of a new fluidised bed reactor.

Questions and Discussion

Hiltmar Schubert: Germany had complaints from Ukraine about unsymmetrical dimethyl hydrazine (UDMH) – does he know how Ukraine handled their disposal?

> **Answer:** No, I am unaware of that.

José Campos then noted that it is a 17 year old problem not yet solved. In 2001 (Porto NATO Advanced Research Workshop (ARW)) it was seen as a mounting issue. There are however some reuses for propellant in small quantities, e.g., the fireworks industry.

Øyvind Voie: What is the cost of a facility for chemical destruction, compared against burning of propellant?

Answer: We don’t actually know the expense of *existing* technologies. However, the new techniques will be more economically feasible.

Adam Cumming asked Larry Nortunen to comment, since the US have similar amounts of rockets to Russia! The US uses the process of cryocycling to breakdown 5” rocket motors. These can be subsequently used to prepare mining charges. However, the mining industry requires a continuous supply, which isn’t possible. Other technology possibilities are still at the R&D stage.

Adam Cumming commented that the Czechs also break down rockets motors for use as mining charges.

Tom Jenkins suggested that unsymmetrical dimethylhydrazine (UDMH) can also be used as a fuel, whilst Adam Cumming noted there have been some suggestions of using it as a synthetic starting material for other products.

Hiltmar Schubert commented that Germany has tried to look at propellants for the mining industry. However, there are strict regulations relating to performance, content, etc. This makes it very difficult to get a license. Also, there is not enough volume to get a reproducible product. This, not the technology is the major issue.

Larry Nortunen explained that in America the propellant is simply handed over to industry, who then deal with the qualification issues.

Sonia Thiboutot noted that the discussion so far had focussed on solid propellants. The issue of liquid propellants requires a totally different approach.

David Towndrow explained how the UK dealt with MLRS (multi-launch rocket system) ammonium perchlorate (AP) containing propellant. These are sent abroad to Nammo. The motors are broke down using water jets, and the propellant removed and burned in incinerators. The water run-off is treated chemically. This was seen as a good way of dealing with the problem.

Adam Cumming then asked the participants if there were any other problems with liquid propellant systems. Or any other glaring gaps that ought to be considered before moving on?

José Campos noted that it is logical to give the materials straight to industry (as is the case in America). The major problem however is the lack of organised information. People are repeating the same experiences in different countries without communicating with each other.

Adam Cumming noted the importance of predicting both risk and performance when producing new munitions.

Joakim Hagvall pointed out that Swedish explosives are not manufactured to NATO standards. The world is changing, with countries such as Korea and Japan (who are also not members of NATO) also having large demilitarisation problems. The issue is availability of information. There is not yet availability on a broader scale.

Serge Secco admitted that the French also had a similar issue with availability of information.

Adam Cumming suggested that the final report of AVT-115 would contain a portion of this information, with links to other sources. Even if we can’t have information on specific systems, it shouldn’t stop us discussing the technology. Security problems may exist. However, there are ways around this.

Larry Nortunen explained that the US are developing a web based product called ‘Technology Tree’, covering different technology types. The aim is to get people to provide information which can be made available on a database. This would provide the user with alternatives for a specific system/product.

Hiltmar Schubert mentioned the problem of scale. Germany has a large amount of TNT left over from former East Germany (DDR) days. This TNT was offered to BASF as a feedstock for isocyanate conversion. However, the company required 100,000 tonnes before they would consider it! This is an order of magnitude greater than what was actually available, and highlights the scale that civil industry operates on.

Adam Cumming noted that a possible way around this problem is through small scale, high value products. Can we find a route to these from demilitarised munitions?

Jim Carr observed that some of the information in our heads is so basic that we wouldn't consider it worthwhile putting on a database. However, it is precisely this sort of information which can be extremely useful to other users.

3.2.3 Ways of Dealing with Problems: Sea Dumping, etc. – *Moderator Dr. Sonia Thiboutot (DRDC Valcartier, Canada)*

3.2.3.1 Introduction

Recently, the Canadian government has been concerned by the presence of underwater UXOs coming form great amount of shipwrecks and ammunition that are present in its territorial waters. Underwater UXOs represent a worldwide problem and they are coming mainly from two sources, shipwrecks and sea dumping. Underwater UXOs do not only represent an environmental risk, but also a security risk since population can eventually get in contact with these UXOs. In Canada, the first incident happened when a citizen picked up a 155 mm shell lying on a beach close to Lac St-Pierre and put it in a fire resulting in his death and a lot of people injured. A second situation happened in the mid-nineties in Point Amour, Labrador, when local residents discovered ammunition shells rolling on the beach. With further inspection, it was discovered that the shells were in fact UXOs, and that the safety of local residents may be endangered by the close presence of these objects. The UXOs were coming from the wreck of HMS Raleigh, a Royal Navy cruiser that ran aground in 1922. In the Halifax harbour, many ships sunk and are still full of munitions that are slowly corroding as the remaining parts of the ships.

Sea dumping was practiced by many countries including Canada but it is now banned. As a result, in many parts of the world, sea dumps are found and can contain very large quantities of unfired items that are found sitting at the bottom of the ocean. In these sea dump areas, where sediments often cover the areas as a result of particle movement and sedimentation in water, the items are slowly corroding. These ammunitions contain explosives such as trinitrotoluene (TNT), picric acid, RDX and HMX, which will eventually leak in the ocean following perforation by corrosion, and increase risks of contaminating sea life involved in the food chain. Furthermore, the shells and the ignition systems contain metals that are slowly dissolved in sea water. This can represent an important adverse impact to the marine environment.

For these reasons, the interest regarding underwater UXOs is constantly growing but research in this domain is still very recent. The total amount of ammunition dumped in this area is still unknown but extremely large quantities of munitions were dumped after World War II. The best solution to this problem would be the removal and destruction of the items but the costs are prohibitive. There are no easy ways to deal with this important problem and participants will try to identify the best practices and solutions to mitigate the adverse impacts of underwater UXOs. Ways of dealing with the destruction will have to be identified and applied to these problems.

3.2.3.2 Investigation of Risks Connected to Dumped Munitions in Surface Waters Dr. Nico van Ham, TNO, Netherlands

Abstract

Large amounts of ammunition were sea dumped after World War II. Occasionally ammunition was encountered by public, raising the question of risk for the community. TNO investigated the risk of

explosions and the possible negative effect to the aquatic environment. The risk of explosions was estimated to be very low and negative effects to the aquatic ecosystem could not be detected. The monitoring of the dump site was strongly advised by TNO.

After World War II 122,000 tonnes of ammunition were left behind in the Netherlands. Most of this was dumped in shallow waters. This produced a potential safety and environmental risk. Work was carried out to assess the risk of munitions detonating. The conclusion was that this risk is extremely low, as was the risk of it being used for criminal activities.

The rest of the presentation dealt with assessing the environmental impact of the sea-dumped munitions. Cameras were used to assess specific sites, with divers bringing back samples of munitions. Concentration/ time profiles were produced. Predictions were made that it would take at least 500 years for all the components to dissolve into the seawater.

The fauna of the impacted areas was also studied to ascertain if the munitions were having an effect. Active biological monitoring was carried out using mussels. No explosive materials were detected, even at very low detection levels. However, due to degradation of the casings, hazardous materials will eventually leak into the environment. The important point to note is that the effect these processes will have on the environment depends upon their precise location. When there is sufficient dilution, natural attenuation may be acceptable. However, if the concentrations are high, the area may need to be isolated.

Questions and Discussion

Øyvind Voie: The conclusions seemed a bit different from the results. There didn't appear to be a problem at the sites. Many investigations have been carried out showing no significant problems. So maybe sea dumping is a good solution?

> **Answer:** There are a number of considerations to be made. Firstly, we need to make sure that no one can reach the munitions. Also, we don't have enough information on the environmental fate of the sites. Therefore we need to measure the effects on a regular basis. Since we don't know for sure the long-term effects of sea dumping, we cannot advise that anyone should do it.

Narimantas Cenas: What was the main degradation product of TNT found in the water, and at what concentrations?

> **Answer:** The main degradation products are 2-amino dinitrotoluene (DNT) and 4-amino DNT. The concentrations found were between 5 and 1,000 ppt (or 1 ppb). In general, the concentration of the amino products is around 25% of the TNT concentration at that location.

Michel Lefebvre: Are the shipping channel areas ever dredged?

> **Answer:** This is not required since the channels are very deep (30 – 55 meters). In the 1940s this was considered the ideal spot to dispose of the ammunition (the area also contains strong currents).

Michel Lefebvre: Could the currents transport the ammunition?

> **Answer:** There has been no movement of ammunition detected. Only the plastic containers have been found washed ashore.

Adrian Wilkinson commented that sea dumping is once again being looked at as a demil solution. It is a very emotive subject. From the 1950s onwards most NATO countries agreed to only sea dump in very deep waters. Now it is completely banned (last carried out in 1991). However, legal advice is that *some* ammunition could be removed from the banned list, and could be dumped under supervision. Under complete environmental modelling there is a strong argument for deep sea dumping to resume.

Sonia Thiboutot asked the general question, are there any countries with no sea dumping sites? She then responded to Adrian Wilkinson point by saying that there is a fear that because sea dumping could be seen as such a cheap and easy option, there may be a risk of *everything* being disposed of in this way.

Adrian Wilkinson responded with two points. Firstly, most countries who have large munition stockpiles haven't actually signed the sea dumping treaty anyway. So they could go ahead and do it if they wanted to! Secondly, Sea dumping isn't necessarily the cheap and easy option that it appears to be.

Adam Cumming noted that a risk assessment had been carried out for sea dumping in the UK. It found that lots of munitions previously dumped on the continental shelf have found their way back, washed up on British shores. There is very little likelihood of the UK returning to sea dumping. He also pointed out that most of the nations that Adrian mentioned do not have access to deep sea. Any dumping in this manner would require crossing borders. This issue would need to be resolved, making it a politically not technically based decision.

David Towndrow noted the importance of at least being able to debate the *potential* of sea dumping at panels such as these.

Jim Carr commented that is it never a good idea to dump sea mines in this way (tend to get explosions). However, sea dumping in general, when it was carried out in the 1970s was a very technical process, and by no means a cheap option.

Adrian Wilkinson mentioned that it is not much cheaper that other techniques, although it is a lot quicker. It is important to deal with the reality of the situation, and not just treat it as an academic exercise.

3.2.3.3 Disposal of Energetic Materials from Munitions – Integrated Fluidised Bed Incineration Prof. José Campos, University of Coimbra, Portugal

Abstract

Many stocks of energetic substances can not be used because their durability is outdated or they are not within the minimal quality requirements. Most of these materials are from old munitions, from wash out process with heated water jets, or from operations of detection and seize of illicit energetic materials. Their integration as components in other energetic systems is often difficult.

There are different ways to eliminate energetic substances, ranking from their open air combustion or explosion to the transient storage in silos (until the stocked amount is enough to justify an incineration operation). Meanwhile, there is a certain inadequacy concerning the laws about the emission of polluting gases such as NO_x, SO_x and CO and solid ashes. Conventionally the solid energetic substances are traditionally classified in two groups, related to their normal regime of combustion – detonation for explosives and deflagration for propellants. The incineration of explosives and propellants in rotating kilns are discussed and commented. The method now proposed is to incinerate energetic substances using a fluidised silica sand bed (FBI), considered like one of the safest and reliable incinerating process that allows, not only the direct injection of water slurry of energetic materials (from wash out), but also the temperature control and residence time profiles during the incineration process. A FBI also allows a very good flexibility of incinerated mass amounts.

Portugal is a small country with only small amounts of missiles to dispose of. This presentation discussed the use of rotary kiln incinerators for their disposal, before introducing a new fluidised bed incinerator design which uses silica as a substrate.

Questions and Discussion

Zinfer Ismagilov: What was the energetic material used in the experiment?

Answer: TNT. There are problems when moving to emulsion derived materials. These cannot be used in the mining industry, since they have a very poor shelf life (one year).

Zinfer Ismagilov: The problem of feeding into fluid beds is an important one. What type of nozzle was used in these experiments?

Answer: Two types. Either inject liquid directly, or use a twin screw extruder. With the latter a tube is used to confine the twin screw. Bubbling is required inside the twin screw to prevent flow.

Joakim Hagvall: You say that it is cheap to build. Exactly how much would it cost?

Answer: It's very cheap. The cost of the main component is less than € 4,000. I can supply you with the drawings. So far 50 FBIs have been built, and are used mainly for direct applications, such as on board ships.

Jim Carr: It works with explosives such as TNT, etc. If it was to be tried with a composite explosive (which includes aluminium), will you get a eutectic composition produced? Would aluminium salts be formed as a by-product?

Answer: The process also works well with polymer bonded explosives (PBXs), since these generally contain a nitramine derived energetic material and a plastic binder (with a high carbon content). If metal is present, metal oxides are formed as the by-product. Work on these incinerators began in 1991. Many have now been manufactured.

Hiltmar Schubert commented that the efficiency of the incinerators depends upon particulate size. Because of difficulties Germany prefers to use rotary kiln incinerators.

Adrian Wilkinson commented that he failed to see the utility of the design. There is still the problem of removing the explosive before it can be used in the incinerator. Market forces dictate that it is easier to sell off the explosive as it is to industry. This method doesn't solve the main problem, which is getting the explosive out of the shells.

It was commented that FBI is not designed for washed-out explosives. It is designed for small amounts, were transportation is expensive, and there are issues with flexibility. FBI is small, and has excellent flexibility. It is very useful when using elicit materials, were there is no knowledge about what's inside (e.g., at airports). It's not meant as an industrial technique, but it fills a gap as part of an integrated solution.

Adam Cumming summed up the day's proceedings: We've made a good start and covered a lot of ground. The day's activities have started an interesting debate. We have to deal with the issues that Adrian Wilkinson has raised on what is acceptable in real life. We need to apply technology now available. Not just for 'old NATO' countries, but also those with specific legacy issues, and those attempting to modernise. It is important to learn how to 'clean up after ourselves'. This involves doing as much as we need, but *no more* than is sensible.

This can be summed up as a BATNEEC (Best Available Technology Not Exceeding Excessive Costs) approach, and avoiding CATNAP (Cheapest Available Technology Narrowly Avoiding Prosecution)!

3.3 DAY 2

3.3.1 Ways of Dealing with Problems: Contaminated Land – *Moderator Dr. Sonia Thiboutot (DRDC Valcartier, Canada)*

3.3.1.1 Introduction

For many years, DRDC Valcartier in Canada has been involved in the evaluation of the environmental impacts of the live-fire training to characterize and mitigate adverse environmental impacts on training ranges and thereby sustain the military activities. Over the years, many efforts have been conducted to assess the environmental loading of explosives at most of the major Canadian Forces bases. To date, these efforts addressed mainly heavily used target areas where contamination was though to be the most important. Many of these studies were conducted in collaboration with the US Army Corps of Engineers, Cold Regions Research and Engineers Laboratory (CRREL) in Hanover and Environmental Laboratory (EL) in Vicksburg. All this work was conducted to understand the fate of explosives in the training areas once deposited. It was understood from the very beginning that explosives are crystalline compounds and that conventional sampling and the existing analytical chemistry were inappropriate for the determination of the contamination by these compounds. Sampling strategies and the analytical chemistry were developed in collaboration between Canada and USA. Under the auspices of The Technical Co-operation Program, Key Technical Area (KTA 4-28), a protocol to address the characterization of explosives contaminated land was written to address these complex issues. This protocol can be found on the web at http://www.em-guidelines.org/.

Later, it was observed that the firing positions were also experiencing a build-up of energetic residues, and since then, a number of studies have been dedicated to the characterization of the firing positions. It was found that the firing positions are more contaminated than the target positions and that NG and or 2,4-DNT embedded in nitrocellulose fibers are the main contaminants deposited in front and around firing positions. Moreover, a common practice in Canada and in the United States is to burn excess propellant bags that are removed from the munitions to adjust the ballistic parameters directly on the ground following artillery training exercises. This practice results in an improper incomplete combustion of the propellants and therefore, has adverse environmental consequences. This practice is currently being assessed by DRDC Valcartier and Director Land Environment.

As a result of these findings, many efforts are currently done to assess and understand the contamination caused at the firing positions by all the military systems such as 105, 155 mm artillery guns, 105 mm tank gun, mortar, small arms, shoulder type weapons, etc., live firing. This understanding of the fate and behaviour of explosives at firing and target positions is helping us to find mitigation techniques and solutions to address the issues of explosives contamination in our lands. Finally, it came to our attention that the gunners often experienced headaches and other health effects after gun firing exercises. This resulted in studies that are now addressing the gaseous emissions, the particle size distribution and the health impacts of being at the firing positions during the live firings.

During this session, presentation of the Canadian and American programmes will be given to show the results that were obtained so far and to ignite the interest in countries where little work has been done to understand the explosives contamination. Studies of remediation of white phosphorous contaminated lands performed in Alaska will also be presented.

3.3.1.2 Energetic Constituents on Military Training Ranges: Deposition, Accumulation, Characterization

Thomas Jenkins, U.S. Army CRREL, USA

Abstract

The mass of propellant residues deposited when rounds are fired, and the mass of explosives residues deposited when rounds detonate have been determined for a number of different U.S. munitions. By far, the largest source of energetic residues occurs when warheads undergo low-order (partial) detonations. Rounds that detonate high order produce only minimal residues.

The accumulation of energetic residues has been determined at a variety of training ranges at both firing points and impact areas. The distribution of residues within impact areas can be described as a set of distributed point sources, largely at locations where low order detonations have occurred. Residues of

gun propellants are present at firing points, but the concentrations differ widely depending on the munition. These residues contain either nitroglycerine or 2,4-dinitrotoluene depending on the type of propellant. Residues from shoulder-fired rockets are much higher, particularly behind firing points due to the back blast from these weapons.

The total error for characterization of surface soil contamination at these ranges includes sampling error, sub-sampling error, and determinative error. Research has demonstrated that the largest sources of uncertainty are the inability to collect truly representative samples from the areas of concern (sampling error), and the ability to obtain representative subsamples in the laboratory (sub-sampling error). The use of multi-increment sampling within individual exposure areas, and pulverizing the entire sample prior to sub-sampling have been successful in minimizing these sources of uncertainty.

The aim of the study was to determine propellant residue at firing sites, and explosive residue at detonation points. Residue is deposited as finite particles and can be collected on snow. Low and high order detonations are observed. High order results in very little residue, whilst low order can produce significant amounts of residue. Ranges all over US and Canada were studied. Large NG deposits were found behind the firing line due to back blast from firings. On all the sites there was evidence of partial detonation of rounds, resulting in contamination. Most of this contamination was found at the surface, with very little at depth. Another major potential problem is migration of energetics off ranges in aqueous solutions. The presentation also discussed issues of obtaining truly representative samples.

Questions and Discussion

David Towndrow: Do you think there's going to be a point when we'll be able to predict the environmental impact of a particular weapon?

> **Answer:** We can do that just now for propellant. The problem with the delivery load, is predicting when low order detonations occur on impact areas. High order detonations can basically be ignored as they give off very few contaminants.

David Towndrow: Is there an aspiration within DoD for a sheet of paper for each weapon predicting the likely environmental impact of a weapon on ranges?

> **Answer:** Yes there is, although this is probably not feasible.

Narimantas Cenas: Have you detected any TNT derivates?

> **Answer:** Yes, sometimes in concentrations higher than the actual TNT.

Øyvind Voie: It would be really useful to be able to calculate the emissions to groundwater, but can you use the data to predict the risk to people directly exposed to the soil?

> **Answer:** It is a possibility, although it's not really been looked at yet.

Nico van Ham added that this is something the Netherlands have looked at. As well as the calculations, we have also given soldiers personal monitoring devices to establish what there are exposed to during exercises.

Narimantas Cenas: What was the maximal square analyzed for the explosives residues in the firing field? Did you analyze the dynamics of the explosive concentration in the soil?

> **Answer:** 10 cm to 1 hectare. No.

Nadir Serin: In the presentation, it was said that the residue of HMX is 100 times higher than TNT after the detonation of M72. It is known that the warhead consists of octol explosive, composed of a mixture of HMX and TNT. What is your opinion about the situation of finding 100 times higher HMX compared to TNT?

Answer: We think it's because TNT degrades very fast and is soluble in water. It therefore disappears quickly from the soil. HMX is less soluble and therefore accumulates.

Jim Carr: There seems to be a rather large concentration of TNT, even after detonation of the mortar. Was this a design fault?

Answer: This is caused by the high dud rate (40 – 50%) of this particular weapon which leads to rounds that break open upon impact and expose 100% of the octol to the environment.

David Towndrow commented that studies have been carried out in the UK. It was found that it depends upon the flight path of the mortar projectile. If the angle is such that it penetrates the ground, there isn't a problem. However, if it stays on the surface and remains exposed to other shells, then there can be a contamination issue.

3.3.1.3 Canadian R&D Programme on Environmental Aspects of Weapons
Dr. Guy Ampleman and Dr. Sonia Thiboutot, DRDC Valcartier, Canada

Abstract

Fifteen years ago, an R&D programme was initiated by DRDC Valcartier in collaboration with various national and international partners to evaluate the environmental impacts of military training. The main goal of our programme was to understand the various impacts of training with live weapons to find solutions to protect our environment, sustain operational military activities and maintain the readiness of our Armed Forces. Our main objectives were to evaluate the dispersion of munitions related residues at the surface of military live-fire training ranges and to better define the environmental impacts of detonation processes in live-fire and blow in place scenarios. Once deposited at the surface, the explosive residues can migrate towards groundwater and the geology and hydrogeology of major Canadian training ranges were studied to determine the fate and transport of these contaminants. Our programme involved also many other research topics such as the study of corrosion of unexploded ordnances, the leaching of explosives from cracked munitions that may contaminate various terrestrial and marine environments, the study of the biodegradability of various explosives and their ecotoxicological impacts upon many receptors as well as the bioavailability of metals and explosives. All these results gave directions for the development of new green weapons and also influenced the conduct of future live-fire training practices. This presentation will give an overview of the Canadian situation related to training and contamination by munitions related residues. It will also present the knowledge acquired over the years and its influence for the future of munitions development and live fire training in Canada and highlight the need for the development of a strong ecotoxicological knowledge related with munition residues.

The first part of the presentation was delivered by Sonia Thiboutot. This introduced the situation in Canada, and discussed the state of the ranges, sampling techniques employed, sources of contamination and work carried out. Initially the military were wary of scientists on their ranges. However, they now realise that the aim is to help the sustainability of the tasks carried out there.

Guy Ampleman gave the second part of the presentation which covered the issue of UXOs on Canadian ranges. Some are blown up. However, low order detonations can occur, which leads to contamination. In the past, munitions have been dumped off the coast of Halifax. No contamination has yet been detected in the sediment. However, UXOs are slowly corroding.

Demil was also discussed. There are no major facilities available in Canada. However, the Canadian Government does pay to install and support facilities abroad. A committee was recently tasked to review all options for Canadian demil both for the obsolete stockpile and for range scrap. Finally, future projects were discussed, such as 'greener' weapons design.

Questions and Discussion

José Campos commented that when you compare new PBX type weapons with older munitions, the newer grades contain a higher percentage of energetic material (i.e., less metal and more explosive). He also mentioned that RDX is less soluble when encapsulated by binders.

> **Response:** There are problems in finding binders to make the RDX completely insoluble. Eventually the RDX will degrade away from the formulations. Therefore, alternatives to RDX should be sought.

José Campos noted that to improve the environmental impact of PBXs, it is very important that we look at alternative binders.

> **Response:** This is correct. Current PBXs are not recyclable. This is a problem that needs to be looked at.

Nadir Serin remarked that in most PBX explosives, HTBP (Hydroxy Terminated PolyButadiene) is used. It is true that it's more difficult to recycle than conventional explosives. However, there are methods to recycle HTPB as discussed in the presentation of Prof. Zinfer Ismagilov.

> **Response:** Yes, I agree. Acidic hydrolysis can be done with HTPB polymer thermosets as described by Prof. Ismagilov. But it involves organic solvents less desirable than melting a thermoplastic elastomer and recycling it. Another aspect of recycling PBX-filled munitions is the difficulty of removing them from the shells. The Dutch scientists have used water jet to empty the shells, but it renders the polymer useless.

David Towndrow: Can you put an estimate on the extra costs of 'green' ammunition?

> **Answer:** It is difficult to calculate the cost. However, this has to be weighed against the cost of remediation and also the environmental cost.

Sonia Thiboutot commented that Canada is still very interested in international partnerships, and the issue of costs is something that has to be examined.

Narimantas Cenas: What effects of explosives on human health are you going to investigate?

> **Answer:** This will be examined by our expert colleagues, mainly the effects of the gaseous explosive residues. For example, Gunners have complained about headaches after using gunpowder. Negative effects such as these generate a public pressure, which leads to more studies being performed. We can measure what is in the gas, and pass on the results to medical experts who calculate the effects on the human body.

Hristo Hristov noted that new higher performance weapons will be inherently greener than previous designs. This is because they will be more efficient, with less shots being required.

José Campos agreed, adding that better explosives require less material for the desired effect.

Jim Carr: You mentioned that the failure rate of the LAW 72 was 50%! Do you really want to continue using it?

> **Answer:** In the past the Canadian Government made the mistake of purchasing the cheapest version of M72 available. It proved to be faulty, consequently leading to a high dud rate. This mistake will hopefully be avoided in the future, but at that time the only parameter for purchasing the weapon was the lowest cost possible. The dud rate and related future remediation costs were not put into the overall cost balance.

Jim Carr commented that sympathetic detonation of munitions is a standard NATO test. Information should be available on this. Jim also pointed out that in Sweden (BOFORS) they have produced green propellant which can subsequently be used as fertiliser.

Response: FOI invented this propellant. But it all depends upon what you define as 'green'. We have to use a systems approach.

Sonia Thiboutot agreed with a point made by Jim Carr: If done properly, on the correct components, open detonation can sometimes be the greenest approach in dealing with surplus energetics.

3.3.1.4 Remediation of a White Phosphorus Impact Area Marianne Walsh, ERDC, USA and Environmental Assessment of Open Burning and Open Detonation Michael Walsh, ERDC, USA

Abstract

Chemical residues from ordnance detonations have potential adverse ecological consequences in addition to any threats to human health. One United States Army training range was closed in 1989 due to the suspicion that high explosives (HE) residues were poisoning ducks and swans. Sampling of the impact area did not detect HE residues but did reveal the presence of another munition, white phosphorus (WP). Detonation of projectiles containing WP, an obscurant, in the shallow ponds of the wetland impact area left sand-size particles of WP that were subsequently ingested by dabbling ducks. A few milligrams of WP are lethal to waterfowl and thousands of waterfowl were poisoned. As a result of these findings, the army suspended training with WP at all impact areas that have wetlands. Once the cause of the waterfowl mortality was identified, the impact area was reopened for training with HE and illumination rounds during the winter months when ice cover prevents disturbance of the underlying sediment. Investigations of the extent of the WP contamination and remediation activities took place during the summer. In the early 1990s, the distribution and fate of WP were studied and potential remediation and monitoring methods were tested. In 1998, temporary pond pumping was chosen as the most effective and least destructive remedial option. As of the summer of 2007, all the large ponds have been decontaminated and waterfowl mortality is low (25 waterfowl carcasses were found in 2006 when the estimated waterfowl population was 4,500). Current issues are the reopening of the impact area for year-round training and methods to deal with unexploded ordnance that contains WP.

There are two major issues with open detonation and disposal of munitions and propellants: Environmental contamination and the availability of significant quantities of high explosives, both resulting from incomplete consumption of energetics during the disposal process. In impact areas, unexploded ordnance is addressed in two manners. It is either rendered safe or detonated. Both processes are considered blow-in-place operations. A detonation procedure will consume most energetics in a high-order explosion. In a render-safe operations, the breached round detonates low-order and significant quantities of explosives remain. On demolition ranges, the disposal of munitions can occur in a more controlled manner. In the United States, munitions are typically detonated using an external donor charge, a block of C4 explosive. This is known as open detonation, and if conducted properly, little residue will remain. However, large quantities of C4 have been found on demolition ranges, indicative of the inefficiency of unconfined detonation of high explosives. Another method used in the past for both propellants and munitions is open burning. When used with munitions, breached and ejected rounds occurred, and the fuel used for burning often soaked into the surrounding soil. This method is rarely used today because of environmental concerns. Open burning is still used for propellants. Even when done properly, the deflagration process is incomplete, and if done improperly, raw propellant will be scattered from the burn point. This talk summarizes findings from tests conducted on various ranges and environmental and security issues arising from munitions disposal.

The first presentation dealt with contamination at Eagle River Flats (part of a range in Alaska). This contamination resulted in a large number of bird carcasses being discovered. Initial thoughts were these deaths were being caused by RDX. However, further analysis proved the presence of White Phosphorus (WP). WP can persist indefinitely as a solid underwater. However, if it is warm and dry enough *it will sublime to non-toxic phosphate species. Drainage was conducted in the worst contaminated area of the wetlands and has proven quite successful as a remedial action.*

Questions and Discussion

Guy Ampleman: Are the ducks still dying?

> **Answer:** Some of them are, in the small, marshy areas. However, the frequency of deaths has decreased following the remedial actions undertaken.

Guy Ampleman: Could you till the land to remove the contaminated layer?

> **Answer:** We considered this, but because of the presence of UXOs, this would have to be carried out remotely.

Peter Courtney-Green commented that in Azerbadjan WP munitions are currently a big problem. There are tens of thousands of UXOs covering land, resulting in a hugely contaminated area. A project is currently running to try and solve this problem. He mentioned that Mrs. Walsh or any interested Workshop attendee would be more than welcome to come along and observe.

Jim Carr: Would Red Phosphorous produce the same toxicity as White Phosphorus?

> **Answer:** No. It is very insoluble in water. Any toxicity is due to the presence of WP as a contaminant.

David Towndrow added that in addition, the Red Phosphorus disperses differently to WP, with smaller lumps formed.

David Towndrow: When DoD realised that there was a problem with WP, did they want to ban it outright, or did they consider that although a problem existed, it was one that could be managed on the ranges by using the correct procedures?

> **Answer:** WP is banned from firing in training areas with wetlands. However, it is still part of the US arsenal, with no current plans to change that.

Michel Lefebvre commented that in Belgium a mobile detonation chamber is used to dispose of WP, and the process works well.

Øyvind Voie: Is it possible to use models to predict the time for WP to disappear without remediation?

> **Answer:** If the area dries naturally, with high temperatures it can remediate itself. However, if it remains saturated then the problem will persist.

Michael Walsh's presentation dealt with the issue of OB/OD from a US perspective. How these operations affect their surrounding environment. Two specific recent studies were mentioned: OD of 155 mm projectiles, and OB of propellant.

Peter Courtney-Green commented that OB/OD is sometimes unavoidable. It is often done badly, leading to contamination and to injuries as well. Therefore we need to minimise its use, and also offer better training to the operatives.

Guy Ampleman: What would you recommend to always achieve high order detonations?

> **Answer:** It is important to have the donor charge directly beside the round, because shock propagation results in detonation. Also, don't remove the fuzes so the rounds are more efficient when they do detonate.

Jim Carr added that it is important not to pile up mortar charges when burning them.

> **Response (from David Towndrow):** The UK looked at burning propellant. There is some temporary environmental damage and some chemicals are left behind, therefore we try and minimise as far as possible. However, it is important that we continue to have the option of burning locally. The alternative of having to move large amounts of potentially dangerous propellants creates a huge safety issue.

Michael Walsh commented that mobile burning boxes might be a good solution to this problem.

David Towndrow responded that in the UK there are lots of relatively small testing areas dispersed around the country. Therefore it would be difficult to make this technology available everywhere. Therefore it is not cost-effective. The important issue is to get better at the actual burning process.

Larry Nortunen commented that in the US if munitions are returned in bags, it has to be treated as hazardous waste. Therefore we always make sure that burning pans are used. It is not complex technology, but works well as long as the metal is thick enough (clay liners are used for particularly hot explosives).

Michel Lefebvre: Are underground detonations used in the US?

> **Answer:** Not to my knowledge. I can see how it'd be a more efficient process, but unlikely to be an option taken up by the US military.

Nico van Ham added that in the Netherlands the bags are placed in 30% water and moved to a central location where they can be dealt with. It is a cheap and easy way to deal with the problem. The water can be burned off in the incinerator, leaving little contamination.

Sonia Thiboutot ended the session by commenting that Canada is very open and willing to collaborate/share information on this issue. You are welcome to visit and observe some of the research being carried out on our ranges. Also, the strategic environmental R&D programme (SERDP) is a useful source of information and potential funding in this field. She mentioned that the next SERDP symposium was scheduled for early December and to visit www.serdp.org to seek more information.

Richard Martel provided a document giving details on the study of energetic materials (EM) transport under unsaturated/saturated conditions at the active anti-tank range Arnhem (see Annex B).

3.3.2 Demilitarisation/Disposal and Counter-Terrorism: Round Table Discussion – *Moderator Nadir Serin (Defence Industries Research and Development Institute, Turkey)*

3.3.2.1 Introduction

There is a security problem with surplus weapons and ammunition. The cost of keeping surplus items in secure buildings is high. Many surplus items haphazardly stored in depots that are poorly designed and maintained. Surplus items are vulnerable to theft and diversion. Low cost disposal methods can be attractive. The method of reduction of surplus weapons/munitions should be well planned based on international liabilities on counter-terrorism.

The remaining dud munitions at hot regions are another problem. Millions of UXOs are located in hot regions of the world. After the 2006 Israel-Lebanon conflict 1,000,000 unexploded explosive ordnance (UXO) were left in Lebanon according to U.N. Problem is proportional with munition's "Dud Rate". The possible terrorist use and environmental impact of these UXOs is a question mark. The use of self-destruction mechanisms can reduce the size of the problem.

There is one more problem related with dud munitions at training ranges. Many dud munitions dispersed on the training ranges. The use of munitions for training which completed their life cycle increases the number of duds in ranges. Training ranges covers large areas. There are difficulties in avoiding trespassing.

Dumped munitions at sea bed can create another serious problem. Many munitions have found in the past in the sea by fishermen, pipeline layers, etc. Many hand grenades, mortars, etc., found at beaches. Especially explosives enclosed by found munition can be in usable condition. Dumped munitions are open to terrorist access.

Nadir Serin began with a few slides to aid discussion (see Annex B), whilst stressing that we shouldn't feel bound by them. After introducing the issues, he asked Drahoslav Hagara to start the discussion.

Drahoslav Hagara began by saying he was very glad that this discussion was taking place. He pointed out that the previous presentation given by Michael Walsh did in fact answer some of these questions. Others have now also been answered with previous discussions at NATO meetings between industry and the EOD community.

With regards to the questions that Nadir Serin raised:

Does development of low cost disposal technologies help?

> **Answer:** Yes.

What about possible terrorist use and environmental impact of these UXOs?

> **Answer:** This is really a question of the skills and competencies of the UXO officers responsible. Also, can they transport these munitions safely? In general the answer is yes. International help is also requested and given when required. The priority is always security, followed by the environmental effect.

Could self-destruct mechanisms be a solution?

> **Answer:** Yes, but only obviously for newly designed weapons. This may be a question of future international conventions.

Do training ranges need to be secure?

> **Answer:** Yes they do.

Hristo Hristov was then asked to comment: Bulgaria doesn't have this problem. The biggest problem is in the technical aspects of demil.

Adrian Wilkinson added that SEESAC have a CD which shows the costs of storage versus destruction or selling of munitions. In general if you hang on to them for 3 to 4 years, this will cost more than any of the other solutions.

Terrorists aren't stupid enough to use dumped munitions, when it is much easier to use alternatives or make their own. However, stockpiled munitions would be an attractive option to them. Another growing problem is with people breaking into stockpiles for the scrap metal available. Casualties have resulted from these acts.

Environmentalists need to be careful when interfering with humanitarian mine clearing operations. Often this can make matters worse. These areas need to be cleared quickly and safely, otherwise fatalities can occur.

On the issue of self destruction, it could be a solution. However, there is still a problem with high failure rates. Fail to safe mechanisms are being worked upon. However, for an EOD team this is not really useful since there is no way of knowing if it has worked or not. Therefore they will tend to err on the side of caution and blow it up.

Adam Cumming noted that UK policy is to be a responsible owner. Part of this is clearing up after yourself and managing the risk. Within the context of NATO this should also mean that it is in our interest to ensure that the munitions of those we operate with are as safe as possible. We also have to make sure terrorists can't get access to our munitions. However, they can still manufacture explosives such as TATP relatively easily. This would never be considered safe enough for military use, but for terrorists that is not an issue. More important is to reduce the temptation and manage the problem. It would be good to have a regional system that can handle the issue. Terrorism is real and will look for opportunities. We have to make sure that we don't give them these opportunities.

With regards to the potential use of dumped munitions, Peter Courtney-Green agrees that terrorists aren't stupid enough to consider this. However, large calibre ordnance is desirable to them. This has had a big impact in Iraq for example.

Hiltmar Schubert noted that there are lots of products that terrorists can use. Since they are not too concerned with either safety, security or performance their palette is huge. Mixing of materials to make explosives is straightforward, as long as you're not concerned about the stability. At this time we have no solution to this problem.

Adam Cumming responded that this underlines the issue. All we can really do is exercise good stewardship of those things which are under our control.

3.3.3 Ways of Dealing with Problems: Demilitarisation – *Moderator Joakim Hagvall (FOI, Sweden)*

3.3.3.1 Introduction

Under this part of the Workshop we discussed how the problem with disposal of munitions can be handled. This was made up of three very different presentations.

First out was Dr. Schubert who explained how Germany had done under their reunification. This was followed by a presentation of US demil capabilities and research. Last but not least was a presentation from NAMSA explaining how they handle demil in their programmes.

Summarising the whole thing is that the attendees gained a picture how it is possible to do demil. Probably the attendees have realised that there are several problems with demil. Demil today is not only a technical issue but also a policy and political question. There would be a consensus that we have the technology to handle most of our stockpile the only difference in opinion is which technology we should use. This difference seems to be based on the standpoint of why we do demil and to who we explain why we do demil.

Each of the presentation was followed by many interesting question and many of the debates was carried on for the whole Workshop.

3.3.3.2 German Demilitarization Experiences after Reunification
Dr. Hiltmar Schubert, Fraunhofer Institut – ICT, Germany

Abstract

The demilitarization of explosive material of the "National Peoples Army" (National Volksarmee, NVA) was the consequence of the reunification of Germany. There was no similar task in modern times belonging to the volume and diversity of munitions and urgency, because the ammunition depots in

Eastern Germany did not meet the western safety requirements. Following the time of reunification research and development actions have started and many experiences have been obtained. All scientific and technical results by these actions have to be evaluated by the conditions belonging to economic aspects and given environmental regulations. In this paper the general conditions of this disarmament are mentioned and main results and experiences are described.

Dr. Schubert began the presentation by stating that with each new generation the same problems are repeated. Therefore a plea to younger colleagues: please read the literature! This could save you time and money. Older generations were not stupid. There already exists lots of useful ideas for the solving of today's problems.

Demilitarisation after reunification had to be carried out as quickly as possible, due to safety concerns caused by the poor state of the munitions. Initially the German Government thought that they could earn money from the demilitarisation process. This turned out to be very wrong! Reports are available from ICT on studies from the early 90's.

Super critical fluid techniques were considered. These were shown to work. However, due to time and cost issues closed incineration was considered the only viable option. In Germany OB/OD has been forbidden since the early Nineties. Disposal plants have to fulfil the limiting values of the BImSchV. (OB/OD was only allowed for a short time after the fall of the wall.)

Recycling energetics is to be encouraged. However, in most cases this will only help to off-set the cost of demilitarisation (which can be the same order of magnitude as producing the munitions in the first place), rather than produce an overall profit. Also, it is important to engage with industry as early as possible, in order to ascertain if they'd be interested in purchasing the recycled products. You have to be sure that price and demand will remain high over an extended time period.

Finally, it is important to realise demilitarisation can be an expensive process. However, if the problem is ignored (as with Soviet legacy munitions), the munitions become less safe and more costly to dispose of.

Questions and Discussion

David Towndrow stressed the importance of making informed and appropriate decisions on the best demilitarisation process. At the end of the day it is not viable to spend large amounts of money on avoiding a negligible environmental effect. Where do you draw the boundary?

Joakim Hagvall pointed out however that the decision is not always in the hands of the person tasked with disposing of the munitions. It is a societal and political decision. In Sweden, the MoD is not allowed to do environmental harm, no matter how costly the alternative. For example, David's point in the first session about it costing £ 1 per Barmine for open burning of the munitions, compared with £ 13 per Barmine for processing in Europe, would not be an issue in Sweden. The MoD would have no choice but to go for the £ 13 option, if this was thought to be the more environmentally friendly technique.

David Towndrow pointed out that the carbon footprint also has to be considered, i.e., shipping munitions for processing results in extra CO_2 being produced.

Joakim Hagvall responded that at least by shipping for processing you're getting something back: explosives for reuse. This produces an overall reduction by benefiting another phase in the lifecycle. It is important to look at the overall system.

David Towndrow noted the problem initially highlighted by Hiltmar Schubert: As far as civil industry is concerned, the amounts of energetic material we can supply are trivial.

Joakim Hagvall pointed out that this is not always true. Quite often industries are very interested in the high specification products that the military can supply. In Sweden, the MoD cannot keep up with demand from mining industries.

Peter Courtney-Green stressed the role that experts like ourselves can have in influencing the political processes, in order to ensure that the decisions made are intelligent and informed. He also paid tribute to the work carried out in Germany, who led the way in Europe in terms of demilitarisation. The arguments made about market value are correct. However, it is important to note that they are specific for the country. For example, TNT and recycled RDX *do* have a market value in Eastern Europe.

José Campos: Do you think that demilitarisation in the future will cost more or cost less than today?

> **Answer:** It will cost more.

José Campos: Do you accept demilitarisation without physical confinement? i.e., is it possible to have open spaces in Europe for demil?

> **Answer:** Demilitarisation is a global problem. However, there are very strict regulations in place in Europe. You could argue that the very small amounts of contaminants produced from munitions aren't problematic in terms of global pollution. However, it is still a problem which has to be dealt with. It is important to consider the whole system (e.g., incinerator design, effects of transport). But because of the issues of degradation of the munitions, it is also very important not to take too long to decide.

José Campos agreed that it is a problem that we have to deal with ourselves. It will never be possible for European ammunition to be sent to Africa for disposal!

3.3.3.3 United States Munitions Demilitarization Priorities and Capabilities
Larry Nortunen, Defense Ammunition Center, USA

Abstract

The U.S. Army is the single manager for conventional ammunition. As such, the Army conducts the majority of the munitions demilitarization and disposal for all military services. The work is performed at army storage depots and manufacturing plants, and by commercial contractors. The presentation will characterize the US demil stockpile and US priorities for demilitarization, and will highlight existing capabilities for demilitarization and disposal of the components and materials generated from 105 mm high explosive cartridges.

In 1997 the US Army was made the single manager for conventional ammunition. This included: procurement, storage, service, demilitarisation, etc. There are eight major demilitarisation goals. These are:

- Reduce the stockpile;
- Emphasise closed disposal;
- Implement R^3 (Resource, Recovery, Recycle);
- Promote design for demil;
- Match demil execution infrastructure capability and capacity to execution requirements;
- Use strategic planning to guide operational action;
- Pursue, transition and integrate R&D technologies that close capability gaps; and
- Safety and environmental stewardship.

Reducing the stockpile is seen as a major aim. There are currently 0.5 million tons earmarked for disposal (that's approx. 1/6th of the total stockpile), with another 0.5 million tons not yet released, but likely to be destroyed in the near future. Before a munition is destroyed, other possibilities are always considered, e.g., reuse, refurbish, sell it or give it away.

Reliance on OB/OD has been reduced from 80% to 15%. Half of the demil budget goes to private industry, with half being spent on DoD owned plants. OB is seen as a very good option in *certain* cases, but not in others. For example, there is a ban on the use of OB/OD for chemicals such as tear gas, red and white phosphorus, etc.

The aim of demilitarisation in the US is to seek safe, efficient, environmentally acceptable processes. However, there is no 'silver bullet', and it is always likely to be an expensive process (although there may be one or two cases were it is possible to break even). Also, we still retain the authority to use OD to dispose of items unsafe to move.

The presentation ended with an invitation to attend the 2008 Global Demilitarisation Symposium and Exhibition. This will take place 5th – 9th May, Salt Lake City, Utah. (email: mcal.td-functions@conus.army.mil). Last year 400 people attended, with 13 countries represented.

Questions and Discussion

Guy Ampleman: Have you considered chemical neutralization versus a flashing furnace to remove explosives residue from projectiles? (less costly)

> **Answer:** Not currently in use at depots on plants. They use the most cost effective methods, and have chosen not to use chemical neutralization. In some cases they work with industry smelters to accept the projectiles without decontamination, as long as the removal process was relatively efficient.

Jim Carr offered that there are incinerators that process munitions and use the heat energy (from afterburners) to flush materials at low or no costs.

Michel Lefebvre: What is the status of cryofracture technology?

> **Answer:** R&D at McAlester's Army Ammunition Plant (AAP). Expect to go live in 2008, to process ADAM mines: Mines are loaded in 155 mm projectiles. Liquid nitrogen cryogenic bath, crush mines in press, separate epoxy body (with DU salt hardener) from kill mechanism, then incinerate kill mechanism. It is a very difficult mine to demil. Items such as M42 grenade and bomblet would be easier to process. They are also hoping to get a process for converting propellant to fertiliser online by 2009.

Peter Courtney-Green commented that there are currently four operational cryofracture plants in Europe.

Jim Carr: Incendiary projectiles (20 mm) will/may not function in a deactivated furnace (incinerator). How do you destroy these devices?

> **Answer:** Incendiary projectiles are currently an identified closed disposal "capability gap" in the US Army Joint Munitions Command. They could be open detonated.

David Towndrow: Comment. At USA Demil Symposium, China Lake distributed a CD with demil capabilities for select processes, including alternatives, costs and waste streams. I think this would be a good model for comparing/selecting best practices (see Annex B).

> **Answer:** I'm not aware, but will look at it and include in development of our "Technology Trees". We expect to have system available at next year's Global Demil Symposium in May 2008 at Salt Lake City, UT. I will also look into making MIDAS component/constituent on-line database available to the international community.

Larry Nortunen ended by supplying a document which described some US demil capabilities in slightly more detail (see Annex B).

3.3.3.4 Management of Surplus Munitions – The NAMSA Approach
Peter Courtney-Green, NAMSA, NATO

Abstract

NAMSA supports pollution prevention in its demilitarization business by applying common standards to demil contracts in NATO and PfP countries, and by requiring maximum recovery and recycling. Recycling is important because it produces waste streams that can considerably reduce the overall cost. However, there is no point recycling materials that have no value if that adds to the cost of the process.

Several demilitarization companies have come and gone in the last 15 years or so. The remaining companies that are able to handle large scale environmentally responsible demilitarization programmes are in Germany, Norway, Sweden, France, Italy and Spain; and to a more limited extent, UK. NAMSA also does demilitarization business with demilitarization centres (all are government agencies) in Albania, Serbia and Ukraine.

We have also been working with the Turkish Ministry of National Defence to build and equip a new ammunition demilitarization factory in Anatolia. This factory was designed and built in less than 2 years in a project managed by NAMSA. The project was driven by Turkey's need to dispose of its anti-personnel landmines stockpile by March 2008. The processes involve the maximum degree of automation, with munitions and parts being moved from station to station by robotic arms. Plant and machinery exist for disassembling and sectioning munitions in a variety of ways.

A Turkish designed system with 10 autoclaves is capable of removing TNT based fillings from projectiles of all calibres, producing TNT flake as the end product. The only imported plant is an armoured rotary kiln explosive waste incinerator that was manufactured in the USA. This is of the standard APE 1236M design.

The facility was formally opened on 8 November 2007. The first priority will be destruction of Turkey's 3 million anti-personnel landmines.

The explosive industry is governed by a plethora of legislation at national level, plus regional and local permits and licences. At the supra-national level the most significant legislation is the European Union Directive dealing with emissions to the atmosphere from the incineration of waste. NAMSA incorporates this legislation into its demilitarization contracts for all contracts awarded in EU countries. NAMSA also aims to achieve similar standards in contracts awarded in Partnership for Peace countries, although strict adherence to these standards is not always possible.

An apparent contradiction is the Nammo NAD company in Norway, which uses chambers deep underground to detonate HE-filled munitions. The gases generated by these detonations are drawn to the surface through tunnels and chambers dripping with moisture that act as a natural gas scrubbing system. Readings at the surface confirm that the quality of the air emerging from the mines after each detonation is in line with the EU Directive (although the directive does not apply to such a process).

The explosive waste incinerator installed at the ULP-Mjekës factory in Albania as part of a PfP Trust Fund project has a dry air pollution control system based on an afterburner, gas cooler, cyclone and fabric baghouse. This EWI was running continuously (24/7) for 18 months, destroying up to 10 million small arms cartridges every month.

Similar incineration systems are installed in demilitarization factories in Germany, France, Italy, UK and Ukraine. The armoured rotary kilns are very similar, but gas scrubbing systems vary widely, with both wet and dry scrubbers able to reduce the off-gases to suitable levels to satisfy the EU Directive.

Metals such as iron, steel, copper, brass, tin, lead and tungsten are increasingly valuable and can all be recovered and recycled for peaceful commercial purposes. Examples are recasting the iron bodies of fragmentation mines as manhole covers; converting steel shell bodies into reinforcing rods for concrete; recycling TNT into explosive charges for civil construction; using guided missile containers as water reservoirs; and recycling the plastic bodies of anti-personnel landmines into children's toys.

Most recently in Northern Azerbaijan an area cleared of unexploded ordnance has been ploughed and planted with onion seed, and the area will soon be enriched with fertilizer made from reprocessed rocket fuel at another project in Southern Azerbaijan.

The latest cause celebre is the movement to ban cluster munitions (generally known as the Oslo Process, with Norway leading the movement). There must be some doubt as to whether this will ever have the same almost universal acceptance as the movement to ban anti-personnel landmines, since cluster munitions are so much more effective than single point detonating munitions. However, it is likely that most countries will acknowledge the need to replace first generation sub-munitions with more reliable, self sterilizing sub-munitions. A number of countries are well on the way to realizing this, and NAMSA has contracted for the demilitarization of a wide variety of air dropped and gun fired cluster munitions. The most significant of these is a contract for the destruction of the UK and Netherlands stockpiles of MLRS M26 rockets.

Peter Courtney-Green presented on the activities of NAMSA: NATO Maintenance and Supply Agency. NAMSA is a non-profit, non-loss making organisation within NATO.

Recycling for its own sake is a pointless exercise, unless it is in some way profitable. All demil activities under NATO are done under competition. The lowest bid which meets the pre-determined requirements will be the one chosen. However, to achieve the lowest bid it is likely that some form of recycling will be required.

European directives concerning incineration of waste are incorporated in NAMSA demil contracts. Germany led the way in installing industrial scale incinerators which are compliant with these laws.

The rest of the presentation dealt with specific examples of demil facilities available within the European community. For example, Nammo's underground facility in Norway, and the new industrial scale autoclave facility built in Turkey, for the recycling of flaked TNT. In the Ukraine anti-personal mines are manufactured into children's toys, in the same factory! France has very good facilities for the conversion of WP into phosphoric acid (which is then sold to the soft drinks industry!).

European demil industry:

- Norway: Nammo NAD;
- Sweden: Nammo; Vingåker;
- Germany: Nammo Buck; ISL; EST;
- UK: QinetiQ;
- France: Alsetex;
- Spain: Faex;
- Italy: UEE Italia (Maxam); Esplodenti Sabino;
- Albania: ULP-Mjekës; KM-Poliçan;
- Serbia: TRZ Kragujevac;
- Turkey: Kirikkale; and
- Ukraine: Pavlograd; Donetsk; Shotska.

(Presentations on some of the available capability in Germany had been given at a meeting at ICT, and are included in Annex B.)

If munitions are in sufficiently large quantities then it becomes affordable to invest large amounts of money in its demilitarisation. The profitability is also affected by the market price of any recyclable products. Demilitarisation will not make money. However, the use of R^3 can help reduce costs considerably (by at least 30%).

Questions and Discussion

Jim Carr: What happened to the MLRS propellant?

> **Answer:** The propellant was incinerated. Not an ideal solution, but it's not cost effective to recover the 18% aluminium content of the propellant.

Guy Ampleman: What is the recovered TNT used for? Mining or military applications?

> **Answer:** It's mixed for slurry explosives for mining and quarries. It's not suitable for military applications.

Nadir Serin: We saw M42 ammunitions demilled using the cryogenic method. Why didn't they use a cheaper method as with the disposal of M77 bomblets?

> **Answer:** These two demil tasks occurred at different times. Different companies have different solutions. It is driven by industry not Government.

General Discussion on the Day

Larry Nortunen reported that the previously discussed MIDAS database is currently only releasable to US Government and US Government contractors. However, in the future they wish to make it available to the international community.

Peter Courtney-Green added that NAMSA have access, and may be able to pass on information to others. He also stressed the importance of everyone who has an interest in demil, attending the annual Global Demil Symposium.

David Towndrow highlighted the fact that no one technique is a suitable solution to every scenario. It is important to analyse your arisings and match this to the best available technologies and capabilities.

Adam Cumming commented that changes have to be discussed in partnership with industry, but they should not be solely driven by them. There are many things which industry is good at. But for stewardship and planning for the future, this is something which needs to driven by long-term thinking within Government.

It is also important to realise that we are dealing with a moving target. What is acceptable, changes on a regular basis. Germany dealt with the problem well with the resources they had available at the time. We need to be able to offer other solutions if the political and public perception changes. This requires the knowledge to offer proper advice. We also need to work alongside our Eastern partners, helping each other and offering alternative ways of thinking. It is important to question our own assumptions.

Peter Courtney-Green agreed that it is Governments who have to set the bar. He also made the point that because of the level of detail contained in MIDAS, only the US could afford to run it.

David Towndrow also pointed out the importance of careful interpretation of the data available on MIDAS. We need experts to do this.

Larry Nortunen responded that it's best to think of it as a planning tool. The munitions in question can change however. It's a good starting point, but at the same time you need to appreciate its limitations.

Adam Cumming agreed, pointing out that in the UK pyrotechnic components can vary depending on when they were produced, even though the manufacturing process is suppose to be exactly the same!

Peter Courtney-Green commented that one of the major problems in demilitarisation of ammunition is that often there are no records available. Fortunately a huge amount of expertise has been built up in industry in ascertaining what's inside munitions.

José Campos noted that building a capability requires a large investment of time. The US are very good at keeping their institutions (such as Lawrence Livermore Laboratory), and therefore their knowledge base. However, in Europe this is much more difficult because of privatisation of the institutions. Often this knowledge is lost.

Joakim Hagvall stated that we need to ask ourselves: why are we doing all this? To many, environmental issues are a new and strange entity, which is evolving very fast (e.g., climate change over the past 15 years). The problem we are handling is not the environment, but rather how we deal with the stockpile.

Peter Courtney-Green pointed out that stockpiles do actually affect the environment in a very direct way: they eventually blow up! There have been many fatalities associated with stockpiles over the years. There are enormous stockpiles across Europe, and we are not yet nearing the end of the problem. Many countries haven't even started dealing with the issue yet! Therefore there are still huge challenges ahead.

Nico van Ham commented that one of the main aims of demil is to remove risk to people. If we have the choice of an environmentally sound, and also safe technique then we should go with this option.

Jim Carr pointed out that in Bosnia an OB/OD facility was built. Local people went to court to block its use, and won!

Peter Courtney-Green responded that this shows it is not just Western Europe where people are concerned about environmental issues, and able to voice their opinions.

David Towndrow responded that this also highlights the importance of arguing our case to the public. We need to show them that in certain situations there can be serious consequences if we don't deal with problem munitions quickly.

Adam Cumming stressed that the technical argument is only part of the issue. It may be very good, but it might not convince. Therefore we need to have other options.

3.4 DAY 3

3.4.1 What Must be Done Now and in the Future: Technology Gaps – *Moderator Prof. Hristo Hristov (Rakovski Defence and Staff College, Bulgaria)*

3.4.1.1 New Energetic Materials and the Future of Demil
Joakim Hagvall, FOI, Sweden

Abstract

This presentation will show the development in the field of new energetic materials and what situations we are facing with this new development.

New energetic materials and new munitions are becoming more and more complex. Before 1990 almost all new munitions had energetic who where TNT based, today this is rarely so. We face in the near future an increased variety of substances in energetic materials, this also increase the difficulty of disposal. An element in the total calculation is that these new energetic are much more expensive than the old. The cost for the new energetic can be measured in the order of 1000 times the energetic we used to use. At the same time defence materials are under the pressure of growing societal demands for environment considerations. We can no longer handle the munitions as we have done, we must take into considerations the environmental damage our materials does.

All of this combined makes the future manufacturing and disposal of munitions a real challenge for the whole industry. Unfortunately we will pay for our mistakes, the question is when will we pay and how much. Usually the longer we wait the more we pay. This presentation tries to look into the future so that we can avoid unnecessary costs.

Energetic materials currently being developed have to have reduced sensitivity and better performance than their predecessors. We need to ask the question why do demil? The key issue is safety. How it is carried out is determined in large part by economics. However, environmental concerns, legislative and societal demands are becoming more important.

To obtain IM materials the most common route is to use PBXs. However, this will create huge demil problems in the future, since these materials cannot be easily separated. Do we want to have future munitions designed to be easily taken apart? This has security implications.

Reuse of materials will become much more important in the future (due to legislative and economic reasons). In Sweden there is a very high demand for military spec TNT in civil industries. In the future, the high cost of new energetic materials will increase demand for reuse/recycling of these materials (this can help reduce the cost of demil). However, developing special techniques to recycle each new explosive composition is a complicated and expensive process. Sweden cannot afford to do all this by itself.

Life cycle thinking has to cover ‘cradle to grave’, and not just ‘gate to gate’. This is difficult to do because of all the information required. There are lots of complicated issues to consider. Are we focusing on the right parts? For example, most of a munition is made of metals. Their environmental impact is often ignored, even though metals are actually often much harder to recycle than the energetic material. In Sweden we are now moving towards ‘design for demil’. This is very important because in Sweden 98% of the stockpile is stored for a period of time, and then destroyed! In the future we are likely to move away from incineration as a disposal technique, due to the amount of CO_2 and noise pollution it produces.

There are ever increasing restraints put on our activities. Military needs are no longer considered as an exception to the rules. Environmental issues are becoming a major issue, and a costly one. When will we pay? It’s not enough just to focus on today’s stockpile, since this will only leave us with the same problem in 15 years time. We as authorities need to lead the way. We need to put limits on industry (since they will not necessarily like many of the changes which need to be implemented).

Questions and Discussion

Adam Cumming commented that it is important to consider the *whole* picture. ‘Cradle to grave’ is only part of it. The situation must be considered *before* the starting point, e.g., designing for disposal; redefinition of materials for other uses. ‘Lust to dust’ would be a better description! The overall package must be considered, e.g., performance, insensitive munitions (IM), lifeing, environmental. It doesn’t matter if we wish to stick with what we’ve got, because the requirements will change.

However, performance will always be the main requirement. Issues like IM and the environment will always just be *constraints* which effect our decisions. However, if we don't make an effort, then people with less of an understanding of the overall situation will make these decisions for us.

One of the other things we need to consider is that someone could use future weapon systems against us. How do we deal with this? We need knowledge, awareness, understanding and stewardship.

Peter Courtney-Green expressed surprise that environmental concerns are the number one issue in Sweden. This is definitely not true in most other countries. Performance will always outweigh the environment. Winning wars is the number one concern. If there is a choice between easier demil, or 3 cm extra penetration through armour, then the latter will always win.

We must be able to fight against any *unnecessary* restraints made against us.

David Towndrow pointed out that the UK would be unlikely to buy FOX-7 explosive if it was so expensive.

Adam Cumming responded that the UK is indeed considering it for certain systems. It might work out as the cheapest option when future environmental constraints are considered. Also, the cost of the energetic material is trivial when compared with other parts of the weapon, such as guidance systems, etc. But it is 'horses for courses'.

Hiltmar Schubert noted the need for a lightweight, carry-on system for detecting explosives. This is to help solve two important problems: First is the issue of mine detection. Lots of money has been spent on artificial devices, but still nothing completely practical. Demining could still be a problem in 100 years time! Secondly, there is a requirement for stand-off detection of terrorist explosives. We need a device capable of detection from 10 to 100 m away.

Nico van Ham pointed out that compared against the average lifetime of a munition, we are not involved in wars for long periods of time. We also have to make sure the personnel using the weapons are not exposed to unnecessary chemical risk. New green munitions may be a little more expensive. However, by using them you gain the benefit of spending fewer resources on cleaning up ranges, producing a cost and safety benefit.

Serge Secco agreed with this point on cleaning up of ranges. France is developing greener ammunition. Since most ammunition is fired on ranges, clean-up is a big problem in France.

Nico van Ham further commented that in the Netherlands, contaminants were found on ranges open up to the public. Therefore there is a duty of care to improve the land. Also, lots of people involved in disposal of munitions die prematurely of cancer.

David Towndrow believes that any response must be informed and proportionate. Sometimes if a potential problem is found on a range, clean-up is not necessarily the best option. If a risk assessment is carried out by a responsible and experienced individual, a decision could be made that clean-up is not necessary (e.g., if no receptor can be identified). This can save resources, better spent on situations were a problem does exist.

Adam Cumming responded by saying that whilst this is true, you have to be careful and look at every situation individually. There is a danger of arguing yourself into doing nothing. You do whatever is appropriate.

David Towndrow answered that in the UK scoping studies are carried out on the inventory. It's not a case of doing nothing, but it needs to be manageable and appropriate.

Sonia Thiboutot commented that one range in Canada has been successfully remediated. It's feasible, but a very costly and tricky process. The best approach is to try and alleviate any problems, to avoid/lessen future costly remediation of ranges.

The world is getting smaller. Hopefully countries can begin to learn from each other's experiences. We also need to try and reduce our stockpiles, keep it simple.

Marianne Walsh pointed out that protecting our drinking water should be a major concern. We also need to protect our land from environmental damage (since this is where most of our weapons are fired). If we don't do this, what are we fighting to protect?

Nadir Serin stated that there are three parts to the problem: short, medium, and long term. In the short term we have huge stockpiles to destroy. We would like to do this in as environmentally friendly a manner as possible. However, many countries have different ways of doing this, with different viewpoints on what's important. TNT was the past explosive of choice. As Sonia Thiboutot pointed out this is actually the best 'green' explosive in use at this time (since it disappears easily in the soil). However, in the medium term its use will decrease, as we change to PBXs for other considerations (e.g., IM). As Peter Courtney-Green pointed out performance is the main driving force for the military. We need to spend more resources on research into how to deal with PBXs in the medium term (say 20 years), in time for its demil. For the long term, a lot more research is required for future explosives. Developing new weapon systems takes a lot of time.

3.4.2 Poster Session

During the meeting three posters were displayed illustrating activities in the field. These are provided in the Annex B and abstracts are given below.

3.4.2.1 The Situation in Lithuania: The Studies on the Explosive Contamination, Their Toxic Action and Biodegradation

R. Černiauskas[a], A. Jagelavičius[b], A. Kutanovas[b], J. Šarlauskas[c], A. Nemeikaitė-Čėnienė[d,e], N. Čėnas[c]*

[a]Juozas Vitkus Engineering Battalion, Lithuanian Armed Forces,
[b]Ministry of National Defence of Republic of Lithuania, Vilnius,
[c]Institute of Biochemistry, Vilnius,
[d]Institute of Immunology of Vilnius University, Vilnius, [e]Military Gen. J. Žemaitis Academy, Vilnius, Lithuania

As the result of the WWII actions and the activities of the former Soviet Army in 1940 – 1990, ca. 250 km^2 in Lithuania remain heavily contaminated by the unexploded ordnance residues (Pabradė, Kairiai and Gaižiūnai firing fields, the forests of Kazlų Rūdos region, etc.). Besides, the unexploded devices (the aviation and artillery bombs, the infantry mines) are frequently discovered in the rural and urban areas of Lithuania even in the late 2000s. At present, the impact of this contamination on the ecological situation in these regions, as well as the recommendations for the pathways of the explosive (bio)remediation remains to be clarified and elaborated. In line with this, since 1997 we have been carrying out the extensive studies on the mechanisms of the toxicity of nitroaromatic explosives in the mammalian cells, including the studies of the enzymatic reactions and the quantum-mechanical calculations. The obtained results (www.bchi.lt, www.imi.lt) show that the toxicity of the nitroaromatic explosives increases upon an increase in their single-electron accepting properties (oxidative stress-type toxicity). In turn, the rates of the biodegradation of the nitroaromatic explosives by *Enterobacter cloacae* nitroreductase and *E. cloacae* PB2 pentaerithrite reductase also increase upon an increase in their electron accepting properties pending the differences in the enzyme inhibition by the certain explosive substrates. These data provide some guidelines on the enzymatic pathways of degradation of certain new generation nitroaromatic explosives.

3.4.2.2 Assessment of the Impacts of Military Training on Soil and Groundwater at CFB Shilo, Manitoba, Canada

R. Martel[1], C. Gauthier[1], R. Lefebvre[1], G. Ampleman[2], S. Thiboutot[2], A. Gauvin[1], M. Parent[3]

[1] Québec University, Institut national de la recherche scientifique Eau, Terre et Environnement
[2] Defence Research and Development Canada (DRDC Valcartier)
[3] Geological Survey of Canada

Many activities of the Canadian Forces such as the firing of ammunitions, may lead to the dispersion of heavy metals, energetic compounds and other munitions-related contaminants in the environment. German and Canadian soldiers trained from 1977 to 2000 at CFB Shilo under the Canada-Germany agreement German Army Training Exchange Shilo (GATES). Different German and Canadian tanks, armoured vehicles and weapons were used, including MILAN missiles containing radioactive Thorium-232 (232Th) in their guidance system. Following the departure of German troops in 2000, an extensive characterization campaign was thus undertaken over a three-year period to determine the impact of training activities on water and soils in the training areas. Geological and hydrogeological investigations highlighted the vulnerability to potential contamination of the underlying unconfined sand aquifer. High metal concentrations (Bi, Cd, Cr, Co, Pb, Mg, Ni, Zn) were detected in the soils of rifle and grenade ranges, as well as low concentrations of energetic materials in the grenade range and in battleruns. Groundwater analyses revealed no indication of aquifer contamination with metals or energetic materials. Finally, low thorium-232 concentrations (below 2.5 μg/L) were found in groundwater in training areas. The presence of thorium-232 outside and upgradient hydrogeologically from some training areas remains difficult to explain. This study served as a template for other studies on military training areas and helped ensure training grounds can be used in the long term without compromising the health and safety of military personnel, surrounding populations and ecosystems.

3.4.2.3 Canadian R&D Programme on Environmental Aspects of Weapons

G. Ampleman, S. Thiboutot, S. Brochu, E. Diaz and P. Brousseau, DRDC Valcartier
R. Martel and J. Lewis, INRS-ETE
G. Sunahara, P.Y. Robidoux and J. Hawari, BRI-CNRC
T. Jenkins, J. Pennington, A. Hewitt, M.E. Walsh, M.R. Walsh and S. Taylor, US Army CRREL and EL.

Fifteen years ago, an R&D programme was initiated by DRDC Valcartier in collaboration with various national and international partners to evaluate the environmental impacts of military training. The main goal of our programme was to understand the various impacts of training with live weapons to find solutions to protect our environment, sustain operational military activities and maintain the readiness of our Armed Forces. Our main objectives were to evaluate the dispersion of munitions related residues at the surface of military live-fire training ranges and to better define the environmental impacts of detonation processes in live-fire and blow in place scenarios. Once deposited at the surface, the explosive residues can migrate towards groundwater and the geology and hydrogeology of major Canadian training ranges were studied to determine the fate and transport of these contaminants. Our programme involved also many other research topics such as the study of corrosion of unexploded ordnances, the leaching of explosives from cracked munitions that may contaminate various terrestrial and marine environments, the study of the biodegradability of various explosives and their ecotoxicological impacts upon many receptors as well as the bioavailability of metals and explosives. All these results gave directions for the development of new green weapons and also influenced the conduct of future live-fire training practices. This presentation will give an overview of the Canadian situation related to training and contamination by munitions related residues. It will also present the knowledge acquired over the years and its influence for the future of munitions development and live fire training in Canada and highlight the need for the development of a strong ecotoxicological knowledge related with munition residues.

3.4.3 Meeting Conclusions and Recommendations

Adam Cumming began by commenting that we've had an exciting week. We've had a useful debate, hearing from both ends. We've dealt with both the present situation, and future options.

Adam Cumming then added that there was one question still be discussed, which is "Do we have the technology at the moment to deal with PBXs?" Yesterday we discussed problems with composite rocket propellants. The conclusion is that we have most of the technology available to deal with the munitions we have at the moment. However, the main issue is that not everyone knows what technology is available. *There is a huge communication problem!* We also need to understand the materials we're using, both old and new.

Drahoslav Hagara commented that he was glad Hiltmar Schubert raised the problem of detection. There is big overlap here between stopping terrorism and the environment. If we can detect all future ammunition, then we can solve this problem.

Adam Cumming added detection allows you to quantify the risk and not cause future problems.

What *is* the major issue? What exactly do we need to know?

Sonia Thiboutot commented that one of the things we need to agree on is what actually constitutes a green munition?

Michael Huggins (AVT Chair) pointed out that the purpose of the Task Groups within AVT is to explore the common issues. It is interesting this issue of lack of communication in certain areas. It might therefore be worthwhile exploring the next stage beyond a Task Group. That is holding a symposium on some of these issues (e.g., life extension, where is green going?). If a national interest exists then NATO tries and matches this to when AVT next visits this country.

Adam Cumming commented that a symposium might be a useful next step. Or we could set up another Task Group in a slightly different area (perhaps working towards a symposium).

David Towndrow asked if there were any other environmental Task Groups working within NATO at the moment?

Michael Huggins replied that AVT-115 is the only current one, although they do tend to come and go.

Adam Cumming noted that within the Munition Safety Information and Advice Center (MSIAC) there is a group working on environmental issues, although just as a limited subset of 6 or 7 nations.

Adam Cumming ended the meeting by thanking Hristo and his colleagues for hosting us. He also thanked Ulf Ehlert (AVT Panel Executive) for working tirelessly to ensure we got funding for the meeting and attendees. Thanks were also expressed to the rest of the AVT-115 Panel, and finally, to all the participants for attending, taking part, being interesting and argumentative enough to make it a useful meeting.

Hristo Hristov officially closed proceedings and also offered thanks to Adam, the RTO, Mike Huggins, Ulf Ehlert and the Bulgarian MoD and staff.

3.4.3.1 Recommendations

- Recommend a best practice solution for the disposal of today's weapons.
- Recommend best practice solutions for minimising environmental impact.

Chapter 4 – CONCLUSIONS, AREAS OF CONCERN, REQUIREMENTS AND RECOMMENDATIONS

4.1 CONCLUSIONS

After the review and extended meeting it was concluded that:

- OB/OD is not generally acceptable, though there are dissenting opinions and the use of amelioration technology is possible. *Note: Forensic studies have shown that residues do remain after detonation – these are used as court evidence. Whether these are meaningful in contamination terms needs discussion.*
- Technology exists for most current problems – current munitions can generally be dealt with, though EOD arisings may need special treatment and pyrotechnics can pose significant problems.
- Technology and needs are separated in many cases – e.g., the US has technology/information and it is needed in Georgia.
- Availability of surplus munitions must be considered as a target for terrorists as an easy source of materials.
- Surplus munitions can also be targets for terrorist action, which may trigger an event.

Further conclusions are noted below:

- Problems increase with time and therefore early assessment and action saves money.
- Legislation and restraints increase with time. Detailed understanding can assist all involved parties, including legislators, to shape legislation to meet real goals.
- Cost of environmental remediation and disposal is not normally considered in the definition and procurement of new munitions. It needs to be considered and factored into cost analyses for life management of new munitions and weapon systems.
- Environmental assessment and management methods are available and continue to develop, therefore information transfer and problem definition is urgently required. Education and support for the use of these tools within life management systems is also needed.
- Environmental assessment is needed for any new materials as part of formal qualification for service use. This could be a ‘spend-to-save’ issue and may make certain materials more desirable for use.

4.2 AREAS OF CONCERN

Areas of concern remain, such as:

1) Design for disposal is still an issue.
2) Greener munition technology is becoming available for application, but needs validation.
3) Definition of greener munitions is required.
4) Funding and knowledge transfer mechanisms seem to need improvement – these may require a better understanding of the need for mutual support and the benefit to NATO of sustaining and developing initiatives across the whole Alliance and Partners.

4.3 REQUIREMENTS

It is critical that NATO nations do not delay with disposal – this requires a co-ordinated national or NATO disposal plan.

It is also essential to provide/develop data for proper environmental assessments, linking this to the best expertise in NATO. Assessments should be effective and realistic – general NATO support may be required for this. It is clearly desirable that this be in line with STANAG development.

Finally, there is a need for the development of a central information centre – possibly using MSIAC or a similar body. There is also a good case for support of formal training to ensure information transfer – advanced Workshops to address this will also provide a benefit to NATO Partners.

4.4 RECOMMENDATIONS

The AVT-115 Technical Team recommends further work on the issues noted above. We propose the development of a Technical Team and the organisation of a Symposium with the aim of aiding communication and assisting in developing a forum for mutual education and support.

As an initial proposal for further discussion and development, the Team suggests the following topic – "*Munitions having minimal detrimental effect on the environment during manufacture, storage, use and disposal*".

The aim should be for all of NATO to have access to proven methods in order to minimise environmental impact – these will be based on available technology.

Chapter 5 – BEST PRACTICE RECOMMENDATIONS

5.1 RECOMMENDATIONS

NATO best practice will include applying the factors mentioned in Chapter 4. A realistic assessment of surplus munitions is necessary – this requires the following:

1) A regularly updated inventory of munitions with location.
2) Details of the components included within each type of munition.
3) Information on the hazard properties of the munitions with an indication of the history so that degradation/risk can be assessed.
4) A standard plan for range contamination management – including the handling of contaminated range scrap.
5) A maintained database (perhaps via MSIAC) providing analysis of risks and experience in disposal.
6) An independent agency (possibly NAMSA) maintaining and auditing contractors capable of disposing of munitions in a secure and acceptable manner in line with relevant legislation.
7) Technical awareness updates, for example through training courses, to ensure that best practice is maintained.
8) Counter-terrorism awareness to ensure control and prompt disposal.

There is a need to look to the future and to assess environmental impact which will require:

1) Access to research and technology on greener materials and their exploitation.
2) Design for disposal techniques for future munitions based on an accurate and cost effective assessment of life.
3) Support for assessment of environmental impact on ranges and in use, together with assessments of toxicity for users.
4) Training for assessments with independent support for this across NATO.

A consultant registry to provide support for all such activities is suggested and such activities could form part of the remit of such a body as NATO CASG/AC326. Training and awareness will be essential to maintain the ability to assess and to respond to changing circumstances including perception and political pressure.

5.2 OTHER SUPPORTING MATERIAL

Throughout the meetings of the Team, various documents were provided or mentioned during discussions and it was considered that these should be collected as a further reference source. Annex C contains these documents and resources.

Annex A – PRESENTATIONS AND DOCUMENTS SUPPORTING CAPABILITY ASSESSMENTS

During the early meetings of the Technical Team several papers and presentations were provided in evidence to support the assessment of the technical state-of-the-art and to provide an understanding of the problems faced by NATO. These presentations are included for reference in this Annex.

1) Environmental Impact of Demilitarization *(in PDF format)*
   by Peter Courtney-Green

2) Demilitarization: Canadian Status *(in PPS format)*
   by Sonia Thiboutot and Guy Ampleman

3) Overview of R&D in Sustainable Training Programme *(in PPS format)*
   by Sonia Thiboutot and Guy Ampleman

4) Contamination of Soil on Sites Potentially Contaminated by Explosives *(in MS Word format)*
   by Fred Volk, Adam Cumming, Miroslav Horacek and Petr Mostak

5) DEMIL 2000 *(in PPS format)*
   by Richard Owen

6) Defense Ammunition Center – Technology Directorate – Demil Capabilities Matrix *(in MS Word format)*
   by James Wheeler and Larry Nortunen

7) Effects of Ordnance, Munitions and Explosives on the Environment *(in PPS format)*
   by Peter Eickhoff

8) Experiences Studying New Concepts for the Recycling, Reprocessing or Disposal of Explosive Materials / Munitions-Related Hazardous Components of The Former Eastern Army *(in PDF format)*
   by G. Bunte et al.

9) Munitions Dumped at Sea: A Literature Review *(in PDF format)*
   by J. Beddington and A.J. Kinloch

10) Disposal of Ammunition and Explosive Substances Specialist *(in PDF format)*
    by Spreewerk

11) Review of Demilitarisation and Disposal Techniques for Munitions and Related Materials *(in PDF format)*
    by Josh Wilkinson and Duncan Watt

12) NAMMO Presentation *(in PPS format)*
    by NAMMO

13) Characterization, Evaluation, and Remediation of Distributed Source Contamination (UXO-C) on Army Ranges *(in PPS format)*
    by Judy Pennington

14) Utilization Process State of Ammunition with Expired Storage Term in Republic of Bulgaria to 2005 *(in PPS format)*

    by Hristo Hristov

15) Experiences During the Disposal of Ammunition of the Former Eastern German Army NVA *(in PDF format)*

    by Gerhard Hubricht

16) SALW Ammunition Destruction – Environmental Releases from Open Burning (OB) and Open Detonation (OD) Events *(in PDF format)*

    by SEESAC

17) The Possible Mission NAMMO Video *(in MPG format)*

    by NAMMO

18) Demilitarization of Rockets and Missiles in the Czech Republic *(in PPS format)*

    by Marcel Hanus

19) Design for Demilitarisation *(in PPS format)*

    by David M. Stalker

Annex B – PRESENTATIONS, PAPER/POSTERS AND VIDEOS FROM THE SOFIA MEETING

This Annex includes all the presentations, including video clips, which were provided during the Sofia meeting and formed the basis for the discussions. It also includes posters that were provided as additional information during that meeting.

PRESENTATIONS *(in PPS format)*

1) NATO RTO AVT-115 – Sofia Meeting 12-14 October 2007 – Welcome

   by Adam Cumming

2) UK MoD Munitions Disposal

   by David Towndrow

3) CNAD POW DAT – EOD Introduction

   by Drahoslav Hagara

4) The State of Bulgarian Utilization Process in 2007

   by Hristo Hristov and Yancislav Yanakiev

5) Priorities and Experiences in Disposal Surplus Munition Materials in Georgia

   by Avtandil Dolidze

6) Development of Physicochemical Principles and Technology for Utilization of Large-Scale Composite Solid Rocket Propellant Charges

   by Zinfer Ismagilov

7) Investigation of Risks Connected to Dumped Munitions in Surface Waters

   by Nico van Ham

8) Disposal of Energetic Materials from Munitions – Integrated Fluidised Bed Incineration

   by José Campos, J. Gois, S. Almada, L. Duraes, A. Andrade-Campos and A. Portugal

9) Energetic Constituents on Military Training Ranges: Deposition, Accumulation, Characterization

   by Thomas Jenkins, Alan Hewitt, Michael Walsh and Marianne Walsh

10) Canadian R&D Programme on Environmental Aspects of Weapons

    by Guy Ampleman and Sonia Thiboutot

11) Remediation of a White Phosphorus Impact Area

    by Marianne Walsh and Michael Walsh

12) Environmental Assessment of Open Burning and Open Detonation

    by Michael Walsh

13) Demilitarization/Disposal and Counter-Terrorism

by Nadir Serin

14) German Demilitarization Experiences after Reunification

by Hiltmar Schubert

15) United States Munitions Demilitarization Priorities & Capabilities

by Larry Nortunen

16) Management of Surplus Munitions – The NAMSA Approach

by Peter Courtney-Green

17) New Energetic Material and the Future Demil

by Joakim Hägvall

POSTERS *(in PDF format)*

18) Disposal of non-Stockpile Ammunitions using Contained Detonation Chamber (CDC) Technology

by M.H. Lefebvre

19) The Situation in Lithuania: The Studies on the Explosive Contamination, their Toxic Action and Biodegradation

by R. Černiauskas, A. Jagelavičius, A. Kutanovas, J. Šarlauskas, A. Nemeikaitė-Čėnienė and N. Čėnas

MOVIE CLIPS *(in various formats)*

20) AblaufBomblett_neu.mpg

21) dscn0129.mpg

22) Fluidised_bed_formation.avi

23) Freeboard_flame_structure.avi

24) IR_flame_strucutre.avi

25) MOV00048.MPG

26) Oosterschelde_ROV.mpg

27) schnitt1.avi

28) schnitt2.avi

Annex C – SUPPORTING MATERIAL AND REFERENCE RESOURCES

Throughout the meetings of the Team, various documents were provided or mentioned during discussions and it was considered that these should be collected as a further reference source. This Annex contains these documents and resources.

CHAPTER 5 DOCUMENTS

Dissolved Energetic Materials (EM) Transport under Unsaturated/Saturated Conditions at the Active Anti-Tank Range Arnhem *(in PDF format)*

United States Munitions Demilitarization – Conventional Ammunition Demilitarization Capabilities *(in PDF format)*

CHINA LAKE DT DOCUMENTS

Evaluation of Alternative Technologies to Open Detonation for Treatment of Energetic Wastes at the Naval Air Weapons Station, China Lake, California *(in PDF format)*

Emissions from the Energetic Component of Energetic Wastes During Treatment by Open Detonation *(in MS Word format)*

OD-ECWChamberTests-Nov03 (Folder)

Final China Lake Report *(in MS Word format)*

Appendix A *(in MS Word format)*

Appendix B *(in Excel format)*

Appendix C *(in MS Word format)*

Appendix D *(in Excel format)*

Appendix E *(in Excel format)*

Appendix F *(in Excel format)*

Appendix G *(in Excel format)*

Appendix H *(in MS Word format)*

Appendix I *(in MS Word format)*

Appendix K *(in PDF format)*

OD-Metals-NAWCWD-TP8528-Mar05 (Folder)

Errata Sheets for NAWCWD TP 8528 *(in PDF format)*

Metals Emissions from the Open Detonation Treatment of Energetic Wastes *(in MS Word format)*

SEESAC USEFUL DOCUMENTS

Ammunition Stocks: Promoting Safe and Secure Storage and Disposal *(in PDF format)*

Ammunition Technical Assessment of Montenegro *(in PDF format)*

SALW Ammunition Destruction – Environmental Releases from Open Burning (OB) and Open Detonation (OD) Events *(in PDF format)*

EOD clearance of ammunition storage area explosions *(in MS Word format)*

Targeting Ammunition: A Primer – Chapter 8: Stockpile Management of Ammunition *(in MS Word format)*

Targeting Ammunition: A Primer – Chapter 9: Disposal, Demilitarization and Destruction of Ammunition *(in Ms Word format)*

UN GGE Policy Brief – Ammunition Depot Explosions *(in MS Word format)*

UN GGE Policy Brief – Disposal and Destruction *(in MS Word format)*

UN GGE Policy Brief – Liquid Rocket Propellants *(in MS Word format)*

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's References	3. Further Reference	4. Security Classification of Document
	RTO-TR-AVT-115 AC/323(AVT-115)TP/274	ISBN 978-92-837-0105-7	UNCLASSIFIED/ UNLIMITED

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14. Abstract

The environmentally acceptable disposal of surplus munitions has become a major problem for NATO and others. The NATO Research Technology Organisation carried out a study of the problems and tried to identify both gaps and possible research directions to fill these. It covered not only disposal but also land contamination and included a Workshop in Sofia in September 2007. The conclusions and recommendations will be outlined.

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