International Workshop on Munitions and Environment, Lillestrøm, Norway 14-16 May 2008

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Summary

The report is a summary of the International Workshop on Munitions and Environment that was hosted by the Norwegian Defence Research Establishment at Hotel Arena in Lillestrøm, Norway 14-16 May 2008. Twenty four participants from Canada (Defence Research and Development Canada and National Scientific Research Institute), Finland (Finnish Defence Forces Technical Research Centre and The Construction Establishment of Defence Administration), Norway (FFI and The Norwegian Defence Estates Agency), Sweden (Swedish Defence Research Agency) and The Netherlands (TNO defence), United Kingdom (Defence Science and Technology Laboratory, Porton Down) attended the meeting. The main objectives of the workshop were to gain knowledge of ongoing research in other countries, to facilitate a closer collaboration between the countries, and to agree on strategies for future collaboration. Topics that were discussed included environmental levels and distribution, toxicity and exposure, risk assessment and remediation of pollutants. The emphases were on explosives, metals and pyrotechnics. Acknowledgments are given to the organizing committee, which comprised of Dr Øyvind Albert Voie, Ms. Tove Engen Karsrud and head of department Mr. Kjetil Sager Longva from FFI.

Sammendrag

Rapporten er et sammendrag av "International Workshop on Munitions and Environment" som ble arrangert av FFI på Hotell Arena i Lillestrøm fra 14 til 16 mai, 2008. Det var i alt 24 deltakere fra Canada (Defence Research and Development Canada og National Scientific Research Institute), Finland (Finnish Defence Forces Technical Research Centre og The Construction Establishment of Defence Administration), Sverige (FOI), Nederland (TNO), og England (Dstl, Porton Down). Hovedmålet med workshopen var å få en oversikt over arbeid innen feltet "ammunisjon og miljø" i andre land, å stimulere til tettere samarbeid mellom landene, og å bli enige om strategier for hvordan man bør samarbeide. Temaer som ble diskutert inkluderte nivåer av forurensninger i miljøet, toksisitet og eksponering, risikovurdering og opprydningstiltak. Av typer forurensninger ble det lagt vekt på eksplosiver, metaller og stoffer fra pyroteknikk. Arrangementkomitéen bestod av forsker Øyvind Albert Voie, forsker Tove Engen Karsrud, og prosjektleder Kjetil Sager Longva fra FFI.

Contents

1 Introduction

Early winter 2008 the Environmental group, Department of Protection at Norwegian Defence Research Establishment (FFI) invited collaborating partners to an international workshop on Munitions and Environment. The main objectives of the workshop were to gain knowledge of ongoing research in other countries, to facilitate a closer collaboration between the countries, and to agree on future strategies for collaboration. Topics that were discussed included environmental levels and distribution, toxicity and exposure, risk assessment and remediation of pollutants. The emphases were on explosives, metals and pyrotechnics. Twenty four participants from Canada (Defence Research and Development Canada and National Scientific Research Institute), Finland (Finnish Defence Forces Technical Research Centre and The Construction Establishment of Defence Administration), Norway (FFI and The Norwegian Defence Estates Agency), Sweden (Swedish Defence Research Agency), The Netherlands (TNO defence) and United Kingdom (Defence Science and Technology Laboratory, Porton Down) attended the meeting (Fig 1). During the first day of the workshop, each country presented their research program and some of their perspectives in understanding the environmental impacts of use of munitions. This was to communicate current knowledge and status since the different countries and institutions experience substantial differences regarding legislation, environmental conditions and focus of interest. The second day was dedicated to teamwork in small groups to identify in more detail common knowledge gaps and how these could be filled. Furthermore, it was discussed how this could initiate new strategies for future collaboration. On the two last days, the workshop included a visit to the new training range at Rena, Regionfelt Østlandet.

Fig. 1 Participants of the Workshop (photo: Ms. Martel)

This report gives a summary of the workshop where the aim has been to identify main common interests and goals. First part gives a short summary of each presenter's reports which is followed by a section where the activities were systematized and main common fields of interest were identified. The second part summarizes the teamwork, which includes characterization and identification of important knowledge gaps and how this could lead to future collaboration. Four groups were established that covered different topics: I) Heavy metals in shooting ranges, II) Explosives in military ranges, III) Munitions in lakes and oceans, IV) Risk assessment and remediation.

2 National reports

2.1 National report from Canada (DRDC-Valcartier and INRS-ETE)

The perspective in environmental defence research at DRDC is to "understand and minimize the environmental impacts of weapons". Three main topics were outlined: I) environmental fate, II) impact of unexploded ordnances (UXO) and III) demilitarization.

2.1.1 Environmental fate

DRDC covers most aspects on environmental fate of munitions in their research, either in collaboration with national or international partners or at their own institute. This includes source characterization of munition contamination (protocols for site characterization and sampling strategy), fundamental data on fate of explosives (distribution in soil and water, dissolution kinetic, partition coefficient, transformation rate), hydrogeology (groundwater table elevation, modeling of aquifer flow and direction, surveillance programs and protection of sensitive receptors), biotransformation, bioavailability in humans and animals, and toxicological studies. In order to study environmental behavior of energetic materials and metals, they perform both laboratory studies and field studies. Models are developed in order to predict behavior of energetic materials in the vadose zone.

2.1.2 Impact of unexploded ordnances (UXOs)

UXOs is the most important source of contamination. DRDC investigates the fate of UXOs in the environment, which includes corrosion mechanisms in soil and water, lysimeter studies of cracked shells on top of soils and fate of underwater UXOs (water and sediment sampling for monitoring, biotransformation). They also investigate the use of C4 to destruct UXOs since it often spreads RDX into the environment and may lead to low order detonation that spreads even more explosives into the environment,

2.1.3 Demilitarisation and disposal

DRDC have ongoing projects that covers training area scrap management, handling of obsolete materials at their end life (small caliber munitions, explosives, gun propellants, rockets) and handling of old munitions. Canada is presently trying to identify the best technologies for Canadian demilitarization.

2.1.4 Future and ongoing projects at DRDC

Some topics were outlined as important projects: design of new sites/ranges, more research on geology, hydrogeology and soil corrosivity in connection with munitions, modify training practices, blow-in-place optimization and green munition development. High levels of gun propellant residues can be spread at firing positions and DRDC has initiated investigations on human health and air quality assessments.

2.2 National report from Finland (PVTT)

The Finnish defence forces technical research centre (PVTT) has ongoing projects on environmental effects of disposal of old ammunition in Finland. They are practicing open burning disposal (small caliber ammunition on steel plates), industrial disposal (melting and recycling TNT and metals), and open surface detonation. After open surface detonation several parameters are analyzed such as gaseous emissions (NO_x, HCN, NH_3, CO_x, volatile hydrocarbons), organic explosive residues and their conversion products (in soil and atmosphere) and metal emissions (Fe, Al, Cu, Ba, Cr, Ni) in soil, atmosphere, blueberry and spruce needle wax. This is performed in order to characterize the emissions and to evaluate the environmental impact of emissions.

2.3 National reports from Norway

2.3.1 Norwegian Defence Research Establishment (FFI)

The environment group at FFI is involved in several research and consulting activities covering most aspects of risk assessment and analysis of environmental effects of high energetic compounds and heavy metals, as well as remediation. Cost-benefit analysis and risk assessment make the basis for choosing effective corrective actions. Other activities involve development of environmentally friendly smoke grenades (mortars & howitzer), marine contamination of POPs, noise from firing ranges and effects of sonar on marine mammals. FFI has also, for the Norwegian military organization, developed an environmental management information system: The Norwegian Defence Environmental Database (MDB). Important research activities are testing of filter systems and soil additives (both small scale in laboratory and full scale in the field) in order to clean metal contaminated run off water from small arm shooting ranges; develop sampling strategies at shooting ranges and methods for chemical analysis of high energetic compounds; survey toxicological properties of munitions and metals for risk assessment purposes as well as doing exposure assessment of animals being at risk for exposure. Recently, a study on animals grazing behavior on a TNT contaminated area was initiated.

2.3.2 Norwegian Defence Estates Agency (NODEA)

NODEA is responsible owner and managing agency of shooting ranges and training areas on land and at sea. They are the agency responsible for safety and protection, occupational health as well as environmental management. NODEA aims to bring R&D results and knowledge into management plans for shooting ranges, develop suitable and cost effective methods for prevention of pollution, and coordinate research efforts to facilitate cost effective projects.

Current activities includes monitoring of heavy metals, WP in runoff water from approx. 60 shooting- and training areas, use of a field laboratory to investigate cleaning of runoff water from small field firing ranges and perform experiments with bullet traps, and back stop design and materials. NODEA also monitor biodiversity and measure noise and nuisance at shooting ranges.

2.4 National report from Sweden (FOI)

The background for the environmental research at FOI is the dumping of large amounts of military ammunition in old mine shafts, in lakes and along the Swedish coast line. The main research has been on TNT, which is one of the main components in Swedish military ammunition. The environmental group at FOI covers most aspects on risk assessment of TNT, which include analytical chemistry, environmental toxicology, microbiology, and geology and soil science. Much effort is done in establishing good sampling techniques in the field, modeling fate of TNT in sediments and soil, and transport of pollutants in the vadose zone. Another important topic is modeling of atmospheric fate of explosives residues in dust. FOI aims to extend the collaboration with universities and research authorities, especially on ecotoxicology and lysimeter investigations, in order to do more reliable environmental risk and fate analysis of e.g. TNT and Pb. FOI collaborates with several national and international institutions and is involved in international projects such as on remediation of fuel contaminated military sites.

2.5 National report from the Netherlands (TNO)

The background for the environmental research at TNO in Holland is the dumping of large amount of explosives after World War II along the coastline and at estuaries. In addition there are some shooting ranges where munitions are fired into waters. Beside that, the MoD is concerned about the health effects of explosive residues in training areas. TNO covers several aspects on environmental effects of explosives and have put much effort in understanding the fate of TNT and RDX. This includes risk assessment of munitions dumping, risk management consulting, environmental impacts caused by present defence activities in for example Lake Jsselmeer, and removal of munitions. Important topics are sampling techniques in target areas (soil and water), analysis of both energetic materials and metals. Much effort is put on RDX, which includes batch (aerobe and anaerobe) and column experiments to evaluate fate in different soil types, and soil stabilization with e.g. lime addition. TNO also does research on all aspects about green ammunition, which includes propellants testing, environmental impacts, cost, testing of bullets with different origin, analysis and risk assessment, and chemical analysis of content as well as ballistic tests. Future topics of interest are environmental fate and risk, life cycle analysis of tungsten, biological degradation of RDX, and dust emission from munitions use (environmental risk and composition). TNO works in close collaboration with national and international partners.

2.6 National report from the United Kingdom (DSTL).

The environmental assessment and management of environmental risks from munition use and disposal on military ranges in the UK is supported by a variety of stakeholders within MoD as well as industry and academia. Research to date has primarily consisted of desk studies and scoping studies to better understand potential contamination issues and to determine whether

there is a requirement for further in-depth research or field survey. Previous work has included reviews of US and Canadian research on the environmental effects of OME use at military firing ranges, the environmental impacts of OB/OD, the fate of phosgene in sea dumped chemical munitions, the environmental effects of white phosphorus, tungsten and perchlorate in the UK environment, and chemical weapon contaminated land. Current projects include a scoping study of possible ammunition contamination on DTE ranges and training areas (risk ranking and site prioritisation for further investigation), targeted land quality assessments of Salisbury Plain Training Area Central Impact Area and Bulford Rifle Range, an investigation of lead in the marine environment, a study of environmental corrosion of UXO, and a capability gap analysis for the environmental assessment of munitions.

Progress is now being made in the UK on issues of 'munitions and environment', although work is still required to gather more detailed scientific data and undertaken comprehensive in-field measurements.

3 Teamwork

Objectives of the teamwork were to characterize some important common knowledge gaps that should be filled in order to reach our goals, elucidate the differences regarding legislation, discuss environmental conditions and how knowledge gaps should be filled, and brainstorm different ways to collaborate on these issues. Four main topics were established: I) Heavy metals in shooting ranges, II) Explosives in military ranges, III) Munitions in lakes and the ocean, IV) Risk assessment and remediation.

3.1 Heavy metals in shooting ranges

Several topics were emphasized in the discussion, both as common challenges that we face in our work in order to accomplish proper assessments as well as important knowledge gaps. Common challenges appear to be lack of recognized protocols. This includes protocols for waste disposal (berms), soil remediation, maintenance (berms), soil and water sampling as well as good protocols for ecotoxicological testing and evaluation of human health effects. Shooting ranges face distinctive characteristics due to the heterogeneous distribution of contaminants. A number of knowledge gaps were identified. These included analytical methods for identification of different metal species and the most toxic metal species, research on bioavailability of different metal species and on factors (physical and chemicals) that determine mobilization and transformation of metals and metal species in soil. Literature is available on toxicity of lead and copper, but especially in Norway antimony run-off is regarded as a problem, and there is inadequate knowledge about antimony toxicity in order to do a proper risk assessment.

In some areas, animals are grazing in the ranges and little information is available about what they are exposed to in the ranges. Health effects of particle exposure, especially small size particles from shooting ranges, were identified as knowledge gaps. These include exposure through air and dust (both indoor and outdoor), levels of metals in air and dust of which users are

exposed, and wind dispersion and atmospheric spread. Leakage and spread of metals into run-off water and groundwater are common topics and there is a need for more work on method development in general to prevent leaking and spreading of metals (barriers, stabilization techniques, and filter systems). The development of cost-effective methods and protocols to reduce leakage is important as well as the development of cost-effective methods for soil disposal, reuse, and maintenance of berms.

To initiate collaboration, a good start would be to exchange information in order to identify specific common topics of interest. This could include an approach to standardization of some methodologies and collect site specific information about shooting ranges in a joint database. It was suggested that an establishment of joint web site could be convenient for sharing information. It was emphasized that reports should be written in English. Having regular workshops was considered important especially in connection with other meetings/conferences to reduce the frequency of travelling.

3.2 Explosives in military ranges

This group identified some main topics that included establishment of a common database on munitions, knowledge about deposition of propellant, sampling strategies to identify hot spots, and chemical analysis. There are no good databases on information about the content of different ammunitions. It was suggested that each country makes a list of the most used ammunitions including data on use and composition in order to develop a common database. In Norway a reporting system on ammunition use is established. Knowledge about deposition of propellant is lacking in addition to strategies for sampling techniques to identify depositions. It was stated that there is a need to compare methods and run common trials in sampling. Furthermore, to evaluate analytical methods of the propellants, it was suggested to exchange samples in order to compare and validate the analytical methods between the laboratories. Another topic was the development of different sampling techniques to detect hot spots. Some countries have ongoing project on this topic, which include detection with different hand held detectors and hyperspectral cameras, as well as with dogs. Exchange of experiences about these projects should be shared in the future.

Suggestions for collaboration included biannual meetings on selected topics (e.g. in connections with other meetings), exchange of samples for analysis, comparing methods, participation in field work, translation of national report-titles into English (or making English summaries), and exchange ecotoxicological information on energetic materials/compositions.

3.3 Munitions in lakes and the ocean

The group identified a number of knowledge gaps. Security aspects of dumped munitions should be investigated. There is a need to know the status of the detonators of various munitions in the aquatic environment as well as to assess the risk for terrorists reusing energetic materials. Concerning the environmental impacts, there is a lack of knowledge on dumping locations as well as on fate and transport of explosives and chemical warfare agents such as mustard gas. However, some information on impact from phosgene and mustard gas is available from UK. An

approach to fill these knowledge gaps would be to run a worst case scenario. This has actually been done in a report in English published by FFI. There is no information on how high risk sites should be handled. UXO in proofing ranges might have some of the same impacts. Worst case scenarios should be run as well as risk assessment on health and environment. Information on the chemical content of the munitions is critical. Suitable sampling methods should also be investigated.

Collaboration on a topic should start once it has been identified and specified. It should be possible to combine the trilateral agreement and the ANNC, but Finland and the US should also be included. The status of the bilateral agreement between Norway and Canada has to be checked out. It is important that publications and reports are written in English, and that informal contact between researchers is sustained. It is possible to decide now if there should be a meeting next year. The meeting should be combined with another regular meeting such as NATO meetings (e.g. Lisbon May 09). Another possibility would be to create a NATO AVT group to discuss these topics allowing all the countries to be part of the collaboration with reduced paperwork.

3.4 Risk assessment and remediation

Modeling migration of contaminants in soil, water and air is an important part of risk assessments. Better models should be developed that makes risk assessment cheaper and quicker. The possibility to create an integrated model for the fate of unexploded munitions related to risks in contaminated ground should be investigated. There is also a need for calculating the risk of exposure from heterogeneous distribution of contaminants. Bioavailability of explosives and current species of metals should be included in risk assessments. Investigations of different species occurring in different environmental conditions should be studied in more detail. It is important to agree on standard suitable ecotoxicological tests to be included in risk assessments. Other countries than Canada and US should take part in the development of ecological soil and water criteria for munitions related compounds in order to ease the burden of these countries. When it comes to remediation of munitions related compounds, there is a wide variety of technologies available. The challenge is to be able to choose the best suitable among them. Experience or studies regarding evaluation of these different remediation techniques would be appreciated. Studies from Norway indicate that antimony and its species are very mobile. Risk reduction seems also to be a problem since antimony escapes filters and soil amendment products. Therefore, it could be wiser to investigate the environmental chemistry of antimony, than developing risk reduction methods. Field ranges on bogs and marshes represent a problem. How can we remediate the bogs and marshes without ruining them? Furthermore, the substitution of weapons by green weapons is another type of risk reduction that should be further investigated. The group also asked whether it would be possible to establish a black list of compounds that we considered harmful to the environment and that these should be banned from munition formulations.

4 Summary of teamwork

4.1 Main topics discussed as important

The teamwork revealed several topics that were of common interest, and the countries representatives emphasized the importance of future regular contact to share information and initiate more collaboration. Below is a list of main topics that where discussed and regarded as important.

1. Environmental fate of explosives and propellants
    a. Distribution and levels of various remnants from munitions
    b. Properties in soil
    c. Degradation; biological and chemical
    d. Spread
2. Mathematical models on spread of metals and explosives
    a. Atmospheric spread
    b. Spread in vadose zone
3. Ecotoxicological data
    a. Screening methods
    b. Ecological Soil and Water Screening Levels
    c. Biouptake and effects in relevant organisms
    d. Effects on grazing animals
4. Exchange of information about content in different munitions
    a. Munitions database
    b. Information exchange standards
5. Standardization of methods
    a. Sample collection and preparation
    b. Chemical analysis
    c. Lysimeter studies
    d. Remediation
    e. Maintenance of ranges (e.g. berms)
    f. Ecotoxicological tests
6. Effects on human health and human exposure
    a. Exposure to airborne dust and particles at outdoor ranges (indoor?)
7. Green weapons/munitions
    a. Substitution
8. Metal pollution in shooting ranges
    a. Antimony
    b. Lead in marine environment
    c. Properties in soil
    d. Bioavailability

9. Shooting ranges placed at peat land and marshland
    a. Vulnerability
    b. Contamination and spread
    c. Remediation
10. Communication
    a. Exchange of competence and literature lists
    b. Publishing in English

4.2 Future objectives and points for action

There was an agreement between the countries that future Workshops on Environment and Munitions should be arranged. To make progress in further collaboration, all countries were asked to carry out the tasks listed below. Suggestions on mechanisms of collaboration would be appreciated.

1. Each country is asked to make a list of some of the topics mentioned in the previous chapter that you think would be suitable for collaboration in a way or another. Please suggest mechanisms of cooperation for each group (e.g. it could be an exploratory group within NATO AVT). Below we have made some proposals:
    a. “Chemical content of munitions”:
        i. “Development of munitions database”
        ii. “Standardization of information exchange for use in munitions databases”
    b. “Green weapons”
    c. “Ecotoxicity”
        i. Screening tests standardization
        ii. Soil and water criteria
    d. “Explosives”
        i. Fate, transport and exposure.
    e. We also suggest that an inter laboratory test program on analysis of explosives is established e.g. under the trilateral cooperation between Sweden, Canada, and The Netherlands.
2. Each country should make a list which summarize their competence
    a. List of names with CVs
    b. List of published literature/reports, which covers your activities
    c. List of main projects with main hypothesis and collaborating partners
3. The different countries should suggest time and place for next meeting on Munitions and Environment. Preferably in connection with another meetings or conferences. The workshop can be ahead of a NATO-meeting or e.g. the JSEM-conference and we should invite other countries as well (US, France, Germany etc).

A contact person should be appointed with a responsibility to follow up the matters.

Appendix A List of participants and programme

List of participants

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Programme for the international workshop on munitions and environment, Lillestrøm, 13-16 May 2008

Tuesday 13 May

19.00 Evening get-together-dinner

Wednesday 14 May

08.30 Welcome and introduction
(Kjetil Sager Longva, NDRE, Norway)

09.00 Presentation of participants (everybody)

09.15 National report from The Netherlands

10.05 Coffee break

10.20 National report from Sweden

11.10 National report from England

12.00 Lunch

13.00 National report from Norway

13.50 National report from Canada

14.40 Coffee break

15.00 National report from Finland

15.50 Concluding remarks and discussion
(Øyvind Voie, Kjetil Longva, Norway)

17.00 Time on your own

Thursday 15 May

08.30 Environmental research goals
(Øyvind Voie, NDRE, Norway)

09.00 Efficient international collaboration
(Kjetil Sager Longva, NDRE, Norway)

09.30 Working in groups
Group I: Heavy metals in shooting ranges
Group II: Explosives in military training areas
Group III: Munitions in lakes and the ocean
Group IV: Risk assessment and remediation

10.15 Coffee break

10.30 Working in groups

12.00 Lunch

13.00 Working in groups continues

14.00 Presentation of results from working groups
14.00 Group I
14.20 Group II

14.40 Coffee break

15.00 Group III
15.20 Group IV

15.40 Summary and conclusion

16.00 Bus leaving for the viking ship museum

19.00 Banquet at the national heritage museum

Friday 16 May

08.30 Bus leaving to the new training range at Rena

12.00 Lunch

15.30 Bus leaving from Rena to Lillestrøm

18.00 Return

FFI Forsvarets forskningsinstitutt
Norwegian Defence Research Establishment