Conference Proceedings 2013

European Conference of Defence and the Environment

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European Conference of Defence and the Environment

2013

Conference Proceedings

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FOREWORD

European Conference of Defence and the Environment took place in May 2013 in Helsinki, Finland and was the first symposium event in Europe that offered topics relating to environmental protection of military activities on a wider scale. The preparations for the event started in December 2012 which means that it was announced publicly rather late in the early 2013. Despite the late marketing it was able to attract participants from most European nations and several North American colleages as well. The total amount of participants exceedided 100 on both days and the conference provided 35 high quality presentations on environmental protection of military operations, small caliber shooting ranges, shooting and training areas, contaminated soil, environmental noise, environmental management and reporting.

This publication inlcludes short articles on most of the topics presented. In addition to high quality expert presentations, the conference had a motivational plenary session with political leadership (Finnish Minister of Defence Carl Haglund, Member of Parliament Pekka Haavisto), management of Defence Forces (Chief of Logistics, BG Timo Rotonen) and international organization (UNEP, Ivan Blazevic).

On behalf of the organizing committee, I want to warmly thank all the participants, presenters and everyone who helped this event to become reality on such a tight time frame. The success of this conference underlines the importance of environmental protection as a supporting action to sustain the mission. It is our belief that there is a need for such an event also in the future, maybe every other year and hopefully organized with a round-robin system with each European nation taking care of the preparations on their turn.

Matias Warsta

Editor

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SUSTAINABILITY OF SEMI-PERMANENT BUILDINGS IN INTERNATIONAL OPERATIONS

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Turkka Ehramaa's master's thesis in architecture on the subject of "*Developing building solutions for peace support operations*" was written in 2011 in Tampere University of Technology and financed by Construction Establishment of Finnish Defence Administration.

The thesis complements the Construction Establishment of Finnish Defence Administration's camp design guide by taking the focus from camp design level to building design level. The aim was to develop more efficient, more sustainable and better quality building solutions for military peace support operations.

Operations and areas of operation

Examination of Finland's past operations, focusing on troop numbers and the duration of Finland's participation revealed that there have been altogether 36 operations of which 16 have been considerable in terms of troop numbers, meaning that Finland has contributed at least a company (100-200 soldiers) to the operation. Of these 16 operations 8 lasted roughly a year or less. The rest lasted from 6 to 19 years, the 19-year operation being UNIFIL I in South Lebanon. An average duration of an operation was 6 years.

Climate conditions of past areas of operations were also studied by tabulating the average temperatures of central cities. Results were as expected: on the average it has been much warmer in the areas of operation than in Finland. The average heating season lasts only 2-3 months. Cooling season is dominant.

Lifespan of structures

The US Army in Europe has construction standards for different phases of an operation. The initial phase lasts up to 6 months and mainly tents are used. In the temporary phase, from 6 months to 2 years, tents, containers and SEA huts are used. The semi-permanent phase starts after 2 years and lasts up to 25 years. Containers, SEA huts, prefabricated and masonry buildings are used.

In the past operations Finland has mainly used tents and containers, which are meant for initial and temporary use. However, the average duration of an operation has been 6 years which creates a need for semi-permanent building solutions. Two goals were defined: The first goal was to develop a semi-permanent building with a lifespan of 20-25 years. The second goal was to make it easy enough to construct, so it could be built after 6 months.

Spatial concept

In international operations, as well as in ordinary housing and offices, most of the space is structurally simple, dry multipurpose space. Construction time is short, the risk of construction errors on site is low and the consequences of errors aren't serious. Therefore these spaces can be built or assembled from components on site.

Complementing spaces, such as sanitary and technical facilities have more complex structures and construction errors are usual even in ordinary housing. These spaces don't need to be multipurpose, because for example the need for sanitary facilities is constant. Therefore it's sensible to bring these spaces to the site as ready-made modules, for example containers. This is a very common procedure in many operations nowadays.

The properties of a space should match the function conducted in a space. For example, the sleeping quarters need to be cool enough for sleeping but equipment doesn't necessarily need to be stored in air conditioned space. To achieve this, spaces are divided into different zones. The spaces where people spend most of their time, sleeping or working, are to be insulated and cooled. However, the spaces that are visited only temporarily can be uninsulated. Common spaces, assembly areas, storages and passages are suitable to be placed in uninsulated space. The goal is to optimize the share of insulated interior space. By doing this construction and transport costs can be lowered, construction time shortened and energy consumption reduced.

The basis of the spatial system is the insulated module which is assembled from prefabricated components on site. 46,8 square meters of insulated space can be divided into 2-4 independent rooms, each with their own door and window. One module can house 4-8 persons. The modules constitute most of the insulated space in a system. Insulated and uninsulated space can be efficiently combined by connecting modules with a central passage. Complementing spaces, such as sanitary containers, can be connected to the building's facade by changing a wall panel.

Structural concept

For the structure of a sustainable temporary portable building there are two opposite solutions: the building could be constructed out of cheap natural materials and disposed after every operation. But often operations are short in duration and lots of resources would be wasted. There are also technical problems: it's hard to find a natural insulation material that works in every climate.

On the other hand, if the buildings were constructed completely out of durable and expensive materials, they should be cycled back to homeland for maintenance and redeployment. However, also transportation is very expensive.

The concept is a combination of the two opposites. Part of the structure is disposable and part is durable. It was concluded that complex structures and materials should be durable and simple structures and materials can be disposable. The insulation layer which has to work in both hot and cold climates and holds also the doors and windows, is technically complex and should be durable. The building's frame and its shell can be made of simple materials such as timber.

To achieve the division between durable and disposable materials, also the structural components were separated. The shell is the weather protection layer, the frame supports the building and serves as a roof and wall cavity. This enables a continuous insulation layer and the freedom to flexibly decide which spaces to insulate.

The idea is to cycle the durable materials, in this case EPS insulation panels, doors, windows and steel roofs and wall sheathings, from one operation to another. Disposable materials, in this case the wooden frame, wooden finishing and wall sheathings, can be left in the area of operation. This enables considerable reductions in transportation costs.

To save construction time and to minimize construction errors it is important to use prefabricated components. In this case wall panels, insulation panels, roof panels and roof trusses are prefabricated. Rest of the components, for example beams, are precut.

Transportation

The prefabrication, combining disposable and durable materials and using uninsulated space makes a big difference in transportation costs. All the structures of a 2 module building were modeled in AutoCAD and packed in virtual containers to assess how many 20-foot containers are needed to transport the building to the operation and back. According to the study, it takes 5,5 containers to ship a complete building to the area of operation but only 2,5 containers to bring the durable materials back to Finland. In comparison: it would require the shipping of 15 containers to construct a container building of the same size.

Passive cooling methods

5 principal methods of passive cooling were examined: Building orientation, shading of facades, cool roofs, window shutters and room layout.

Building orientation is the most important passive cooling method. It is the basis for almost all the other methods. The rule of thumb is that the long facades of a building should face north and south. This derives from the sun's path: sun rises from the east, reaches its peak in the south and sets in the west. Because of this, the east and west facades and the roof get the most solar radiation. It's also very difficult to shade them, because the sun shines from a low angle. Therefore it's good to minimize the windows on the east and west facades. Windows facing south are easy to shade with a overhang, because the sun shines from a high angle.

The roof of the building receives most solar radiation. Studies show that a white PVDF-coated steel roof reflects up to 65 % of the radiation and radiates up to 85 % of the absorbed radiation back to the atmosphere. Combined with a good roof cavity and insulation, the heat flow to the interior is minimized.

In a correctly orientated building the insulated modules form zones of different temperatures. The southern module is warmer and the northern module is cooler. When designing room layout three criteria should be considered: 1. activity / function 2. utilization rate 3. inner heat load. Rooms of temporary use, such as meeting rooms should be placed on the warmer zone.

However, windows cannot be fully shaded with overhangs. It is important to stop solar radiation before it reaches the indoors. Integrated window shutters protect the rooms from solar radiation, flying debris and noise. They can also be used to darken the room. The efficient use of window shutters should be instructed to the soldiers. For example, the shutters should always be closed when the room is uninhabited.

Building materials

The life cycle of a semi-permanent building is somewhat different from ordinary. The phases of the life cycle are similar but their effects on nature differ. In an ordinary building the operation and maintenance phase is the longest and consumes most energy. A semi-permanent building has a much shorter lifespan, which means that the manufacture of building materials and the demolition phase become equally important.

Energy consumption and CO_2 emissions of manufacturing the building materials were studied. Wood materials stand out as low energy materials. Wood stands out even more when CO_2 emissions are studied, because it holds carbon. As a result the goal was to maximize the share of wood. Wood constitutes almost two thirds of the building's weight.

Manufacturing insulation materials is very energy intensive. The insulation panels consume more than half of the total energy used for producing the building materials. Two insulation materials were compared: polyurethane and expanded polystyrene EPS. Manufacturing polyurethane consumes considerably more energy than manufacturing EPS. As energy intensive materials, the insulation materials have also high CO_2 emissions. EPS is again better than PU.

It was concluded that EPS should be preferred over polyurethane: although EPS panels are thicker than polyurethane panels with the same U-value, polyurethane weighs more and its manufacture consumes more energy.

Recycling

After an operation the disposable materials of the building are disposed in the area and durable materials are reused in the next operation after maintenance.

There are three processes of recycling: product, material and feedstock recycling. The last option is incineration, utilization of energy.

Product recycling should be the primary process. The durable materials of a semi-permanent building go through the product recycling process to the next operation and do not consume any more energy. Prefabricated wooden components, such as the wall panels, can also be utilized in this process by the locals. Wood works in all the processes of recycling. In the end the locals can use it for firewood. It can be concluded that the recycling process should be considered early in the design process to avoid waste problems.

ENVIRONMENTAL TOOLBOX FOR DEPLOYING FORCES

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The purpose of the toolbox is to provide a deploying military unit—specifically the commander, the environmental officer, and soldier/sailor/airman—a toolbox of environmental awareness training resources to plan and implement sound environmental practices. Sound environmental practices are force multipliers that will help:

- ensure mission execution
- protect the safety and health of deploying troops, host nation troops, civilian personnel, and local nationals
- facilitate coalition and international cooperation and interoperability
- promote efficient use of resources
- ensure legal compliance
- contribute to environmental protection in the deployment area and more generally raise environmental awareness in military operations, and
- foster good will with the local government and community.

The value and benefits of sound environmental practices notwithstanding, it is recognized that, in the event of a "*conflict*" between environmental considerations and the military mission, the latter takes precedence to ensure success of the operation. Equally important, when making choices on procedures and equipment to be used, it is vital to take a holistic approach, considering the full range of factors, to ensure the most feasible option is selected.

The toolbox of materials includes guidance, methods, technology information, and other resources intended to assist forces in planning, establishing and properly managing the environmental component of the military mission. The toolbox was developed by subject matter experts from Finland, Sweden, and the United States in 2011-2013. This work reflects a shared commitment to proactively reduce the environmental impacts of military operations, promote the efficient use of resources, and above all, to protect the health and safety of deployed forces. Two caveats about this material must be noted. First, while this effort was supported by the U.S. Department of Defense, the Swedish Armed Forces, and the Finnish Ministry of Defence, the materials contained herein do not necessarily reflect the official policies or doctrine of any nation. Rather, they represent the combined knowledge and ideas of the contributors, who have significant expertise in this area. Second, the information provided is meant only as guidance, and the authors recognize that different countries will have different rules for how environmental practices and policies will be pursued, to include how they might apply to contractors in a deployed location.

Why Environmental Considerations and Associated Educational Tools are Important

Prior to recognizing the need for environmental educational tools, it is essential to obtain buy-in that environmental considerations matter. As a first step, it is necessary to have command-level commitment to environmental considerations. At the highest level, the overall Commander establishes this commitment in his Commander's intent, the initial Operations Plan (OPLAN), and during various meetings where he provides senior commander guidance. He may need to identify requirements such as intergovernmental agreements to cover transboundary waste management. At the mid-level (e.g., regional headquarters), commanders may need to develop Operational Orders that implement the necessary Commander's intent and OPLAN environmental concepts specific to their area of responsibility. They need to understand the resources required (personnel, equipment, and money) to support the established environmental goals. They must also provide visible leadership support to the environmental program within their chain of command. The local (base camp) commander must similarly provide leadership emphasis, to include encouragement and enforcement of the environmental requirements. These commanders must secure the necessary manpower, equipment and funding through established channels. In the command chain, the lower the level of the commander, the greater the need for detailed knowledge, awareness, and understanding. Fundamentally, each and every person—from the commander to the lowest ranking soldier—who deploys in a military operation has an environmental responsibility. An appreciation for this responsibility is essential from the top down, although it is very helpful to have such buy-in from the bottom up as well.

The availability of appropriate awareness training tools leads to better environmental management practices at all personnel levels, but they do not currently exist in as complete or integrated manner as desired. While such materials are well developed in some countries, in other countries they are much less so. And in all circumstances, efforts to develop a more integrated approach across nations are welcome and needed.

Motivations for Creating This Toolbox

Under the umbrella of Memoranda of Understanding among the three nations, there has been an established, successful cooperation among subject matter experts from Finland, Sweden, and the United States on defense-related environmental issues. This toolbox is a companion to the Environmental Guidebook for Military Operations, developed in 2007-2008 as part of our trilateral cooperation program, and which is now being used in various national and international venues. To illustrate the fact that the toolbox is a supplement to the guidebook, this toolbox uses the cover design from the guidebook in the upper left corner of the slides in each of the modules. This supplemental toolbox seeks to fill a gap by suggesting common practices and offering practical guidance on environmental considerations for deploying forces. This coordinated effort to assemble environmental protection educational resources not only saves us all time and money, but also enhances future possibilities to:

- synchronize and harmonize procedures, thereby facilitating interoperability (including in international operations, such as those led by the North Atlantic Treaty Organization (NATO), the United Nations (UN), or the European Union (EU)).
- educate new personnel quickly and efficiently in these matters prior to deployment, and
- standardize environmental requirements and considerations in technical procedures.

Structure of the Toolbox

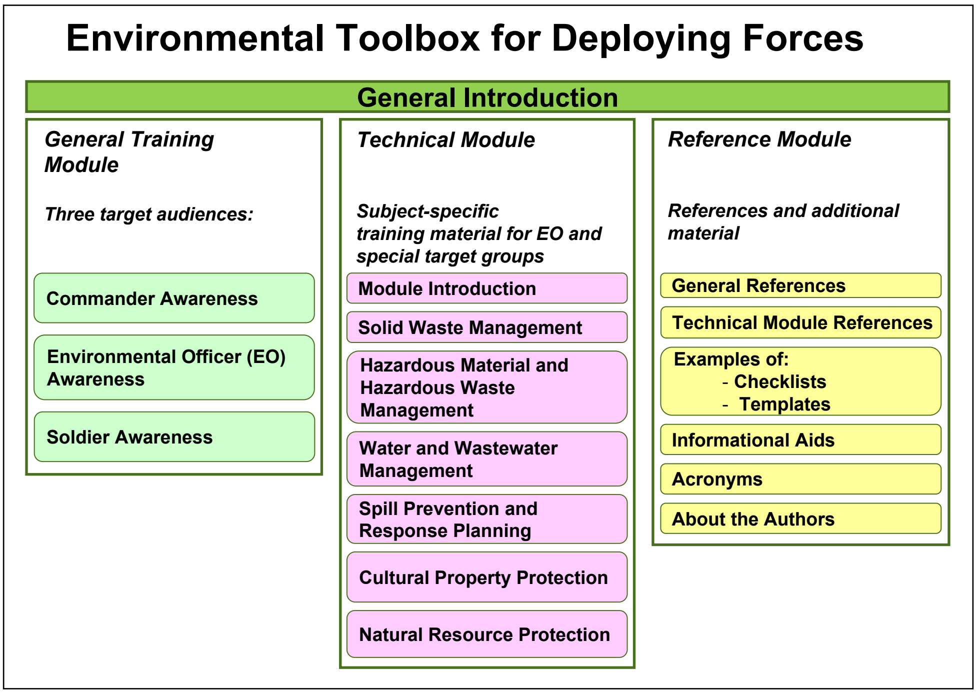
The toolbox is comprised of three main areas: a general awareness training module, a technical module, and a reference module, as shown in the figure below. Virtually all the briefing slides in the general awareness training and technical modules contain additional information in the notes pages to provide fuller explanations of the bullet points on the slides. Therefore, please be sure to view the slides in "*notes pages*" format. Also, while many of toolbox materials refer to the need to be aware of legal requirements, the underlying expectation is that the environmental officer will have at his/her disposal sufficient legal advice and expertise. It will be the legal staff's responsibility to determine issues such as whose environmental legislation and regulations prevail in given circumstances. It is simply necessary for the EO to know that legal staff should be consulted as appropriate.

The general training module consists of annotated briefing slides which are designed for three target audiences: commander-level, environmental officer (EO)-level, and soldier-level. The content of these briefings is tailored to the skill levels and knowledge requirements for each group. Thus, the commander-level training focuses on raising awareness, command responsibility for force protection and environmental management, communication, and legal issues. The EO briefing is more detailed, to include specific responsibilities and suggestions of ways to increase environmental awareness among the troops. Recognizing the variable background of those designated as an EO, for some EOs this briefing may be a useful refresher course, but for others it may offer the first insights into new and important duties. This briefing is supplemented by the materials contained in the technical module, as described below. Some of the EO-level training material can also be used to provide environmental protection training in specialist training programs, such as for logistics and transport forces. Finally, the training material targeted at the soldier/sailor/airman focuses on practical issues and raising environmental awareness through a number of examples of good practices and bad practices. These examples of good and bad practices are included in the EO briefing as well.

The technical module focuses on the following subject areas: solid waste management, hazardous material and hazardous waste management, water and wastewater management (both grey water and black water), spill prevention and response planning, cultural property protection, and natural resource protection. This technical information is for use primarily by the person who has the environmental protection (EP) responsibility, although there may be others who will find this information useful in particular circumstances.

The reference module offers additional materials from both international and national sources for each of the modules in this toolbox, which are based on the knowledge and research of the toolbox contributors. The references therefore do not pretend to be all-inclusive. Indeed, each user of this toolbox has the responsibility for checking other applicable documents, including his own country's laws and requirements. The reference module contains, for example, many documents generated by NATO, the UN, and the EU. It does not, however, promise to be fully exhaustive even for these international organizations. Another important component of the reference module is the technical documentation, which offers various templates that might be used (or adapted for use) in a given deployment. These include examples of Standard Operating Procedures (SOPs) and various checklists. Finally, the reference module includes a list of acronyms used in this toolbox and biographical information about the contributors to this toolbox.

Table 1: Schematic presentation of the toolbox



Caveats Concerning Use of this Toolbox and Its Scope

The toolbox is not intended to replace any national guidance or directives. Rather, it is intended to offer suggestions about the ways in which various countries might address environmental considerations in their training and education programs. The information offered here can be used either to develop or to enhance existing programs. This product, as with its precursor, is designed to be used by military personnel throughout the world. Thus, while we have drawn from our own nations' experiences and knowledge base, we have sought to develop products that are generic in nature and can be used either as is or can be tailored to fit a particular nation's specific requirements.

The information contained in this toolbox also does not seek to be comprehensive, but rather representative of the resources and techniques currently available. We have further focused our attention on techniques and technologies that are suitable to support up to 1,000 deployed personnel. The approaches adopted in a specific deployment will be affected by the number of troops and the planned duration of the deployment (factors which can certainly change over time).

Finally, we readily appreciate that training requirements for deploying forces are stringent and time is limited. We have therefore designed this initiative to minimize any additional time requirements, and have sought to identify ways in which some of these themes can be integrated into more traditional, already existing training and educational mandates.

Additional Environmental Factors to Consider

There are additional environmental considerations for deploying forces, more focused on management than on technologies, which are not addressed in this toolbox. While a detailed discussion of such issues is beyond the scope of this effort, at least a brief mention of some of them is merited.

In the pre-planning and planning phases, the potential environmental impact of a deployment can be minimized in several ways. First (and at least in some cases, the one requiring the longest lead time), is energy use. Enhancing the energy efficiency of overall operations can contribute to a reduced environmental footprint. For example, using less non-renewable energy—through more efficient insulation, the use of alternative energy sources, energy conservation, more effective energy distribution systems, etc.—reduces transportation and storage requirements, which can in turn help reduce the risk of spills and leaks. This is an important factor which is receiving more and more attention. However, to address the full range of energy considerations and how they can be reduced represents a stand-alone effort. While it is unquestionably a worthy endeavor, it is beyond the scope of this toolbox.

Second, adoption of different supply management techniques can affect environmental considerations. For example, reducing the amount of packaging used in shipping goods to the deployment area then reduces the amount of waste that must be treated or disposed of on-site. In addition to minimizing packaging, the potential for buying goods locally in the deployment area can be investigated. (Such initiatives must of course consider requirements of meeting necessary quality standards, reliability of suppliers, ability to supply the goods in the necessary quantities, and potential impacts on supply availability for the local community.)

Finally, in the planning phase, it is important for the decision-makers to at least be aware of environmental considerations when selecting the site for a base camp (recognizing that there are many factors to be considered in making this selection). Similarly, once a site has been selected, in the pre-deployment phase, it is important to integrate environmental factors into the camp layout. Once deployed, initiatives such as segregation of waste streams and recycling also come into play. These latter elements are, in fact, discussed in more detail in the technical module of this toolbox.

Availability of the toolbox and point of contacts

The toolbox will be published on DVD by the end of July 2013. The DVD will be available to all who have interest to the material. If one has a questions or other interest to the toolbox one should take contact to the following point of contacts:

- Finland Point of Contact: Sami Heikkilä at sami.heikkila@defmin.fi
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During the work we received very good comments from several reviewers. There were also many national experts who gave their valuable input to the work. That has helped us a lot to improve the quality and structure of the toolbox.

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RECENT BASELINE AND CLOSURE STUDIES OF INTERNATIONAL OPERATIONS

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Model for environmental surveys in Finnish Defence Forces' international operations has been developing for almost 10 years. Environmental division in Construction Establishment of Finnish Defence Administration (CEDA) has been sampling Finnish Contingent's (FINCON) camp sites since 2004.

In 2008 trilateral workgroup (FIN-SWE-USA) published "*Environmental Guidebook for Military Operations*" in 2008 which gives basic guidance to environmental surveys. Book lists topics which should be planned and registered to environmental logs when planning the operation, transferring sites to other contingents or closing camps. Latest Finnish camp closure reports were done in 2009-2010 in KFOR, Kosovo and now, spring 2013 Finland is sampling new camp location in UNIFIL, Lebanon. The Guidebook can be downloaded from Ministry of Defence web pages (www.defmin.fi).

The main purpose for environmental surveys is to make an assessment about the environmental impacts of different activities inside the camp area. Report will be attached to legal documents, especially when the site is handed over to other contingent in the operation or local land owner. Environmental baseline studies (EBS) must be done in the beginning of the use, so it is possible to separate contamination caused by FINCON or other users. At the same time it is also possible to evaluate the condition of local environment in general.

Environmental survey focuses on soil and water sampling. Air quality has not been monitored. Activities that can possibly contaminate soil are first mapped out. Also former activities (oil storages) or new, planned structures will be sampled before building the new structure. After years of use the sites will have baseline results which are useful when later assessing the soil and water quality.

Surveys in Kosovo 2009-2010

In Kosovo, Camp Ville was built by FINCON in 1999 on a former paper factory site. Same area was also used as a municipal water plant (Lipljan commune, 16 000 inhabitants) and all the groundwater wells were located inside the camp area. Wells were about 11-17 meters deep and the soil type in the area was sandy till. This type of soil prevents contaminants (oil products) to seep in to groundwater.

Because the Camp Ville area was used by a local paper mill the site was full of paper and plastic waste, the area was categorised as industrial site, not residential. Area was cleaned by FINCON before Camp Ville was built. Camp Christina was built on a governmental farm site from the 1950's. Camp Christina, which was of a rather small size, was located a few kilometres away from Camp Ville, in Suvi Do village. Both sites were handed over to UNMIK (United Nations Interim Mission in Kosovo), which continued the work with the sites and made contracts with their legal owners.

Several areas in both camps were sampled and many of these locations were found contaminated by oil products. Sampling took place near power machines, old and present fuel stations, fire training area, parking areas, abandoned vehicles area, vehicle washing areas and possible landfills in embankments surrounding Camp Ville. Some oil contamination was found on the site and a recommendation for clean up was given and oily soil eventually removed before FINCON left the areas.

During the two environmental surveys also local heavy metal concentrations in soil were studied. Natural heavy metal levels are higher in Kosovo than in Finland. Also industrial fallout had caused higher metal concentrations in topsoil. There was mining activity, ferronickel smelter and lignite burning power plants in the vicinity.

Mining lignite and operating lignite power generation plants is a major air pollution source in Kosovo. Kosovo's proven lignite reserves are the fifth largest in the world and are significantly more abundant than any other lignite source in the Balkans. Power plants are located in Obilic about 15 km north-northwest from Camp Ville. The NewCo Ferronikeli smelter is a metallurgic complex (smelter and three open-pit mines) that produces commercial ferronickel. The plant is one of the largest nickel smelting and mining operations in Europe. Plant is located in Drenas/Glogovac, about 15 km northwest from Camp Ville. Iron (Fe), nickel (Ni), cobalt (Co) and chromium (Cr) are expected to be present in the air.

Soil samples were taken from natural locations where there had been no activities or buildings. Natural concentrations and fallout effect was also discussed in the report, because contamination guidelines were taken from the Finnish legislation. It is not possible to follow Finnish guidelines, if natural concentrations are higher. Also cleaning the site should not take place by sending nations if the area is contaminated by local industry. Concentrations in Kosovo samples are compared to Finnish guidelines in Table 1. Highest concentrations were found in top 10 centimetres.

Table 1: Heavy metal concentrations in Kosovo camps, compared to Finnish guidelines

	Camp Christina (mg/kg)	Camp Ville (mg/kg)	Finnish limit values: threshold, natural / lower guideline / higher guideline (mg/kg)
Cobalt	26-100	21-77	20 / 100 / 250
Chromium	130-290	79-1000	100 / 200 /300
Nickel	120-2900	89-1400	50 / 100 / 150
Lead	60-180	70-270	60 / 200 / 750

Survey in Lebanon 2013

The first environmental baseline survey report (EBS) is prepared this spring (2013). UNIFIL IRISHFINNBATT post UNP 2-45 is located in southern part of Lebanon, near At Tiri village, Israel and Blue Line. Report will be based on field survey conducted in March 2013.

FINCON will take host nation responsibilities from Ireland in the camp in November 2013. Ireland has been the host nation in the main post 2-45 and also smaller posts 2-46, 6-50 and 6-52. Area was built by France in 2007 and they left the site in 2012. There has been no known activity before 2007.

Post 2-45 is located on a high hill near Blue Line, which is unofficial border line between Israel and Lebanon. Post doesn't have own groundwater well. It has been estimated that water is about 850 meters deep. Even if the well would be drilled, nobody can be sure if there would be enough water for the camp use (500 soldiers). Water is now transported to all IRISHFINNBATT posts from Malesian post 6-40. This post was visited during the survey.

UNP 2-45 area is 22 hectares but about half of the camp is in steep hill. Several soil samples were taken from clean areas without any contaminating activities. Heavy metal concentrations were studied from different depths. Soil samples were also taken form areas where fuel station or parking areas were located. Some oil concentrations were found but results were not alarming. Interviews with local workers at the fuel station indicated, that spills or accidents may occur and the risk is quite high. Oil storages are underground and filling the storage on vehicles can be careless. Half of the fuel station is paved with asphalt and there is no oil separator for surface water.

Some parking areas with large oil spills were sampled just to find out the concentrations in these spots. Results were high, 10 – 17 000 mg/kg. One of the small bases near Blue Line had power machine fuel tank in a very bad condition. Tank was sampled from different sides and depths. Oil concentrations were remarkably high, almost 50 000 mg/kg. In fuel-related cases it is normal to have a clean-up guideline of about 1 000 -2 000 mg/kg.

Recommendations will be written about these found contaminated spots in IRISHFINNBATT posts. Power machine tank must be changed, soil removed and cleaned (e.g. composted). All risky activities must be handled with more care in the future.

Lessons learned

Surveys in international operations are more challenging than surveys in Finnish garrison sites. History of the camp site is sometimes unknown and background levels for metal concentrations can be higher than in typical Finnish soil. Also comparing the results to local environmental legislation or even finding environmental authorities, land owners and contractors or landfills can be very difficult.

Soil remediation processes should be standardized when applicable and legal requirements should be uniform for all sending nations in an operation. Also former users of a site should be held responsible for their contaminating actions.

Surveys are conducted in two or three phases, depending if there is a need for soil removal. First phase can be partly taken care by a desk study but inspection on-site with interviews must be included. List of conclusions is produced as a result from phase I and this will be the base for phase II: site survey. Final report is written after soil and water results from environmental laboratory are done. This might take a few months. Report includes also maps and pictures from the area.

Recent studies have shown that current preventive actions have not always been adequate and more protective structures should have been construted to avoid spills. Planning and implementation of standard operating procedures for handling of oil products, waste management or treatment of sewage water has to be improved. Local workers or companies should be audited if they are used for risky tasks (e.g. filling oil storages, hazardous waste demolition, sewage water treatment, waste management). Local conditions must be understood and following Finnish standards is not always feasible.

Taking soil or water samples in operations sets sometimes very different requirements than at home. Soil and groundwater conditions vary and may differ considerably from Finnish geology. The equipment such as drills used at home are often not available and almost everything has to be brought from Finland with the team. Even taking basic field equipment like XRF or PetroFlag to plane can be challenging with all paper work needed and even finding possibilities to freeze cold packs for samples is often difficult. Sometimes finding internet connection is impossible.

When sampling, the host nations population has to be properly taken into accord. Sometimes taking pictures of local people should be avoided and all discussions or interviews must be conducted politely respecting the cultural differences. It is important to try to avoid accusing local people during the sampling and auditing procedure.

HOLISTIC CAMP PLANNING TO ADDRESS THE CUMULATIVE ENVIRONMENTAL FOOTPRINT FROM MILITARY AND CIVILIAN ACTORS OPERATING IN THE SAME AREA

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This paper deals with a recently developed Center of Excellence (CoE) for camps and compounds. In particular it deals with the growing demand for sustainable compounds in peace operations and humanitarian action. Sustainability in this case refers to capacity and capability to sustain the mission as well as environmental, social and economic sustainability. A "*systems of systems*" approach is needed in order to address the complexity of complex issues encountered in the area of sustainable compounds. This holds equally true whether we discuss military base camps, peacekeeping compounds, refugee or IDP camps. What matters most is the cumulative footprint of many actors present in an area at the same time and in addition, over time.

Introduction

Peace operations[1] play a fundamental role in stabilizing conflict-affected regions.[2] However, their presence has inevitable environmental impacts on surrounding communities (Waleij et al 2011a, UNEP 2012, Hull et al 2009). This assumption holds equally true for the humaitarian community (Barrett et al 2007). As Sweden like many nations have decided to more closely link foreign, development, security and defence policies together in these efforts, the prospects of Sweden contributing to peace, security, democracy and development in the world, are assumed to consequently improve (Govt Comm.2007/08:51).[3] However, unless the environment are taken into account when excuting these high ambitions, history shows that failure is all too likely.

Deployed operations, regardless of thier nature, depend on local natural resources such as water, gravel and construction material such as timber to various extent. They also produce large quantities of solid and liquid waste and smaller, but still significant amounts, of hazardous waste, that may cause exposure risks to the local population as well as the deployed personell if not managed properly (Waleij et al 2011a, Waleij et al 2011b Martinsson et al. 2010a, Martinsson et al., 2010b). In addition, other unintended consequenses may occur, like negative impact on the local culture and the reciving nations's economy, or contributing to sexual exploitation and spread of HIV/AIDS (Hull et al 2009).

In fact, peace operations as well as their humanitarian counterparts, intended to bring security or relief to the recieving nation often leads to environmental and resource degradation, that can result in tensions and conflict with the local community, in particular in resource-scarce environments. Sound environmental management (due diligence) of operations and

1 For the purpose of this paper, peace operations is used as a unifying term to describe peace support operations, peace enforcement and peacekeeping operation as well as peace building. See St-Pierre 2008.

2 Peace operations (i.e. peacekeeping expenditure) have proven to be effective in reducing the risk of conflict reoccurrence by 70 % according to the Center of International Cooperation (2009).

3 Swedish involvement in international peace operations is ultimately intended to contribute to maintaining international peace and security and consequently to facilitate fair and sustainable global development. Underlying the strategy is defence of a number of universal norms and values, such as democracy, human rights, gender equality, human dignity and sustainable (i.e. social, economic and environmental) development.

camps/compounds directly contributes to the security, health and safety of the troops, civilan personell and displaced populations as well as reduces costs, and enhances the self-reliance of the camps. Unfortenately, in reality, such sound environmental management is far to seldom carried out in practice.

Problem statement

Military, peacekeeping, humanitarian, refugee and IDP camps are all similar with respect to several aspects such as some of the impact these camps may have on the host community and surrounding environment. However, they also vary greatly in other aspects, such as planning assumptions for several issues including water supply and waste production.

A recent example of an unintended, but a severe impact from a compound is the introduction of cholera to Haiti, as a result of lax waste water management in the aftermath of the 2010 earthquake (Liljedahl et al., 2012). The suspected source for the epidemic was the Artibonite River, from which many of the affected people extracted water for human consumption. Cholera, previously not present in Haiti, had in January 2013 taken over 7,900 lives, and is still severely affecting the country. In addition, liability claims against the UN peacekeeping was raised, causing negative coverage in the world press.[4] Although no official blame has been established, the negative publication this caused the UN, it could surely have done without.

Another example includes oil polluted soil and/or groundwater around thousands of generator farms in military, peacekeeping and humanitarian camps worldwide (Figure 1). Since the limited logistic support available to remote areas naturally increase the environmental impact in the field, lack of spare parts has for instance turned minor oil spills to continuous leakages that over time that have created major damage to soil and aquifers (Waleij et al., 2011).

A third example is water abstraction that performed in an unsustainable manner, lowers water tables, alters flow patterns, causes salt water intrusion or increases local competition and conflict over water sources (Figure 2). By not integrating environmental considerations in the routine business of operations, long term impacts causing environmental, livelihood, health and even security concerns indeed have occurred and will keep on occurring (Waleij et al., 2011a, Waleij et al., 2011b, Waleij et al., 2008).

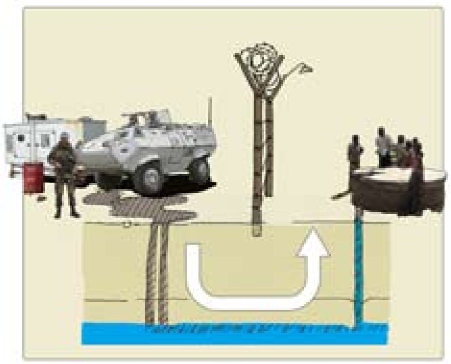

Figure 1. A visualisation of POL (Petroleum, Oil, Lubricants) polluting the groundwater in a mission area

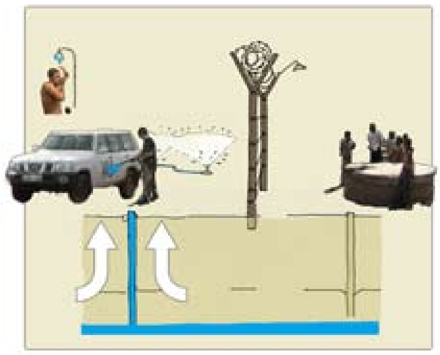

Figure 2. A visualisation of the impact of competition for water in a mission area. Pictures: Hans Lundholm

The demand for sustainable camps and compounds, in particular if located in fragile and/ or remote areas, is hence fast growing, driven by a need to:

4 Such as Washington Post and the New York Times

i) save lives and livelihoods; ii) minimize the unintended environmental and socioeconomic footprint during conflict and disaster situations and, iii) save costs and avoid litigation.

The Swedish Defense Research Agency (FOI) has vast expertise and experience in the field of peace operations, camps and compounds. In fact, a number of tools have been developed by FOI to solve specific issues specifically in the area of assessing vulnerability against potentially lethal attacks to a camp, sensor protection and environmental and health assessments of operations and camps (Liljedahl et al 2012, Edlund et al 2010, Waleij et al 2011a, Waleij et al 2011b Bosetti et al 2008, UNEP 2012).

In addition, related strategic issues such as conflict analysis, assessing how to best ensure a whole of government, that is a comprehensive approach, gender sensitive approaches and protection of civilians, i.e. issues that go beyond the base camp perimeter, but may still be included in the mission mandate[5], are other core competences that FOI possesses (MacDermott & Hanssen 2010, Hull & Derblom 2011). Hence FOIs expertise is regularly requested and utilized in the area of peace operations, camps and compounds. Until recently however, this collective knowledge was not well coordinated and integrated into a complete and holistic approach to enable a system of systems thinking, even within FOI. Therefore, in 2012 a Center of Excellence (CoE) for camps and compounds was stood up to enable the diverse in-house skills from all FOI divisions to be integrated into a holistic concept where synergies between technical, practical and more theoretical skills are utilized.[6]

Lessons identified

Over the past decade FOI has addressed challenges related to sustainability for temporary communities in conflict and disaster areas. Lessons identified but seldom learned, has shown that the legacy of these temporary communities regardless of purpose and type, is too high to ignore. For instance, the cumulative impact, that is impacts which are caused from one or several separate events, but together magnify each other, of many actors present in an area at the same time, as well as over time, may be much greater than each individual impact seen in isolation. For instance, a cumulative water footprint may in fact exceed an aquifer's natural recharge rate, resulting in the straw that breaks the camel's back, causing irreparable damage to the local environment. Environmental intelligence as well as hydrogeological assessments and monitoring of water extraction is hence critical, especially in semi-arid and arid developing regions alhough rarely undertaken in practice (Liljedahl et al 2012, Lewis and Liljedahl 2010). This kind of situation my seem fictional. However, this is the situation in e.g. Sudan, where peacekeepers, humanitarians, refugees and internally displaced persons in fact are competing for the same scarce water resource, causing friction with the host communities.

For the UN peackeepers 80 litres of water for domestic use (such as ablution, laundry, and food preparation) and 5 litres for personal drinking consumption per day are assumed in line with the provisions of the DFS camp design specifications (UN DFS n.d.). NATO also requires at least 5 liters of potable water per person per day and in addition the demand for other needs between 70 to 200 liters per person per day (NATO 2010). For refugees the planning assumptions are significantly lower. Althogether refugees and internally displaced perons may however outnumber the deployed personell by orders of magnitude, and the sum of the water extractions may end up being way to large for the aquifer to bounce back from. The pattern of a camp's resource consumption varies considerably during its life cycle. Achieving sustainability therefore requires environmental considerations to be planned into all phases of a camp's operational life. Effective planning from the earliest stages of a mission's inception and effective and equitable resource conserving procurement policies have the potential to substantially reduce a field mission's environmental footprint. While many of the challenges faced by camps concerning e.g. natural resource management have parallels with

5 Peacekeeping missions that have been clearly mandated to assist the host country better manage its natural resources are the UN Mission in Liberia (UNMIL) and the UN Organization Stabilization Mission in the Democratic Republic of the Congo (MONUSCO).

6 For more information see for instance http://www.foi.se/thecamp

those challenges faced by small cities, others are unique and require innovative solutions to be developed internally.

Experience shows that merely and randomly adding environmentally sound technological components does not ensure sustainability of a camp, if the systems are not correlated (Martinsson et al. 2010a; Martinsson et al., 2010b). On the contrary, if not well planned and coordinated, an investment in for instance an energy saving system in one side of the camp may in fact cause increased pollution at the other side of the camp or further downrange. Another example is the choice of potable water supply (e.g. production and distribution), which will impact energy consumption as well as waste production (Figure 3). Quite often low tech solutions and retrofitting may be the best feasible option, given that environmental training and awareness campaigns for personnel are conducted in parallel.

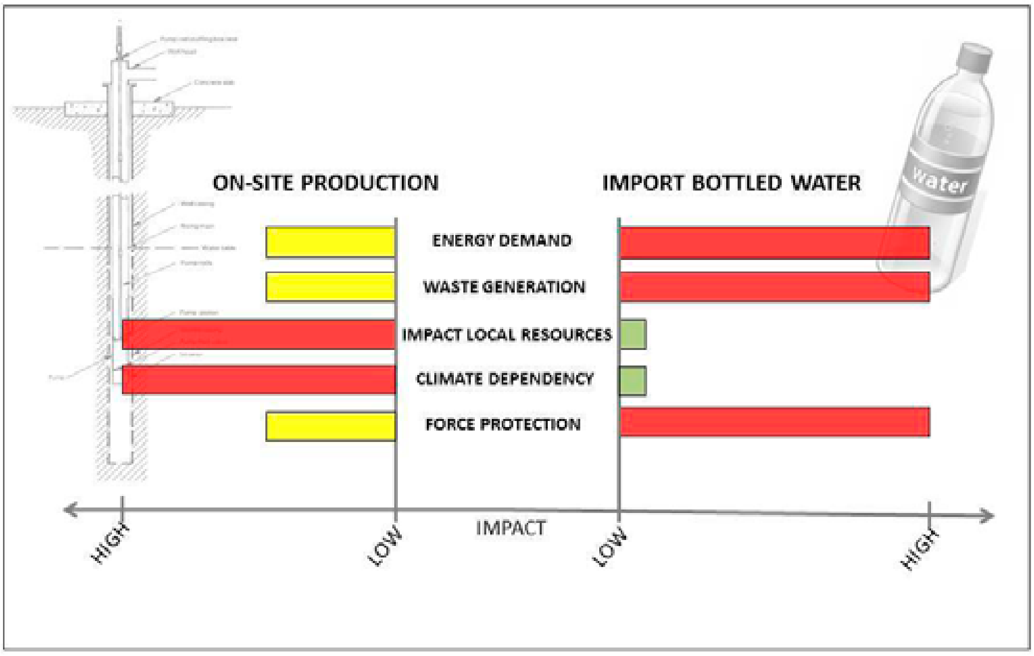

Figure 3: Comparison of selected impact between onsite water production and imported water for a fictive camp site

The platform

Many aspects of current camps and compunds are structured according to pre-established logistical and security requirements. These requirements often favour initial capital cost savings over sustainability, non-tangible benefits and long term payoffs. Unless tangible strategic advantages can be demonstrated, these requirements are very difficult to modify due to a fundamental resistance to employ untried technologies in situations that are percived to have the ability to affect security. However, tangibly demonstrating the advantage of more resourse conserving and sustainable technologies would require that they actually be used in the field, thus creating a catch-22 situation. To address this challenge, attempts to model the ideal camp model has been initiated.[7] The idea is to develop strategic guides for future camp designs, while remaining free from any of the current constraints imposed by the UN, NATO or EU concerning camp structure. The design is constantly iterated, with input sought from various subject matter experts from the military, peacekeeping, humanitarian, sciencentific and civil engineering communities. The Camp Authoring Tool (CAT) is used as a platform for camp planning. A three dimensional virtual model of the camp area, created from geo data

and stellite images, is used as the base for the platform. On this virtual model objects, such as buildings, containers, vehicles etc are added via the user interface of the tool (Figure 4).

7 Already in 2007 FOI, the Swedish Armed Forces (SwAF) and the United Nations Department of Peacekeeping Operations (UNDPKO) organized a workshop which sought to design an ideal base camp from scratch, with an emphasis on mission capacity, force protection and sustainability

Figure 4. Camp Authoring Tool workspace showing different views of the scenario and its objects

These objects holds various types of information that are of interest for the domains involved in camp planning. The platform works as a common ground for understanding challanges during camp planning and can be managed by all the user groups involved. Thus, it is possible to adjust the camp model in order to communicate variuos needs and requirements of their particular area of expertise to other groups involved in the design and operation of the camp. The Camp Authoring Tool also opens up for simulations and visualisation of various effects, both inside CAT and in external applications as all information can easily be exchanged to and from the CAT scenarios.

Discussion

In order to minimize short and long term negative environmental or social impact for camp facilities in fragile areas with limited existing infrastructure, it is crucial to ensure that a holistic approach is taken, and that not only technical solutions are addressed, but equally management, including sufficient spare parts and emergency resources, and training and awareness amongst personnel. Moreover, a new camp must be assessed in its present and future context, and also in a cumulative impact context. When further developed, the digitized camp planning tool will enable visualizing in 3D, and for instance simulate the camp's internal processes, calculate materials and personnel needed as well as water, energy and waste flows based on various scenarios. Optimal location of various features in regards to, for instance, the effects of explosions can also be assessed but also "softer issues" like gender issues and courses of action for protection of civilians. The added value of the tool is also that the preparedness for changes in threat and vulnerability levels as well as size and duration of the individual camps can be considered at the onset of the planning process. In addition, the fluidity of the total camp pressure on the local environment can be factored in, adding to the value of better preparedness for addressing the cumulative environmental footprint and facilitate a comprehensive approach in practice.

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BEST AVAILABLE TECHNIQUES FOR SMALL ARMS RANGES

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The Finnish Defence Forces (FDF), with its almost 200 small arms ranges on 48 separate locations, is the most significant operator of outdoor shooting ranges in Finland. The main environmental considerations of outdoors shooting ranges are noise and heavy metal emissions. Finnish environmental permits for shooting ranges commonly include demands regarding emission control, with references to the Best Available Techniques (BAT) –principle. As BAT for small arms ranges is not defined on European or national level, divergent views on how to meet the requirements have been presented by operators and authorities. In 2009 the FDF initiated the process of producing a national BAT reference document for outdoor small arms ranges. The work was started in 2010 as a co-operation between the FDF, other range operators and environmental authorities, and will be completed in 2013. The scope of the document covers soil and water protection and noise control techniques and practices for rifle-, pistol- and shotgun ranges.

The main objectives of the "*BAT for Small Arms Ranges*" -project are:

- To produce assessment criteria for environmental protection requirements for outdoor ranges
- To evaluate the functionality and cost-efficiency of existing technical solutions and to produce feasible model designs of BAT-solutions
- To develop tools for determining the most appropriate techniques for different types of ranges, considering the technical characteristics of the installation and local environmental conditions

The project organization consists of two independent but interacting specialist working groups, the Soil and Water Group and the Noise Group, and a Steering Committee that guides and co-ordinates the work.

At present time, a draft document containing the BAT-conclusions, a set of model designs and relevant background information about the environmental effects of small arms ranges, has been drawn. The draft will be presented to various stakeholders and other interest groups for evaluation, and the final report will be published by the Finnish Environment Institute.

Heavy Metals Emissions Control

The main contaminants from small arms ranges are lead (Pb), copper (Cu), antimony (Sb) and zink (Zn) from bullets and shots. The leaching of metals into the environment is greatly effected by site-specific characteristics, such as the pH, permeability and clay and organic content of the soil, and the hydrogeological and hydrological conditions. The total heavy metal load and corrosion/mineralization degree of bullets, defined by the volume of operation and age of range, also play an important role in characterizing the emission risk, as does ammunition type.

To establish a baseline for the soil and water protection work, the results of 36 existing studies of the environmental impacts of small arms ranges in Finland were analyzed. The main conclusions were that elevated heavy metal concentrations (Pb, Cu, Sb, Zn) are commonly only found in the top 0,5 m of the soil and that leaching is not directly proportional to the amount of metals accumulated. Heavy metals are frequently found in surface waters (ditches and small streams) and sediments in the immediate surroundings of the range, but further spreading seldom occurs as the dissolved metal portion is low. Impacts on groundwater have been detected, especially in small or shallow aquifers and areas of low hydraulic conductivity, but there are no known cases of a groundwater source becoming unusable due to impact from shooting with small arms. The main contaminant found in groundwater is lead.

With the results of the study and a literary review as a starting point, a frame for soil and water protection requirements for small arms ranges was set up. The chosen approach is based on site-specific risk assessment rather than generic conditions. When the volume of operation exceeds a certain limit, an Environmental Baseline Study including an environmental risk assessment has to be carried out. The scope and contents of the Baseline Study vary according to the volume of operation, the hydrogeological and hydrological settings and the sensitivity of the environment. The risk assessment is in most cases carried out qualitatively, but the risk is quantified using a points system specifically developed for this purpose.

To meet the varying environmental protections needs of different ranges, four levels of environmental impact control requirements were set up. A draft version of these so called BAT-levels is presented in Table 1.

Table 1. Suggested soil and water protection requirement levels for small arms shooting ranges, "BAT-levels"

	LEVEL 1 Basic	LEVEL 2 Demanding, surface water	LEVEL 3 Demanding, groundwater	LEVEL 4 Very demanding
Estimated risk potential According to baseline survey and risk assessment	Very low risk of pollutant migration Existing ranges only	Long-term risk of pollutant migration to surface waters New range, not on gw-area	Long-term risk of pollutant migration to groundwater on classified groundwater areas or other aquifers used for potable water extraction New range in insensitive gw-environment	Acute or short-term risk of pollutant migration and possibly severe impacts New range in sensitive environment
Environmental protection requirements	Record keeping and reporting	Runoff water control and treatment if necessary or bullet containment	Contact water control in backberm and treatment if necessary or bullet containment	Contact- and runoff water control in backberm, firing and range area. Bullet containment. Double protection for new ranges. Remediation if necessary.

Next, existing technical solutions for heavy metal emission control were identified and evaluated on basis of functionality, viability and cost-efficiency.

Examined techniques for ranges with a fixed target area (i.e. backberm) include:

- different types of liners (bentonite, dense asphalt, plastic) in a traditional earthen backberm, coupled with water control and treatment systems

- steel bullet traps (box trap, deceleration trap)
- rubber granulate and other bullet traps
- roofing of backberm
- stabilization of contaminants by soil amendments
- alternative bullet materials

Liners were found to be the favoured solution in most cases, as they don't affect the technical characteristics and the use of the range. Liners are also more cost-efficient on rifle ranges, whereas bullet traps are often a functional and cost-efficient solution on pistol and .22 caliber rifle ranges.

Due to the characteristics of shotgun shooting, like the high trajectory and wide distribution of shots, and variations in shooting direction, the contaminants are spread on a very large area (several ha).

Evaluated techniques for shotgun ranges include:

- berms, curtains and walls to reduce the shot fallout area
- water management and treatment systems for the most critical areas
- covering the soil for easier shot collection

All examined techniques result in considerable costs, as intercepting the flight path of shots requires high and wide structures, and the area of dense shot fallout, on which the water/shot management measures should be focused on, is large. Different types of berms, walls and curtains are the most tested solutions, and when well-designed, they also serve noise control purposes.

The general process for BAT selection for soil and water protection on small arms shooting ranges is presented in figure 1.

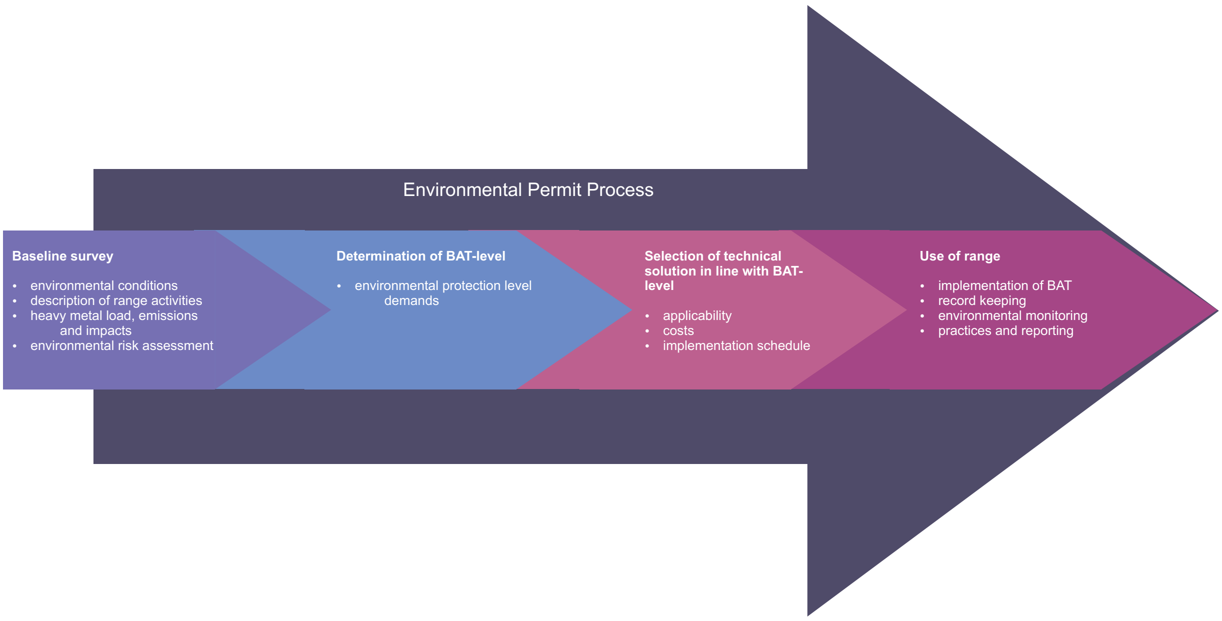

Figure 1. Process for BAT selection for soil and water protection on small arms shooting ranges

Model designs of the following structures have been produced and will be published as annexes to the BREF-document:

For small arms ranges

- Backberm with bentonite liner
- Backberm with plastic liner
- Backberm with plastic liner
- Bullet trap (boxtrap for .22 cal)
- Roofing of backberm
- Treatment of contaminated water

For shotgun ranges

- Runoff water control and treatment
- Reduction of shot distribution area
- Asphalt covered shot distribution area

Noise control

The BAT-definition process for noise control was carried out much in a similar way to that for heavy metals emissions. First, an overview of small arms shooting range noise was summarized from literature and specialist sources.

The noise emission of a shooting occasion is caused by the muzzle blast and the bullet noise. The sounds do occur almost simultaneously and can not be separated by the ear or standard measuring devices. The noise emission radiates spherically from the point source, and is attenuated with distance. There are guidance values for environmental noise in Finland, but these are not intended to be used as limit values for shooting noise. In absence of other guidance, however, this is often the case.

Methods for controlling shooting range noise were identified and their functionality, limitations and cost-efficiency evaluated. The methods are well-known but there is a lack of documentation of the effects and limitations. Basically, noise control methods can be divided into two subgroups: technical noise abatement methods and practices that can be used to reduce the noise emission.

Evaluated technical noise abatement methods are:

- Acoustically absorbing shooting stall
- Absorbing divides in the stall
- Noise control berms and walls

Other methods for noise control include:

- Weapons and ammunition related methods: Sub-sonar speed bullets, sound suppressors, reducing caliber

- Scheduling of range operations
- Planning or re-arrangement of range lay-out
- Land-use planning
- Communication

Efficient noise reduction often requires a combination of both technical and practical methods. The above mentioned techniques are all considered BAT, as they contribute to noise abatement in different ways. Acoustically lined shooting stalls reduce noise most efficiently on sides and behind the stall. Adding absorbing divides between shooting positions reduces noise within the stall, improving the noise conditions for the shooters and instructors. Noise abatement in front direction is best obtained by using berms and walls. The possibilities of these are limited by economical realities: very high structures might be required to obtain adequate results. Weapons and ammunition related noise control methods are cost-efficient, but the use of these is limited, for example by competition rules and defence forces' training needs. Planning or re-arrangement of range lay-out is a considerable option in cases where noise emissions cause impacts only in certain directions. Scheduling of range operations and thoughtful communication are often a good way to support and enhance the effect of other noise control methods. In cases where noise is more a nuisance than actually harmful, or the frequency of noise occurrence is low, scheduling alone might be considered adequate noise control.

The suggested environmental protection requirements for noise control on small arms shooting ranges are summarized in Table 2.

Table 2. Suggested environmental protection requirements for noise control on small arms shooting ranges

Noise zone	Less than 10 000 r/y	Rounds annually: 10 000 - 100 000 r/y		Rounds annually: > 100 000 r/y	
		Persons exposed to noise: 1 - 10	> 10	1 - 10	> 10
> 75 dB	Red	Red	Red	Red	Red
70 - 75 dB	Yellow	Yellow	Red	Red	Red
65 - 70 dB	Green	Yellow	Yellow	Yellow	Red
60 - 65 dB	Green	Green	Green	Yellow	Yellow
< 60 dB	Green	Green	Green	Green	Green

Red	Unacceptable situation. Efficient noise abatement measures necessary.
Yellow	Functions should be planned in a way that ensures that the noise level does not exceed guidance or limit values. In some cases the noise load can be partly reduced by scheduling of operating hours.
Green	The nuisance caused by noise is minor, generally no need for noise control measures, though scheduling of operating hours might be necessary.

Vacation housing, recreation and nature protection areas and institutions are placed one step higher than their actual placement in the chart.

In addition, the draft includes the following recommendations:

- Noise reduction between 5-15 dB should generally be considered technically and economically feasible

- No noise abatement is necessary on .22 caliber weapons ranges because of the low emission of these weapons.
- No noise abatement is necessary on ranges with an operation volume less than 200 rounds/year. The frequency of the noise occurrence is so low that the impacts can not be considered harmful.

Model designs of the following structures have been produced and will be published as annexes to the BREF-document:

- Acoustically lined shooting stall, 3 types
- Noise abatement walls
    - Reflecting wall
    - Absorbing wall

Experiences 2012-2013

In 2011 the Finnish Defence Forces produced a plan for systematically developing the sustainable use of small arms ranges. The plan includes training needs analysis, qualitative risk assessment, action planning, cost calculations and prioritisation to create a 5-year, 20 M€ plan for raising the level of environmental protection of small arms ranges. The realisation of the plan started in 2012. Though not published yet, the general conclusions of the BAT-project have been implemented in the planning and execution of the noise control and soil/water protection measures, generating in exchange valuable information on feasibility and costs of the various technical solutions.

So far improvement of the technical environmental protection of shooting ranges has been carried out on three ranges, and four more are under construction in 2013. Planning and baseline surveys have been started on 14 ranges.

The three completed ranges differ in terms of settings and operation volume, and different solutions for emission control have been piloted on them. A summary of the work done in 2012 and the costs of the different components are presented in Table 3 and Figure 2.

Table 3. A summary of the small arms range improvement work carried out in 2012, and the costs of the different components (1000 €)

	Parolannummi	Hätilä	Vekaranjärvi
Range capasity	3 ranges (94 sp), 2 ranges removed	4 ranges (135 sp)	5 ranges (230 sp), 1 range removed
Environment	GW-area, housing area		Vacation housing
A. contaminated soil management	140	120	200
B. Water protection	140 (asphalt liner, water monitoring and infiltration)	100 (ditches, setting ponds)	100 (plastic + bentonite liners, setting ponds)
C. Shooting stalls	390	480 (2 new stalls, 2 acoustic linings)	800 (3 new stalls, 1 lining, 1 expansion of range)
D. Noise walls	120	0	100
E. Electricity	50	100	200
F. Other infra	170 (improvement of roads)	250 (expansion of range)	900 (expansion of range)
G. Planning and supervision	110	110	210 (consultant)
ALTOGETHER	1010	1050 (not yet finished)	2300 (not yet finished)

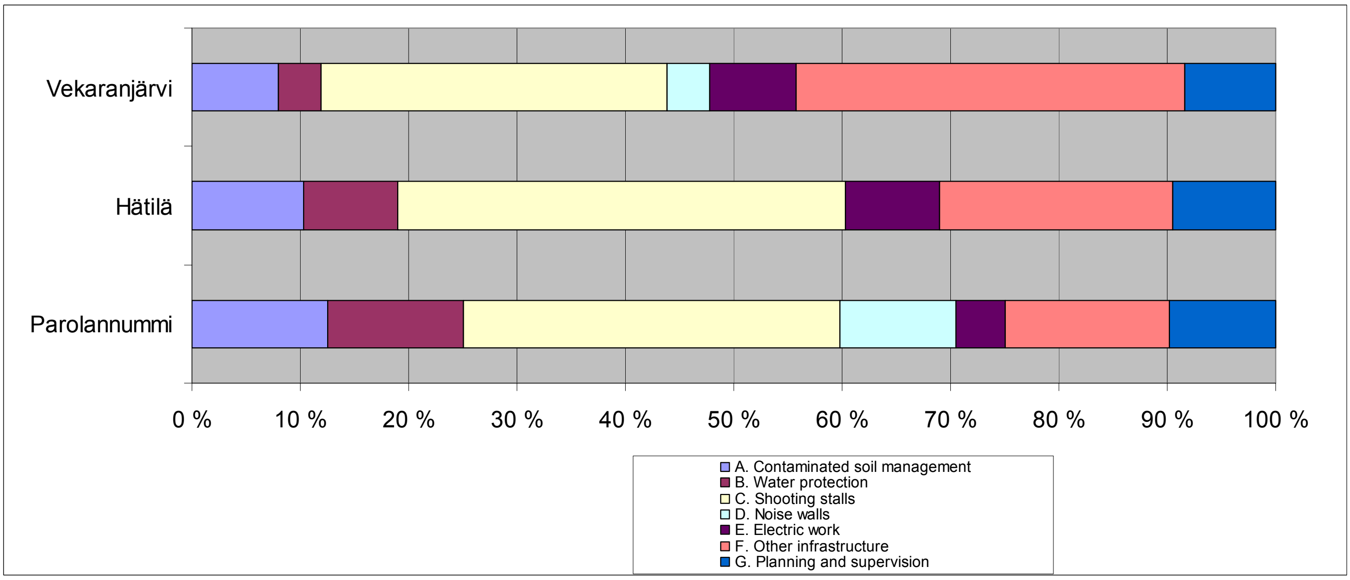

Figure 2. The distribution of the project costs

The information obtained in the pilot projects will be used for further development of the techniques and updating of the cost-efficiency evaluations in the BAT-project.

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IMMOBILIZATION OF ANTIMONY (Sb) IN SHOOTING RANGE SOIL BY SOIL AMENDMENT

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Each year large amount of metals and metalloids, such as copper (Cu), lead (Pb) and antimony (Sb), is deposited in shooting ranges. The ammunition residues may leach into the soil and surrounding watercourses and may pose a threat to exposed wildlife and humans [1,2]. Much of the metals are deposited in the stop-butts, which can be regarded as a main source for environmental spread. Sb is a particular problem when the contaminated soil is to be deposited at waste disposal sites. Several shooting ranges in Norway have been closed and subjected to remediation in order to bring back the areas to new owner or to recreational purposes. The soils from shooting ranges are, however, often categorized as hazardous waste due to the high mobility of Sb, which may increase considerably the cost of the remediation projects. To reduce the leaching potential of metals from contaminated soil one can add stabilizing agents into the soil. Stabilizing agents, or soil amendments, are reactive sorbents that have affinity to metals that are mobilized from the soil due to weathering processes. Soils from a shooting range contain both cationic (Pb^{2+} and Cu^{2+}) and anionic species ($Sb(OH)^{6-}$) of metals [3,4] and ideally the agent should have affinity to both. In this study we have mixed four different soil stabilizing agents into four different ammunition polluted soils from different shooting ranges. The stabilizing agents were hydroxyapatite (HA), elemental iron (Fe^0) – powder, Merox iron oxide and fine grained olivine, which is a magnesium iron silicate. The agents were mixed with an amount of 3% on a weight basis. The soil were put into large columns and exposed regularly for simulated precipitation. The soils were exposed to rain water, which had been filtered through a 0.45 μm filter. The water, percolating the columns, was collected with a vacuum pump.

Materials and Methods

Preparation of columns

The columns (height 70 cm, diameter 38 cm) were made in PVC and equipped with a porcelain sieve at the bottom, which was covered with 5 kg quartz sand (0.4 – 0.8 mm grain size, Sibelco Norway) to avoid possible clogging of the sieve. Aliquots of the soil (60-80 kg) were then mixed with or without amendments (3% amendments on a wet weight basis) on a cement mixer and prepared on the columns. Four different soil from four shooting ranges (Sessvoll, Evjemoen, Ulven, and Rena) were mixed with four different amendments: A) hydroxyapatite ($Ca10(PO_4)6(OH)2$), B) Finely grounded olivine sand ($(Mg,Fe)2SiO_4$) (Vanguard 10-63 μm, Sibelco, Norway), C) Zero-valent iron (Fe0) powder (≥ 99 % with particle size < 150 μm), and D) Merox® iron oxide powder (Fe_2O_3). The bottom of each column was connected with Teflon tubes (5 mm i.d) to 5 L glass bottles (Duran) and a hydraulic vacuum pump (Trivac B) to increase water yield. The metal contents in the collected water from the reference soil were compared with water from treated soil. The water samples were conserved with 0.5% HNO_3 (final concentration) and subjected to element analysis.

Rainwater application and sampling

Rainwater was collected in situ before the start of the experiment onto a 1 m^3 plastic container and then filtered through a 0.45 µm pore size filter. The water was delivered to the columns with a sprinkler system to mimic precipitation. Each column was connected to a nozzle. Each nozzle delivered 53 (± 4.6 SD) ml water/min in average. Rainwater was added for approximately 60 min once a month from March 2009 to July 2011 and each column received a mean nominal amount of 3700 ml (± 230 ml) water each application.

Element analysis of soil and water

Aliquots of the soil samples were dried at 110 °C over night and sieved with a 2 mm sieve. Approximately 0.5 g of the soil with particle size < 2 mm was transferred to Teflon containers and micro wave oven digested with Aqua Regia (1 part ultra pure nitric acid and 3 parts 25 % ultra pure HCl). The acid extracts were then diluted by deionized water and subjected to element analysis. The water samples and soil extracts were analyzed for Sb with an ICP-MS (Thermo X-series II). Each sample was added internal standard and quantified with use of a four points standard curve (0-200 ppm). To ensure correct quantification a reference solution of known metal concentration (TM 23.3 Analytical reference material, Environment Canada, Canada) was analyzed in addition to an in-house made standard. A deviation of 5% from the given concentration in the reference solution was accepted. Blanks were regularly analyzed to control background contamination.

Results and Discussion

The concentrations of Sb in the soils used in the study varied substantially (Table 1). The concentrations in the soils reflect the shooting activity at the range and the type of ammunition used. The Norwegian Army has replaced the use of Pb ammunition in small arms to a more environmentally-friendly steel ammunition. The soil collected from the stop-but at Ulven contained primarily remnants from steel ammunition.

Table 1. Concentrations of Sb in the soils used in the study. The results are mean concentrations (± SD) from three separate analyses

Soil	Sessvoll	Evjemoen	Ulven	Rena
Sb (mg/kg)	240 ± 60	1050 ± 170	260 ± 100	2900 ± 660

The columns were regularly added rainwater and the water percolating the soil were collected and analyzed for Sb. The concentrations of Sb in the leachates from the reference columns were high (Table 2), showing the high mobility of this element in the soils.

Table 2. Concentrations of Sb in the leachates from the reference column. The results are mean concentrations of Sb (± SD) in the leachates from 18 samples. The median concentrations are shown in brackets

Soil	Sessvoll	Evjemoen	Ulven	Rena
Sb (µg/L)	1080 ± 310 (1040)	3050 ± 1760 (3810)	1220 ± 390 (1280)	6620 ± 2070 (6230)

According to the requirements set by the Norwegian waste regulations (FOR 2004-06-01 nr 930) the concentrations of Sb were above the threshold limits for hazardous waste as measured by column tests. This may limit substantially the amount of sites the contaminated soil can be deposited and also increase the cost of soil deposition at landfills.

The addition of stabilizing agents into the soil may reduce the mobility of Sb in the soil and implies a safer and more economical feasible waste disposal. Stabilizing agents may also lead to reduced spread of Sb from the stop-butts into the surrounding environment. Four different stabilizing agents were tested: hydroxyapatite (HA), finely grounded olivine sand, zerovalent iron (Fe^0) powder and Merox® iron oxide powder (Fe_2O_3). Both the addition HA and olivine lead to a substantially increase of Sb leakage from the soils (Table 3 and 4).

Table 3. Concentrations of Sb (µg/L) in the leachates from the soil added 3% (wet weight) soil stabilizing agents. The results are presented as mean concentrations of Sb (± SD) in the leachates. The median concentrations are shown in brackets. The results of HA, olivine and iron oxide are the mean of 11-13 samples, whereas the results of Fe0-powder are from 18 samples.

	HA	Olivine	Iron oxide	Fe^0-powder
Sessvoll	2430 ± 610 (2450)	2130 ± 520 (2150)	420 ± 170 (430)	17 ± 15 (13)
Evjemoen	3450 ± 711 (3370)	2870 ± 820 (2740)	520 ± 260 (450)	110 ± 38 (120)
Ulven	1300 ± 280 (1380)	1340 ± 360 (1490)	730 ± 170 (760)	29 ± 7.0 (28)
Rena	13200 ± 2230 (12600)	13400 ± 3590 (14730)	4670 ± 1060 (4820)	1710 ± 550 (1730)

Hydroxyapatite has previously been used to reduce leakage of Cu and Pb [5, 6], but appears to be not suited to stabilize Sb. HA probably increase Sb leakage due to anion exchange with phosphate (PO_4^{3-}) [7]. Finely grounded olivine has in Norway been used in the field as a leakage barrier to reduce leakage of metals from disposed shooting ranges. Olivine is a mineral containing Fe oxides with presumed binding properties to both cations and anions, such as $Sb(OH)^{6-}$ and Pb^{2+}. The mechanisms of which the olivine powder increased leakage are not known, but may be due to mobilization of anions in the mineral, such as carbonates or phosphates facilitating anion exchange with Sb. Iron oxides have charged surface groups that can form complexes with both cations and anions [8]. The ferric oxide (Fe_2O_3) from Merox® had some stabilizing effect of Sb in the tested soils. In three of the soil types it was able to reduce the concentrations in the leachates to below the threshold limits for hazardous waste (Table 3 and 4). This implies that the soil can be deposited at land fillings approved for hazardous waste.

Table 4. Percent reduction or increase of Sb in the leachates from the soil added 3% (wet weight) soil stabilizing agents. The results are presented as mean concentrations (± SD). The medians are shown in brackets. The results of HA, olivine and iron oxide are the mean of 11-13 samples, whereas the results of Fe0-powder are from 18 samples.

	HA	Olivine	Iron oxide	Fe^0-powder
Sessvoll	-113 ± 54 (-98)	-84 ± 53 (-80)	63 ± 15 (64)	98 ± 1.9 (99)
Evjemoen	-232 ± 37 (-224)	-174 ± 57 (-117)	50 ± 31 (62)	90 ± 3.6 (89)
Ulven	-20 ± 52 (-6.4)	-12 ± 25 (-12)	36 ± 19 (40)	97 ± 1.3 (98)
Rena	-107 ± 33 (-118)	-106 ± 31 (-102)	26 ± 16 (19)	72 ± 9.3 (69)

Although the iron oxide reduced leakage of Sb from the soils, the Fe0-powder performed even better. In two of the soils iron powder reduced leakage of Sb below the threshold limits for inert waste (100 µg/L), and in a third soil below the threshold limit for non-hazardous waste (150 µg/L) (Table 3 and 4). In three of the soil types Sb-leakage was reduced more than 90% (Table 4). During the oxidation process of iron, amorphous Fe oxyhydroxides are formed creating a variety of sorption sites with a high surface area that may lead to a high capacity of sorption [8-10]. The adsorption is governed by pH and the iron oxides iso-electric point. At low pH, a predominantly positive charge will favor sorption of anions (such as Sb and As), whereas at high pH, a predominantly negative charge will favor sorption of cations (such as Pb and Cu) [11]. The iron oxide from Merox reduced Sb leakage, but to a lesser extent. The poorer performance may be due to a different chemical state of the iron oxides compared to the oxidized iron grit, such as a higher portion of crystalline forms of the iron oxide and a less portion of hydrated iron oxides. In conclusion zerovalent iron is a promising product as a soil stabilizing agent and should be subjected to more studies to evaluate its performance in different soil types and soil textures. A challenge may be that the iron induce crusting and compaction of the soil due to oxidation process.

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AN ENVIRONMENTAL RISK ASSESSMENT METHOD FOR TRAINING AND SHOOTING RANGES

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The Swedish Fortification Agency owns and manages Sweden's military training and shooting ranges. These ranges occupy about 1% of the total land area of the country. The ranges are used by the Swedish Armed Forces and their activities are mainly live firing with small and large calibre weapons, detonating explosives and demining exercises. However, these activities create an accumulation of scrap metal and unexploded ordnance (UXO) , which are both a security and environmental concern.

As a consequence of cuts in the Swedish defence budget, a number of training and shooting ranges have been scheduled for closure. Some sort of risk assessment and remediation is normally necessary before the range area can be converted to civilian usage. Two types of risks are identified. The first is the risk of explosion of UXOs, which can cause significant injury. This type is called "security risk". The second type refers to the risk from leakage of ammunition constituents' chemical components such as primary explosives and metals, which can affect soil and groundwater. The latter is referred to as "*environmental risk*".

Since a training and shooting range contains a large amount of UXO and munitions constituents that are unevenly distributed within each target area, only a more general environmental risk classification can been implemented. The environmental risk method (MRM) presented in this study is based on the number of UXO, type of ammunition, chemical profile, vulnerability map of groundwater and natural geochemical conditions. The MRM risk classification follows the idea of the Swedish Environmental Agency methodology for the inventory of contaminated sites (MIFO).

In Sweden the MIFO method is normally used for environmental risk classification of contaminated sites.   If one equates UXO contaminated lands with industrially contaminated areas, it will be possible to apply the principles of the MIFO method. By doing so, important advantages are won since the Swedish authorities are comfortable with the MIFO method and because the Armed Forces have already used the method for their contaminated sites.

The main purpose of using MIFO is to denote the polluted area into one of four risk classes based on short-and long-term risks as to the current situation and land use for the area affected by pollution (impact area). An environmental risk assessment includes both an assessment of the situations that might happen, as well as an assessment of the probability for this to happen. Risk means the likelihood that humans will be harmed by exposure to pollutants or that the environment will be damaged. The final risk classification forms a basis for prioritization,   decisions on further investigation, remediation or other measures.

When using MIFO, four different aspects are considered,

- Hazard assessment i.e. ability to conflict harm on humans and the environment.
- Contamination level from comparison with some guideline values
- Migration potential

- Sensitivity/protection value for the area.

The risk associated with each of these aspects is assigned a value of one to four. The boundaries between the levels are set so that conditions at all possible contaminated sites – from those which present only a slight risk, to the most severely contaminated – are taken into account. Finally, the four aspects are weighed together in a comprehensive assessment on the basis of which the site is assigned to one of the four risk classes. Assessments of current conditions and deviations from the reference values are conducted according to the same principles as those applied to the other five major categories of environmental quality criteria.

The following risk classes have been used:

- Class 1. Very high risk
- Class 2. High risk
- Class 3. Moderate risk
- Class 4. Low risk

A test of the MRM method

The MRM has been tested on the Artillery firing range Grytan that was active during the period 1893-2004. The infantry, artillery and air force have all used the Grytan range. The Swedish EOD and Demining Centre (SWEDEC) estimates that artillery and infantry units have shot 262,000 shells at Grytan.

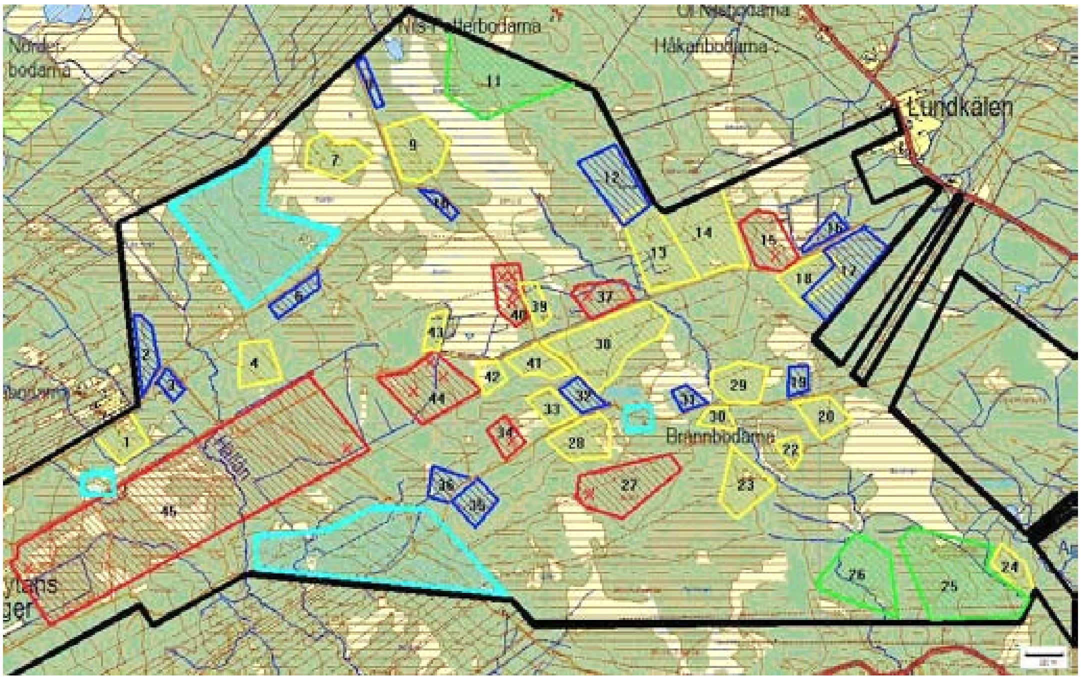

Figure 1. Map shoving the Grytan training and shooting range. Each number refering to a target area

Chemical profile

From the data of the UXO density map and ammunition type it is possible to calculate the Chemical profile for a target area. Since the UXO is unevenly distributed within the area it is not possible to identify *"hot spot areas"*. The amount of contaminants such as explosives and metals can only be estimated for a given target area. The MRM method assumes that 10 % of the used ammunition ends up as UXOs and that 2 % will leak chemicals instantaneous.

Contamination level

As mentioned earlier UXO has an heterogeneous distribution in the area. This means that the contamination level can only be given as content for the whole target area based on the amount of UXO and the ammunition type and the possible amount of broken UXO.

Precondition for transport

Information on pollutant transport is derived from geological and hydrogeological maps or other types of geological information from the area. A groundwater vulnerability map for the area can be seen in figure 2. The vulnerability is given in four classes green to red colors where green means low infiltration rate and red high. According to the map, all target areas in the example have a "*very low*" to "*low*" infiltration rate, which infers a low risk for groundwater contamination.

Figure 2. Example of a groundwater vulnerability map

Sensitivity/Protection for the area

In order to assess the severity of contamination at polluted sites, it is necessary to determine and describe the degree of exposure to humans and the environment today and in the future.

Risk assessment

The risk assessment section describes the comprehensive assessment and classification of the current and future risks posed by the contaminated area to human health and the environment. This is achieved by weighing together the hazard assessment, the contamination level, the potential for migration and the sensitivity and the protection value.

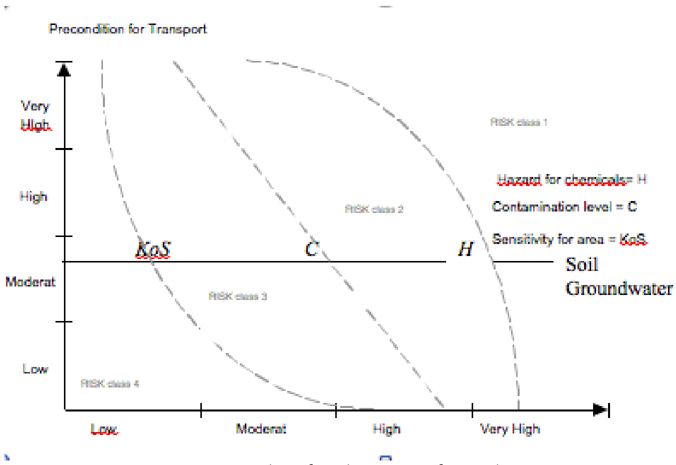

Figure 3. Example of a diagram for risk assessment

Conclusions

It is possible to assess and classify the environmental risk of underground UXOs at training and shooting ranges by using the proposed method (MRM). An important advantage is that MRM builds on ideas of the well-established MIFO-methodology. Results of UXO mappings by SWEDEC form a crucial input. The next step would be to apply MRM at more ranges.

U.S. ARMY INTEGRATED TRAINING AREA MANAGEMENT (ITAM): ACHIEVING SUSTAINABLE USE OF U.S. ARMY TRAINING LAND IN EUROPE

Steven Bowley

The U.S. Army Integrated Training Area Management (ITAM) program is part of the broader Sustainable Range Program (SRP), which represents the U.S. Army's overall approach for improving the way in which it designs, manages, and uses its training areas and ranges to ensure long-term sustainability.

The SRP falls under the direction of the U.S. Department of the Army Management Office G-3/5/7 –Training Simulations (DAMO-TRS) Training Support Systems (TSS) Division. The SRP and ITAM program are implemented in Europe by Training Support Activity Europe (TSAE), located at the Joint Multinational Training Center (JMTC), Grafenwoehr, Germany.

U.S. Army Sustainable Range Program (SRP)

SRP integrates existing programs that are affected by live training with the goal of maximizing the capability, availability, and accessibility of ranges and training land to support doctrinal training, mobilization, and deployments.

The core functions of SRP are as follows:

- The Integrated Training Area Management (ITAM) Program
- The Range and Training Land Program (RTLP)

The SRP is founded on three principles:

1. Information Excellence

Ensures the U.S. Army is using the best available information and science to support its ranges and land assets. Information excellence also ensures that the U.S. Army has an increased understanding of the environmental impacts of live-fire training and a user assessment of the doctrinal implication of U.S. Army transformation that affects live-fire training.

2. Integrated Management

Ensures that management is functioning correctly, such that ranges and land assets are integrated effectively into supporting the training mission. As indicated in the name, the ITAM program works cooperatively with multiple stakeholders, such as the Training Command, the Garrison Command, the host nation military, the local environmental authorities, and the surrounding local population.

3. Dedicated Outreach

Provides an outlet for the U.S. Army to explain to the public why training activities are essential to the U.S. Army's mission and improves the U.S. Army's understanding of public perception of, and concerns about, the U.S. Army training and range operations.

SRP Goals

SRP goals are to maximize the capability, availability, and accessibility of Arm Ranges and Training Lands. Each of these is described below:

1. Capability

Enhance, modernize, and improve USAREUR's Ranges and Training Lands to satisfy the tactical communities training requirements. RTLP and ITAM support these efforts by providing the Regional Training Support Divisions (RTSDs) with the following:

- Full spectrum project support from concept to completion
- Full spectrum engineering support for all approved projects
- Technical support
- Program assistance and oversight

2. Availability

USAREUR SRP, in conjunction with the RTSD and Training Support Center (TSC) staff, manage, and operate USAREUR's Ranges and Local Training Areas (LTAs).

3. Accessibility

Ranges and LTAs in USAREUR are the foundation for Home Station Training. Accessibility to these key training assets is crucial for ensuring USAREUR units are trained and combat ready. RTLP and ITAM support accessibility by ensuring the following:

- Addressing and resolving encroachment issues, as quickly as possible.
- Checking full compliance all environmental laws and regulations on LTAs and ranges.
- Providing funding so that ranges and LTAs are unaffected by encroachment and free of liabilities, which may arise from noncompliance issues with HN environmental laws and regulations.
- Unit Training Requirements: Ranges and LTAs are staffed and managed so that they are always ready for unit training requirements.

Integrated Training Area Management (ITAM)

ITAM's goal is "*optimum, sustainable use of training lands through uniform land management*". This involves understanding and balancing the needs of the environment with the needs of the training mission.

The objectives of the Army's ITAM program are to:

- Achieve optimum, sustainable use of lands for the execution of realistic training and testing by providing a core capability that balances usage, condition, and level of maintenance.
- Implement a management and decision-making process that integrates Army training and other mission requirements for land use with sound natural resources management.
- Advocate proactive conservation and land management practices by aligning Army training land management priorities with the Army training and readiness priorities.

The five components and objectives of the ITAM program are as follows:

Component	Objectives
TRAINING REQUIREMENTS INTEGRATION (TRI) Provides training support procedures that integrate training requirements with management of natural and cultural resources.	• Ensure sustained access to training lands that support realistic training conditions. • Quantify training land carrying capacity, and provide military trainers and land managers with quality information with which to make sound decisions.
RANGE AND TRAINING LAND ASSESSMENT (RTLA) Characterizes and monitors an installation's natural resources, geospatially and temporally.	• Assess training lands by identifying issues (e.g. erosion degradation) and recommend corrective actions. • Provide Command-level information to assist with force structure and stationing decisions at Command and Department of Army (DA) levels.
LAND REHABILITATION AND MAINTAINANCE (LRAM) Implements preventive and corrective land repair projects that ensure availability of training lands.	• Sustain overall condition of installation lands to ensure long-term military viability. • Increase available and accessible maneuver land. • Enhance realism of training environment to replicate the operational environment.
SUSTAINABLE RANGE AWARENESS (SRA) Promotes visibility of environmentally sensitive issues and instills a stewardship ethic among unit commanders, ground troops and neighboring communities.	• Educate land users and provide operational awareness for environmental professionals to ensure no net loss of trainingcapability. • Support High Payoff Building Partner Capacity activities.
GEOGRAPHIC INFORMATION SYSTEM (GIS) Provides accurate, complete and standardized spatial data. GIS data and products adhere to Federal, DoD and Army spatial data standards.	• Create, manage, and distribute authoritative standardized spatial information, products, and services for the execution of training strategies and missions on USAREUR ranges and training lands.

SRP Geographic Information Systems

A Geographic Information System (GIS) is an information system that integrates, stores, edits, analyses, shares and displays geographic information for informing decision making. GIS applications are tools that allow users to create interactive queries, analyze spatial information, edit map data and present the results of these operations. GIS is a core component of the SRP, and supports and underpins the decision making, analysis, and information sharing of all other SRP components.

SRP GIS Mission

The SRP GIS mission is to create, analyze, manage, and distribute authoritative standardized spatial information, products, and services for the execution of training strategies and missions on U.S. Army ranges and training lands. The SRP GIS Program strives to provide the SRP community, Trainers, and Soldiers with the ability to leverage the most accurate and complete geospatial datasets through easily accessible and user-friendly products and applications.

USARER SRP Regional Support Center (RSC)

The SRP Regional Support Center, located at Headquarters - Training Support Activity Europe (TSAE) at Grafenwoehr Training Area, Germany, provides centralized Geographic Information System (GIS) support to over 200 U.S. and joint use training sites throughout Europe and Africa.

The primary RSC functions are to (1) ensure that a standard SRP GIS capability exists at all SRP installations; and (2) gain efficiencies through standardization and centralized support.

Spatial data is provided through many types of media: paper and digital maps, the Army Range Mapper internet mapping application, and the ITAM Viewer desktop mapping application.

The RSC also participates in and coordinates outreach events, creates and distributes program information and promotes cooperation between partner organizations though hosting and participating in working groups, workshops, training events and conferences.

The SRP RSC provides the following services to support SRP tenants:

- Spatial data collection, standardization, management and publication
- Standard and Custom map creation for SRP customers and training units
- SRP GIS website (https://srp.usareur.army.mil)
- Bulk purchase initiatives for software and imagery
- ITAM project GIS / mapping support
- RTLP project GIS / mapping support

Partnerships

SRP GIS works closely with military and civilian geospatial organizations at the installation, headquarters and HQDA level to ensure the latest geospatial data is available and collated to provide a complete picture of USAREUR training areas for planning and training purposes. These partnerships include the National Geospatial-Intelligence Agency (NGA), Installation Management Command (IMCOM-Europe) Installation Master Planning, Environmental Divisions and Host Nation organizations such as the German Bundeswehr and Bundesforst.

Geospatial Product Development

The RSC maintains and publishes a series of standardized and custom map products in digital and hard-copy format, which are available to U.S. military and DoD civilians to support training and training land management. These products include Military Installation Maps (MIM) completed to NGA specifications, support for development of NATO standard installations maps, 3D plastic raised relief maps, aerial image maps, range maps and land navigation maps. The RSC also produces a series of Soldiers Field Cards, containing training area maps, useful emergency / MEDEVAC route and contact information, and environmental stewardship information / do’s and don’ts.

Technical GIS Support

- Spatial Data Acquisition. The RSC assists with sourcing aerial or satellite imagery, topographic data, or elevation data for a specific training location.
- Spatial Analysis. GIS is a powerful tool for analyzing the characteristics of terrain, such as slope, aspect, visibility, and distance. The RSC has the capability to generate line-of-sight calculations and produce shaded relief maps to assist with terrain visualization.
- Range Planning. The RSC uses the Range Managers Toolkit (RMTK) suite of GIS tools to develop Army standard range designs for planning and siting new range facilities.

SRP GIS Applications

The following GIS applications have been developed by SRP to maximize access to SRP GIS data and products, and provide the analytical and visualization tools of GIS software to all Army units and civilians.

ITAM Viewer DVD Set

The ITAM Viewer DVD set contains basic GIS data viewing software bundled with a collection of the latest SRP GIS data, including aerial and satellite imagery, topographic maps and vector GIS layers covering 158 U.S. and host nation training areas in Europe and Africa. Since 1999, this product has evolved from a one-CD product to the current five-DVD volume.

ITAM Viewer Software Capabilities:

- Create custom maps
- Explore high resolution aerial imagery at various scales
- Add and remove additional GIS data layers
- Identify training facilities and training site attribute information
- Edit feature attribute information
- Calculate areas and lengths
- Annotate maps with shapes and comments and export screenshots
- Export annotation to GIS shapefile format

Army Range Mapper (ARM) web-mapping service

The Army Range Mapper (ARM) is an internet mapping service hosted on U.S. Army networks. It enables users to explore the latest geospatial data and high resolution imagery for all training locations, ranges, drop zones and forward operating sites in the USAREUR area of responsibility. The system disseminates authoritative, standardized geospatial products and services, overlays, imagery and topographic base maps to support the USAREUR SRP mission online. It serves as a one-stop shop for all USAREUR SPR GIS customers – the war fighter community, range safety personnel, training planners, environmental analysts and installation management staff. The ARM infrastructure combines an enterprise GIS system consisting of ESRI's ArcSDE and Oracle's relational database management system (RDBMS) with seamless online map and imagery backgrounds provided by ESRI and Bing Maps.

Army Range Mapper Capabilities:

- Zoom to any of over 200 installations, training areas and ranges in the USAREUR area of operations
- View high resolution aerial and satellite imagery over installations
- View Microsoft Bing Streetmaps, commercial Imagery and regional topographic maps around installations
- Switch layers and imagery on/off
- Identify locations of range and training area features
- Click on installation push pins to access links to download PDF maps and other train-

ing area information

- Query map layers and view feature attributes
- Enter and read off coordinates, and convert between coordinate systems
- Calculate route lengths and areas
- Convert units of measurement, mass, temperature and volume
- "*Swipe*" layers or imagery over other layers to allow visual comparison
- Mark up maps with annotation and graphics
- Print customized map views

TAPIN – Training Resource Explorer

The "*TAP IN*" web-mapping application enables users to search for information on ranges, training areas or other training facilities, such as simulators, through a web-map interface. Users can search by training facility type, and query information from the Range Facility Management Support System (RFMSS) database, which stores range scheduling information. The schedule can be viewed for a user specified time period.

TAP-IN Capabilities:

- Query real-time and future RFMSS (Range Facility Management Support System) scheduling data for all USAREUR training facilities.
- View location of training facilities over a variety of basemaps, both topographic and imagery.
- Auto complete search function for training support facilities and training sites.
- Download facility-specific electronic documents in PDF form (e.g. maps, SOPs, handbooks).
- After Action Review (AAR) submission.
- Geodata Services

In order to maximize the potential of and return on investment in GIS data development, the SRP GIS team is leveraging ESRI ArcGIS Server software to publish raster and vector data holdings as geospatial web-services, which can be consumed by other desktop GIS, CAD, web and mobile users throughout the Army network. These services give other desktop GIS users direct access to the live changing data being developed by the SRP GIS team, such as range boundaries, target positions, restricted access areas, environmental layers and roads and buildings infrastructure. The geodata services also provide access to basemap services containing aerial image and topographic map data collected and stored by SRP.

Mobile Applications

USAREUR SRP is developing a series of Mobile applications to deliver geospatial information and tools into the hands of units and civilians in the field. These applications are currently available on Apple iTunes, with Android releases planned for the near future.

Army Range Mapper (ARM) Mobile

The Army Range Mapper is available as a mobile application, covering all USAREUR training areas with the following functions:

Army Range Mapper (ARM) Mobile Functionality:

- Facility Location Search – Installations, Training Areas and Training Support Centers
- Route Planning – gate to gate navigation instructions, including Esso gas stations
- Commercial topographic and imagery base maps

Mobile Soldiers Field Card App

The Mobile Soldier's Field Card Application includes training area maps, safety information and environmental stewardship guidance specific to each installation. Information in foreign languages is provided where available.

Mobile Soldiers Field Card App Contents:

- Medical Evacuation Request (MEDEVAC) Information
- Emergency Numbers and Frequencies
- Spill Prevention / Response (including HAZMAT / POL)
- Vehicle Movement
- Washrack Procedures
- Training Area DOs and DON'Ts
- Wildlife
- Policing Training Areas
- IED/UXO Report
- Camouflage
- Weather
- Safety Risk Assessment Model
- Fire Prevention
- Training Area Maps

USAREUR Environmental Officer Guide

The Environmental Officer guide includes valuable reference material targeting unit environmental officers, including the You Spill, You Dig brochure, Garrison Spill Response Plans, guidance documents, risk matrix, and Material Safety Data Sheets (MSDS).

Acronyms

AAR – After Action Review

ARM – Army Range Mapper

CAD – Computer Aided Design

DAMO-TRS – Department of the Army Management Office – TrainingSimulations

DPW – Department of Public Works

GIS – Geographic Information System

HAZMAT – Hazardous Materials

IED – Improvised Explosive Device

IMCOM – Installation Management Command

ITAM – Integrated Training Area Management

LRAM – Land Rehabilitation and Maintenance

LTA – Local Training Area

MEDEVAC – Medical Evacuation

MIM – Military Installation Map

MSDS – Material Safety Data Sheets

NATO – North Atlantic Treaty Organization

NGA – National Geospatial Intelligence Agency

POL – Paints, Oils and Lubricants

RFMSS – Range Facility Management Support System

RSC – Regional Support Center

RTLA – Range and Training Land Assessment

RTLP – Range and Training Land Program

RTSD – Regional Training Support Division

SOP – Standard Operating Procedure

SRA - Sustainable Range Awareness

SRP – Sustainable Range Program

TRI – Training Requirements Integration

TSAE – Training Support Activity Europe

TSC – Training Support Center

USAREUR – U.S. Army Europe

UXO – Unexploded Ordnance

ENVIRONMENTAL SAMPLING: FROM DISCRETE TO MULTI INCREMENT®

Charles Ramsey[1], Marianne Walsh[2] and Michael Walsh[2]

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The collection of discrete samples has been popular in the environmental field. However, there is a move away from discrete samples for a variety of reasons. The main reason is that discrete sampling is the least efficient sampling design. It provides the least amount of information for the most amount of money. Multi Increment sampling, on the other hand, provides the most amount of information for the least amount of money.

From a monetary and public policy point of view, the real concern should not be only the money spent on sample collection; it should also be the amount and quality of information gained. Insufficient information can lead to erroneous estimations of contamination levels resulting in costly incorrect decisions.

Comparison of information content and quality of discrete and Multi Increment sampling will be presented, and many of the "*myths*" of discrete sampling will be addressed. The reasons for the lack of information from discrete samples will also be presented.

Introduction

The field of sampling theory has been around for more than 50 years and is working its way into the environmental field. This is very fortunate as much of the data currently collected is inadequate for its intended purpose. The Multi Increment sampling process incorporates the tenants of sampling theory, data quality objectives, and quality control into a comprehensive sample collection and decision making methodology. This paper addresses some of the limitations of discrete sampling and illustrates the benefit of MI sampling through application of theory and experimental data.

Data Quality Objectives

The first step in developing sampling plans is determining the data quality objectives (DQO). DQO establish the decision unit (lot, population), the question to be answered by the sampling campaign, and the confidence required. The confidence that the data reflects the true concentration of the decision unit is determined by the error in the measurement process. The major errors in the measurement process are the field sampling error, the laboratory subsampling error, and the analytical measurement error. Of these three major errors, the field sampling error is by far the largest error. If these errors can be controlled (minimized), then confident decisions will result.

The Myth of the Maximum Value

One common misconception that makes people reluctant to let go of discrete sampling is the idea that the maximum value is important to decision making. This logic is flawed on many levels. First of all, the true maximum concentration cannot be known from the results of a few random discrete samples. That would be similar to sampling 10 people from Finland and then stating that the tallest person in that country is the tallest person observed in the sample.

Second, it is not the maximum concentration that is required for risk based calculations, but rather the average. Risk can be calculated based on a dose to a receptor or the potential to contaminate something such as groundwater. Take the case of groundwater contamination from surface soil contamination. If there is one square centimeter of surface soil contamination at a high concentration, it will not have much, if any, impact on the groundwater contamination. However, if there is a much lower contaminate concentration over a large area, there may be enough mass that it can easily cause a groundwater contamination problem. It is not the concentration that is the ultimate issue in most environmental investigations, it is the mass. As Paracelsus said 500 years ago, "*All things are poison, and nothing is without poison; only the dose permits something not to be poisonous.*" The problem in the environmental field is that the dose cannot be measured directly so the concentration is measured. Water sampling incorporates this concept and utilizes concentration and volume to estimate a mass on contaminant. Sometimes the concept of estimating a mass/dose is missing in the sampling of solid materials.

Third, it is impossible to determine if a maximum reported value for a sample does indeed contain that amount of analyte or if there is error in the sampling or analysis that yields a result that is not indicative of the true concentration in the decision unit. When values are reported from the laboratory, it is assumed that the numbers are real and they have an associated error. However, error implies that the numbers from the laboratory are not indicative of the true concentration in the decision unit. Relying on discrete samples to make decisions will result in many incorrect decisions.

Sampling Error

Sampling error is caused by heterogeneity which is always present to some degree. There are two types of heterogeneity: compositional and distributional. The larger the heterogeneity, the more difficult the sampling problem. Sampling errors are a consequence of uncontrolled heterogeneity. The magnitude of these sampling errors is reduced with larger sample mass and collection of numerous increments. Increments are small portions of the decision unit that are collected at random within the decision unit. These multiple increments are aggregated together to form the field sample. If the field sample does not contain sufficient mass and increments, the sample cannot properly represent the decision unit. Therefore, the measured concentration of this sample will not be a good estimate of the true concentration in the decision unit.

Experiments with Discrete and Multi Increment Samples

In contrast to a Multi Increment sample of sufficient mass is the typical discrete sample which does not consider mass and only has one increment. Thus, the discrete sample has the largest error of any sample that can be collected. This error is illustrated by the large concentration variation in co-located duplicate samples. Jenkins (1996) illustrates this with the CRREL wheel. Six discrete samples were taken equidistance along the perimeter of a 1.2 meter diameter circle, and a seventh sample was taken at the center. The difference in concentration of these discrete points is more than two orders of magnitude. In a study by Walsh

(2005) 100 discrete samples were taken on one meter spacing in a 10m by 10m area. The values ranged six orders of magnitude. Heterogeneity of this magnitude prevents any useful concentration information from discrete samples.

In the Walsh (2005) study, 10 Multi Increment samples were also collected in the 10m by 10m decision unit. Each of these samples consisted of 30 randomly located increments. The purpose of this experiment was to illustrate the differences of the two sampling schemes, not to establish a sampling scheme. The range of values of the 10, Multi Increment samples was only a factor of two. Taylor (2011) documents several training range studies where the span of results from discrete samples is several orders of magnitude. Concentration values utilizing Multi Increment samples have much lower variation.

In another study by Walsh (2010), 100 discrete samples were collected in a 1m by 1m area (10cm spacing). This data (Figure 1) demonstrates the extreme variability of discrete data and the futility of using discrete samples to estimate concentration, even in a very small area. The collection of multiple discrete samples does not help the situation and only adds to the cost. Collection of many discrete samples would not be helpful to estimate the true concentration in this small area based on the extreme variability of discrete values.

0.08	0.75	57.8	1.17	10.3	0.16	0.15	0.2	0.07	2.43
0.88	0.12	1.53	0.96	7.19	11.9	2.16	1.58	1.82	0.11
12.9	2.02	2.91	2.4	68.9	17.3	8.43	2.27	0.15	0.08
5.64	0.55	1.66	14.4	26.6	95.8	61.3	12.5	1.06	0.3
87.1	4.02	11.1	286	5630	284	43.4	6.93	1.61	0.27
1.65	0.89	10.8	46.7	203	281	30	1.89	3.57	6.31
1.4	0.83	0.94	3.99	8.97	72.1	43.5	29.2	13.6	5.53
0.07	0.94	46.1	3.04	0.39	9.15	20.6	17.7	2.06	3.42
0.2	0.21	0.11	0.06	0.18	0.01	0.03	3.91	1.84	5.95
0.02	0.03	0.05	0.08	0.05	0.03	0.1	0.29	0.77	3.06

Figure 1. 100 Discrete Results from One Square Meter

Revised Analytical Method

The analytical method for explosives, EPA Method 8830, was updated in 2006 (8330B) to incorporate critical sampling concepts into the analytical method. The logic behind this departure from most analytical methods is that it is worthwhile to produce analytical data on samples that are not representative. This method requires that Multi Increment samples be collected. The exact detail of sample collection is a function of the Data Quality Objectives but follows this general outline:

- Collect minimum 1kg field sample from at least 30 random increments
- Sieve the sample to 2mm (defined as the size of soil)
- Grind the entire field sample with a ring and puck type grinder
- Select 10 grams of ground material for analytical extraction.

Conclusion

There is a move in the US toward understanding the total error in the measurement of the environment. Since the largest source of uncontrolled error is the sampling design the focus is beginning to shift from the laboratory to the field.

The United States Cold Regions Research Engineering Laboratory (CRREL) has dedicated many resources to the study of defendable decision making on training ranges. The main cause of decision errors is the ability to collect and analyze a representative sample. The standard of collecting one or several discrete samples is inadequate. Multi Increment samples have proven to be reliable in making proper decisions at training ranges.

The United States Environmental Protection Agency has also recognized this problem and based on the work of CRREL has changed the analytical method for explosives to include proper field sampling and laboratory subsampling. This method, 8830B , incorporates the concepts of mass and increments to help ensure the representativeness of sample collection.

The concepts of sampling theory are not unique to explosives, but are utilized for metals, organics, etc. in a variety of media including soil, waste, and water.

®Multi Increment is a registered trademark of EnviroStat, Inc.

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QUANTIFYING ENERGETICS CONTAMINATION FOR LIVE-FIRE TRAINING ON MILITARY RANGES

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Live-fire training is an integral part of military preparedness. This training involves the use of energetic materials such as propellants and explosives. These materials are never completely consumed during training and will leave residues of the original formulations on the range (Jenkins et al. 2006, M.R. Walsh et al. 2010, 2011, 2012c). Energetics often contain contaminants of concern, such as dinitrotoluene, nitroglycerin, perchlorate, and other toxic or hazardous compounds. Many of these substances are water soluble and can migrate to groundwater, threatening public health and range sustainability (Racine et al. 1992, M.E. Walsh et al. 1996, Clausen et al. 2004, Johnsen et al. 2007).

Models that are used to predict contaminant fate and transport require a source term (Brown et al. 2004). Determination of the source term for energetic materials on military training ranges has been problematic in the past (Johnsen et al. 2008). Characterization of training lands in the US and Canada has demonstrated that high levels of energetics compounds can occur (Ampleman et al. 2011, M.E. Walsh et al. 2010, 2011, Jenkins et al. 2006). As most ranges are multiple use, it is not possible to determine from which weapon systems the contaminants originated. It is also not possible to determine the in-situ fates of the compounds as there is no way to determine how long each particle resided at the site. For detonation points, which are located within impact ranges, there are the added impediments of the presence of unexploded ordnance and restrictions on range access.

Method

The US Army Cold Regions Research and Engineering Laboratory (CRREL) and Envirostat, Inc, have developed several methods to enable the environmental characterization of ranges and range activities. Among these is a procedure for obtaining energetics residues samples on snow surfaces that allows the determination of energetics source terms on a per-round basis (Walsh et al. 2012b). Snow presents an ideal medium for sampling of energetics residues as it is clean, contains no confounding substances, and allows straightforward determination of the area affected by the training activity (Figure 1). The sampling method for three common range training activities – firing of weapon systems, detonation of munitions, and burning of excess propellants – will be described here.

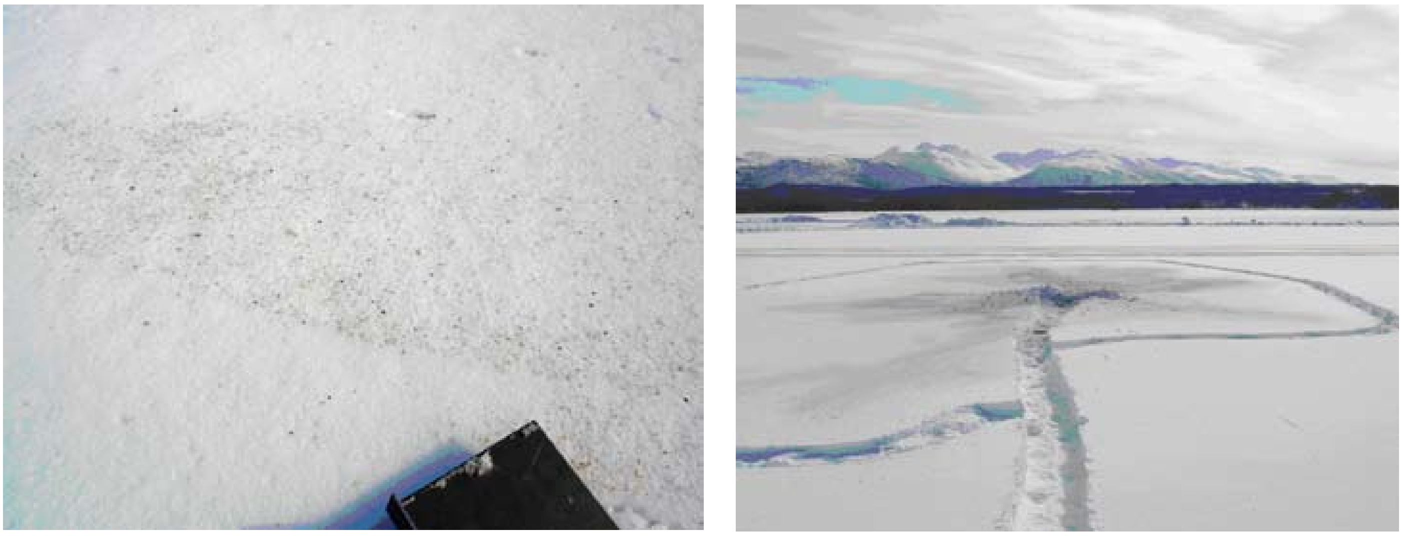

Figure 1. Energetics residues on clean snow surfaces

a. AT4 Rocket propellant residue (10-cm scoop) *b. 60-mm mortar round detonation plume (≈350 m^2)*

The basic concept requires that the energetics residues be generated in clean snow-covered areas. The snow surface separates the activity for which data is desired from prior range activities. For detonations, we use an area that is ice-covered in winter with an overlay of snow. The ice prevents the penetration of the blast into the soil and protects the researchers from unexploded ordnance from past training activities. For firing points and propellants, a clean snow cover is all that is required for testing. Thus, in all cases, there will be only residues and snow (water) in all the samples, greatly simplifying analyses. Following cessation of the test activity, the area of contamination is demarcated. Deposition areas, called plumes, are demarcated by walking the edge, determined qualitatively by visually ascertaining where the residues density approaches zero. A geographical position system is used to record the outline of the plume and compute the area of deposition. Most activities leave a discernable plume on the snow surface. For quality assurance (QA), we demarcate for sampling a 3-m annulus around the main plume area and, in some cases, an annulus extending from 3- to 6-m outside the plume (OTP).

Sampling of the demarcated areas (sampling units) then occurs. We use 10- x 10-cm polytetraflouroethylene-lined scoops to collect multi-increment (MI) samples in each sampling unit. We sample to a depth of 2 cm. A systematic-random approach is used to collect each sample (Figure 2). For the main sampling unit (the plume), three MI samples consisting of approximately 100 increments each are collected in special clean polyethylene (PE) lab-grade bags. For OTP units, we collect between 40 and 100 increments. Normally, one OTP sample is collected per plume, but triplicate OTPs are taken around random plumes for QA.

Figure 2. Sampling a detonation plume

Initial processing of the samples takes place at our site lab near the test range. The samples are logged in, rebagged, placed in clean PE tubs, melted, and filtered. The filters containing solid residues are air-dried in a clean, dark location and stored under refrigeration until shipment. The aqueous samples, consisting of two to four 500-mL aliquots, are stored under refrigeration until enough are accumulated to perform solid phase extraction. Solid phase extraction is then performed on one to three of the 500-mL aliquots using 5 mL of acetonitrile (AcN) as the solvent for a 100:1 concentration. The concentrate is split 1.5:3.5, the smaller splits along with the filters shipped to our analytical lab in Hanover, NH.

Final processing and analyses are performed at our analytical laboratory in Hanover, NH. Here, the filters containing the particulate residues are shaken with AcN and extracted. The extractions are then run on a liquid chromatography or gas chromatography instrument. Mass deposition is back-calculated from the analytical concentrations using the sampling unit size and number of increments. QA samples are taken throughout the process to determine if cross contamination exists and to check the performance of different tasks.

For firing positions, the procedure is very similar. The plume of residues is visually demarcated by the presence of propellant residues on the snow surface. As the residue signature is not great, we typically take 0-3 m and 3-6 m OTPs. We also have done downrange MI transects, typically 3 x 10-m in area, at 10- to 20-m intervals. For some weapon systems, such as shoulder-fired rockets, an area behind the firing position is also sampled as most residues occur in a backblast area. Larger direct-fire weapon systems such as tanks have a violent muzzle blast causing much mixing of the snow in front of the gun. For these systems, we sample below the increments taken from the surface to obtain data on residues at depth caused by mixing. These are called sub-surface samples and can contain significant amounts of residues. Subsurface QA samples are also taken for impact point detonations but are not as critical.

At propellant burn points, the snow at and surrounding the burn is sampled if the propellant is burned on the snow surface or the snow surrounding the burn unit is sampled to characterize the activity. With surface burns, it is necessary to take subsurface samples as well as surface samples. Surface sampling of soils is also done, but the data is more characterization in nature than depositional as there is typically no data on what has been burned over the years.

Results

Energetics deposition rate data have been collected for 22 weapon systems and 26 munitions. General results will be presented here. For a complete tabulation of data, see Table 1 at the end of this section and the following publications: Walsh et al. 2010, 2011, 2012b, 2012c, 2013.

Detonation Points

Detonating rounds are normally quite efficient. Consumption of energetic compounds is generally higher than 99.99%, which we consider the threshold for a high-order detonation. The larger, thicker-walled rounds have a higher efficiency than smaller, thinner-walled rounds. For example, a 155-mm howitzer round detonating high order is 99.99999% efficient, whereas an 81-mm mortar round with the same high-explosive filler (Composition B) is only 99.999% efficient. This is still quite good. Problems start to occur with the new insensitive munitions, which contain insensitive high explosive (IHE) compounds. Tests on rounds containing PAX-21 IHE that detonated high order (>99.99% consumption of RDX and 2,4-dinitroanisole (DNAN) explosives) had residue levels of ammonium perchlorate, a component of the formulation, averaging 15%. Initial results from testing of rounds containing IMX-104, which contains RDX, DNAN, and 3-Nitro-1,2,4-Tiazol-5-one (NTO) indicate that while the efficiencies of RDX and DNAN indicated high-order detonations, the NTO was only 98% to 99% efficient, leaving gram-quantities of the highly soluble compound in the environment.

Blow-in-place operations, when a donor charge is placed on an unexploded piece of ordnance (UXO) in the field to detonate the round for disposal, follow the general characteristics of high-order detonations. Explosives residues tend to be about two orders of magnitude higher for most components, excluding perchlorate and NTO. Larger rounds are cleaner detonating and, as with the high-order detonations, the new insensitive munitions have problematic composition components. The PAX-21 BIP detonations left 35% on average of the perchlorate in the residues, while the NTO remaining after the IMX-104 BIP detonations ranged up to 98% of the original mass.

The most significant source of contamination from rounds fired into an impact area comes from rounds that do not detonate or don't detonate properly. A single breached UXO can lead to more contamination in a single location than 100,000 high-order detonations will deposit over a whole impact area. Functioning rounds that detonate in close proximity to UXO can lead to breaches or low-order detonation of the UXO. A low-order detonation may leave half its explosive filler scattered in a relatively small area, on the order of square meters.

Firing Points

Firing point residues generally consist of particles containing the same ratio of energetic compounds as unreacted propellant. The exception is propellant with "impregnated" grains that have one energetic compound infused into the surface of the base propellant. The result is a much greater consumption of the infused compound compared to the base compound during firing. This was first observed in a direct comparison test of 40-mm munitions between a standard multicomponent double-based propellant and an impregnated propellant, both using nitrocellulose (NC) as the base energetic and nitroglycerin (NG) as the additive energetic. The mass of energetic residues from the impregnated propellant was 720 mg/round, with about 2 mg of NG/round. This is about 0.3% of the original NG in the grains, 1/30th of the original concentration. For the standard propellant, the estimated total propellant residue was 410 mg/round, of which 76 mg was NG, or 19% of the residues. This is the same as in the original propellant grains.

Rockets are different as well. The unconfined nature of the propellant burn results in lower pressure and temperature of combustion. Some formulations contain perchlorate to boost the efficiency of the propellant burn, and that was seen in our results for the shoulder-fired weapon systems. Two weapons tested utilized double-based propellants and one used double-based propellant with potassium perchlorate. The system utilizing the formulation containing perchlorate burned 100 times cleaner (0.19% vs. 14 – 73% NG deposition) than the two systems using propellant not containing perchlorate. The large 204-mm rockets, which burn perchlorate-containing propellant, had extremely high efficiencies, >99.9999%.

For gun systems, bigger has proven to be better. Large caliber, high propellant charge guns, such as 155-mm howitzers and 105-mm tanks, are quite clean, with residues rates below 0.002% of the original compound of interest (nitroguanadine (NQ), dinitrotoluene (DNT), or NG). Shorter-barreled, smaller caliber weapon systems such as small arms are less efficient, leaving residues containing 1% - 5% of the original mass of the compounds. Mortars, which have smooth-bore tubes, have firing point residues rates range up to 3%. It is interesting to note that a 9-mm pistol will leave more residues per round (2.1 mg) than a 155-mm howitzer (1.2 mg), even though the howitzer utilizes over 6,000 times as much propellant per round.

Propellant Burn Points

Following training with indirect fire weapon systems, there are often excess propellant charges that require disposal. In the US, the propellant is burned on the ground near the firing positions or transported to a rudimentary burn device, typically an open-topped steel pan. These sites have been found to be highly contaminated. Up to 18% of propellants may remain unburned following a disposal action. Soils surrounding a burn pan are highly contaminated. At one site in Alaska, we measured 35 mg/kg of DNT, 6.4 mg/kg NG, and 5,100 mg/kg lead in the soil surrounding the pan. In Michigan, lead levels were measured at 5,100 mg/kg and DNT at 48 mg/kg. Regulatory limits in Michigan for lead and DNT are 400 mg/kg and 2.0 mg/kg. This soil contamination is highly concentrated in a small area and can become a point source for pollution. The fine particles of lead are also a dangerous and immediate inhalation hazard.

Table 1. Energetics residues from common military training activities

Test /Weapon	Energetic Material	Energetic Compound	Residues / Round (mg)	Consumption Efficiency
Live-fire detonations				
Mortars				
60-mm	Comp B	RDX / HMX	0.073	99.999
	PAX-21	RDX / HMX	9.2	99.99
		DNAN	7.1	99.99
		AP**	14,000	
	IMX-104	RDX/HMX	4.5	99.9
		DNAN	5.3	99.9
		NTO	2,200	9[illegible]
81-mm	Comp B	RDX / HMX	8.5	99.99
	IMX-104	RDX/HMX	16	99.9
		DNAN	27	99.9
		NTO	1,900	99.[illegible]
120-mm	Comp B	RDX / HMX	19	99.9
Howitzers				
105-mm	Comp B	RDX / HMX	0.095	99.999
155-mm	Comp B	RDX / HMX	0.30	99.999
	TNT	TNT	-ND-	—
Rockets				
227-mm	PETN-109	RDX	-ND-	—
Hand Grenades				
–	Comp B	RDX	0.025	99.999
Rifle Grenade				
40-mm	Comp B	RDX	1.6	99.[illegible]
Blow-in-place Detonations				
Mortars				
60-mm	Comp B + C4	RDX / HMX	200	99.[illegible]
	PAX-21	RDX / HMX	874	99.[illegible]
		DNAN	741	99.[illegible]
		AP**	35,000	
	IMX-104	RDX/HMX	4,300	99.[illegible]
		DNAN	10,000	9[illegible]
		NTO	47,000	
81-mm	Comp B + C4	RDX / HMX	150	99.[illegible]
	IMX-104	RDX/HMX	20,000	9[illegible]
		DNAN	45,000	
		NTO	233,000	
120-mm	Comp B + C4	RDX / HMX	25	99.9
Howitzers				
105-mm	Comp B + C4	RDX / HMX	50	99.9
155-mm	Comp B + C4	RDX / HMX	15	99.99
	TNT	TNT	5.9	99.99
	C4	RDX	5.9	99.9
Demolitions				
Demolition block				
–	C4	RDX	19	99.9
Bangalore Torpedo				
54-mm	Comp B + A3	RDX	110.0	99.9
Shape Charge				
18-Kg	Comp B + A3	RDX	4,200.0	99.[illegible]

Test /Weapon	Energetic Material	Energetic Compound	Residues / Round (mg)	Consumption Efficiency
Firing points				
Mortars				
60-mm	M9 - Ign. Ctg.	NG	0.088	99.99%
81-mm	M9 - Charge 5	NG	1,000	96.7%
120-mm	M45-Charge 2	NG	350	98.6%
Howitzers				
105-mm	M1- Charge 5	DNT	34	99.9%
155-mm	M1-Charge 7	DNT	1.2	99.99952%
155-mm (British)	L8 - Charge 3	NQ	-ND-	—
		NG	-ND-	—
	L8 - Charge 5	NQ	-ND-	—
		NG	-ND-	—
	L10-Charge 8	NQ	-ND-	—
		NG	-ND-	—
Tank				
105-mm (Canadian)	M1	DNT	6.7	99.998%
Rockets				
84-mm	AKB 204	NG	95,000	27%
84-mm (Canadian)	AKB 204	NG	20,000	86%
66-mm (Canadian)	M7	NG	42	99.8%
204-mm	AR 360B	AP	<1.6	> 99.99999%
204-mm	AR 360B	AP	-ND-	—
Small Arms				
9-mm Pistol	WPR289	NG	2.1	94.68%
5.56-mm Rifle	WC844	NG	1.8	98.90%
5.56-mm MG	WC844	NG	1.3	99.29%
7.62-mm MG	WC846	NG	1.5	99.4%
		DNT	0.0018	99.95%
12.7-mm MG	WC860 / 857	NG	11	99.3%
Medium Caliber				
40-mm	F15080	NG	2.2	99.4%
	M2	NG	76	91.6%
Burn points				
Mortar -Snow				
81-mm	M9	NG	84	98.4%
120-mm	M45	NG	2,273	82.5%
Mortar-Frozen ground				
120-mm	M45	NG	664	94.9%
Mortar-Pan				
120-mm	M45	NG	27	99.8%
Howitzer-Dry sand				
105-mm	M1*	DNT	620	99.0%
155-mm (British)	Charge 4	NG	3	99.998%
		NQ	33	99.99%
	Charge 7	NG	2.0	99.999%
		NQ	16	99.998%
Howitzer-Wet sand				
105-mm	M1*	DNT	650	99.0%

*Notes: *The energetics mass per round for the 105-mm burn point tests is the combined total of a charge 6 and 7 bag*

For AP, the percent levels are reported for perchlorate (ClO4)

ND = No analyte detected in samples.

Summary

Training with live ammunition will result in the deposition of energetics residues on training lands. Some of the compounds used in munitions are quite toxic, such as DNT, NG, and perchlorates. To reduce environmental risk, ensure range sustainability, and avoid future cleanup liabilities, it is important to know which activities and weapon systems are most problematic. With this knowledge, actions can be taken to mitigate the environmental risks associated with training.

Risk assessment should start before any new munition is fielded (Voie 2009). In the US, a life cycle environmental assessment (LCEA) is conducted on all new munitions as part of the developmental and certification processes. However, this assessment does not evaluate the actual detonation efficiency of the rounds in a fielded condition and does not consider post-detonation residues. In addition, the US Department of Defense has the Strategic Environmental Research and Development Program, which funds projects related to investigating or solving problems in various areas of interest to the military, including environmental restoration (Leeson 2013). CRREL and DRDC have been funded over the last 14 years to investigate the various environmental impacts of live-fire training on military ranges. In March of 2012, analysis of residues following detonation testing of a newly fielded insensitive munition revealed that large quantities of perchlorate would be released to the environment (Walsh et al. 2013). Our data resulted in the cessation of training with these munitions, preventing the use of over 380,000 rounds. Had these munitions been used, over 3 trillion liters of water (3 x 10^{12} L) would have been contaminated with perchlorate above US drinking water standards. Perchlorate is a highly soluble, persistent, and mobile contaminant. The LCEA indicated no significant impact would result from the use of these rounds. Obviously, the time to test the environmental impact of munitions is before they are fielded.

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MINIMIZING ERRORS ASSOCIATED WITH LABORATORY ANALYSIS OF SOIL SAMPLES COLLECTED FOR DETERMINATION OF EXPLOSIVES AND PROPELLANT RESIDUES

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Live-fire military exercises take place on heavily-utilized training ranges over many years and can potentially result in the accumulation of energetic residues in the environment. Some of these residues could ultimately serve as a source for groundwater contamination and off-site migration. Energetic residues, if present, are concentrated in the surface soil as solid particles. To determine the extent of contamination, samples of soil need to be collected using a method that will overcome sampling error due to the heterogeneous sizes, compositional variability, and spatial distribution of the energetic particles. Actual sampling experiments on more than 10 ranges have proven that discrete samples will not provide valid mean estimates of energetic concentrations; rather MULTI INCREMENT® samples that are composed of a minimum of 30 soil aliquots must be collected. These multi-increment samples tend to weigh at least one kilogram and can be several kilograms. After collection, the analytical lab must process this large field sample in a way that preserves the representativeness of the sample. This processing is done to enable the collection of a much smaller analytical subsample for solvent extraction and generally involves air-drying, sieving, splitting, grinding and subsampling. This presentation will provide results from experiments that demonstrate the severity of the errors that are associated with each step in the processing of training range soils and review the analytical methods used to determine energetics in soil.

Background

After a multi-increment® soil sample is collected, the sample is submitted to an analytical laboratory to determine the concentrations of energetics. Analytical labs use solvent (acetonitrile) to extract the energetics from the soil, and a small portion of the acetonitrile is analyzed by chromatography. Because of the expense associated with the purchase and eventual disposal of acetonitrile, the volume of acetonitrile that is used for soil extraction must be minimized. Minimal solvent usage is accomplished by taking the smallest subsample from the field sample that will still represent all the constituents of interest in the same proportion as the native soil.

In most cases, the multi-increment sample will contain very few energetic particles or fibers compared to the total number of particles in the soil matrix. For example, if the multi-increment sample contains one energetic particle in each 100 grams of soil, a typical analytical subsample (a few grams) will not represent the proportion of energetic particles in the field sample. Most of the subsamples will have very low concentrations, but some subsamples will have much, much higher concentrations than actually exists in the multi-increment sample. Fortunately, the physical properties of most energetics (i.e., low vapor pressure) permit the processing of a soil sample so that a small subsample (10 g) can represent the much larger multi-increment sample (>1,000 g).

The processing involves the following steps: air-drying, sieving, and machine grinding until all the particles in the multi-increment sample are very fine (<75 µm), followed by subsampling. Reduction in particle size results in the formation of many, many fine energetic particles so that a small analytical (e.g., 10 g) soil subsample can have the same proportion of constituents as the processed multi-increment sample.

The ultimate goal of this procedure is to adequately represent the several tons of soil in the field with the few grams of soil that are actually subjected to solvent extraction and analysis in the lab. The data presented in this paper are results from some of the research that was used to revise of the standard method of analyses for energetics in the Unitied States: U.S. Environmental Protection Agency SW-846 Method 8330 Nitroaromatics, Nitramines, Nitrate Esters by High Performance Liquid Chromatography (HPLC). The revision, named Method 8330B (US EPA 2006) has an appendix that addresses proper sample collection and processing methods for energetics.

How to Process Multi-Increment Samples to Determine Energetics

Step 1. Air dry the entire sample

Soils samples with energetics should be stored at <4°C (can be frozen) until they are ready for processing. Samples that are known to have very high energetic concentrations should be isolated from samples that potentially have low or undetectable energetic concentrations to prevent cross-contamination.

The first step in processing is to air-dry the soils. Drying arrests microbial activity that could biotransform some of the explosives and it enhances the ability to further process the soil. The entire field-moist multi-increment sample is spread onto a clean tray and air-dried away from light. The time required to thoroughly air-dry a sample depends on the relative humidity and the initial soil moisture content. Generally, two to three days are required. Oven-drying IS NOT acceptable due to thermal degradation and/or sublimation of the energetics.

Once a soil sample is air-dried, it may be returned to a sample bag and stored at room temperature in the dark. Table 1 shows data (Walsh and Lambert 2006) for soils that were used in the development of the processing method. The first set of results have much greater variance than the second set; the second set were obtained after the soils were processed according to the procedures described in this paper. There is no evidence of anlatye loss after many years of storage.

Table 1. Stability of the Concentration of Energetics in Air-dried Soils

Soil	Additional Processing	Year 1st Analyzed	1st Results* mg/kg	2005 Results*† mg/kg
Milan AAP	10 Mesh sieve	1999	RDX 23 ± 10 HMX 4 ± 1	RDX 29 ± 0.3 HMX 6.6 ± 0.1
Volunteer AAP	Manual grind, 30 mesh sieve	1995	TNT 10.5 ± 0.3 DNT 1.4 ± 0.04	TNT 10.2 ± 0.3 DNT 2.7 ± 0.08
Fort Lewis Hand Grenade Range	None (n = 12) 50 g / each	2001	RDX 3.8 ± 1.8 HMX 1.0 ± 0.24 TNT 1.4 ± 0.88	RDX 3.8 ± 0.08 HMX 0.95 ± 0.01 TNT 0.96 ± 0.05

* Concentration (mg/kg) n ≥ 3, † Samples machine ground, AAP = Army Ammunition Plant

Step 2. Sieving or Manual Removal of Oversize Fraction.

Unvegetated or sparsely vegetated soil samples are forced through a #10 sieve. The #10 sieve has a mesh with 2-mm openings, the size division between course sand and gravel (USDA 1993). Most of the energetics are found in the <2-mm size fraction (Table 2 and 3). Soil aggregates and dried vegetation such as moss or grass should be broken apart while sieving the soil. Each size fraction is weighed, the less than 2-mm fraction processed further as described below, and the oversize (>2-mm) fraction is saved for further study if needed to meed the objectives of the investigation.

At some ranges, the mineral soil may be overlain by a thick (>3 cm) organic layer, and the multi-increment samples will be primarily composed of dry, decomposed and/or partially decomposed organic material with little mineral soil. These samples are not easily forced through a sieve, so the oversize fraction consisting of pebble-size or greater rocks and woody sticks are manually removed and the rest of the sample is machine-ground as described below (Walsh et al. 2007).

Table 2. Size fractionation of three soils from a hand grenade ranges and the mass of energetics found in each fraction

	Mass of Fraction (% of Total Mass)		
Size Fraction	Soil Mass	RDX Mass	TNT Mass
>2 mm (#10-mesh)	257 g (21%)	6.2 µg (0.3%)	58 µg (0.8%)
>0.595 mm and < 2 mm	243 g (20%)	1,500 µg (66%)	5100 µg (74%)
<0.595 mm (#30-mesh)	713 g (59%)	790 µg (34%)	1,800 (26%)
>2 mm	188 g (17%)	4.3 µg (1.1%)	67 µg (5.6%)
>0.595 mm and < 2 mm	212 g (19%)	150 µg (40%)	710 µg (59%)
<0.595 mm	711 g (64%)	220 µg (59%)	420 µg (35%)
>2 mm	239 (14%)	7.2 µg (0.2%)	23 µg (1.8%)
>0.595 mm and < 2 mm	302 (18%)	2,050 µg (49%)	1,000 µg (77%)
<0.595 mm	1,183 (69%)	2,100 µg (51%)	280 µg (21%)

Table 3. Propellant residue in three firing point soils and the mass of 2,4-DNT found in each fraction

	Mass of Fraction (% of Total Mass)	
Size Fraction	Soil Mass	2,4-DNT Mass
>2 mm	1,870 g (44%)	<d (0%)
>0.595 mm and < 2 mm	800 g (19%)	1,500 µg (69%)
<0.595 mm	1,610 g (38%)	680 µg (31%)
>2 mm	1,260 g (43%)	<d (0%)
>0.595 mm and < 2 mm	500 g (17%)	1,650 µg (73%)
<0.595 mm	1,160 g (40%)	600 µg (27%)
>2 mm	1,600 g (43%)	<d (0%)
>0.595 mm and < 2 mm	610 g (17%)	780 µg (61%)
<0.595 mm	1,470 g (40%)	500 µg (39%)

Step 3. Machine Grinding

The less than 2-mm fraction is ground using a puck mill (Lab TechEssa LM2 or equivalent). Other types of grinders do not adequately grind the energetic particles (Larry Penfold, TestAmerica, personal communication).

Soils from impact areas that contain only high explosive residues (i.e., HMX, RDX, TNT) are ground for 60 s. Soils from ranges that contain propellant residues (i.e., firing points, demolition areas, rocket impact ranges) are ground for five 60-s periods with a cooling time between grind. The extra grinding time is needed to pulverize the propellant fibers.

Grinding reduces the particle size of the course soil to the texture of flour (<75 μm) and it significantly reduces the uncertainty associated with subsampling (Table 4, Walsh and Lambert 2006).

Table 4. Data showing the reduction in subsampling uncertainty obtained by machine grinding soils with energetics

RDX Concentration (mg/kg)

Army Ammunition Plant		Hand Grenade Range	
Unground	Ground	Unground	Ground
21	31	7.3	3.8
24	31	3.0	3.8
29	32	2.0	3.7
22	32	1.6	3.8
29	31	2.5	3.8
28	31	3.2	3.7
32	31	2.0	3.8
26 (Mean)	31 (Mean)	3.1 (Mean)	3.8 Mean

Step 4. Subsampling

The ground sample is spread evenly over a clean surface in an exhaust hood. The thickness of the sample should be about 1 cm. A spatula is used to obtain increments of soil through the thickness of the sample. Generally, at least 30 increments from random locations are combined until a 10 g subsample is obtained.

Table 5. Concentrations of energetics found in subsamples of ground samples and the concentration found by extracts of the rest of the >1 kg ground sample

Concentration (mg/kg)

a) Soil from a Demolition Training Range

Mass (g) Extracted	HMX	RDX	2,4-DNT
10 g (Rep 1)	1.98	11.7	4.6
10 g (Rep 2)	2.00	11.6	4.9
10 g (Rep 3)	1.98	11.8	5.2
1770 g (Rest of sample)	2.02	11.9	4.8

b) Soil from an Artillery Impact Area

Mass (g) Extracted	HMX	RDX	2,4-DNT
10 g (Rep 1)	2.72	14.1	1.60
10 g (Rep 2)	2.72	14.1	1.60
10 g (Rep 3)	2.60	13.9	1.63
1300 g (Rest of sample)	2.76	14.3	1.56

The data in Table 5 were used to verify that a 10 g subsample can indeed represent the concentration in a >1 kg field sample after the field sample is processed properly (Hewitt et al. 2009). In the two cases presented, each processed soil was subsampled in triplicate, then the rest of each sample was extracted with solvent. Results for HMX and RDX are shown with three significant digits for the explosives for illustrative purposes only.

Step 5. Extraction with Solvent

The energetic compounds are extracted from the soil matrix using acetonitrile. Extraction kinetic studies conducted many years ago using field-contaminated soils from arsenals showed that equilibration time varied with concentration, the soil, the solvent, and agitation method. Acetonitrile was superior for extraction of the nitramine explosives (HMX and RDX) and it is compatible with the analytical instruments used to determine the energetics. Equilibration using a sonic bath was achieved rapidly for higher concentrations from sandy soils and slowly for low concentrations and clay soils. An 18 hour time was sufficient for most soils. The 18 hour extraction is not a necessarily a burden. Solvent can be added to the subsamples in the afternoon and extracts prepared for analysis the following morning. More recent studies showed that a platform shaker can be substituted for a sonic bath (Walsh and Lambert 2006).

Step 6. Analysis

Concentrations of energetics are measured using a liquid chromatograph (LC) equipped with a UV detector (Figure 1). Identifications are based on retention time, so all measurements must be confirmed, either different chromtographic conditions that result in a different retention order, a mass spectrometer, or another method such as gas chromtography with an electron capture detector (US EPA 1999). The method using the UV detector has proven to be extremely rugged over the years (high accuracy and high precision) for the analysis of most soils. The mass spectrometer is needed when analyzing complex matrices that contain many other UV absorbing compounds.

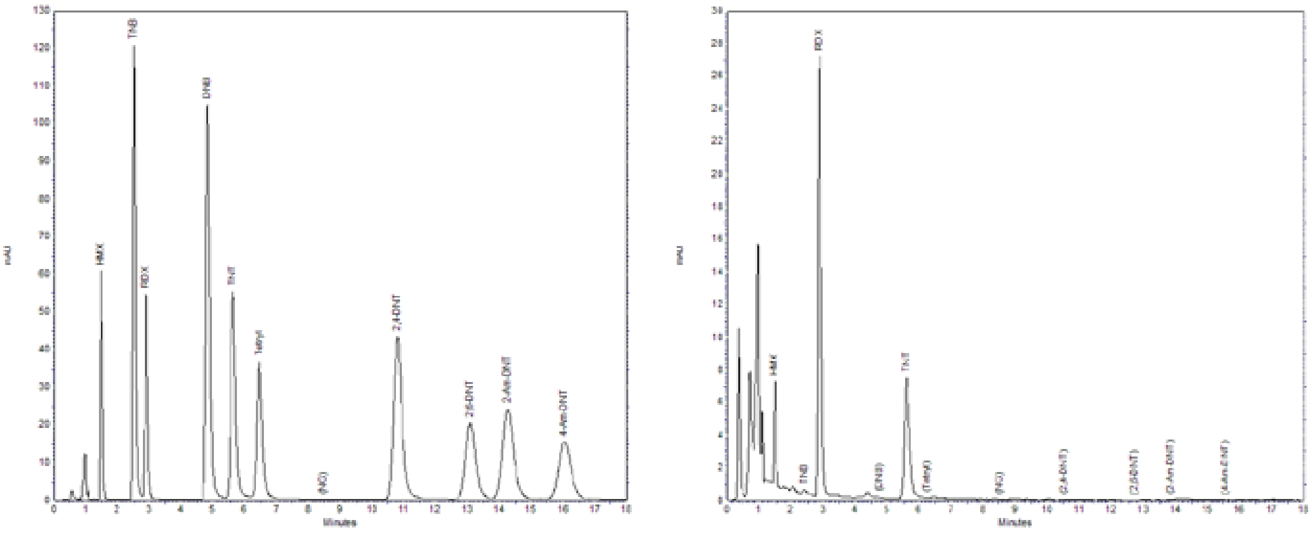

Figure 1. Typical LC-UV chromatograms for a calibration standard and a solvent extract from a training range soil

Summary

The entire sample received by an analytical lab must be processed (not just a small portion off the top). Alternative sample preparation procedures, such as different types of grinders, solvents, or extraction methods must be verified with field contaminated soil, not spiked soils. Appropirate analytical methods must be used. Standard method for other types of semi-volatiles are not appropriate for explosives and propellants.

Method 8330 continues to be revised and updated with improved technologies in analytical columns and instrumentation.

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CANADIAN PROGRAMME ON THE ENVIRONMENTAL IMPACTS OF MUNITION

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A large effort was dedicated in Canada over the last years on the characterization of military live fire training ranges for munitions residues and on the study of the environmental fate and ecotoxicological impacts of munitions constituents (MC). The patterns of contamination of each type of ranges, such as grenade or antitank ranges were identified and sampling guidance documents were published. The laboratory and large scale fate and transport of MC were assessed. Efforts were also made to define geological, hydrological and hydrogeological contexts of the major Army training ranges. Features such as the hydraulic head and the water quality, groundwater flow and direction were used to model the underlying aquifer. Attributes of each specific site were used to create vulnerability and hazard maps. The evaluation of the risk of aquifer contamination by military training activities was conducted by combining vulnerability and hazard maps. These maps will be used in Canada as range management tools to guide various decisions, such as new range location, current site relocation or range closure. All the information acquired over the last years allowed a deep understanding of the deposition, fate, toxicity and transport of MC. This paper will describe the Canadian approach towards understanding and minimizing the environmental footprint of munitions to support Forces readiness and the sustainable management of our ranges and training areas.

Introduction

The readiness of the Armed Forces is closely related to well-trained troops and continuous enhancement of their arsenal. Sustained live-fire training is critical to preparedness for potential missions abroad. Military live-fire training activities generate source zones of munitions constituents (MCs) in the environment, which threaten range sustainment. A source zone may be defined as an area where chemicals are deposited, usually on the surface soils, which poses a threat to ecological or human receptors. The Canadian Sustainable Training Research & Development (R&D) program is aimed at maintaining both military readiness and environmentally friendly defense activities in order to ensure the long-term usage of military ranges and training areas (RTAs). In order to understand the various aspects related to the dispersion and fate of MCs, multidisciplinary collaborations were established with national and international research centers. The main collaborators are the Institut National de la Recherche Scientifique – Centre Eau, Terre et Environnement (INRS-ETE) as well as the National Research Council of Canada (NRC-Canada) and the the Engineering Research & Development Center, Cold Regions Research and Engineering Laboratory (ERDC-CRREL). Over the years, various aspects of research were supported by many stakeholders, including Defence R&D Canada (DRDC), DRDC thrusts (Munitions and Firepower, as well as Sustain thrusts), Director General Environment (DGE), Director Land Environment (DLE), and an U.S. peer-reviewed funding program, the Strategic Environmental Research and Development Program (SERDP, Arlington, VA). In order to better understand the extent of the problems, DRDC initiated a research program for the environmental assessment of the Army's RTAs. The characterization work was conducted both in Canada and the U.S. and was done in collaboration with U.S. scientists from ERDC-CRREL to better understand the nature and extent of contamination (Jenkins et al., 1997, 1999, 2001, 2004, 2005, Hewitt et al., 2003, 2007, 2009, Thiboutot et al., 2002, 2010, 2012a, 2012b and Walsh et al., 2002, 2004, 2007a). Extensive surface soil characterization of most of the Canadian RTAs was done in conjunction with hydrogeological studies performed by INRS-ETE. Moreover, the study of the environmental fate of energetic materials (EMs) was conducted in close collaboration with NRC scientists. Protocols were published in Canada, the U.S. and Norway to effectively characterize the huge tracks of military live-fire lands (Hewitt et al., 2009, Jenkins et al., 2005, U.S. EPA 2006, Thiboutot et al., 2012a, 2012b, Voie et al., 2010). The RTAs characterized over the years are spread out all over North America, which allowed the study of the effects of various geological formations and various climates.

The understanding and evaluation of the source terms for most weapons, both at impact areas and firing positions (FP) were needed to better assess the actual source term of contaminants generated by the live-firing activities. Various trials were dedicated to estimating the deposition rates of most weapon platforms and characterizing the accumulation both at firing point and at target areas. (Ampleman et al., 2010, Jenkins et al., 2008, Pennington et al., 2006, Poulin et al., 2008a and 2008b, Poulin and Diaz, 2008, Thiboutot et al., 2008, 2009, 2010, Walsh et al., 2006, 2009). This allowed a better understanding of the contamination pattern at the firing positions. Several studies have also been performed on the wider fate of munitions constituents, mostly in collaboration with INRS-ETE and NRC-Canada (Bordeleau et al., 2007, 2008a, 2008b, Halasz et al., 2002, Hawari et al., 2000a, 2000b, 2001, Lewis et al., 2009, Mailloux et al., 2008, Martel et al., 2007, 2009, Monteil-Rivera et al., 2004, Robertson et al., 2007, Zhao et al., 2004). A large effort was also dedicated in Canada on the study of the ecotoxicological impacts of MCs (Doddard et al., 2005, Lachance et al., 2008, Sarrazin et al., 2009, Robidoux et al., 2000, 2001, 2005, 2006, Rocheleau et al., 2008, Sunahara et al., 2001, 2009). This paper describes the North American approach towards understanding and minimizing the environmental footprint of munitions in a live-fire context.

Contaminants of concern and their sources

Accurately detecting the type and quantity of contamination from MCs and their breakdown products in water, soil and sediments is vital for assessing the extent of contamination and ultimately the risk to human and ecological receptors. The contaminants of concern that might be dispersed in the environment following live-fire training are mainly EMs and metals. Conventional weapons for live-fire training use EMs in the form of propellants (propulsion) and main charge explosive (detonation). The explosives that are most frequently detected in RTAs are: RDX, 2,4,6-trinitrotoluene (TNT) and its main degradation products 2-amino-4,6-dinitrotoluene (2-A-DNT) and 4-amino-2,6-dinitrotoluene (4-A-DNT) and high melting explosive or octrahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). Propellants include both rocket and gun propellants. Most rocket propellants consist of a rubbery binder filled with ammonium perchlorate (AP) oxidizer and may contain powdered aluminum as fuel. Propellants may also be based on nitrate esters, usually nitroglycerine (NG) and nitrocellulose (NC),. Gun propellants are usually referred to as single base (composed of NC), double base (composed of NC and NG), or triple base (composed of NC, NG and nitroguanidine (NQ)). Single-base propellants may also contain 2,4-dinitrotoluene (2,4-DNT) with traces of 2,6-dinitrotoluene (2,6-DNT). Propellant formulations contain several other minor components such as stabilizers, plasticizers and burn rate modifiers, but they represent less than 2 % by weight of the propellants and have never been detected as MCs in soil surfaces.

In summary, the main EMs of concern in RTAs are: RDX, HMX, TNT, 2-A-DNT, 4-A-DNT, 2,4-DNT, 2,6-DNT, NG, NQ and AP. NC is not included in this list, as it is a polymer of very low toxicity and bioavailability and complex to analyze in environmental matrixes.

Live-firing of munitions also spread inorganic contaminants in the environment. Metals are deposited onto range soils by a variety of processes. High-order detonations generally disperse very fine metal particles, with the exception of pre-fragmented rounds, which might produce large fragments even in high order scenarios. Much larger fragments are generally produced by low-order detonations. Metals can be transformed in other metallic compounds not originally present in the munitions. All the metals originally present in munitions are dispersed in RTAs after detonation, either in their original state, or as other metallic compounds.

In the case of the FPs, several environmental assessment studies have shown that residues coming from the incomplete combustion of gun propellant accumulate as solid fibrous particulates in front of the FPs of guns, from small arms to large calibers (Ampleman et al., 2010, Jenkins et al., 2008, Poulin et al., 2008a and 2008b, Poulin and Diaz, 2008, Quémerais et al., 2007a, 2007b, Thiboutot et al., 2008, 2009, 2010, Walsh et al., 2006, 2009). Constituents of concern at FPs are mostly 2,4-DNT and NG. Concentrations up to 140 mg/kg were observed at the FPs of small arms ranges (Walsh et al., 2007a) while concentrations as high as 6100 mg/kg of NG were detected behind antitank firing positions (Thiboutot et al., 2012a). Accumulation of NG and 2,4-DNT in the environment is cumulative over the years, as the NC matrix protects MCs from degradation and dissolution processes. A study on the fate of propellant residues was conducted on a former antitank FP that had been inactive for more than 35 years (Thiboutot et al., 2010). This study demonstrated that levels as high as 4000 mg/kg of NG are still detected in the surface soils, showing that the residence time of propellant residues was long, consistent with work conducted by Dontsova et al., 2009a. A comprehensive review paper on propellant deposition rates for various munitions has been presented at a NATO RTO symposium (Ampleman et al., 2011).

Another source of propellant residues identified in RTAs comes from the burning of excess artillery propellant charges. Following a gun firing operation, discarded propelling charge increments were open burned near the gun position on the soil surface or on snow/ice in the winter. Sampling of the surface soils demonstrated that burning residues built up and represented a threat to the environment and human health. A recent fate study conducted by INRS-ETE demonstrated that 500 g of burning residues spread over 1 m2 of surface soil may lead to the contamination of more than 7.5 millions of liters of groundwater in the first infiltration (Martel et al., 2010). Contrary to the particles deposited at the gun mouth, which lead to a very slow dissolution rate of 2,4-DNT or NG, open burning lead to a highly leachable fraction of 2,4-DNT which is rapidly brought to the groundwater (Martel et al., 2010). This situation mandated the development of a safe and environmental alternative destruction method for the excess propelling charges. Overall, the following areas can be considered potentially contaminated by propellant residues in RTAs' FP:

- In front of guns FPs, from small arms to 155-mm calibers;
- Behind and in front of antitank rockets FPs;
- At former excess propellant field expedient burning sites.

At the other end of the range, target areas were highly suspected of being contaminated by explosive residues. Many trials were dedicated to better understand the deposition pattern of explosive residues from various scenarios (Pennington et al., 2006, 2008a, 2008b, Walsh et al., 2005b). The conclusions drawn from this work are presented in this sub-section. The following sources of explosives have been studied: high-order detonations, low-order detonations, Unexploded Ordnances (UXO) blow-in-place (BIP), UXO shell cracking and UXO corrosion.

High-order detonations are defined as detonations that reach the desired pressure and detonation velocity. The evaluation of explosives deposition following high-order detonations is not a simple task. The detonation process involves high pressure and temperature and the deposition pattern can be very complex to assess. Various trials were conducted and led to the development of a set-up involving detonation on pristine snow cover, which allowed an easier delineation of the deposition plume (Jenkins et al., 2002, Walsh et al., 2005b, 2007b, 2011a). The quantities of explosive deposited from high order detonations are very small, almost at the forensic levels. The quantities are spread over large areas, and do not lead to the build-up of concentrations of concern of explosives. Low-order detonations might happen in various scenarios in live firing events. A large percentage of the fired munitions function as designed and generate high-order detonations. A fraction varying from 1 to 50 % of rounds might generate low-order detonations or UXO. The failure rate of munitions depends on the type of round, and in general, artillery rounds have a malfunctioning rate around 1-5 % while some antitank rockets have a malfunction rate as high as 50 %. Low-order detonations were achieved on purpose by using a weak detonation trigger (Pennington et al., 2006, 2008a, 2008b) and it was found that while high-order detonations deposit micrograms of fine explosive dust, low-order detonations deposit gram quantities of explosives from fine dust to large chunks. In order to solve the safety risk that a surface UXO represents in our RTAs, Explosive Ordnances Disposal (EOD) teams regularly proceed to UXO BIP operation that consists of detonating C4 blocks nearby the UXO (without moving it). The impacts of disposal operations conducted on RTAs when encountering UXO by detonating them with C4 is now better understood. The use of unconfined C4 blocks generates the dispersion of RDX in the surrounding of the detonation point (Pennington et al., 2006, 2008a, 2008b). Therefore, locations such as demolition ranges where intense BIP has been conducted present measurable concentrations of RDX from the C4 and also of other explosives from the UXOs. Canada is undertaking trials at the present time to assess the replacement of RDX based C4 explosive by German or Norwegian equivalents passed on PETN and HMX.

Finally, an important source of explosive in RTAs was identified through the quest for understanding the explosive contamination pattern. Surface UXOs in impact areas are susceptible of being hit by flying razor sharp fragments coming from close proximity high-order detonations. Designed experiments using 81-mm mortar shells demonstrated that this phenomenon is very easy to achieve and led to grams and kilograms quantities of explosives in the surrounding environment (Lewis et al., 2009, Walsh et al., 2011a). This indicates that the surface to near surface UXOs which are exposed to other rounds that explode nearby represent an important source of explosive in the surface soils. The broken shells can release as much as the totality of their explosive content in the environment. A detailed review paper on explosive deposition rates for various munitions has been presented at a NATO RTO symposium (Walsh et al., 2011a). On a longer-term perspective, corrosion of the munitions casings represents also a source of explosives in the environment and a related risk to the underlying groundwater. The corrosion rate is a complex phenomenon, which depends on soil conditions, on heating/cooling and wet/dry cycles, on soil physico-chemical characteristics and many other parameters. It is assumed that corrosion represents a long-term source term, that is still undefined and that most of the risk is not related to surface soils but to groundwater.

The major conclusions from RTAs characterization and explosive deposition studies are:

- A forensic amount of explosives is deposited when a round is functioning as designed.
- BIP detonations deposit a greater percentage of residues than live-fire high-order and deposit RDX from the C4 donor charge.
- By far, the largest explosive residues deposition is from low-order detonations and particles deposited range from micrometers to centimeters in diameter.
- As a rule of thumb: it takes 10,000 to 100,000 high-order detonations to deposit the same amount of explosive as one low-order detonation.

- Surface UXO cracking may expose as much as 100% of the explosive filler to the environment and represents also an important source of contamination.

Sampling strategy for munitions constituents in surface soils

The primary objectives in RTAs characterization are:

- To measure the surface soil contaminants that may pose a threat to the health of military users that may come in contact with the contaminants (human exposure);
- To measure the surface soil contaminants that may further be dissolved and brought to the surface water bodies or groundwater;
- To measure the surface soil concentrations that may pose a threat to local ecological receptors (ecotoxicity);
- Combination of some or all of the above.

There are numerous challenges in obtaining representative results of the level of contamination by MCs on military live-firing ranges that cover many square kilometers and where a multitude of activities involving munitions are conducted. First of all, the nature of explosive and propellant dispersion comprises both compositional and distributional heterogeneity. The compositional heterogeneity is due to the intrinsic nature of the explosives and propellants: the formulations are complex and are inhomogeneous in nature from their conceptions. In other words, compositional heterogeneity is described as the variability of contaminant concentrations between the particles that make the population which leads to a fundamental error. The fundamental error is managed by collecting and analyzing sufficient sample mass to address the compositional heterogeneity. There is also a very high distributional heterogeneity in the dispersion of MCs. Taylor and Jenkins have studied extensively the high heterogeneous pattern associated with explosive and propellant distribution (Jenkins et al., 1999, 2004, 2005, Taylor et al., 2006). Solid particles may vary from very fine dust to large chunks of explosives, up to centimeter size. This heterogeneity results in a segregation error. In order to minimize the fundamental error and compensate for compositional heterogeneity, a greater sample mass must be collected and in order to minimize the segregation error and compensate for the distributional heterogeneity, multiple sub-samples must be collected. To achieve that, it is recommended to use a composite sampling strategy with a judgmental systematic random sampling design to characterize the average concentration of MCs within a chosen area. Using composite sampling, reliable estimates of mean concentrations for the specified area of virtually any size are obtained. Properly collected replicate samples should lead to a relative standard deviation lower than 30 % between replicates. With the exception of ranges where the surface is regularly physically moved, the highest concentrations of MCs are always present in the top 2.5 cm surface soil. Splitting the sample in the field to reduce the volume sent for laboratory analysis is not recommended. The whole samples are stored in the cold and dark and sent to the laboratory for homogenization and analysis. Whole sample homogenization is critical for a representative result. Two methods are presented in Thiboutot et al, 2012a and 2012b.

Fate and transport of MC

In general, explosives and propellants have low vapor pressure. Therefore, their fate is driven by dissolution/leaching, transformation and mineralization. NG and 2,4-DNT have higher vapor pressure but when dispersed in a NC matrix, volatilization is highly limited. The risk is associated to the effect of each MC, their metabolites and their fate. Their fate is driven through transport and degradation.

Propellant residues have a long-term environmental residence time since they are embedded in a NC matrix that protects them from dissolution and further biotic or abiotic processes (Hewitt and Bigl 2005, Thiboutot et al., 2010). Therefore, the risk to the groundwater is low and most of the MC remain at the soil surface in the first 2.5 cm of soil for many years, even decades. One exception is 2,4-DNT liberated by field expedient burning of excess artillery propellants. In this case, there is a fraction of highly leachable 2,4-DNT that is available to dissolution and degradation processes (Martel et al., 2012b). The remaining fraction is embedded in NC and will remain at the soil surface for years and will be immobile except for nitrate that can leach out from the degradation of NG (Martel et al., 2012b). Composite rocket propellants may lead to the dispersion of AP in the environment. It has been demonstrated that when normal functioning occurs, the combustion in the rocket is very effective and AP is not dispersed in RTA (Jenkins et al., 2007, Thiboutot et al., 2008). Ammonium perchlorate is also included in a few other weapons such as M72 antitank rocket propellants or smoke formulations.

Efforts were dedicated to better understand the complex fate and transports mechanisms of explosives (Halasz et al., 2002, Hawari et al., 2000a, 2000b, 2001, Lewis et al., 2009, Mailloux et al., 2008, Martel et al., 2007, 2009, Monteil-Rivera et al., 2004, Robertson et al., 2007, Zhao et al., 2004). Overviews of the main process descriptors for explosives have been published by Brannon and Pennington (2002), Halasz et al., (2002) and more lately by Monteil-Rivera et al. (2004) and Kaldersi et al. (2011). The main processes that control their fate are: solubility and dissolution, adsorption, transformation, biodegradation, photolysis and volatilization. For instance, TNT is a nitroaromatic and tends to degrade by photolysis, while nitramines like RDX and HMX can be photo-degraded but to a much lower extent. However, if HMX is dissolved, it can be photo-degraded within one week (Hawari et al., 2011). Some photodegradation by-products of TNT are well known, while other species are still to be determined. TNT is also more soluble and dissolves more rapidly in water than RDX or HMX (HMX being the least soluble). TNT can degrade into more than 20 different metabolites with various solubilities and toxicities. For example, the aminodinitrotoluenes (A-DNTs) that result from the photolysis or biodegradation of TNT are much more soluble than the parent compound, but they can easily bind covalently to humic acid. Therefore, these metabolites are stabilized by the formation of an amide with the organic content of the soil. Moreover, sorption mechanisms for TNT and its metabolites are stronger in soils that contain clay minerals than for RDX and HMX (Dontsova 2009b). Therefore the relative rates of soil leaching of these three explosives can be explained in terms of the relative water solubility's and adsorption strengths. RDX leaches out faster than TNT, which in turn leaches out faster than HMX. TNT and its metabolites are more soluble than RDX, but their migration is inhibited by strong bonding interactions with soil constituents. On the other hand, HMX has a tendency to remain at the surface of the soil, because it is much less soluble in water. Interactions with the soil are an important factor when characterizing explosives in terms of bioavailability and extractability. All data acquired up to now tend to indicate that most TNT metabolites are rapidly strongly bound to soil humic acid, which limits greatly their bioavailability. Therefore, even if TNT and its metabolites are considered toxic, they are not readily available for receptors.

The fate and transport of heavy metals in the environment will depend strongly on their solubility in water (which depends on their speciation, pH and reduction potential) and their capacity to bind to the soil constituents. A metal compound with a high solubility and a low binding capacity has a higher mobility and presents a larger potential for leaching in groundwater and/or travel far away from the range. However, a compound having a low solubility will most probably stay on the surface of the soil, and a compound with strong binding affinities will most probably stay either on the surface or in the subsurface, where a specific bonding agent is encountered. In addition, small particles tend to be more mobile, either in solution or as colloids.

Metals can also be oxidized in their ionic form and will form various salts with soil constituents, all having a different solubility and bioavailability. As a general rule, nitrates, chlorides, bromides and acetates are readily soluble in water, and sulphides are considered to be insoluble. However, the solubility of hydroxides, sulphates, phosphates, and carbonates will vary depending on the heavy metal counterpart, and on the pH of the water. Thus, caution must be exercised when trying to decrease the leaching of soils containing multiple heavy metals by controlling the pH of the soil, because the solubility of some heavy metal compounds may increase when exposed to basic pH.

Hydrogeological characterization of RTAs

The potential for MCs to travel to water bodies in RTAs varies from quite low probability for NC-embedded propellant residues to very high probability for RDX and AP. Therefore, it is imperative to monitor both surface and sub-surface water bodies quality. In Canada, a large effort was dedicated to the hydrogeological characterization of major RTAs. This approach is carried out as part of a collaborative effort with INRS-ETE. Hydrogeology typically provides detailed information on the quality and flow direction of surface water and groundwater, on the water table depth and on the various types of soil on which the ranges are built. The approach is stepwise and, in general, the work is accomplished in sequential phases over a period of three to four years. The number of wells installed per phase is approximately between 15 and 20 and is combined with a detailed surficial and three-dimension geological survey. This stepwise approach allows the better localization of wells and optimizes the process.

The major concern for the installation of wells in UXO contaminated ranges is the possibility of encountering buried UXO during well installation. Another concern is that the wells might be destroyed by military activities. The installation of flush mounted wells has eliminated this issue, and these types of wells have been installed within impact ranges across Canada (Bordeleau et al., 2008b, Martel et al., 2009). Before any drilling is to be conducted within an area potentially containing buried UXO, UXO avoidance activities shall be completed. Qualified personnel (EOD or UXO technicians) will clear pathways to proposed sampling locations, usually done using magnetometers and EM-61 type detectors. Mailloux et al., 2008 used a hollow stem auger to drill wells at the Arnhem antitank rocket range at CFB Valcartier in Canada. It is critical that wells be installed within the proper aquifer to assess questions of offsite migration. More details on well installation can be found in Martel et al., 2012a. There are several sample collection methods that are commonly used for groundwater sampling. These include the use of bailers, low-flow pumping with a peristaltic pump or a bladder pump, or passive diffusion samplers. The Canadian approach used a low flow sampling technique with a dedicated system made of Teflon tubing connected to a flexible Viton tubing via a Teflon connector to avoid any cross contamination. Groundwater samples are to be collected in a 1-L amber glass bottle to prevent photodegradation, cooled to 4 °C and shipped by overnight carrier. The stability of energetic compounds can be extended if the water is acidified to pH 2 with sodium bisulfate after collection (Jenkins et al., 1995). Sample analysis is conducted as described in SW846 Method 8330B (U.S. EPA, 2006). Water samples are generally pre-concentrated using solid phase extraction to provide adequate detection capability. Most analyses have been conducted using reverse phase High Pressure Liquid Chromatography (HPLC) using an ultraviolet (UV) detector.

The hydrogeological data collected led to the preparation of several thematic maps such as hydraulic head and surficial geology. The following step is the groundwater flow and contaminant transport modeling. This is generally performed using numerical model such as FEFLOW, which needs to be fed in with input parameters such as the three dimensional geological model, the measured hydraulic heads, the measured hydraulic conductivity of the various hydrostratigraphic units and the recharges. This model allows the reproduction of the behavior of groundwater at regional and local scales, and the prediction of the transport of contaminants, which is extremely important to perform risk analyses of the ecological and human receptors surrounding RTAs. A conceptual model is then built following the geological model and from the knowledge of the environmental fate of EMs. The risk analysis is completed by building hazard, aquifer vulnerability, and risks maps. The vulnerability map reflects the vulnerability of a given aquifer to surface contamination. The hazard for a range is evaluated with an index system specifically developed and based on residue deposition frequency, on the environmental dangerousness of each type of explosive used and on the surface area of the range where the munitions are used. The environmental dangerousness is based on five criteria: drinking water toxicity, solubility in water, natural biodegradation, photodegradation and adsorption on the organic fraction of soil, and is evaluated for each possible EM released in a range. The surface area index is inversely proportional to the surface area of the training area or range. Firing positions have very small deposition areas (order of 100 m2) on, behind or in front of them whereas impact areas may extend to millions of square meters which dilute the concentration at the surface; impact areas consequently have a lower surface area index. The frequency index, the environmental dangerousness index and the surface area of deposition index are multiplied together to give the hazard value for each of the energetic materials used for a given range. The aquifer vulnerability map and the hazard map are combined to generate the risk map. For more details on aquifer vulnerability, hazard and risk maps see Martel et al., 2011.

Future work

The groundwater and surface water sampling and analysis involve long time delays at the present time. A project is presently ongoing to replace this stepwise approach with a field method that would lead to instantaneous results. The aim is the development of a low-cost sensitive and field rugged method to concentrate and analyze EM in water samples based on Surface-Enhanced RAMAN spectroscopy (SERS). Portable RAMAN spectrometers are available and could be used for the field detection of EM. The research involves the creation of a nano-structured three-dimension material that will amplify the SERS response towards EM. The method will then be compared to standard HPLC method both for spiked and natural water samples. The nanomaterials will be prepared by nanoparticle co-polymerization using liquid ionic polymers. Preliminary work has allowed detecting TNT at low concentrations with a SERS substrate and a Raman system at 633 nm. The aim is now to increase the TNT detection sensitivity and to select a pre-concentration nanomaterial for RDX.

Another topic of recent interest is the potential impact of climate changes in relation with the fate and transport of MC in the RTA. Increased droughts or rain events will change the mobilization of MC and their potential reaching of receptors. Also, climate changes might have various impacts on military readiness such as the potential loosing of flooded ranges, the increased transport of sediments to rivers, which could trigger even range closure. We want to evaluated all the risks to our RTA and mitigate then whenever possible. Finally, there is an increased willingness for military deployment in the Canadian Arctic region. We will be closely involved to evaluate and mitigate if needed any military training involving munitions in this pristine and sensitive environment.

Finally, explosives were recently developed for introduction in new insensitive explosives formulations. These new ingredients such as 2,4-dinitroanisole (DNAN), nitroguanidine (NQ), 3-

nitro-1,2,4-triazole-5-one (NTO), FOX-7, and FOX-12 are now found in explosives formulations deployed in weapons. Little is known about the toxicity, fate and behavior of these new explosives and the new formulations such as PAX-21, IMX-101 and -104, which will eventually be fired in Canadian ranges. The environmental impacts of these formulations are unknown and it was decided to investigate their fate and behavior. NRC is now investigating their fate and transport (Hawari et al., 2012, Perrault et al., 2012) and DRDC is participating in a joint program with CRREL to measure the deposition rate of these formulations following various detonation scenarios (Walsh, M.R. et al., 2013). Preliminary results indicate that in sensitive formulations will lead to higher deposition rate and will represent a challenge from a blow-in-place perspective.

Conclusion

The general approach to obtain representative results from the characterization of huge tracks of military RTAs was refined over the years to overcome numerous challenges, including the high compositional and distributional heterogeneity associated with MC dispersion. The research dedicated to munitions deposition and fate led to the development of a detailed protocol for the effective and safe characterization of range and training areas. The sample collection, treatment and homogenization were carefully studied, and are presently the topic of intense international exchanges for standardization. The large effort dedicated to the measurement of the deposition rate of MCs both at the target impact areas and at the FP led to a good estimation of the source terms of contaminants generated by various live firing activities. Subsequently, the distribution, fate and transport of propellant residues at firing points associated with live-fire training with munitions were studied. This allowed for a better understanding of the contamination pattern at the firing positions. Several studies have also been performed on the fate and behavior of all MCs and their metabolites. This allowed the development of transport process descriptors for current explosives and propellants and their main transformation products. The work conducted on the ecotoxicology of MCs led to international cooperation and publication of soil guidelines and textbook for ensuring military training sustainability. Major environmental issues were identified and the sources of MCs in training ranges are now better understood. In Canadian Army RTAs large efforts were dedicated to characterize the subsurface, and detailed hydrogeological and geological studies were conducted. This led to the acquisition of a large database, and a better understanding of the complex dispersion and fate of munitions-related contaminants toward groundwater. The evaluation of the risk of aquifer contamination associated with military training activities was allowed and produced practical range management tools. Based on the knowledge acquired in the study of the environmental impact of the munitions, our efforts are presently dedicated to the development of future tools and on environmentally sound solutions that will sustain military training and maintain force readiness. This represents a holistic approach towards the ultimate objective of totally sustainable military live-firing ranges.

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ENVIRONMENTAL MANAGEMENT SYSTEM FOR MILITARY TRAINING AREAS IN FINLAND

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A comprehensive environmental management system has been developed for the shooting and training areas of Finnish Defence Forces (Figure 1). In the new system, all the environmental data and military operations are put into same framework, which makes it easier to observe the site-specific environmental risks caused by military activities, to improve the risk management methods, and to develop inclusive environmental monitoring of the shooting and training ranges. The system will be GPS-based, enabling fast and accurate data storing, processing and analyzing of site-specific environmental information.

Introduction

The Finnish Defence Forces is executing military field exercises on about 70 training areas all over the Finland. The use of heavy weapons and explosions is practiced in 25 of those areas. Most of the ranges have been used by Finnish Defence Forces for decades. The largest by size is the Rovajärvi-range, over 107 000 hectares. To be operative these areas often encase depots and garrisons, shooting ranges and fuel stations, which together with heavy weapon shooting and use of explosives, cause emissions and stress to the environment. Being remote and partly restricted areas, they usually include important environmental values, such as important drinking water sources and protected wildlife habitats. In the sites that are situated closer to the inhabited areas, the noise caused by military activities may be considered annoying by the residents.

Figure 1. Shooting and training areas of the Finnish Defence Forces

Therefore, a comprehensive environmental management program has been developed to find out the site-specific environmental risks caused by military activities, to improve the risk mnagement methods, and to develop inclusive environmental monitoring of the site. The goal was to create a program, which fulfils the demands of the Finnish environmental laws and regulations, but also takes in consideration the special characteristics of the military operations. The frame of the management program is presented in Figure 2.

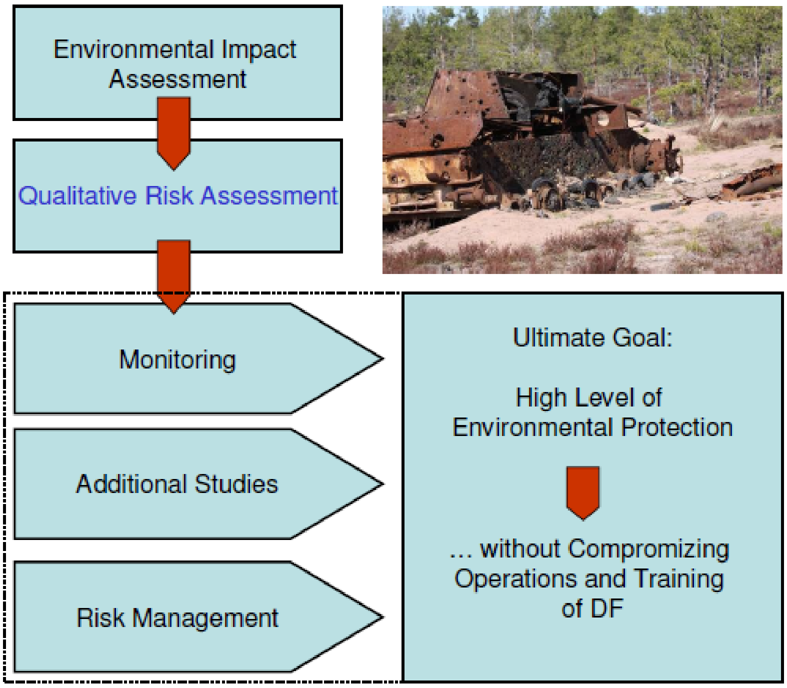

Figure 2. Environmental Management Program

Materials and methods

The first phase includes a thorough search of historical operative and environmental data of the site. Also, information of the endangered species, protected habitats and designated groundwater areas are collected. Furthermore, the locations of the residential areas as well as the use of the area for leisure activities (fishing, hiking, camping) are considered. Importantly, there may be local entrepreneurs that are using the training area for reindeer grazing, and thus has to be taken in count. The data collection process is done in co-operation with local environmental authorities and non-governmental organizations.

After data collection and interpretation, the site survey is conducted. During the survey, shooting and training sites, as well as the supporting operations like fuel stations and garages are inspected. Also, military personnel and maintenance workers at the site are interviewed.

Each activity at the military training area is placed on the map together with the environmental data of the sub-sites. Chemicals and harmful substances used in or caused by each activity are also recorded.

Results and discussion

At the next phase, the conceptual risk assessment for each sub-site is performed. In conceptual model, the source and load of harmful substance(s), the fate and transport of the emission, potential receptor at the impact area, and finally the probability of the emission to expose the receptors are considered.

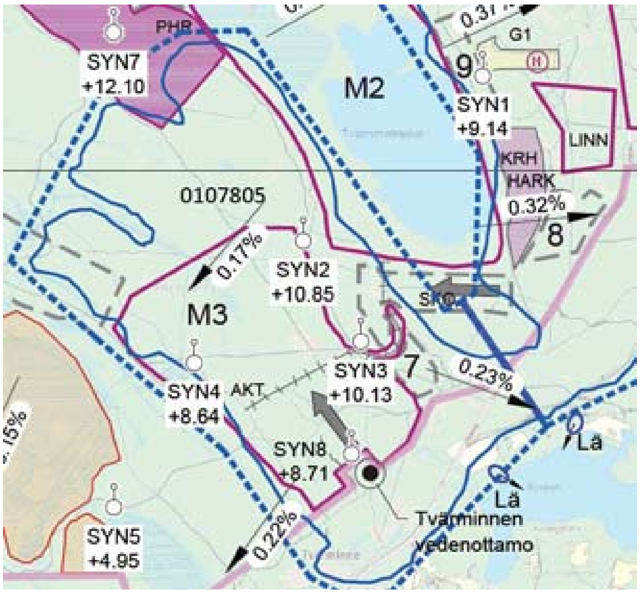

Figure 3. Example of the operational site map. Blue dotted line shows the groundwater area. SYN = Groundwater well. Violet line = Shooting target area. Violet painted area = Explosions. Pink line = Military area. Black line shows the direction of groundwater flow. Grey line = shooting direction

Table 1. Example of the conceptual environmental risk assessment of the sub-site

Source	Exposure medium	Reseptor	Exposure assessment
Harmful Substances	Soil	Health	Not possible
		Environment	Possible exposure
	Ground water	Heath	Not possible
	Surface Water	Heath	Not possible
		Environment	Possible exposure
	Air	Heath	Possible, not significant exposure
Erosion	Soil	Environment	Possible, not significant exposure
Noise	Air	Health	Noted exposure
		Environment	Possible, not significant exposure
Vibration	Air	Health	Possible, not significant exposure
	Soil	Environment	Possible, not significant exposure

Each sub-site is given a risk-status, according to which additional investigations and finally the environmental risk management measures will be planned. Additional investigations may include soil, surface water and groundwater research, as well as habitat surveys or noise measurements.

When proven necessary, the site specific risk management measures are considered and put into effect to reduce the environmental impact of military operations at each sub-site but also at the shooting and training area as a whole. This far the most frequently observed risk has been the exposure of the residential areas to shooting noise. The irritating effects of noise have been successfully decreased by re-scheduling the shootings as well as by active information policy and co-operation with the residents. Furthermore, added sound insulation of the shooting shelters and raise of the embankments has brought the noise levels down notably.

Table 2. Example of the summary table of environmental impacts of military operations at the site. Ranking: White = no impact, gray = minor impact, red = Notable impact, blue = Insufficient data, further studies suggested

Sub-site / Operations	Air	Soil, emission	Soil, erosion	Groundwater	Surface water	Noise, vibration
A/ Multi-purpose	1	2	1			2
B/ Heavy weapons	1	2	2	1		2
C/ Heavy weapons	1	2	1	1	0	1
D/ Pyrotechnique	1	1	1	0		1
E/ Small caliber shooting ranges	1	2	0			2
F/ Shot gun range	1	2	0			2
I/ Training area	1	0	1	0	0	1
J/ Garrison, barracks	1	0	0	0	0	1

One of the most profound conclusions of the environmental assessment system has been the obvious need for comprehensive monitoring of the military operations at the site. As a result, redesigned surface water and groundwater monitoring programs for shooting and training sites encompassing all the risk operations have been concluded in collaboration with environmental authorities and local non-governmental organisations.

The environmental assessment framework is designed to be repeatable and it can and will be updated. Improved assessment and monitoring of the sites has also increased the amount of environmental data. For example, monitoring program of Pohjankangas shooting and training range consists of 25 sampling points (19 groundwater wells, 5 surface water samples and one tap water sample) and 50 different parameters from each water sample. Therefore, to be able to manage, analyze and conclude all that data a computerized program is currently under development.

The monitoring data collected from each training area will be stored into GIS-based management program (KIRAVE), enabling up-to-date production of reports, maps, trends and graphics, thus serving managers as a good decision-making-tool for environmental protection. In the near future, environmental management in Finnish Defence Forces will be able to target its limited resources more cost-effectively. That will also mean higher level of environmental protection in military shooting and training ranges.

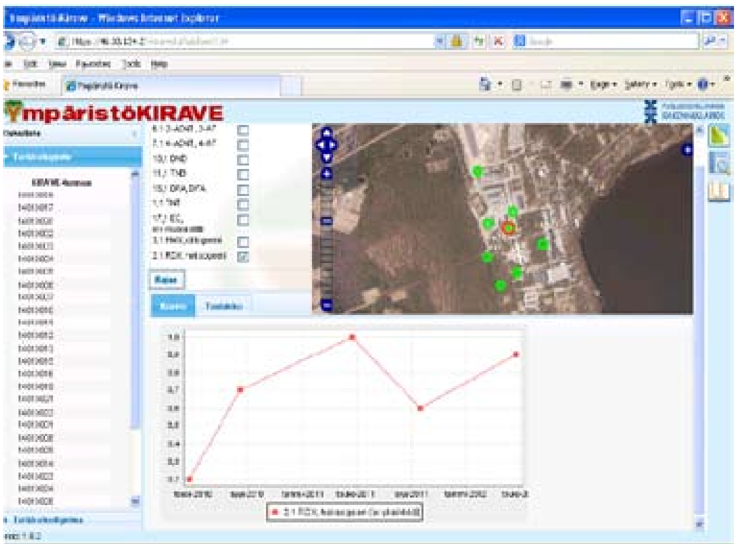

Figure 4. Environmental management system: KIRAVE under development

NEW RANGE DESIGN AND MITIGATION METHODS FOR SUSTAINABLE TRAINING

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For years, DRDC Valcartier has been involved in the understanding of the environmental impacts of live-fire training with munitions within military Range and Training Areas (RTAs). After the extensive characterization of most of the Canadian ranges and R&D projects aimed at understanding the fate and behaviour of energetic materials and their toxicity, issues related to specific military activities were identified. Over the course of our research, it was found that anti-tank range target areas and firing positions were highly contaminated by energetic materials and metals, that demolitions training ranges and grenades ranges showed significant RDX concentrations in the soils that resulted in groundwater contamination, that small arms stop butts and firing positions were heavily contaminated with lead, antimony and, propellant compounds. This paper will describe the efforts conducted to mitigate the negative impacts of training on military ranges through the use of innovative approaches developed by our research team. These approaches and new ways of designing ranges will be proposed to minimize or even remove impacts on the environment. New small-arms bullet catcher prototypes, two concepts for propellant burning tables, and a new design for demolitions and grenade ranges will be discussed.

Introduction

For many years, Defence Research and Development Canada - Valcartier (DRDC Valcartier) has been involved in the evaluation of the environmental impacts of the live-fire training to characterize and mitigate adverse effects on training ranges and thereby sustain ongoing military activities (Refs. 1-17). Over the years, many efforts were conducted to assess the environmental loading of explosives at most of the Canadian Forces Bases (CFB) in heavily used impact and target areas or at firing positions (Refs. 7-26). Many of these studies were conducted in collaboration with the U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire and the Environmental Laboratory (EL) in Vicksburg, Mississippi, USA (Refs. 4-6, 14, 18-21). Over the years, it was found that firing positions for most of the weapon platforms were contaminated by propellants residues, mainly 2,4-dinitrotoluene (2,4-DNT) and nitroglycerine (NG) at different concentrations depending of the weapon types (Ref. 27). The area between the firing positions and the target positions is in general not contaminated but the target positions may be contaminated extensively by the common explosives 1,3,5-trinitro-1,3,5-triazine (RDX), 1,3,5,7-tetranitro-1,3,5,7-tetrazine (HMX) and 2,4,6-trinitrotoluene (TNT) and also by metals (Ref. 28). For this reason, the metals were also included as analytes of interest as a multi-contamination issue, in firing positions, impact and target zones but mostly in small arms ranges where high lead concentrations were always observed in sand stop butts (Refs. 7-9, 11-13, 15). Other metals such as antimony, copper, and zinc were also found at high concentrations in these stop butts.

Extensive research indicates that metal residues result from the pulverization of incoming projectiles leading to contamination and representing a concern for the environment and human health. To better understand the environmental impacts of metals in sand butts, many R&D projects were accomplished and revealed that lead may migrate off the butts by lateral dispersion or go vertically in the butt to eventually reach the groundwater (Refs. 29, 30). It was also found that antimony is more soluble than originally thought and may migrate rapidly to the groundwater (Ref. 30). To avoid this situation, it was decided to develop a bullet catcher that would trap the projectiles protecting the surrounding soils in the butt and avoiding metallic debris to come in contact with water coming from rain and snowmelt thus forbidding dispersion, dissolution and movement of the metals.

In Canada, a large effort was dedicated to the hydrogeological characterization of major RTAs. This approach was carried out as part of a collaborative effort with the Institut de la recherche scientifique- eau, terre et environnement (INRS-ETE). Hydrogeology typically provides detailed information on the quality and flow direction of surface water and groundwater, on the water table depth and on the various types of soil on which the ranges are built. From these hydrogeological studies conducted for years came the development of management tools. Vulnerability maps based on geological information with hazard maps based on munitions fired at that location once combined, generated risk maps that are highly relevant range management tools. Based on these maps, various decisions, such as range relocation or closure can be taken to minimize the adverse measured impacts as reducing the potential for aquifer contamination.

The most important finding of the R&D sustainable programme is that the contamination by explosives comes mainly from the presence of the unexploded ordnances (UXOs). As a rule of thumb, high-order detonations spread very little residues in the environment while low-order detonations spread considerable amounts of explosives. Surface UXOs can be cracked by incoming flying shrapnel generating cracked shells where all the content is exposed to the environment. Corrosion of UXOs results also in the spreading of the all the content to the environment. In addition to this, Blow-in-Place (BIP) operations using C4 blocks to get rid of UXOs generate pieces of RDX ejected from C4 blocks resulting in important issues for the groundwater contamination (Ref. 31). A potential solution to the UXOs would be to develop zero-DUD munitions. In 2008, the Canadian Technology Demonstration Programme (TDP) named RIGHTTRAC for Revolutionary Insensitive, Green and Healthier Training Technology with Reduced Adverse Contamination, initiated efforts in that direction by developing a zero DUD rate greener munitions. The programme aimed at proving that greener and insensitive munitions (IM) can decrease the environmental pressure on RTAs and minimize the health hazards for the users without decreasing the performance of the munitions (Ref. 32). The goals of this five-year TDP are to reach a near-zero failure rate, to eliminate the potential for RDX contamination and the use of toxic and carcinogenic compounds. This will be done by performing significant improvements to the fuzing system, the main explosive charge and the gun propellant (Ref. 33).

Among the training range areas visited, the anti-tank, the demolition, the grenade and the small arms ranges were the most problematic and represent issues to be dealt with. At the anti-tank ranges, high concentrations of HMX (7000 mg/kg) were found around target positions. Some propellant residues were also found around targets because these shoulder-type weapons hitting the targets may break into pieces upon impact and leave unburned propellant residues on the ground. Furthermore, the presence of UXOs and metals make more difficult eventual clean-up of these target positions. At the firing positions, important concentrations of nitroglycerine (higher than over 10,000 mg/kg) were observed since it was found that Karl Gustav 84-mm shoulder weapons are spreading up to 14% of residues at the back of the weapon (ref. 26). The American shoulder-type ATK-4 spreads even more with a deposition rate of 73% of residues (Ref. 27).

Another issue that our department is facing at this moment is related to the demolition and grenade ranges where concentrations of RDX varying from 1 to 90 mg/kg are observed in the soils. RDX is mobile upon dissolution and concentrations above the drinking water criteria were measured in groundwater underlying range training areas. RDX may also moves very quickly through surface water runoffs and be brought to sensitive receptors outside the boundary of training areas. It is therefore imperative to find solutions to mitigate this impact to sustain the activity.

Another important issue is related to the small arms ranges stop butts where metal concentrations up to 70,000 mg/kg of lead, antimony, copper and zinc were identified. Moreover, small concentrations of nitroglycerine are found at the firing positions. One of the solutions to address these high concentrations of metals in stop butts was the development of a bullet catcher.

Considering the concentrations of explosives and metals in our RTAs, the fate and behavior of energetic materials and metals, and the necessity to maintain the training for the preparedness of the Canadian Armed Forces, solutions have to be developed and put in place to sustain the training activities and protect RTAs. Efforts have already been done to address the small arms issues but more problems are arising and need solutions. Two main approaches were used to address the problematic; the first was the development of physical protections and the second was based on chemical treatment solutions. In some occasions, a combination of both approaches may be necessary. Finally as stated previously, the development of greener weapons based on greener ingredients may solve these issues from the very beginning by removing the source of the contamination. This paper will describe all the efforts that were made so far in each of the approaches to develop durable mitigation methods.

Solutions based on physical measures

Burning Table

One of the first contamination issues identified on artillery training ranges was soil contamination resulting from the burning of the excess propellant bags on the ground. Munitions used with the 105 mm artillery gun systems incorporate a 7-charge increment propellant load issued with each round. During training, not all charges are typically used for each round, leading to excess propelling charge bags that were burned directly on the ground near the gun position, often in rainy or snow conditions that inhibit the complete burning (Ref. 34). It was demonstrated that 2,4-DNT, a Class-2 carcinogen in the US, was present in significant concentrations in the soils at these burn points. This compound is water soluble and readily migrates to groundwater (Ref. 35). The development of a burn table was initiated to address this issue. Various table design iterations and trials were conducted and led to the development of the final accepted prototype that is now deployed across all the Canadian Forces bases (Ref. 36). As a direct outcome of this development, the burning of excess propellant charges on the surface soils is now forbidden in Canada. The table allows the safe destruction of 200 kg of excess charge bags per burn and leads to a 99.5% mass reduction. The design ensures a safe process and burn residues can easily be collected and treated as hazardous materials. The gaseous emissions have been predicted and monitored and are still under study. The use of the burn table greatly reduced the environmental footprint of artillery live fire training as environmental contamination from 2,4-DNT and lead are now minimized by this activity. A standard operating procedure (SOP) for the destruction of propellants using the table as well as a procedure for the safe return of the excess charge bags to the ammunition stores was developed and provided to the military users.

In the United States, a parallel development program for burn tables was also begun. In this case, the table is portable, enabling the deployment of the table to the firing point where the training occurs. This allows the soldiers to burn the propellant at the training site while minimizing the contamination from activity. The residues, which will contain energetic compounds in low concentrations and, in some cases, significant quantities of fine particulate lead, can then be efficiently collected for later processing and treatment (Ref. 37). Excess propellants will not need to be transported to remote disposal locations. The portable burn pan has been developed in two sizes, a 70-kg charge capacity unit for mortar training exercises and a 125-kg charge capacity unit for howitzer training exercises. Mass reduction of the charges has been measured at >99 %, the remaining material being mostly metal parts, lead, and flash suppressant. Reduction in energetic compounds was measured at 99.99% over two separate tests. Lead accountability was problematic, with one third of the lead recovered measured outside the burn table. The portable burn table has now been adopted by the US Army National Guard as a best management practice, with plans to integrate the system on all bases with indirect fire ranges (Ref. 38).

Another alternative option to this 7 bags propellant charge is also under study, which is the development of modular charges for the 105 mm guns similar to the modular charges already in service with the 155 mm artillery guns. This would eliminate the requirement for open burning completely and would increase the sustainability even more. This last option fall more under the greener solutions than under the physical approach and will be describe more in detail later.

Bullet catcher

As stated earlier, small arms stop butts are heavily contaminated by metals. Our characterization work combined with studies on the fate of metals involving lysimeters have pointed out the need to move away from conventional sand backstop butts for small arms ranges. It was understood that lead may migrate off the butts by lateral dispersion or go vertically in the soil profile to eventually reach the groundwater. Furthermore, it was recognized that antimony is much more soluble than anticipated and may migrate easily into groundwater. To avoid this situation, it was decided to develop a bullet catcher that would trap the projectiles protecting the surrounding soils and avoiding metallic debris to come in contact with water coming from rain and snowmelt thus avoiding dispersion, dissolution and movement of the metals. Many prototypes were constructed over the last few years ending up with a suitable prototype. The new concept uses the slope of the former stop butt where a cell constructed of steel, filled with sand and recovered by a membrane that forbids water to penetrate, is installed. The cell is also equipped with a reservoir to catch potential water leaks coming from the inside of the cell. The goal was to design a cost efficient bullet trap that could be easily implemented in Canadian small arms training ranges. We were aware of the existence of commercially available catchers, but their related costs were too high for general deployment across Canada. During the fall 2011, a green range was built and instrumented to monitor the efficiency of the catcher. Lysimeters were installed in a freshly constructed stop butt under 13 new prototypes units equipped with two different membranes for comparison. In addition to that, electronic targeting system was installed on that range making it the most modern small arms range in Canada. This green range is presently under study and so far, the results are very promising. If this study is conclusive, these bullet catchers may be deployed across Canada.

Grenade range

There are mainly two types of grenade ranges: hand (C13) and 40-mm grenades. Both ranges are of concern in our RTAs with similar issues and come from the low-order and the destruction of the DUDs. In the 40 mm, the situation is even more difficult to address since this range is much larger. The main concern comes from the BIP procedure of the DUD that generates RDX on the surface soils. In the case of the 40 mm, low order of the grenade that contains RDX represents also a big issue. The problematic of RDX is that it is dissolved by rain or snow melt and leach to surface or groundwater and moves for long distances being not adsorbed by the soils. In these conditions, sensitive receptors may be reached and considering the strict drinking water criterion of 0.3 ppb, water resources must be protected. As a rule of thumb, if there is no water percolating the range, there is no RDX dissolution and no RDX migration. So, two physical approaches can be used, one where water is not allowed to percolate through the range and the other, where the water that percolates through the range is treated. For a greater efficiency, one may combine both approaches. As an example, the use of a retractable roof that can be opened during the training and closed between the activities may be efficient for a hand grenade range, but would be difficult to implement over the wide area covered by a 40-mm range. To overcome this difficulty of putting a roof in the 40-mm range, a stop butt deep enough and made of concrete may be used as the target and would allow the projectile to fall inside this structure and explode inside. If DUD were encountered, it would be easy to blow them up in this structure that protects the zone from water and forbids residues to be ejected in the environment. In addition to this, metallic debris would somehow be ejected mainly in this structure allowing an easy clean-up from time to time. The use of underlying membranes to catch percolating water and adsorb contaminants on an efficient filter would represent a viable physical option. Having reactive membranes may also represent another option but that will fall under the chemical approach.

A Canadian project will soon be initiated to test all these options and it is the intent of our managers to combine the retractable roof with sidewalls and underlying membranes and test reactive membranes in the hand grenade range. For the 40-mm grenade, it seems at this moment that the option of having an underlying membrane under the entire range and treat the percolating water with an efficient filter is attractive. The possibility of having a reactive membrane will also be evaluated. The option of installing a deep stop butt will also be investigated and the costs of construction will be determined.

Demolition ranges

On demolition ranges, wood, concrete and steel cutting trainings are performed routinely using C4 blocks, an explosive composed mainly of 90% RDX with 10% isobutylene. On top of that, Explosive Ordnance Personnel (EOD) is trained to destroy UXOs also using C4 blocks. Since EOD personnel destroy large items such as 81-mm mortars, 105- and even 155-mm artillery shells, the projection of RDX coming from C4 or from the item destroyed may fall at great distances from the detonation point making very difficult to identify efficient mitigation methods. On top of that, cratering training may jeopardize the use of underlying membranes. In demolition ranges, RDX was found at concentrations varying from 1 to 90 mg/kg in surface soils. RDX has also been found in underlying groundwater and in surface water runoffs even if limited surface soil contamination was observed. This situation is the result of RDX being ejected outside of the range and upon dissolution and migration to the water phase, move outside the range boundary. In this case, a retractable roof to forbid water would not be efficient enough because RDX is ejected too far outside of the range. A membrane would be efficient but because of the radius of the RDX ejection, the size of the membrane would have to be enormous. Furthermore, cratering would be difficult to accomplish with the presence of an underlying membrane. One potential solution would be to construct an igloo type building made of concrete reinforced to sustain repeated detonations. The building should have ballast openings for the release of the pressure wave coming from the detonations. In this type of installation, there is no water so, no dissolution and no need to clean groundwater. Cratering training can be done as well as all the other activities. The size of the igloo building should allow vehicles to enter the facility to ease operations especially soil grading after cratering. Maintenance could also be used to treat the contaminated soils. As an example, application of lime in this demolition range could solve the issue of explosive contamination of the soils. An evaluation of the costs to construct such a building will be performed this fall in order to assess the possibility of using such a physical solution.

Anti-tank range

Very little efforts have been made so far to make anti-tank ranges green. The problematic of the shoulder type weapons at the target positions and also the large quantities of propellant residues deposited at the firing positions by these weapons make these ranges difficult to approach with a remedial option. At the target positions, there are UXOs, metallic debris, propellant and explosives residues (mainly HMX) that stays at the surface for very long periods of time. HMX has a low solubility, a low toxicity and is considered almost green. Nevertheless, it is always better to keep all contaminants at their lowest concentrations possible to fully protect the environment. TNT is also present in the explosive formulations but its fate and behavior makes that it reacts with organic matter of the soils and becomes stabilized. Very low concentrations of HMX are found in the groundwater underlying anti-tank ranges and TNT is rarely detected. In addition to that problematic, the shoulder-type weapons UXOs are considered very dangerous, limiting the surface clearance and allowing the build-up of these weapons and restricting access on the ranges.

A possible solution to the target positions would be to construct a large concrete stop butt that would contained the targets and be capable of withstanding the repeated impacts of these weapons. The possibility of adding sand in the stop buts would increase the survival of the stop butt but sieving of the sand using protected equipment would be necessary to do maintenance. A large stop butt deep enough would protect the target positions to be exposed to water and upon cleaning from time to time, a viable solution could be obtained. Treatment of anti-tank contaminated soils have already been done successfully by DRDC Valcartier and National research council of Canada (NRC Canada) leaving a soil contaminated only by metals that could be discarded in secure landfill. The use of a membrane would be difficult in these ranges since these shoulder weapons penetrate deeply in soils upon bad firing increasing the possibility of perforating the membranes.

For the firing positions, a reactive underlying membrane would be a viable option but one has to keep in mind that the concentrations become very high rapidly in these locations and that the membranes have to perform for long periods of time. Protection of the area by a roof may also be considered. Chemical solutions proposed by DRDC Valcartier are under study. These solutions will be explained in the next section.

Seismic/acoustic systems

One of the most important environmental issues encountered in our RTAs is related to the presence of the UXO and their disposal by blow-in-place operations. As already mentioned the BIP operations spread RDX in the environment and solutions are presently under study and will be describe in the following chemical approach section. A difficult aspect of UXO issues is the localization of those generated by the training. Most of the time, UXOs are found afterwards by range control officers that inspect the RTAs and often, many are not found or simply forgotten. Precise identification and localization as well as accounting are not regular practices. Efforts are presently made to correct this situation and lead towards efficient GPS localization of UXOs and their destruction. The ultimate goal is UXO free RTAs where it would be safe to remove metallic debris and most of the potential explosives contamination.

Use of seismic tools to locate the projectile hitting the ground and combination with acoustic technology to discriminate high-order, low-order or simply DUDs would help achieving the objective of finding and destroying the UXO at the end of the day. In addition to that, if low-order detonations can be discriminated and if their GPS localization can be determined, explosives residues may be collected instead of being left on the ground preserving the environment from this important impact. This project was initiated lately and three seismic probes were installed around an artillery impact area in CFB Valacartier. Data were collected in actual live firing events and preliminary results will soon be available.

Solutions based on chemical measures

Alkaline Hydrolysis

It is known that at very high pH, energetic materials are completely destroyed by alkaline hydrolysis. There are limitations about this technology that should not be ignored. Some studies were performed and claimed that metals are stabilized by lime but amphoteric metals can be dissolved in high pH and become bioavailable (Ref. 39). If the area to be cleaned contains large amounts of metals such as an anti-tank target position or impact areas, alkaline hydrolysis should not be used since, even if the energetic would be destroyed, the metals could then move towards groundwater creating another issue. For the anti-tank firing positions, this technology could be applied since there are no metals and propellant residues should be destroyed by the alkaline conditions. DRDC Valcartier will initiate this summer a project to evaluate if degradation of propellant residues occur under these alkaline conditions. If positive results are obtained, the optimal conditions will be adjusted and experienced in the field. If successful, application of lime to a firing position without moving any soils would be easy to accomplish and relatively cheap to apply.

Soil Burning

Burning of soils such as on a firing position would have been attractive. DRDC Valcartier experimented different mixtures of fuels to burn soils and get rid of the energetic materials present at the surface (refs. 40-41). It is known that the explosives are found in the first 10 cm of top soils but it was found that most of the fuel experimented were not destroying deep enough to efficiently remove all the NG. Many different fuels such as methanol, ethanol, ethanol-gel mixtures, propane, petroleum were tried but one should keep in mind that the burning must be environmental-friendly. The temperatures of combustion observed with petroleum were suitable to destroy explosives but the burns were not really environmental friendly. All the alcohols did not have high combustion temperatures and as a result, incomplete destruction or melted explosives were observed instead of complete destruction. On top of that the depth of efficiency was not acceptable. It was found that explosives lower than 2 cm deep were not destroyed leading to 80% removal of NG (Ref. 40). The best result was obtained with an ethanol-gel mixture that burned long enough to destroy most of the contamination but the related cost was prohibitive (Ref. 41). As a conclusion, burning of soils at this moment does not represent a suitable technology to clean or mitigate the environmental impacts of training at firing positions. Burning of soils using a propane burner will be experimented this fall and it is believed that this may be a good solution for the mitigation of firing positions. On the other hand, burning of soils cannot be applied on locations where UXO presence might be suspected.

Shaped charge

As mentioned in many occasions, one of the worst sources of RDX in the RTAs is coming from the use of the C4 Blocks for the blow-in-place operations of UXOs. RDX is ejected from the C4 blocks as a result of being not confined and also from the physics of wave propagation in the blocks upon ignition. Recently, shaped charges were found to be efficient to destroy UXOs and since RDX is confined in these shaped charges, no RDX was spread on the ground and high order detonations were observed for all ammunition used in Canadian Forces. Work is still ongoing to test these shaped charges on some other munitions but also on new insensitive formulations that are more and more put in service. Another advantage of using these shaped charges is the fact that a much smaller quantity of RDX is used in the shaped charge (11-57 g) compared to the use of a C4 block (567 g). The costs of these new shaped charges are also attractive as a replacement for the C4 block procedure.

Green demolition blocks

Even if shaped charges are very efficient at destroying UXO in the field, there is still a need for a malleable explosive. Explosive Ordance Disposal personnel use the C4 block for many other applications such as wood, steel and concrete cutting. Cratering is also performed with C4 and this could not be replaced by shaped charges. All the issues related to C4 are coming from the presence of RDX in the block. It is known that HMX has a lower toxicity and is more powerful than RDX and has a similar structure. Its fate and behavior is far better than RDX and it could easily replaced RDX in a "*green*" C4 block. Fortunately, this "*green*" demolition block containing HMX instead of RDX is commercially available and is named NM-91. DRDC Valcartier will acquire this NM-91 explosive and will test it with military users to verify if it could replace C4 Blocks in their operating procedures. Furthermore, experiments will be conducted to see if the deposition rates of these new NM-91 blocks are acceptable.

There is also another opportunity to move away from the C4 block using another commercial PETN block named DM-12 explosive. DRDC Valcartier already has these blocks in hands and will soon start the evaluation of this DM-12 block to replace C4 in military operations. Similar testing than with the NM-91 blocks will be conducted.

Solutions based on greener weapons

Small arms

The perfect solution to solve an environmental impact is to eliminate the source of the contaminant. With small arms, lead has been detected in small arms ranges at extremely high concentrations. Efforts were made in the past to replace lead by other metals such as tungsten but the end result was not really environmental. More recently, some efforts were made with projectiles made of steel and copper. However it was found that the environmental performance of the steel-copper bullet was highly dependent on the weapon used (Ref. 42). Tighter barrels led indeed to larger emissions of copper and zinc particles due to a significant erosion of the bullet in the barrels, to the point where severe health issues were observed This stresses out the requirement to deal with environmental impacts at the weapon's system level, and not only on specific components of the munitions. At DRDC Valcartier, within the Future Small Arms Research Programme, efforts are being made to develop greener propellant and primers. It is not planned to develop new bullets, but the environmental testing of potential bullets in Canadian Forces (CF) weapons will be performed.

40 mm

These munitions represent a problem because they contain RDX. Moreover, their DUD rate is high so they have to be destroyed by BIP using the C4 procedure and the munitions suffer often low order detonation. All this leads to RDX being deposited on the ground with the known pathway. Discussions will have to take place to convince the weapon producer to replace RDX by HMX in their munitions. This would solve easily the environmental problems of this weapon related with RDX. This is a good example of a modification of a formulation having a big environmental difference without losing performance of the weapon. Also this weapon suffers a high DUD rate that should be addressed. Of course the costs of the weapon may increase because HMX is more expensive than RDX at this moment but if the whole service life is taken into consideration, the final costs would drop significantly. If environmental pressure is high enough to force the manufacturers to ban RDX and use HMX, eventually, the HMX production costs will decrease.

Shoulder-type weapons

It was mentioned that the deposition rates for the shoulder-type weapons are really problematic with deposition rates varying from 0.19% (M-72), 14% (Karl Gustav) to values as high as 73% as encountered with the ATK-4 (Ref. 27). This is a good example where design of the weapons may have tremendous impact on the environment. The 66-mm M-72 shoulder type weapon has a combustion chamber and the formulation of the propellant is different than the Karl Gustav formulation in the sense that it contains a small amount of ammonium perchlorate to help the combustion. The chamber is equipped with a nozzle that directs the thrust to propel the projectile towards the target. A deposition rate of nitroglycerine at 0.19% is observed with that weapon compared to 14% for the Karl-Gustav 84 mm. The 84 mm has a double-base propellant formulation, no ammonium perchlorate, no nozzle and the combustion chamber is closed with a plastic cap. Upon firing, this plastic cap is ejected opening the chamber to atmospheric pressure, and as a result, the energetic materials are no longer confined, resulting in a less effective combustion, and in higher deposition rates. It is believed that if the design of the 66 mm with a combustion chamber equipped with a nozzle was applied to the 84 mm, this would result in a more efficient combustion at higher temperature and pressure leading to lower deposition rates. Discussions with the manufacturer should take place to make them aware of these deposition rates and evaluate if it would be possible to modify the design of these weapons.

Modular charges

The Canadian Howitzer 105-mm artillery guns are using a multi-increment 7-bags system as the propelling charge. To reach different distances, the users remove some of these bags according to a chart to reach definite distances. At the end of the artillery exercises, they end up with a large amount of bags that they were usually destroying at the firing positions by burning them on the ground leaving an environmental issue at these locations. This burning activity is now banned in Canada and a burning table is used to destroy the excess propellant bags. The Howitzer 155-mm artillery guns are using a Modular Artillery Charge System (MACS) to fire their projectile. With this system, there are no bags to burn and the users are allowed to return in their containers the charges that were not fired since these charges can be reused for a following training exercise. This is the ultimate sustainable option in the sense that neither burning nor disposal is needed at the end of exercises. DRDC Valcartier initiated work two years ago to adapt the modular charge system to the 105 mm artillery guns and a demonstration is planned in March 2015.

RIGHTTRAC

Finally, a Technology Demonstration Program (TDP) named RIGHTTRAC, which stands for "*Revolutionary Insensitive Green and Healthier Training Technology with Reduced Adverse Contamination*", was initiated using greener explosives and propellants formulations and a self-destructive device system to produce a near zero-DUD rate greener weapon. The vehicle used for this demonstration is a 105-mm army artillery munitions (HE M1), currently filled with Composition B and using a single base gun propellant (M1 formulation). All energetic formulations under study had to meet current performance criteria of in-use munitions. In addition, the candidate energetic formulations must exhibit a low impact on the environment; all candidates were tested for their solubility, dissolution kinetics, leachability, transport properties and toxicity. The chosen explosive formulation was an octol-based formulation containing an Energetic Thermoplastic Elastomer (ETPE) which decreases the vulnerability of the munitions as well as the leaching of ingredients from the formulations. The chosen propellant is a modular Low Vulnerability Ammunition (LOVA)-type propellant, which can be used for extended-range applications. The self-destruct device is still under development. This technology has been designed to be transferable to medium and large caliber ammunition.

Each of these deliverables can be used separately or as a whole. The final demonstration is planned in 2014. At its completion, it is believed that this project will have proven the possibility of considering the long-term effects of the munitions on the environment right at the beginning of the weapon system development cycle and that this can be cost-effective in the long run.

Conclusion

There are many opportunities at this moment to test different methods, approaches and ideas of concept in order to minimize the environmental footprint of live fire training. New range designs and mitigation methods are presently sought after to counteract the negative impacts of the training. Burning of excess propellant bags in tables and small arms bullet catchers are already in use in Canada. Later this year, the first green grenade range will be experimented and tested. Evaluation of the costs to construct new demolition ranges based on the concept of the protected building may result in the first demolitions range based on the closed environment principle. Physical protection approaches can give in general good technologies but they may be costly. On the other hand, chemical solutions such as alkaline hydrolysis may be appropriate for some situations but will not solve all the issues, neither will do the soils burning . The issues of UXO disposal may find its solutions in the use of shaped charges and the modified procedure with a HMX block equivalent to C4 without RDX. The best solutions would be to have weapons that do not pollute and have no environmental impacts but developing such weapons is time consuming and we will see these weapons fielded only in many years. Canada's RIGHTTRAC project is a good example of that being the results of 20 years or so of R&D work. Eventually these weapons will be put in service but in the mean time, immediate solutions have to be found. This is an exciting time for those researchers who are looking at finding permanent solutions and it is highly probable that the final solutions may come from different projects in different countries.

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ENVIRONMENTAL RISK ASSESSMENT OF A MARINE SHOOTING RANGE, LOHTAJA, FINLAND

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This paper describes results of the environmental risk assessment of Lohtaja marine shooting area, Finland. The area is sensitive due to its use for fishery and its nature values. The shooting activities have continued for 60 years in the area. A phased approach was used. First, the sedimentation pattern in the area was clarified by means of sediment transport modeling. Next, sediment samples were taken and underwater observations were made from carefully selected sampling stations and acoustic profiling lines. A conceptual risk model was utilized. Finally, chemical analyses and biotests were performed in order to compare the target area to reference areas. Impacts of the chemicals originating from shooting activities to marine environment in the area were found to be at low level.

Introduction

Lohtaja marine shooting range is located ashore the Gulf of Bothnia, Finland (Figure 1). The area has been used since 1952 for anti-aircraft training and by coastal artillery which has used tugged rafts as targets. The targets have mostly been located at the open sea, up to 10-20 km offshore. Also infantry weapons systems such as mortars have been used in the area. Coastal artillery shootings finished in 2005. Environmental investigations and risk assessment of marine environment, described in this paper, were conducted in 2010 (Svanström et al., 2011).

Goal of this work was to assess the environmental risks generated by ammunition scrap and explosive residues of low-order detonations. Need for this has become obvious since the marine area is important for fishery, and large part of it is protected on the basis of its nature values. The area includes e.g. rare coastal dune terrain and eel grass bottom nature types. Background data for the work included historical activities at the area, shooting rates and types, location of the activities, and nature studies.

Materials and methods

Due to the large size of the impact area, the investigation strategy was based on a sediment transport model. This type of model has proved to be essential for the selection of feasible remediation methods, and to extract information of contaminant transport pathways and fate. Sediment transport models are needed, in particular, in risk assessments of sediment contamination. It has been realized that the risk paths from the sediment to humans are in many cases much straighter than e.g. from soil to humans (US EPA, 2005; Itkonen, 2013).

The modeling methods used have been originally presented by Håkanson & Jansson (1984) and they are based on Scandinavian lake data. Modifications made to the method have been briefly described in the papers Itkonen (1997) and Itkonen (2007).

The transport pattern of the sediment in the area turned out to be almost completely wind-wave action dominated. The model was further verified by acoustic profiling and by a diving survey. It concluded that the bottom is mainly erosional and consists of rippled sand closer to the shore, and silt further at the open sea (Figure 2). The areas of permanent accumulation of sediment were found to be located some 15 km seawards from the shore (Figure 3).

Figure 1. The Lohtaja shooting area is located on an esker cape that reaches seawards, and associated marine areas

Figure 2. Sea bottom at the Lohtaja shooting area consisted mainly of rippled sand

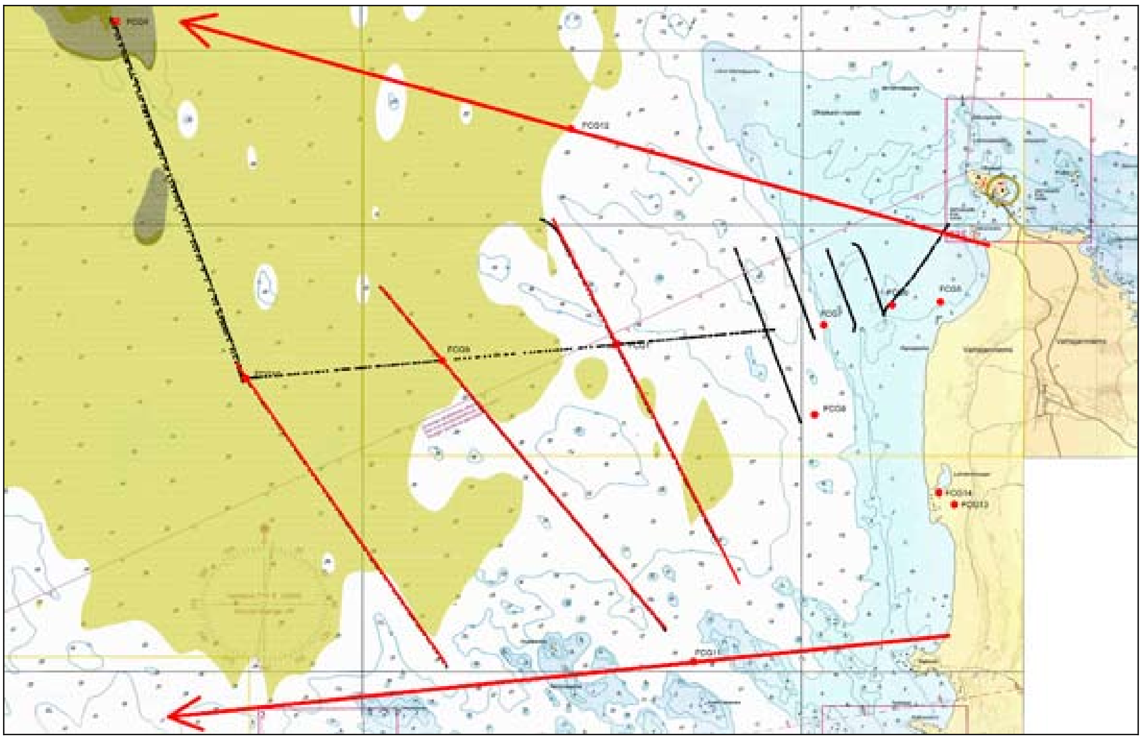

*Figure 3. Part of the sediment transport model. Thick red line = shooting sector, thin red line = target rafts, red dots = sampling stations, black dots = acoustic profiling, dark green = accumulation, light green = transport and the rest of the water area = erosion zone. Map area approx. 24 * 15 km*

Based on information of bottom dynamics on the area, a conceptual model was created. Source of the possible contaminants were identified to be shooting activities and target indication. The actual release of contaminants happens in detonations, or they are released from ammunition remains, fuels or wastes associated with the operations. Contaminants then migrate dissolved in water or bound to particles, and in the sedimentary subsystem. The exposed receiving species considered here were bottom animals, fishes and aquatic plants. After the conceptual model was accepted, field investigations were focused into the identified depositional areas.

Altogether, the risk assessment included sampling of 13 stations, 70 km low frequency profiling, chemical analyses of over 200 compounds, ecotoxicological biotests (*Vibrio fischeri* bacteria, *Phaeodactylum tricornutum* algae, *Acartia tonsa marine* copepods and *Scorphtalmus maximus* fishes), and quantitative assessment of chemical exposure. The contaminant concentration levels in sediment were compared to SQB criteria (= Sediment Quality Benchmark, explosives) and NOEC values (No Observed Effect Concentration, TBT).

Results and discussion

According to the side scan images and underwater observations made by the divers, exposed ammunition scrap is almost absent in the area (Figure 4). Our interpretation is that it is actively buried by the migrating sandy sediment. In deeper areas, the finer grade sediments are expected to bury most of the ammunition scrap immediately after they sink to the bottom.

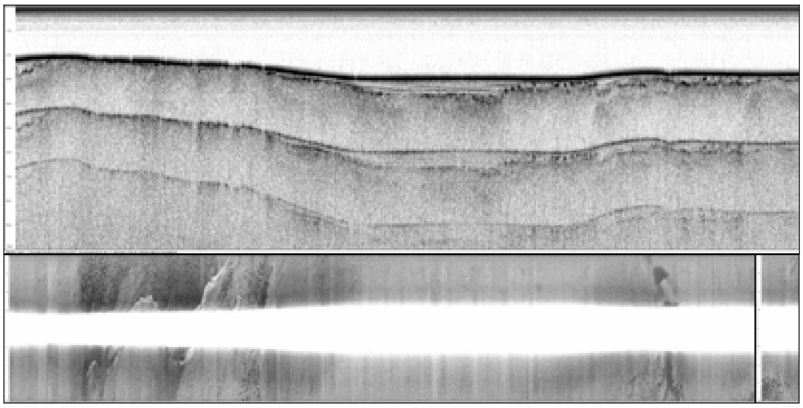

Figure 4. Above: Low frequency acoustic profile showing erosion and transport zone sediments. Below: The same sediments with side scan

No explosive or fuel traces, or significant concentrations of organotin or PAH –compounds, were detected in the sediment. Respectively, concentrations of metals were low. However, slightly elevated concentrations of arsenic, nickel and cadmium were detected at two sampling stations. The elevated concentrations occurred at isolated bottom areas, and no wide-scale contaminations could be identified.

This can be concluded by the acclomorative hierarchical clustering (AHC) of the geochemical data, shown in figure 5. Reference station FCG3, located in front of the nearby City of Kokkola, separates from the rest of the sampling stations at a high level of dissimilarity. The rest of the sampling stations (including those at the inland areas) are relatively similar, and the grouping seems to reflect water depth. The supposedly *"clean"* reference sample FCG2 is a central member of a group of samples taken from approximately the same water depth from the target sector.

Furthermore, bottom animals indicated pristine bottom conditions. The results of biotests with different species were uniform. According to the test results, the toxicity of the target area sediments is low, and does not significantly differ from that of the reference areas. To conclude, no significant or clearly detectable risks were identified in the work. Though some uncertainty is generated by the relatively small number of sampling stations, limited number of chemicals analyzed, and high detection limits of some chemicals, the results are considered sufficient and representative for phase one environmental risk assessment.

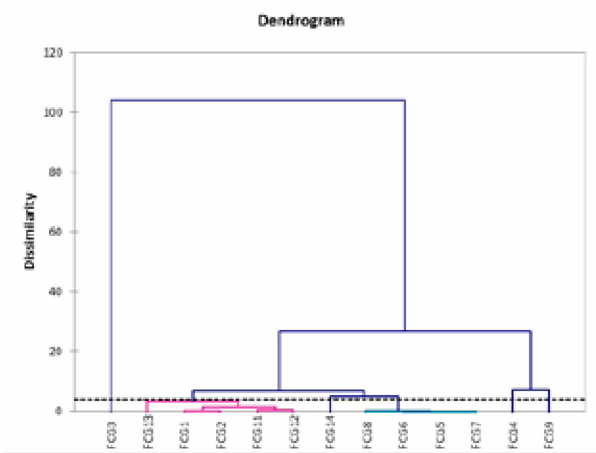

Figure 5. Acclomorative hierarchical clustering (AHC) of the geochemical samples taken

Conclusions

During recent years, sediment transport modeling has become more frequent component of Finnish aquatic sediment studies than before. The method has proved to be very cost effective since it has helped to avoid extensive sampling campaigns. Furthermore, clarification of the sedimentation patterns has increased the quality of the studies. The representativeness of the selected sampling places has also increased.

The Lohtaja shooting area case led to understanding of local sedimentation, and enabled risk assessment. The near-shore areas consisted mainly of relatively coarse grained erosion and transport bottoms. Based on the transport model, a reliable conceptual model was possible to be constructed.

No major health or environmental risk due to the energetic compounds was identified. This was indicated by both the geochemical data and the tested marine organisms. In general, biotests worked well in the case, and gave valuable information of the response of biota to the sediments. The interpreted low level of chemical impact may lay in the openness of the sea area which allows effective mixing and migration of sediment and contaminants further to the open sea. Thus, the possible additional studies should be concentrated on the identified accumulation areas.

One interesting feature was the general lack of ammunition at the sea bed. Based on annual shooting frequency data, more debris should have been identified. The explanation is probably in the regular resuspension of the uppermost sand layer; heavy ammunition is buried in sand or it sinks into the finer grained sediments.

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QUANTIFICATION OF ENVIRONMENTAL RISKS IN CONTAMINATED SITES - TRANSPORT OF SOLUTES AND SOLIDS IN STRUCTURED SOILS

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Natural landscapes in Nordic countries are characterised by variable soil formations residing as rather thin layers over nearly impermeable bedrock. Due to different soil types and climate compared to continental Europe and North America, existing hydrological simulation models struggle to describe water movement in our conditions, especially in structured soils such as clay and till. This introduces uncertainties into water flux and solute transport modelling results. On the other hand, most of the advanced solute transport models are not able to simulate winter time conditions which have a profound effect on water cycle in our latitudes. Winter freezing conditions, substantial snow melt generation and short growing season are the inherent hydrological features that lead to special challenges for quantifying environmental risks in Nordic countries. Thus, there is a need for modelling tools that combine hydrogeological and reactive solute transport processes with a realistic representation of the water cycle.

Objective of the study is to demonstrate capabilities of FLUSH modelling system for describing hydrological pathways of water and transport of solutes and solids in contaminated sites. The model divides the simulated area into two-dimensional overland and three-dimensional subsurface domains. Simulation of overland flow and unsaturated and saturated subsurface flows are supported. The unsaturated domain is important when solving dissolution of solutes, e.g. from munitions constituents, in the top soil layers or on the soil surface. The model can simulate fast preferential flow and solute transport in larger soil pores (macropores) in structured soils. Flow velocities in macropores can be orders of magnitudes higher compared to velocities in the soil matrix resulting in faster than expected contaminant plume movement. Possibility of simulating soil erosion and particle transport is also included which facilitates transport simulation of solutes that are adsorbed on soil particles or colloids. The winter time components, which include snow accumulation and melt, soil freezing and thawing, as well as heat transport between the snow cover and the underlying soil layers, are solved with energy balance approaches. The reactive solute transport system is under development and it includes solute dissolution from source material, transport, adsorption and decay processes. The reaction chains can be customized for the selected substances. One possible application could be lead (Pb) in shooting ranges. The metallic lead shot corrodes rapidly and develops a coating of hydrocerussite and hydrocerussite dissolution releases soluble lead depending on soil pH values. Pb can be transported to groundwater in water soluble form or adsorbed to soil particles or colloids.

Spatial input data is supplied to the system from GIS software and it includes freely available digital elevation maps, spatially distributed soil maps and drainage systems. Temporal data include standard meteorological measurements for estimating potential soil evaporation and plant transpiration. The model has been benchmarked against mathematical analytical models, laboratory experiments and data from several field campaigns in agricultural settings.

Introduction

Transport of solutes in soils is routinely studied with simulation models in different environmental research fields. In boreal conditions, the climate and soils pose special challenges to models including winter time conditions and different structured soils prevalent in the area. The motivation of this study is to analyse these common problems and present a hydrological and solute transport model called FLUSH that addresses these issues.

The climate in the Nordic countries is temperate and the annual precipitations in Sweden, Finland and Norway are 540, 650 and 760 mm, respectively. Approximately half of the annual precipitation is lost via evapotranspiration primarily during the growing season while the other half forms runoff mainly in autumn and spring. Precipitation is distributed relatively evenly throughout the year and during winters it is stored in the snow cover. Major part of the annual runoff and the highest runoff events occur typically during snowmelt in spring, especially in the northern parts of the countries. The spring and autumn periods when runoff is dominant component of the water balance are important from the contaminant transport point of view, because flowing water is the main transport medium for particles and chemical compounds.

Landscape in the Nordic countries is characterised by spatially variable soil formations which are relatively thin compared to the central Europe. Till soils are extremely heterogeneous glacial deposits composed of grain sizes ranging from fine clay particles to large boulders. Clays on the other hand are formed of sorted micro meter scale particles which tend to form aggregates. Water movement in these structured soils is complex due to different flow regimes between fine soil particles (i.e. the soil matrix) and in large soil pores (i.e. the macropores). The macropores are composed of animal burrows, plant root conduits, shrinkage cracks and flow pathways around larger stones and boulders. Shrinkage cracks are formed into clay soil when drying soil loses volume. In dry conditions, flow occurs mainly as a slow seepage in the soil matrix. Precipitation events on macroporous soil during moist periods may activate the macropore flow mechanism. Fast water flow in the macropores effectively bypasses the surrounding matrix and it is hence often called preferential flow. The phenomenon is complicated especially when combined with solute transport because 1) the contaminants are transported faster than expected in the macropores and 2) they have less time to react and decay in the soil matrix. Structured soils are prevalent in Nordic countries and fast transport in soil macropores should be considered in solute transport investigations in clay and till soils as the contaminant plumes may advance with accelerated rates compared to transport in uniform soils.

The objective is to present the FLUSH modelling system and demonstrate its application through two examples. Firstly, a simple theoretical example of the solute transport in the presence and absence of soil macropores is presented. The model implementation in the simple example includes 1) data acquisition, 2) GIS work, 3) running the transport simulations, 4) data visualisation and interpretation, and 5) drawing conclusions from the results. Secondly, snow melt driven surface runoff and subsurface drainflow generation are simulated in a clayey agricultural field in Southern Finland.

Methods

In computational modelling, the problem definition is simplified and reduced into a mathematical form, which is then solved numerically to obtain the solution to the original problem. In our case, this means that the water flow and solute transport processes are represented as partial differential equations which are solved in a computational grid representing the investigated area. Perhaps the best property of computational modelling as a method is the possibility to create a holistic picture of the mass balances of water and solute. In other words, we can include all the processes in the model that we think are relevant in the real site and the model enables us to quantify the contribution of each process. Data from the field is then used to anchor the model to the reality, i.e. calibrate the key model parameters in the respective data points with known state or flux variables. If it proves to be impossible to fit the model into the data it implies that either there are problems with the process descriptions or with the data. Model binds the input and output variables together and is therefore a very strict test of the coherence of the data.

The hydrological and solute transport model FLUSH (Warsta, 2011) was originally developed for estimation of water balance and sediment loads via surface runoff and drainflow at the outlets of agricultural fields. The model divides the simulated area into two-dimensional overland and three-dimensional (3-D) subsurface domains (Fig. 1). The approach supports simulation of overland water flow on the field surface and unsaturated and saturated flow in the soil. Because the model was developed for structured soils, preferential flow in macropores is also included with soil shrinkage and swelling descriptions. The solute transport model describes advection and dispersion and solute exchange between the two pore systems. The model supports simulation of soil erosion on the field surface and suspended sediment transport in macropores.

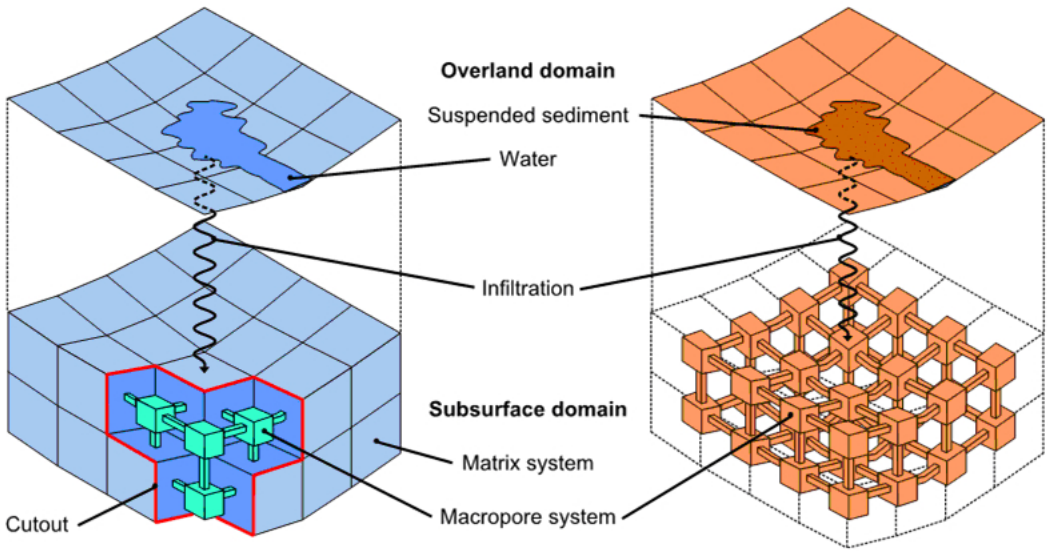

Figure 1. Overland and subsurface domains for water and sediment in FLUSH

Recently, winter time process descriptions were included in the model by Warsta et al. (2012). Snow accumulation and melt including snow heat balance are simulated in FLUSH in a distributed manner in the overland domain. The model computes snow surface energy balance and derives the snow surface temperatures according to the incoming and outgoing radiation fluxes, turbulent fluxes of sensible and latent heat, and heat redistribution within the snow cover (Koivusalo et al., 2001). Heat is also exchanged between the snow cover and the underlying soil profile. Freezing of the soil is computed with accountancy to energy exchange in both heat conduction and phase changes of soil water freezing and melting.

Other technical features recently added into the model include the ability to import data from GIS systems and the parallel computing in clusters and supercomputers. As such, FLUSH includes all the main hydrological processes discussed earlier required in Nordic conditions. The model has been previously tested with data from mathematical analytical models, laboratory experiments and several field campaigns in agricultural settings (e.g. Turunen et al., 2013; Warsta et al., 2013; Warsta et al., 2012; Warsta, 2011; Kesäniemi, 2009).

Results

Hypothetical example of solute transport

We took the field scale parametrisation of the Gårdskulla field in Siuntio (60°10′ 37.936′′ N 24° 10′ 23.535′′ E) derived for FLUSH by Turunen et al. (2012). Solute transport in the field was demonstrated with a hypothetical example application in which a conservative tracer is transported from a rectangular source area with side lengths of 4.0 m (Fig. 2) in till soil using a traditional single pore system model and in clay soil using the preferential flow and transport model (dual-porosity model). Till soil hydraulic parameters were derived from Laine-Kaulio (2011) and clay soil parameters from Turunen et al. (2012).

The main steps in the model application were the following: 1) The digital elevation map was acquired from National Land Survey of Finland, which provides 2.0 m × 2.0 m elevation models created with laser scanning. The weather data including air temperature, relative humidity, precipitation, incoming short-wave radiation, and wind speed was compiled from the Finnish Meteorological Institute. The incoming long wave radiation and potential evapotranspiration data were estimated in this application. The meteorological data period extended from 27 October to 31 October and the simulation length was 100.0 h. The selected time period was wet and the precipitation sum was 49.0 mm (corrected value) and the maximum precipitation intensity was 3.4 mm h-1. 2) The field geometry including the field area, contaminant source area and the drainage systems were drawn in the open source Quantum GIS (QGIS) and exported from QGIS via a Python plugin. The tracer concentration inside the cells in the source area was set to a constant value of 1.0 g l-1. 3) In the beginning of the simulation step, the input data including the meteorological and geometry data is fed into the model and the system generates the computational grid (Fig. 2). In this application, the grid resolution was 80×128×22 cells in x-, y- and z-directions and the horizontal cell size was 4.0 m × 4.0 m.

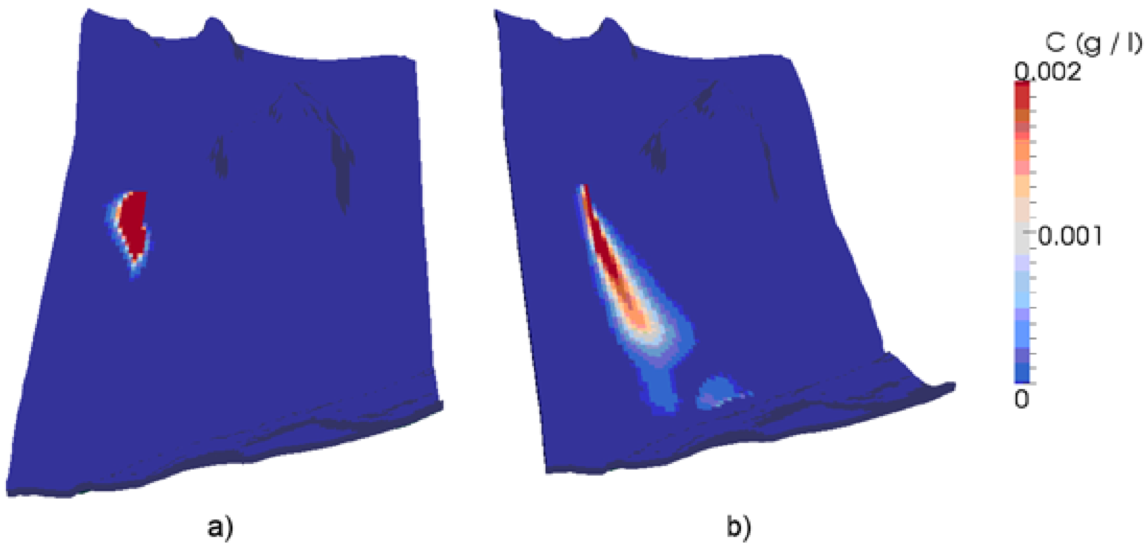

Figure 2. Advancements of the tracer plumes in the simulations with a) a single pore system model (till) and b) dual-porosity model (clay) after 48 h. The visible part of the plume is located 1.0 m beneath the soil surface

4) Simulation output includes time series of runoff and solute fluxes into the drainage systems in the area. The model also saves 3-D computational grids in the Visualization Toolkit (VTK) format during the simulation from specified points in time. These are used to visualise the spatio-temporal evolution of the contaminant plume. The VTK grids can be viewed in a suitable visualisation program such as open source program ParaView applied here. According to the results, the plume in the dual-porosity simulation covered the distance (~250.0 m) from the source area to the stream in the lower side of the grid (Fig. 2) in just 48 h. In the single porosity simulation, the plume advanced only 80.0 m from the source towards the stream during the same period. 5) The results confirm the hypothesis that description of wa-

ter flow in structured soils (till in this case) with a single pore system model can produce notably slower transport times compared to the dual-porosity model (clay). The bulk hydraulic conductivity of the till soil was tenfold higher compared to the clay soil. Because hydrology is the driver of solute transport in structured soils, runoff due to snow melt should be considered in transport simulations conducted during winter time conditions.

Snow and runoff simulation example and comparison against field data

The model was then applied to simulate snow cover and surface runoff and drainflow generation in a clayey agricultural field (3.6 ha) in Kirkkonummi (60º 14′ 28″ N 24º 23′ 5″ E). The measured hourly input data included precipitation, temperature, relative humidity, wind speed, and incoming short-wave radiation. The incoming long-wave radiation was estimated (e.g. Turunen et al., 2013). Simulated period was 1 January to 31 May in 1996. The hydrological model was calibrated earlier to data from 1998 (Warsta et al., 2013). The model results were compared to the measured snow water equivalents (SWE) and surface runoff and drainflow (Fig. 3). The period included clear, distinct periods of snow accumulation and snow melt with measured and computed SWE of 155.0 mm and 135.0 mm, respectively (Fig. 3, top). Total simulated runoff was 95.0 mm and it was dominated by surface runoff (77% of the total runoff) (Fig. 3, bottom) during the period. According to the results, FLUSH was able to match SWE and both runoff components in the simulations. The large share of surface runoff compared to the growing season is an indication that the soil hydraulic conductivity was decreased due to frost. Apparently, the effect of frost is increased if the soil is moist during the freezing time. Increased surface runoff in turn potentially accelerates erosion and transport of soil particles and solutes from the site.

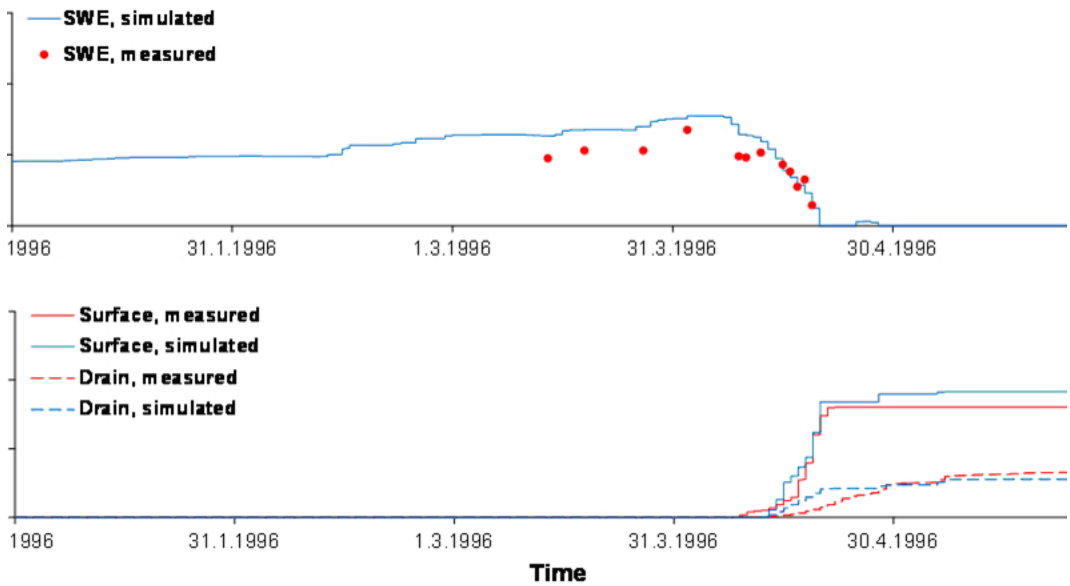

Figure 3. Measured and simulated snow water equivalents in the experimental field in 1996 (top) and measured and simulated surface runoff and drainflow (bottom)

Conclusions

In this study several challenges concerning contaminant transport risk assessments in Nordic areas were presented. Computational modelling is a powerful tool when combined with good quality data in solute transport studies and can provide a holistic picture of the investigated site and quantitative information about the individual processes. The inclusion of the relevant processes in the hydrological model, and appropriate description of water flow pathways is the key to successful solute transport simulations. In long term simulations over multiple seasons, inclusion of winter time processes is crucial while simulations of solute transport in structured soils such as clay and till should include preferential flow and transport descriptions in macropores. Most of the widely used spatially distributed hydrological models do not include computational schemes for both preferential flow and transport, and winter time processes. A simulation model called FLUSH was presented which is developed in Finland for Nordic conditions and includes these features. The model can be a useful tool in simulation of complex multispecies transport of decay products from munitions fragments in the future.

Acknowledgements

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ENHANCEMENT OF SOIL AND WATER PROTECTION MEASURES COMBINING AFTERCARE WITH PRECAUTION AT MILITARY TRAINING RANGES

A new program beyond the existing German Ministry of Defence (MoD) Site Remediation Program

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The German MoD Site Remediation Program applies in its current version to all harmful soil alterations and water pollutions on military sites in use by the German Armed Forces under the operational jurisdiction of the German MoD.

To promptly handle cases of imminent danger, e.g. spills and accidents, the MoD provides a separate "*Spill Response and Reporting Program*". Follow-up remediation measures are then conducted within the Site Remediation Program. Another separate program refers to the detection, removal and disposal of explosive ordnance from World War I and II. However, contaminations caused by energetic compounds released to soil, surface water, sediments and groundwater from unexploded or not fully detonated (so called "*low-order detonation*") ammunition are part of the MoD Site Remediation Program.

The German MoD Site Remediation Program consists of three phases and is primarily considered as an "*aftercare*" program for contaminations. Phase I covers determination and initial evaluation of potential contaminated areas, Phase II appropriate field investigation and risk assessment. Phase III contents, if proved necessary, remediation action. A classification system, used through all three phases, categorises all areas according to the actual risk in one of five different categories, thereby determining further action and type of action or no action.

Under the German MoD Site Remediation Program, remediation at military training ranges currently in use (such as artillery target areas, training ranges for hand grenades, small arms firing ranges and blast training ranges), where contaminants are brought into the environment "*on purpose*", have been regarded as inefficient. Constant military training causes constant input of potential contaminants. Up to now those ranges were only investigated when contaminated surface runoff, seepage water or groundwater water posed a danger to neighboring property or water protection areas.

With regard to sustainable military use and the general work progress of the German MoD Site Remediation Program, the German MoD now focuses on those training ranges. They will now be addressed by a new program combining investigation and remediation as "*aftercare*" with different precautionary measures in order to ensure full military but also sustainable and environmentally safe use in the future by avoiding or at least minimizing the impact on the environment. The new program also comprises a new budgetary approach, which completely differs from the usual complicated budget process mandatory for every single project of the German MoD Site Remediation Program.

To get an idea of how severe intensively used ranges are actually contaminated and how to efficiently investigate those ranges, a pilot study at five blast training ranges had been conducted. The results show low contaminations of polycyclic aromatic hydrocarbons (PAH) and heavy metals, but in several cases significant contaminations of energetic compounds in soil, surface runoff, seepage water and groundwater. Projections revealed that up to several kilograms of energetic compounds are released into the environment per year on frequently used blast training ranges, due to the fact that not all energetic compounds fully react ("*low order detonations*"). Research from the USA shows that in some cases up to 4 percent of the energetic compounds do not react, a phenomenon which frequently occurs in disposal blasts.

Based on these results, a general concept for further activity has been developed. It consists of 3 steps. In step 1 a general selection and prioritisation of relevant training ranges is conducted. Step 2 includes a field investigation at identified ranges. Step 3 combines clean up as aftercare with precautionary measures.

With step 1 certain training ranges with an obviously high threat potential to the environment like blast training areas or hand grenade ranges are selected. For blast training ranges three intensity levels of use have already been determined with respect to the amount of explosives used at the ranges per year, based on the data of the pilot study. For the other types of training ranges the relevant intensity levels still have to be established during step 1. Besides, the geologic, hydrologic and morphologic properties at every range are categorised in five model types focusing on the possible path for surface runoff, seepage water and groundwater. A combination of model type and intensity level will then lead to one out of three potential hazard categories determining the priority for further action. Ranges with clearly no potential to harm the environment can be excluded in advance (hazard category "*low*"). Hazard category "*medium*" calls for further investigation in the long term and hazard category "*high*" for further investigation with high priority. The aim is a reduction of the amount of ranges to investigate. The Federal Institute for Geosciences and Natural Resources has just been tasked to conduct this first step within a year. It also includes the detection of possible other contaminants beyond the now known by screening all single compounds of ammunition used by the German Armed Forces for potential environmental relevance.

In step 2, those ranges identified for further action will be investigated in the field based on a modified and adapted Phase II of the German MoD Site Remediation Program. Step 3 includes necessary remediation according to a modified and adapted Phase III of the German MoD Site Remediation Program directly combined with precautionary measures. These measures comprise operational measures like adjustments to frequency and type of use and certain maintenance as well as structural enhancements to minimise or avoid the spread of contaminants beyond the actual training range, or long term monitoring.

DESTRUCTION OF OLD EXPIRED AND SPOILED MUNITION IN FINLAND - ENVIRONMENTAL EFFECTS OF OPEN SURFACE MASS DETONATIONS

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The Finnish Defence Forces has destroyed obsolete and spoiled munition in open surface mass detonations at Hukkakero fell, in municipality of Kittilä, in Lapland since 1988. The destruction method was learned from Sweden in 1987. The disposal camp is organized every autumn and it lasts four to six weeks. There are one or two detonations on everyday. Gross weight of an average charge varies from 150 to 250 tons and the net weight of explosives from 15 to 25 tons. As a booster there have been used 2 to 3 tons of emulsion explosives. The explosives mainly consist of 2,4,6-trinitrotoluene (TNT) containing smaller amounts of amatol and hexotol. The Finnish Defence Forces Technical Research Centre (PVTT) has studied the environmental effects of these open surface mass detonations since they began in 1988.

The environmental effects of the mass explosions can be divided and studied in three different groups;

1. Gaseous emissions
2. Organic explosive residues and their conversion products
3. Metal emissions

- The gaseous emissions, the cloud, mainly consist of carbon (CO_x) and nitrogen (NO_x) oxides containing very small amounts of ammonia and cyanides. However, the total emissions of the detonations are quite small compared to the total releases of municipality of Lapland where the emissions are mainly coming from the traffic and the heating of houses.
- Organic explosive residues and their conversion products mainly affect to the soil on detonation site, but can also been found in the very close vicinity to the destruction area. The whole area is closed by a fence, whose radius is 1 km. The organic explosive residues and their conversion products can not be found out side the fence.
- Metal emissions: When the charge is detonated, it spreads fragments of the shells over the detonation site. Secondly the explosion generates such a huge amount of heat, that part of the shells evaporate, especially the low melting metals. The vaporized metals blend with the ground dust and create hollow silicate-metal-shots which spread over the destruction area with the winds.

The iron fragments have been gathered by a big electromagnet and recycled in Kemi -Tornio steel factory.

The vegetation and the berries of the area have not used the high metal concentrations of the soil, but the ground dust blown by the winds settle on the surface of the berries and the leaves increasing their metal concentrations. However, the occasional rains may rinse the metals from the surfaces back to the ground.

The metal concentrations of the soil are increasing in the vicinity to disposal area, especially the concentrations of nickel and chromium.

The nearest lake, called Seurujärvi, locates around 11 km north from the detonation site. The metal concentrations of muscles and livers of pikes of the lake were observed to be normal.

The heavy metal deposit range of the explosions has been studied by two different methods and is observed to be 5-7 km. Therefore the total area affected by the metal deposit is estimated to be 100-150 km^2. However, the amount of metal deposit is very low out side 2 km range from the disposal area. The effects can be detected from large areas because the measuring equipment, ICP-MS, is so sensitive.

Introduction

The Finnish Defence Forces has destroyed old expired and spoiled munition in huge open surface mass detonations in Lapland since 1988. The technique was learned from Sweden in 1987. The Finnish Defence Forces Technical Research Centre (PVTT) has studied the environmental effects of the open surface mass explosions since they began in 1988.

The destruction camp is organized every autumn and it normally lasts four to six weeks. One or two charges are exploded every day. Gross weight of a typical charge varies from 150 to 250 tons containing 15 to 25 tons of explosives, mainly TNT. As a booster there have been used two to three tons of emulsion explosives.

The environmental effects of the mass explosions can be divided and studied in three different groups;

- Gaseous emissions
- Organic explosive residues and their conversion products
- Metal deposit

Photos 1-3. (1)A typical charge, (2) Open surface mass detonation seen 8 km form the explosion site, (3) Crater of the explosion

Environmental studies

Gaseous emissions

Pure stoichiometric detonation produces carbon dioxide, water and nitrogen. However, the explosions are seldom stoichiometric and therefore they produce series of carbon and nitrogen oxides as well as smaller amounts of some other gaseous compounds.

According to American Bang Box Test series one ton of TNT produces around 10 kg of nitrogen oxides (NO_x) and 1300 kg of carbon oxides (CO_x). If the destruction camp lasts five weeks and there is one detonation on each day, it means that there are 35 detonations during the whole destruction period. The average amount of explosives in the charge is around 20 tons. Because the explosives mainly consist of TNT, the total gaseous emissions can be estimated by the following calculations:

Emission (NO_x) = 35 shots * 20 tons/shot * 10 kg (NO_x)/ton = 7 000 kg ≈ 7 tons

Emission (CO_x) = 35 shots * 20 tons/shot * 1300 kg (CO_x)/ton = 910 000 kg ≈ 910 tons

According to the Finnish Meteorological Institute - Nitrogen oxide emissions in Western Europe - the nitrogen oxide (NO_x) releases in Lapland are around 12 000 tons per year. Therefore the nitrogen oxide (NO_x) emissions of the destruction camp are around 0,06% of the total emissions in Lapland.

The carbon oxide (CO_x) emissions of the open surface mass detonations are around 910 tons. If we compare the releases into cars, a car produces around 150 g of carbon dioxide (CO_2) per one kilometre. It means that 600 cars produce 900 tons of carbon dioxide, if they are driven 10 000 km/year. Therefore carbon oxide emissions of the destruction camp are about the same as the releases of a small Lapland village.

The composition of the explosion cloud has also been studied by helicopters and by planes. The cloud contains carbon oxides as well as nitrogen oxides, but also smaller amounts of hydrogen cyanide and ammonia. All the observed concentrations were bellow 1 ppm (parts per million).

Organic explosive residues and their conversion products

American Bang Box Test series

According to American Bang Box Test series when one ton of TNT is detonated, it produces the following compounds:

Table 1. The quantity of organic compounds when 600 tons of TNT is detonated

One ton of TNT produces	Quantity		Quantity
Vaporising compounds	*g*		*kg*
Methane	42,5		25,5
Simple hydrocarbons	51,1		30,7
Unsaturated hydro carbons	14,5		8,7
Alkynes	7,5		4,5
Aromatic compounds, not benzene	9,3		5,6
Benzene	2,9		1,7
Terpenes	ND		ND
Partly vaporising compounds		x 20 tons/shot	
2,6-Dinitrotoluene	0,4	x 30 shots/year	0,2

4-Nitrophenol	2,4		1,4
2,4-Dinitrophenol	1,0		0,6
2-Nitronaphtalene	0,6		0,4
2,4,6-Trinitrotoluene	3,0		1,8
Phenol	23,0		13,8
Dibentsofuran	1,2		0,7
Bentsopyrene	2,7		1,6
Dibentsoantrazene	1,6		1,0
N-Nitrosodiphenyylamine	1,2		0,7
1&2-Dimetylnaphtalene	27,0		16,2
1,3,5-Trinitrobenzene	0,025		0,0
2,5-Diphenyloxatsol	66,0		39,6
Naphthalene	102,0		61,2
Phenanthrene	0,2		0,1

The main products are Naphthalene, 2, 5-Diphenyloxatsol, 1, 2-Dimethylnaphtalene and Phenol.

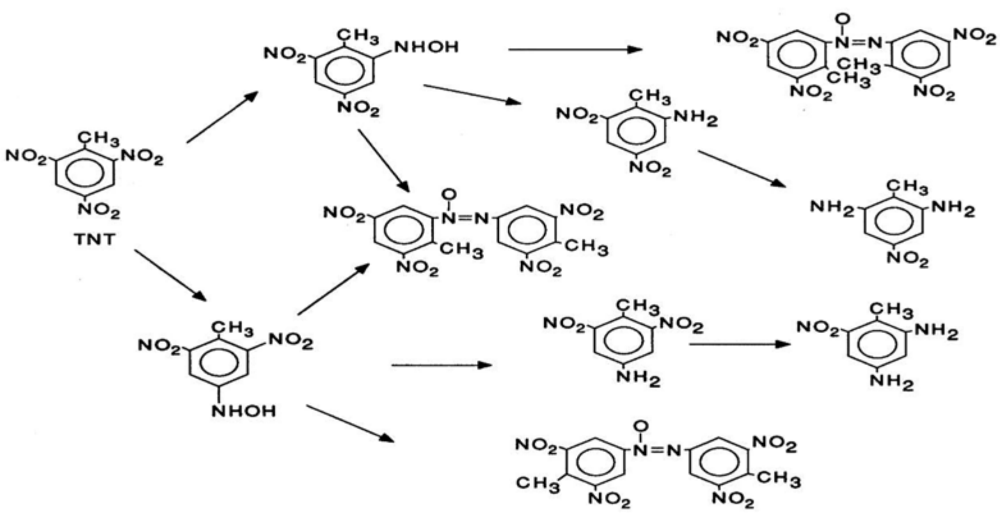
Organic explosive residues in atmospheric samples

Atmospheric samples were collected by helicopter, aeroplane and by high-capacity collectors. A total of twelve samples were obtained. The explosive concentrations of the atmospheric samples were at level of few ng/m^3, while the detection limit was 1,25 ng/m^3.

TNT and its conversion products in soil

When a charge composed of TNT is exploded, the explosive residues can be easily found from the soil of the detonation site. TNT does not dissolve easily into rain waters, but it reduces to other compounds in the soil. The solubility of the reduced compounds into the water is different than TNT. The common conversion products of TNT are;

- 1,3-DNB l. 1,3-dinitrobentseeni
- 2,4-DNT l. 2,4-dinitrotolueeni
- 2,6-DNT l. 2,6-dinitrotolueeni
- 4A-DNT l. 4-Amino-2,6-Dinitrotolueeni
- 2A-DNT l. 2-Amino-4,6-Dinitrotolueeni



Picture 4. The conversion products of TNT

Organic explosive residues and their conversion products in deposit samples

The deposit samples were collected into PP-plastic containers and boron-silicate vessels, which were installed before the destruction period was started and they were collected after the period. The samples were analyzed by Liquid Chromatography - Mass Spectrometry (LC-MS) - instrument, which is extremely sensitive for the organic compounds.

Table 2. TNT residues per hectare after the destruction period

Distance from	TNT	TNT	TNT	TNT
Detonation site	North	South	East	West
(m)	(mg/Ha)	(mg/Ha)	(mg/Ha)	(mg/Ha)
200	Was destroyed	Was destroyed	Was destroyed	Was destroyed
300	Was destroyed	Was destroyed	Was destroyed	110
400	Was destroyed	Was destroyed	330	100
500	140	480	290	330
600	150	300	270	310
800	520	290	590	*
1000	170	200	350	280
1200	270	70	350	110
1400	*	180	*	210
1600	170	*	15*	*

Table 3. The organic explosive residues and their conversion products outside the fence. The detection limit was 2 µg/l

Distance	TNT	RDX	HMX	2A-DNT	4A-DNT	1,3,5-TNB	2,4-DNT	2,6-DNT
(m)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)	(µg/l)
1 170	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1 550	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
2 060	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
2 470	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
3 090	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
8 990	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2

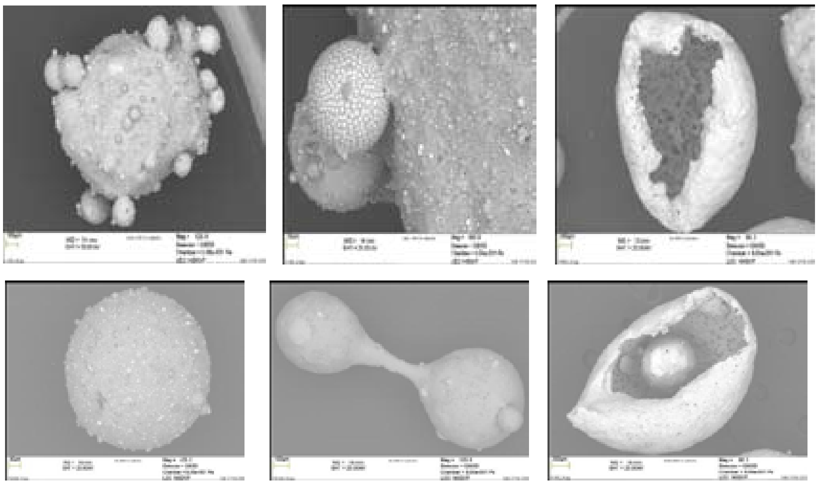
As earlier mentioned, the test area is closed by a fence. The radius of the fence is 1 km measured from the detonation site. Almost all the organic deposit, composed of explosive residues and their conversion products, was limited inside the fence.

Environmental effects of the heavy metal deposit

Spreading mechanism of the metals

When the charge is detonated, the fragments of the metal shells spread all over the detonation site. However, almost all the pieces stay inside the fence, where they can be collected by an electromagnetic system and recycle in a steel factory.

Secondly the explosion generates such huge amount of heat that the metals of the shells, especially low melting metals, partly evaporate into the air and mix to the ground dust. When the high temperature decreases, the vaporized metals start to condensate. Now they start work like glue with the ground dust and produce hollow silicate-metal shots. The size of the shots varies from few microns to several millimetres. At this point the explosive residues and their conversion products also condensate on the cool surfaces of the shots. The heavy and big shots drop down near the disposal area, but the smaller ones fly all over the area with the winds.



Picture 5. Hollow silicate-metal shots magnified by the scanning electron microscope (SEM)

Effects of the metal deposit to metal concentrations of berries

There are three different berries growing near the disposal area; blueberry, lingonberry and crowberry or blackberry. The berries seem not to use the high metal concentrations of the soil. However, the strong winds of the area raises up some soil dust, which settles on the surfaces of the berries increasing their metal content. However, the occasional rains of the area rinse the metals from the surfaces back to the ground time to time. The metal concentrations of the berries have been studied by dividing the berries into two different groups; the berries gathered before the disposal period and after it. These two groups was further divided into two other groups; washed and unwashed berries. The metal contents of all these four groups have been compared to the metal concentrations of the reference berries. After several years studies it can be concluded that the berries are not using, or they are using only minimum amount, the high metal concentrations of the soil. The main problem is the dust.

Metals in the natural waters

The destruction area is surrounded by huge swamps and the nearest settlement locates around 13 km west from the site. There are only two flowing natural waters on the area; Roura-river, which flows from the swamps, and a small streamlet flowing from the hill of the destruction site. The width of the river is 2 to 3 meters and the streamlet around one meter. All the waters of the area flow to big artificial lake called Porttipahta, where the waters are under careful supervision. The European largest gold mining locates around 13 km from Hukkakero fell.

The metal concentrations of the streaming waters increase somewhat after the destruction camp, but not much. However, the concentrations in still waters, ponds and pits, didn't increase after the detonation period. The still waters of the ponds and pits were probably so rich in humus that the fulvonic acids precipitated the ionic metals.

Metals in soil

The metal concentrations of surface soil are very high near the detonation site decreasing as a function of distance measured from the detonation site. However, the nickel and chromium concentrations inside the fence, around 400 - 500 m from the disposal site, are quite high and are going to exceed the limits set for the spoiled soil in a near future.

Metal content of fish

The nearest lake is called Seurujärvi and it locates around 11 km from the detonation site. During summer 2012 three pikes were caught and the metal contents of their muscles and livers were determined.

In European Union there are set limit values only for mercury, lead and cadmium;

- Mercury - 0,5 mg/kg (common value) - 1 mg/kg (higher value)
- Lead - 0,2 mg/kg (common value) - 0,4 mg/kg (higher value)
- Cadmium - 0,05 mg/kg (common value) - 0,1 mg/kg (higher value)

Table 4. Metal content of muscles and livers of three pikes

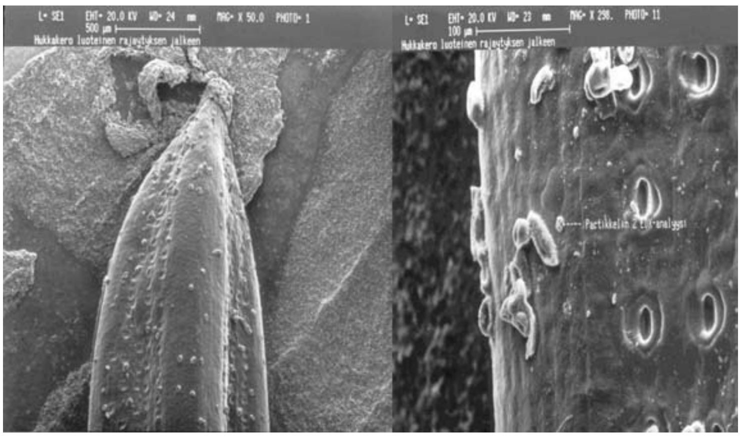
Pike	Ni	Cr	Zn	Cu	Pb	Al	Hg	Fe
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Muscle	< 0.05	< 0.05	3.6	0.10	< 0.01	< 5	0.36	< 5
Muscle	< 0.05	< 0.05	3.2	0.10	< 0.01	< 5	0.42	< 5
Muscle	< 0.05	< 0.05	4	0.14	< 0.01	< 5	0.51	< 5
Liver	0.08	< 0.05	54	13	0.15	10	0.15	570
Liver	< 0.05	< 0.05	30	4.8	0.02	< 5	0.19	210
Liver	< 0.05	< 0.05	32	4.1	< 0.01	< 5	0.17	84

All the samples fulfil the legal guidelines.

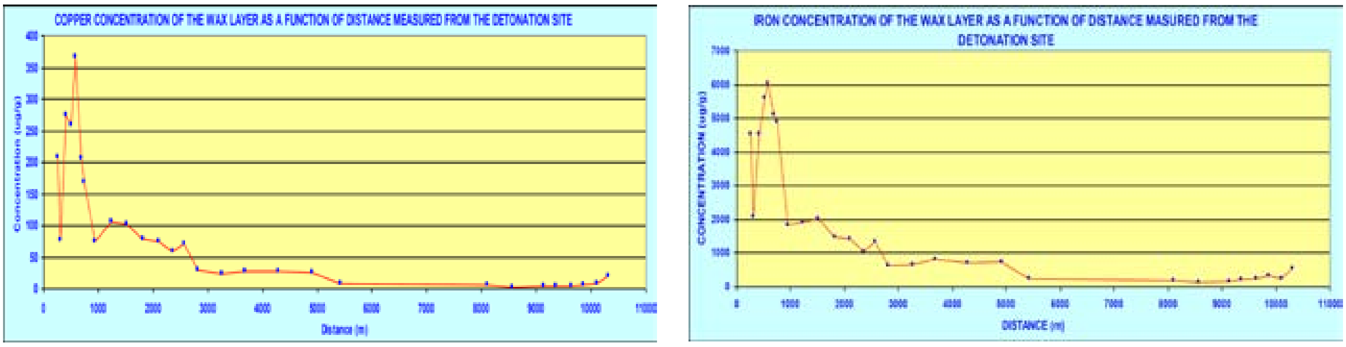
Heavy metal deposit range

The heavy metal deposit range was estimated by using the spruce needles as a bio indicator. There is a very thin layer of wax on the surface of spruce needles and it can work as a trap for the small airborn impurities.

The spruce needles were gathered as a function of distance measured from the detonation site after which the wax layers of the needles were extracted by chloroform and analysed by ICP-MS-instrument.



Picture 6. Surface of a spruce needle by scanning electron microscope (SEM)



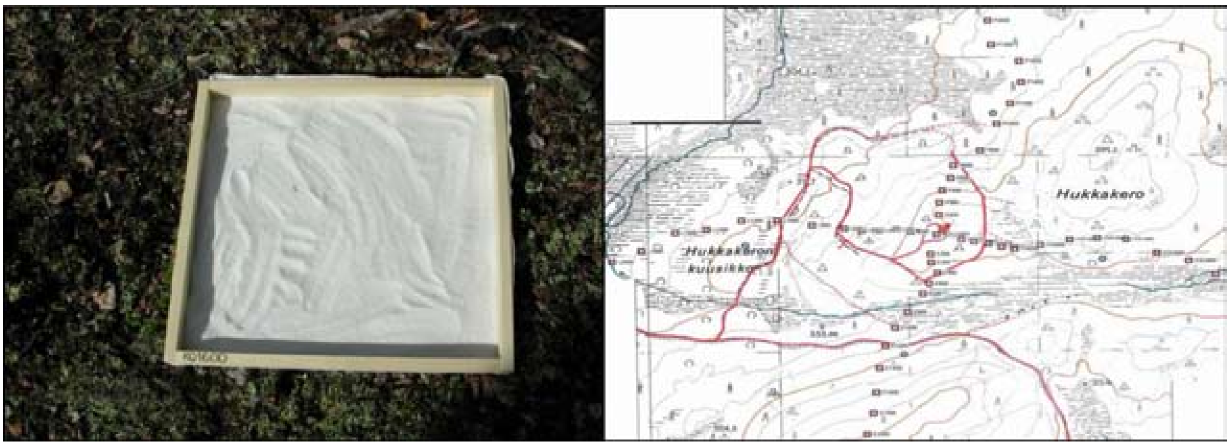
Curves 1-2. (1) Copper and (2) iron concentration of wax as a function distance measured from the detonation site

On the bases of the curves, one can estimate, that the heavy metal deposit range of the open surface mass detonations is around 5,5 km. However, one also has to noticed, that the measuring equipment, ICP-MS, is extremely sensitive measuring unit for the metals and therefore the measured concentrations are - very - very - low.

Amount of heavy metal deposit per unit area

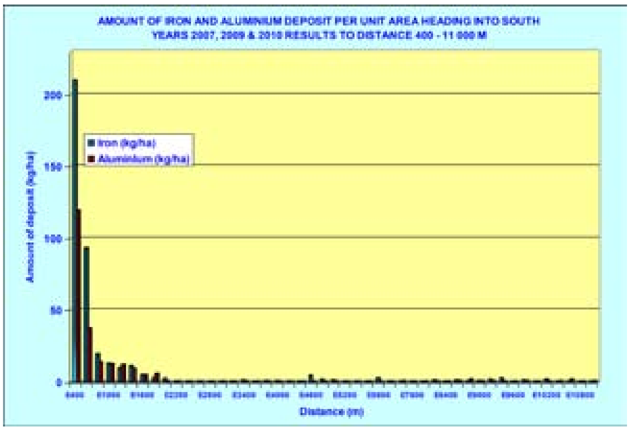
The amount of heavy metal deposit per unit area was estimated by installing samplers as a function of distance measured from detonation site. The sampler consists of wooden frame, 40 cm x 40 cm, with a piece of frost carpet as a bottom plate. Each of the samplers was filled by 800 g of pure standard quartz sand.

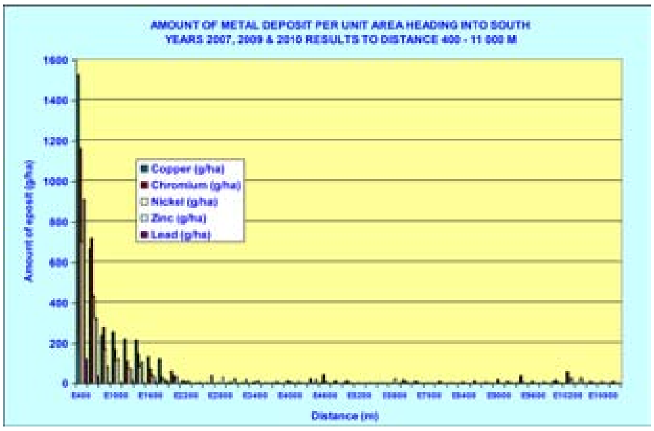
The samplers were installed before the detonation period started and they were gathered after it. Because the exact area of the sampler was known and the metal increments of the frames were analysed, the amount of metal deposit per unit area could be calculated as a function of distance measured from the detonation site.



Picture 7. Sampler filled by 800 g of pure quartz sand and the installation lines of the samplers

The heavy metal deposit range is around 2 km measured from the detonation site. However, traces of the metal deposit can be easily found from longer distances.

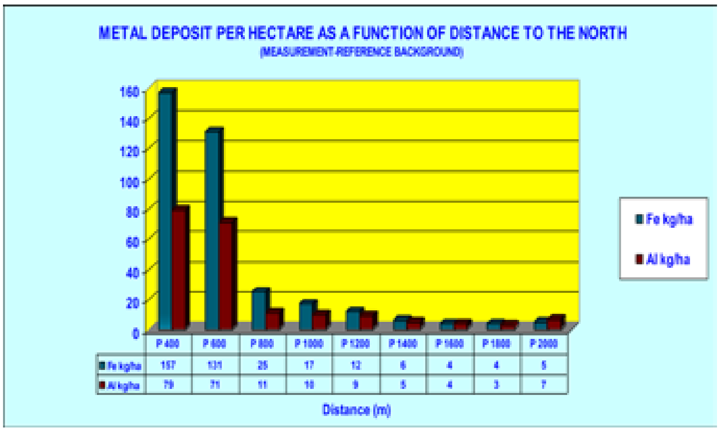


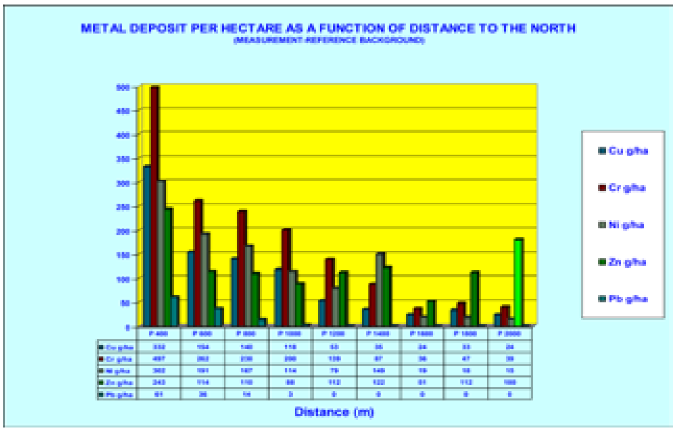


Bar graph 1. Metals as a function distance measured from the detonation site heading to North
- sampling line north 400 m - 2 000 m.

a. Iron and aluminium deposit (kg/hectare)

b. Copper, chromium, nickel, zinc and lead deposit (g/hectare)

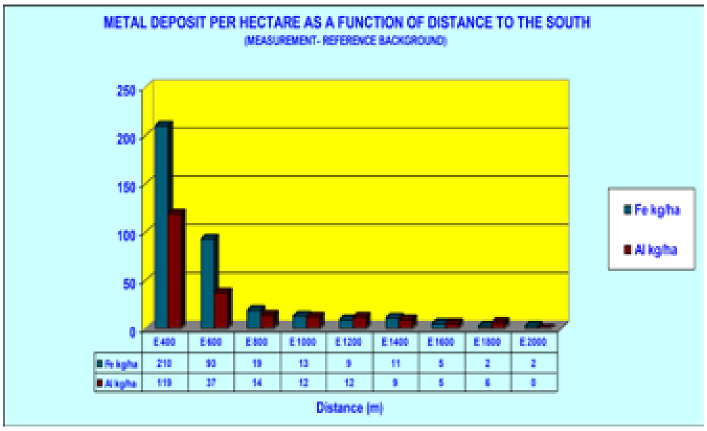


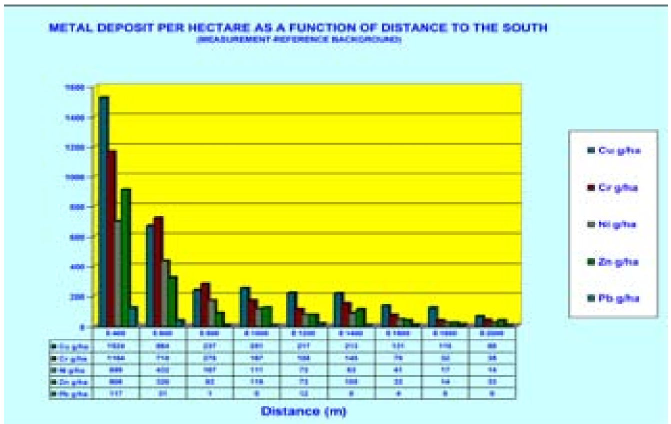


Bar graph 2. Metals as a function distance measured from the detonation site heading to South
- sampling line south 400 m - 2 000 m.

a. Iron and aluminium deposit (kg/hectare)

b. Copper, chromium, nickel, zinc and lead deposit (g/hectare)





Bar graph 3. Metals deposit (kg/hectare) as a function distance measured from the detonation site heading to South
- sampling line south 400 m - 11 000 m

a. Iron and aluminium deposit (kg/hectare)

b. Copper, chromium, nickel, zinc and lead deposit (g/hectare)

Conclusions

The Finnish Defence Forces Technical Research Centre (PVTT) has studied the environmental effects of the mass explosions since they began in 1988. The environmental effects can be divided into three different groups; gaseous emissions, organic explosive residues and their conversion products and the metal emissions.

The environmental effects of the gaseous emissions are quite small to compare to the gaseous releases of Lapland. The effects of organic explosive residues and their conversion products mainly restricted to the detonation area and its immediate vicinity inside the fence. The heavy metal deposit mainly settles down inside the two kilometre range measured from the detonation site.

CANINE SCENT DETECTION IN USE OF LOCATING CONTAMINATED SITES IN FINNISH DEFENCE FORCES

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Oil compounds are used, stored and transported in Finland in many different sites also in Finnish Defence Forces. It can be challenging to locate soil investigations to correct areas after oil spills. If the oil spill or accident is not detected or reported, the oil can spread deeper to ground and even to ground water. Military exercise regions are wide and they are often located on groundwater areas. Equipment using oil compounds are widely used which makes it challenging for environmental monitoring, soil and groundwater protection.

GPS-dog (Gasoline and Pollution Search Dog) was used for assistance of environmental monitoring to locate possible fuel spills in areas where military exercise had taken place and after environmental deviations. Soil samples were taken from the spots the dog had pointed out and analyzed with a field analyzer. According to the field study, a trained dog can reliable point out oil contaminated spots in the ground. With the help of a GPS-dog, soil investigations and sampling were targeted in right areas immediately. Dog's sensitive sense of smell and focused field measurements together make an excellent combination and tool for environmental monitoring, which saves time and money. This combination speeds up the remediation and prevents further damage to the environment. Dogs have been used in a variety of odor discrimination tasks but there is little to be found in written documentation on the use of a dog in environmental monitoring. The aim of this field study is to bring out the advantages and benefits in using GPS-dog in environmental monitoring.

Figure 1. Detection dog at work

Detection dog

Anatomical and physiological features

In order to understand how the dog nose is used in scent detection the knowledge of anatomical features and physiological principles is helpful.

The respiratory system of a dog utilizes the nose, nasal cavity, pharynx, larynx, trachea, bronchi, and smaller passageways to bring air to the alveoli or sites of gaseous exchange within the lungs. Various structures associated with these passageways modify or regulate the flow of air, serve as olfactory receptors, facilitate water and heat exchange, and make phonation possible. (Evans 1993)

The nasal skin is usually heavily pigmented, tough, and moist, supplied with mucous and sweat glands. The dermis of nasal skin is composed of reticular, collagenous, and elastic fibers, together with fibroblasts, blood vessels, and nerves. The blood vessels and nerves are larger in the deeper layers of the dermis than in the more superficial layers. The epidermis of the nasal skin, which averages 630 μm in thickness in adult dogs, is composed of three layers. In heavily pigmented nasal skin there are many pigment granules in the cytoplasm. The epidermis of the nasal skin apparently does not undergo keratinisation, as in other regions of epidermis. (Evans 1993) The epidermis on a dog`s nose has a unique patterning that is much like a human "*fingerprint*" (Aspinall and Cappello 2009). Nose prints, similar to finger prints, can be used to distinguish between individuals (Horning et al., 1926).

The nose in a broad sense refers to the external nose and its associated nasal cartilages as well as to the internal nose, or nasal cavity. The facial portion of respiratory system and the rostral portions of the upper and lower jaws collectively constitute what is called the muzzle. In doligocephalic breeds the muzzle is long and may account for half of the total length of the skull. The external nose consists of a fixed bony case and a movable cartilaginous framework. The cartilaginous portion is movable or distensible by virtue of several skeletal muscles associated with the muzzle. The apical portion of the nose is flattened and devoid of hair. It is called the nasal plane and includes the nostrils. The mobile part of the external nose has a framework composed entirely of the nasal cartilages: the unpaired septal cartilage, the paired dorsal and ventral lateral nasal cartilages, and the paired accessory cartilages. Related to the ventral part of the septal cartilage is the vomeronasal cartilage. When sniffing for olfactory purposes the mobile part of the nose is moved and the shape of the nostrils is altered. This is accomplished by the action of intrinsic muscles and of the nasal part of the levator labii maxillaries and of the levator nasolabialis muscles, which are inserted on these cartilages, (Evans 1993) leading the air to the nasal cavity. After the inhaled air leaves the nasal vestibule it traverses the longitudinal nasal meatuses to reach the nasal part of the pharynx. Each half of the nasal cavity begins at the nostril with a nasal vestibule and ends with the nasopharyngeal meatus and choana and has a respiratory and on olfactory region. The nasal fossa is divided into four principal air channels and several smaller ones. The nostril, the opening into the nasal vestibule, is a curved opening that is much wider dorsomedially than it is ventrolaterally. The nasal vestibule is not an empty antechamber, but rather it is largely obliterated by the large bulbous end of the alar fold that extends to it. Because the end of the alar fold is fused to the inner surface of the wing of the nostril, it acts to divert the incoming air. Upon entering the vestibule through a nostril, air is diverted medially and ventrally into the largest meatus of the nose.

Air entering the nostril is diverted dorsally, medially, and ventrally around the obstructing alar fold, with a resultant increase in velocity and evaporative effect. Perhaps the alar fold or ridges in the vestibule act as a swell body to produce cyclic alternating changes in the air passageway in order to protect the nasal mucosa from constant desiccation. (Evans 1993)

The right and the left nasal chambers are filled with fine scrolls of bone called turbinates or conchae. The chambers and the turbinates are covered by a ciliated mucous epithelium, which is well supplied with blood capillaries. The turbinates arising from the ventral part of the nasal cavity end rostrally in a small bulbous swelling visible through the nostril, the alar fold. The function of the turbinates and their ciliated mucous epithelium covering is to warm and moisten the incoming air as it passes over them. The cilia and mucus help to trap any particles that are present in the inspired air and waft and lead them to the back of the nasal cavity where they pass to the pharynx and are swallowed. The inspired air is therefore warm, damp and free from harmful particles, protecting the lungs from any form of damage (Aspinall and Cappello 2009).

The numerous delicate, bony scrolls are known as ethmoturbinates. Olfactory nerves ramify in the mucosa of the ethmoturbinate scroll they extend into the frontal sinus, and they also reach into the mucosa of the sinus opposite the cirbriform plate. The epithelium on the olfactory part of the sinus has a brown color. The mucosa of the nasal cavity is richly supplied with nerves and blood vessels.

Under normal conditions of inspiration, the respiratory and olfactory currents of air are associated. When a dog deliberately wants to sample the environment, the nostrils are dilated, and with a forced inspiration the dog sniffs the air. This act provides a greater volume of inspired air, which takes a more dorsal course around the ethmoturbinates, where the olfactory receptors are most numerous.

Towards the back of the nasal chambers, the mucous epithelium covering the turbinates has a rich supply of sensory nerve endings that are responsive to smell - this is the olfactory region. The transition from the more peripheral respiratory type of epithelium to the deeper lying olfactory epithelium is not abrupt. These nerve fibres pass through the cribriform plate of the ethmoid bone to reach the olfactory bulbs of the forebrain. The remainder of the mucous membrane is the respiratory region. (Evans 1993)

The olfactory region differs in size by different species being by human 5 cm^2, by cat 4 cm^2 and by an Airedale-Terrier 83,5cm^2 and by German Shepherd 150-170 cm^2 (Lauruschkus, 1942). The amount of cells in olfactory region by human is ca. 20 millions and by dog ca. 200 millions (Nickel, Schummer, Seiferle 1984). Neuhaus (1953, 1954) found that the odor threshold for butyric acid by the dog lies in

1, 3 x 10-18 g and for acetic acid 5, 0 x 10-17 g which means that a dog could detect 1 mg butyric acid in 1 milliard m^3 air.

A sinus is an air-filled cavity within a bone. Within the respiratory system, they are referred to as the paranasal sinuses and lie within the facial bones of the skull. They are lined with ciliated mucous epithelium and communicate with the nasal cavity through narrow openings. It is thought that the function

of the paranasal sinuses is to lighten the weight of the skull, allowing the areas of the skull used for muscle attachment to be larger. The paranasal sinuses also act as areas for heat exchange and as sites for mucus secretion (Aspinall and Cappello 2009).

The paired vomeraonasal organ, long known as Jacobson`s organ, is located in the rostral base of the nasal septum as a tubular pocket of olfactory epithelium partially enclosed by a scroll of cartilage. Each vomeronasal organ opens rostrally into an incisive duct that connects the nasal and oral cavities. Adams and Wiekamp (1984) investigated vomeronasal organ in the dog. They observed both receptor and nonreceptor areas in it. The receptors in the vomeronasal organ of the dog were unusual in that the cilia did not appear to be of the motile type and did not resemble the cilia of the cat or rabbit. The lateral wall of the vomeronasal organ has an extensive venous plexus. The neutral pathways used to transmit stimuli from the vomeronasal mucosa to the brain are distinct from those of normal olfactory mucosa (Scalia and Winans, 1976). The olfactory nature of this organ in mammals was long suspected, it is now known that it plays a role in sexual behaviour and kin recognition via pheromones, some of which have been identified chemically. The incisive duct, formerly called the nasopalatine duct or Stensen`s canal, passes through the palatine fissure and connects the nasal and oral cavities. Three ligaments, composed of one pair and one unpaired, attach the mobile part of the nose to the dorsal portion of the osseus muzzle. The ligaments of the nose are best developed in old dogs of the working breeds. (Evans 1993) The choanae are the openings of the two nasopharyngeal meatuses into the nasal portion of the pharynx. They are oval in shape and oblique in position.

The lateral nasal gland is a serous gland. The functional significance of the lateral nasal gland is being part of the thermoregulatory system in the dog (Schmidt-Nielsen et al. 1970). The nasolacrimal duct carries the serous secretion from the conjunctival sac to the nasal vestibule. A characteristic of a healthy dog is a moist nose, which is maintained in part by the combined secretions of the lacrimal and lateral nasal glands. (Evans 1993)The rhinencephalon, ventromedial part of each cerebral hemisphere, is phylogenetically old and related primarily to olfaction. The rhinencephalon has three components: basal part consisting of the olfactory bulp, the septal part, and limbic part consisting of structures related to the hippocampus. The hippocampal formation is concerned with processing recent memory, and lesions of the conformation or the parahippocampal gyrus result in inpaired learning. The hippocampal formation is categorized as the limbic part of the rhinencephalon. The limbic system is a term applied to collection of brain structures involved with affective behaviour. Emotional drive is necessary to ensure that a dog will exert sufficient energy to preserve itself and its species. Emotion involves autonomic responses and has a great impact on memory and learning. Early in phylogenetic development, when olfaction was the chief sensory modality, much of the rhinencephalon became associated with the essential role of providing emotional drive.

The olfactory nerves, referred to collectively as the first cranial nerve, consist of numerous nonmyelinated axons whose cell bodies are located in the olfactory epithelium covering one half of the ethmoidal labyrinths and the dorsal part of the nasal septum. Axons from these olfactory cells enter the scull through the cribriform plate of ethmoid, deep in the caudal part of the nasal cavity, to reach the olfactory bulps of the brain where they synapse. Included with the olfactory nerves are the terminal nerve and the vomeronasal nerve from the vomeronasal organ, which enter the olfactory bulp. In the submucosa of the olfactory region there are serous glands. Fresh olfactory mucosa is slightly yellowish in appearance owing to pigment in the sustentacular cells. The olfactory nerve cell bodies are large and numeral and all of the folds of mucosa in the region of the cribriform plate are olfactory. The ethmoidal nerve is divided into external and internal nasal nerves. Stimulation of receptors of the internal nasal nerve, as well as the nasal branches of maxillary nerve, lead to sneezing. (Whalen and Kitchel, 1983a) The caudal nasal nerve innervates the nasal mucosa at maxillary recess rostral to the ethmoidal folds and a nasopalatine branch passes to the incisive canal and vomeronasal organ (Evans1993).

Figure 2. (1) Dog head lateral X-rays Picture. (2) Dog head lateral post mortem. (3) Dog's nose and nostrils (Photos by Artillery Brigade and Andersson-Laakso, Kristina, Finnish Food Safety Authority, Evira)

Dog training and use of special search dogs in general

Training modifies the dog´s behaviour to assist in activities and undertake different tasks like for example searching for environmental poison and pollution. Dog training dates at least as far as Roman times, when a Roman farmer trained dogs for herding livestock (Millan 2010). There are numerous amounts of established dog training methods with their positive and negative results. Successful training characteristics are nevertheless being aware of the dog's attributes and its personality and suitability for the task required and accurate timing of reinforcement and good communication skills with the dog. The choice of a future detection dog is the key to successful training. By choosing a dog with limited abilities what so ever; genetics, character, health, lack of concentration, one will end up with a dog with limited abilities.

Konrad Most who began training dogs for police work in Germany and headed the Experimental Institute for Armed Forces Dogs during the Second World War, afterwards ran the German Dog Farm, a center for the training of working dogs, played a leading role in the formation of the German Canine Research Society and Society for Animal Psychology. In his publication; Training Dog: A Manual 1910, he emphasised using instinctive behaviour, such as the prey drive for example to train desired behaviors. Despite several unnecessarily harsh training methods that should not be used any more, the basic principles of Most´s methods are still often used in police and military settings.

Prey drive is the instinctive inclination; involuntary response triggered by certain stimuli, of a carnivore to pursue and capture prey and is often used in training dog new skills. Prey drive consists of the search, the eyestalk, the chase, the grab bite, and the kill bite. The search aspect of the prey drive, for example, is very valuable in detection dogs. In many dogs prey drive is so strong that the chance to satisfy the drive is its own reward. An adequate amount of prey drive is one of the bare necessities for a successful detection dog, because it acts as a motor for the required use. Too high amount of prey drive in a dog on the other hand may lead to difficulties in ability to concentrate on training and working. The prey and praise for work done means play for a dog and is often for example the so called "*tug-of-war*" game with a trainer and a dog. The hunt drive, compulsive search for desired object by scent, can also be used in training for detection dogs. A detection dog should also have a pronounced hunt drive. The absolute necessity for a successful detection dog is an alert mode of expression which can be taught in many ways. It should be so strong that there is no doubt for bystanders that the dog has made a find. In order to achieve this, the dog trainer must communicate his directions in a manner the dog understands.

In 1950´s to 1960`s the specialised search dogs were mostly trained to detect mines. After that dogs were trained to search for arms and explosive material (Arms and Explosive Search Dog), drugs, ore veins, mould, rot, gas, mushrooms, mercury etc. There have been other experiments too, but probably due to lack of money they have not succeeded. In the Finnish Defence Forces the first drug search training course for dogs was started in January 2002. Fire dogs were first trained in the United States in Connecticut in 1986. They were followed by the Europeans in early 1990`s in Holland. In Finland the fire dog training began in 2000 by the Finnish Police Force (Romppainen 2007). The world´s first prospecting dog was trained in Finland. It was used also in other countries for geological research purposes. Geological Survey of Finland had altogether 16 prospecting dogs at its disposal between 1962 and 1994 (Valkama 2011).

In recent studies it has been shown that the dogs are capable of detection of human illnesses from epileptic to cancers (Lippi and Cervellin 2011, Cole 2004, Pickel et. al 2004, Willis et. al 2004,). Yet there is little information on the use of detection dogs in environmental monitoring. Arner et.al. (1986) investigated detection dogs who were taught to locate toluene and 2,4, 6-trichlorphenole and 1,2,3-trichlorpropane. Kurz et al. (1994) investigated dogs searching for gasoline, petrol or paraffin. One finish dog was also trained to detect chlorphenole in saw areas (Häikiö et al. 2001), (Mäkinen and Riikonen 2003).

Environmental monitoring

Environmental monitoring is required by the law in Finland. The Environmental Protection Act (86/2000) requires the operator to identify all the environmental impacts ones operation is causing or might cause. In addition to, operator must be aware of the environmental risks operation may cause and also know the possibilities to control those risks and possibilities about reduction of harmful emissions. The Environmental Protection Act also imposes the other main principles which are precautionary principle (PP) which requires the operator to start immediate actions to prevent the possible pollution and polluter pays principle (PPP). (YSL 2000) Regarding to that principle, operator is responsible of the costs of the pollution prevention and remediation (Ympäristösanasto 1998). The absolute groundwater and soil pollution prohibition is also set in the Environmental Protection Act. (YSL 2000)

The purpose of the prohibition of the pollution and all the other main principles of the Act is to prevent the environmental impacts of the environmentally hazardous substances. Or nonetheless delimit the impacts as minor as possible. Regarding to the law one is not allowed to degrade the quality of the soil by letting any waste, refuse or other substances that may cause danger to people's health or to the environment or causes a substantial reduction in the amenity value or violates public or private interest in some other way. (Ympäristöministeriö 2007).To be able to meet the requirements of the Environmental Protection Act, operator must monitor the environment to be aware of the environmental impacts that operation is causing and to be able to be prepared for the environmental risks and accidents that might occur.

The Contamination assessment and sampling

It is recommended to investigate the extent and nature of the contamination in the areas where operations, that may cause pollution, were or are located. The contamination assessment is also needed when environmentally hazardous substances are detected or suspected or when some adverse effects are discovered. The assessment of contamination and remediation requires information about the operations that have been fulfilled in the area. With the historical data and with on site observation one can assess the extent of the pollution and determine the sampling locations where the soil samples could be taken. The extent and nature of the contamination is investigated through soil analyses. (Ympäristöministeriö 2007)

All the details and factors that have an affect on contamination assessment are shown in a site description. These factors are soil data, bedrock, groundwater and hydrological data and also maps, land use plans and spatial plans. With all this information and with the knowledge of the environmentally hazardous substance properties conceptual model of the contaminated site can be made. The conceptual model images the presence and distribution of contaminants. It also represents the potential target sites which are in danger to expose to contamination. The necessary sampling locations can be identified with the conceptual model, site observation and assessment. (Ympäristöministeriö 2007)

Sampling locations are shown in a research plan which also includes all the important information about taking the soil samples. A Plan includes for example sampling locations, number of sample points and samples, sampling methods, sampling depth, field measurement, samples sent to the laboratory and wanted analysis. The sampling of soil is important because the sample must correctly represent the area about which information is wanted. (FGS 2002)

To find out the exact pollution level and exact quantity of contaminants in the soil, the samples must be carefully analyzed. The most reliable and exact analyze and the content of the hazardous substance is achieved with laboratory analysis. There is also possibility to make on-site analysis with different kind of field measuring device. There is for example hydrocarbon analyzer for detecting fuel and oil contamination in soil or photoionization detector for analyzing VOC-compounds. (FGS 2002)

The Governments Decree (214/2007) on soil contamination and assessment of remediation defines threshold values and guideline values for different substances. Decree clarifies that contamination and remediation assessment has to be done, if one or more substance concentrations exceed the threshold value. Guideline values must be used for assistance in assessing the contamination and remediation. Threshold value for hydrocarbon fractions (<C10 - C40) in Finland is 300 mg/kg. (Ympäristöministeriö 2007).

Environmental monitoring in Finnish Defence Forces

The Environmental Protection Act obligates also Finnish Defence Forces. Operator, in this case the Defence Forces, is obliged to be aware of the environmental impacts the training is causing or may cause. Operator must be ready to prevent or delimit the harmful impacts. To meet requires the Defence Forces carries out environmental monitoring in the areas that it is using. Military training areas can be very large and extensive and that's why the environmental monitoring can be challenging. Historical data and the current usage of the area with all the used substances are well known. So the environmental monitoring and soil sampling are located to the exact areas where the critical and most of the operations are held on. Environmental monitoring in Defence Forces includes environmental risk assessment, visual site observation and evaluation as well as soil sampling based on these assessments. Soil samples are analyzed with field measure or are sent to laboratory for more detailed analyze. The most challenging part in the point of environmental monitoring is the usage of the vehicles and other equipment that utilizes fuels or oils for example engine-generator and field guns. The small oil or fuel spills from vehicles or from refuelling these items are difficult to allocate.

Material and methods

Material

GPS-dog (Gasoline and Pollution Search Dog), a German Shepherd owned by the Finnish Defence Forces called "*Pastori*" (Leca Haus Danzka), was trained to detect oil derivates in year 2004.

The dog was trained with a cocktail made from diesel fuel, gasoline, fuel oil, motor oil and paraffin/kerosene. The liquids were mixed in a same toy, each one absorbed in cotton. The toy was a piece of a water pipe with tiny holes all over it and its endings sealed. The pipe was first only to be used for example in a romp with the handler. In this way the dog got used to the odors that emit from the pipe holes automatically into his nose and mouth and that way they became familiar and pleasant for him because of the positive action they were connected with. The dog developed a so called "*odor memory*". The dog was never in a direct contact with the liquid fuels. After some time the pipe and then only the mixture of odors or one odor at a time without a pipe was hidden in near surroundings and the dog went to search for it and got rewarded with praise. The praise meant play for the dog and it associated it with its toy, the pipe. Next step was to make sure that the dog did not react for any other odors despite the target one. Odor discrimination was arranged in a way other odors were hidden in the same room or area, where the dog was searching for the target odor to disturb it. After testing the dog's ability to find the target odor, the mode of expression, in this case lying down at the target point or beside it, was trained for the dog. Little by little the time before he got his reward after lying down beside the found target, was made longer. He learned that first after this mode of expression he gets his reward, the pipe.

PetroFlag hydrocarbon analysis system is a field analytical tool. PetroFLAG method uses unique extraction solvents, analytical reagents and analyzer that displays the concentrations of harmful substances directly in parts per million. The analyzer measures the turbidity of the reaction product which comes from a reaction between the test substance and the reagent substance. Analyzer must be calibrated with calibration standard because the turbidity of the sample is compared to the calibration standard and then calculated in to the right concentration. Field analyzer is suitable for detecting any type of hydrocarbon contamination. The microprocessor in the analyzer uses the calibration data to convert the optical reading into a preliminary concentration. After that the selected response factor is used to calculate the correct concentration for the wanted analyse. For each hydrocarbon type there is a response factor because different hydrocarbons don't produce the same amount of turbidity. Field analyzer can also be used when analyzing high concentration samples. Normally used 10 gram soil samples may cause an over-range condition on the analyzer, so smaller 5 g or 1 g soil samples can be used to get more accurate results. When using these smaller samples, the result has to be multiplied to obtain the concentration in the sample. With this method it is possible to measure oils containing up to 50 000 ppm. (PetroFLAG 1997).

Methods

Military training area: Military training groups marked and reported the off-road refuelling and emplacement sites with GPS-coordinates and maps during the military exercise. After the exercise the pointed locations were inspected using a trained dog. GPS-dog located the points where fuel was spilled. Soil samples were taken from these spots and analyzed with field analyzer PetroFLAG to find out the concentration of the contaminated soil. Soil samples were preserved in refrigerator. All the samples were analyzed with response factor 5 (diesel fuel). This response factor was chosen because the fuel most often used is diesel. Some of the samples were sent to the laboratory for more exact results.

Environmental deviations: Deviations can be caused by military forces or civilians using machines or vehicles with fuels or oils. The locations of such deviations before and after remediation were also reported and investigated likewise with the GPS-dog and field analyzer.

Volatile Organic Compounds (VOC): Fuel oil was mixed with 44mg sterilized clean sand (97,001g). The concentration was 454 mg/kg. Ventilation factor 0,5 1/h at 20,3-21,6 °C, humidity 50%+ - 3%. The sample was examined with gas chromatograph to analyze the total Volatile Organic Compounds (TVOC). The used equipment were Tenax GR (Standard ISO 16000-6) and GC-MS. The concentration of the compounds was followed in a three weeks period and the emissions were analysed. (Hyttinen 2013)

Results

Table 1. Laboratory results Laboratory results in SGS Inspection services Oy in Finland

sample / date	depth (m)	soil	odor perception	°C	humidity	wind	rainfall	date of analysis	hydrocarbons C10-C21, mg/kg	hydrocarbons C22-C40, mg/kg
LA 1 / 27.8.2008	0,5	sand	positive	+13.4	75	1 m/s	dry weather	29.8.-1.9.2008	**1100**	**20**
LA 2 / 27.8.2008	0,1	sand	positive	+13.4	75	1 m/s	dry weather	29.8.-1.9.2008	**<20**	**50**
LA 3 / 27.8.2008	0,5	sand	positive	+13.4	75	1 m/s	dry weather	29.8.-1.9.2008	**<20**	**<20**
1. / 2.9.2008	0,1	sand	–	+7,5	82	2 m/s	light rain	24.9.2008	**<20**	**50**
2. / 2.9.2008	0,1	sand	–	+7,5	82	2 m/s	light rain	24.9.2008	**90**	**3450**
3. / 2.9.2008	0,1	sand	–	+7,5	82	2 m/s	light rain	24.9.2008	**20**	**140**

Table 2. Emissions of fuel oil

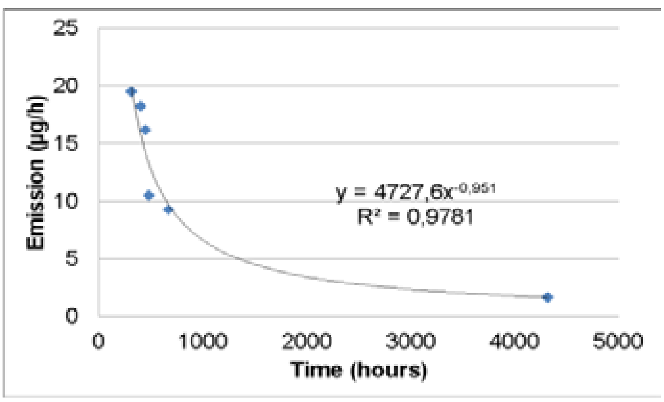

Table 3. On-site analysis results using field analyzer PetroFLAG

sample / date taken	soil	odor perception	°C	humidity	wind	rainfall	date of analysis	sample g	result ppm
1 / 3.12.2010	sand	negative	-8	89	1 m/s	light snow	30.12.2010	10	**1295**
2 / 3.12.2010	sand	negative	-8	89	1 m/s	light snow	30.12.2010	10	**1536**
3 / 29.12.2010	sand	negative	-10	84	2 m/s	light snow	30.12.2010	10	**483**
4 / 29.12.2010	sand	negative	-10	84	2 m/s	light snow	30.12.2010	10	**193**
1 / 25.3.2011	sand	positive	-5	53	6-8 m/s	snow crystals	28.3.2011	10	**106**
2 / 25.3.2011	sand	positive	-5	53	6-8 m/s	snow crystals	28.3.2011	10	**66**
3 / 25.3.2011	sand	positive	-5	53	6-8 m/s	snow crystals	28.3.2011	10	**35**
1 / 29.4.2011	sand	negative	+11	36	2 m/s	dry weather	3.5.2011	1	**13 590**
III / 6.5.2011	sand	positive	+9	38	3 m/s	dry weather	9.5.2011	5	**768**
I 6.5.2011	sand	positive	+9	38	3 m/s	dry weather	9.5.2011	10	**723**
II 6.5.2011	sand	positive	+9	38	3 m/s	dry weather	9.5.2011	10	**354**
IV 6.5.2011	sand	negative	+9	38	3 m/s	dry weather	9.5.2011	10	**1018**
1 / 27.5.2011	sand	negative	+10	45	5-6 m/s	rain	9.6.2011	10	**218**
2 / 27.5.2011	sand	negative	+10	45	5-6 m/s	rain	9.6.2011	10	**1561**
3 / 27.5.2011	sand	negative	+10	45	5-6 m/s	rain	9.6.2011	10	**754**
4 / 27.5.2011	sand	negative	+10	45	5-6 m/s	rain	10.6.2011	10	**2399**
5 / 27.5.2011	sand	positive	+10	45	5-6 m/s	rain	10.6.2011	10	**272**
6 / 27.5.2011	sand	positive	+10	45	5-6 m/s	rain	10.6.2011	10	**822**
1 / 3.6.2011	sand	negative	+17	46	6-7 m/s	dry weather	10.6.2011	1	**10 430**
2 / 3.6.2011	sand	negative	+17	46	6-7 m/s	dry weather	10.6.2011	10	**598**
3 / 3.6.2011	sand	negative	+17	46	6-7 m/s	dry weather	10.6.2011	10	**405**
4 / 3.6.2011	sand	positive	+17	46	6-7 m/s	dry weather	10.6.2011	1	**10 720**
5 / 3.6.2011	sand	positive	+17	46	6-7 m/s	dry weather	10.6.2011	1	**850**
6 / 3.6.2011	sand	negative	+17	46	6-7 m/s	dry weather	10.6.2011	10	**447**
7 / 3.6.2011	sand	negative	+17	46	6-7 m/s	dry weather	10.6.2011	10	**479**
1 / 30.6.2011	sand	negative	+25	52	2-3 m/s	dry weather	30.6.2011	10	**189**
2 / 30.6.2011	sand	negative	+25	52	2-3 m/s	dry weather	30.6.2011	10	**168**
3 / 30.6.2011 5g	sand	negative	+25	52	2-3 m/s	dry weather	30.6.2011	5	**2708**
3 / 30.62011 1g	sand	negative	+25	52	2-3 m/s	dry weather	30.6.2011	1	**2880**
A / 21.10.2011	sand	negative	+5,8	78	3 m/s	dry weather	10.11.2011	10	**1025**
B / 21.10.2011	sand	negative	+5,8	78	3 m/s	dry weather	10.11.2011	10	**1599**
C / 21.10.2011	sand	negative	+5,8	78	3 m/s	dry weather	10.11.2011	10	**824**
D / 21.10.2011	sand	negative	+5,8	78	3 m/s	dry weather	10.11.2011	10	**843**

Discussion and conclusions

The field study proved that the use of GPS-dog and field analyzer was an effective and a quick method to use in environmental monitoring. The dog could point out even smallest oil concentrations with its great sense of smell. The dog could locate fresh and older oil spills from top and even deeper layers of ground every time of the year (-10 °C - +25 °C). GPS-dog works despite the season practically in every temperature. This is a huge advantage in comparison with most field analyzers which need calibration and service once in a while.

According to on site analysis the concentration of oil in soil samples the dog had pointed out varied from 35 mg/kg to 13 590 mg/kg. In laboratory analysis the results varied from under 20 mg/kg up to 3450 mg/kg. The dog's odor discrimination ability is almost far too good for the environmental monitoring in Finland because the contamination and remediation assessment has to be done, not until if one or more substance concentrations exceed the threshold value 300ppm.

According to the analysis where fuel oil emissions were measured with gas chromatography, it was noticed that the sampled air contained hundreds of aliphatic and aromatic hydrocarbons. The concentrations of the lighter hydrocarbons were high at the beginning, but sank very quickly (Trimethylbenzene/decane, Undecane, 2-Propyl-1-Methylbenzene, Docane, 2,6-Dimethyloct, Tetramethylbenzene) . The profile of volatile organic compounds changed later during the measurements. The emissions were then heavier hydrocarbons (Tetradecane, Pentadecane, Heptadecane, 2,6,10,14-tetramethyl, Hexadecane,2,6,10,14-tetramethylTridecane and Hexadecane). The amount of Total Volatile Organic Compounds (TVOC) after four hours was 23629 µg / m3, after six hours 15501 µg / m3 and after 484 hours (3 weeks) 175 µg / m3. It is interesting that the amount of total TVOC of fuel oil sank rapidly in two hours being only 65,6% of the compared 4 hour result. After 3 weeks waiting it was only 0,74% of the compared concentration at the beginning of the experiment. Also the emission components varied from lighter to heavier ones.

Presumably it is the amount of emissions that make the dog react to the find when hunting after the target odor. Theoretically seen all substances evaporate molecules when the temperature is above the absolute zero point. Furton & Myers 2001; Snyder Sachs 1996 suggest that the dogs detect the target odor because of the greater vapour pressure and volatility. According to Furton & Myers 2001 the drug search dogs detect the cocaine after its breakdown product methylbenzoate and not after cocaine.

In our field study the detected locations for oil spills were older than a couple of hours, rather days to weeks. Still it did not make it difficult for our GPS-dog to detect them. This would indicate that it is not the most volatile compounds the dog has made an odor memory from. On the other hand dog's odor thresholds for most substances are very low and ability to detect even the smallest amount of odor what so ever great. The question is also is there one component in all of the different oil products which belongs to the heavier hydrocarbons that the dog points out? In our results the biggest ppm concentration was measured with hydraulic oil product which was not taught the dog in the beginning. This also speaks for the assumption that there must be something in common for all the fossil oil derivates. We don't know yet what the key is for a dog to build up an odor memory and this among many other questions requires further investigations.

This piece of information could be useful and might be valuable to take into consideration in making of future risk assessment surveys. The emission results ought to be compared with the concentration of contaminated soil and the spreading of the contaminants in the ground.

According to this field study, a trained dog can reliably point out oil contaminated spots in the ground. In this way, soil investigations and sampling were targeted in right areas immediately. With the dog's sensitive sense of smell and with focusing field measurements, the soil remediation can take place as soon as possible. When actions to prevent further damage are more rapid, the costs and damage to environment are minor. (Huppunen et al.2012). The combination of a GPS-dog and a field analyzer in environmental monitoring reduces the amount of soil samples sent to laboratory which means lower costs. The results are also in use in hours compared to waiting for lab analyses.

The olfactory sense of a dog gives a numerous variations in which it can be used for. It is only dependable on a trainer's imagination what the applications will be. In the future the use of a GPS-dog could extend to areas as for example spatial planning, real estates under renovation and leakages in heating oil systems.

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BIOREMEDIATION OF TNT CONTAMINATED SOIL WITH FUNGI

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Trinitrotoluene (TNT) is probably one of the most commonly used explosives for the military as well as private companies e.g. in the mining industry. While exploding the reaction of TNT is exothermic though requiring high activation energy. Due to this and that it can additionally safely be poured e.g. into shells it is widely used. But the requirement of high activation energy has also its drawbacks. Improper activation leads to improper explosions or explosions do not take place. In these cases TNT may be spread into the environment in noteworthy amounts. Actually the spreading already begins with TNT production. TNT, which is poorly water soluble (0.13 g/l at 20°C), finds its way to rinsing water, which is also called red water. Improper explosions or storage may produce another load to the environment. More specifically, TNT can originate from witness material contamination, post blast residues, open burning or open detonation, TNT packing material or simply from cracked shells and UXO (unexploded ordnance). The detonation efficiency of the used product determines the amount of TNT load to the environment.

TNT, and also other explosives, spread their energetic residues mainly to the surface of the soil where it tends to concentrate over time (e.g. in shooting areas). Here rain dissolves some of the material, which may be transported to the groundwater or into surrounding aquifers. Unfortunately TNT is highly toxic already in small concentrations. It is listed as a possible human carcinogen (HSDB 2013). Toxic effects are usually the result of inhalation, accidental ingestion (e.g. wildlife) as well as skin absorption, which again cause rashes and skin hemorrhages. Blood disorders are also common and following TNT intoxication symptoms are usually anemia or liver damage. The high toxicity to mammals is caused by mammalian own enzyme system, which converts TNT into more harmful nitroso and hydroxyl amino compounds.

Biological degradation of TNT in the environment is possible but difficult. The combination of a stable benzene ring with the electron withdrawing character of the nitro groups makes it very resistant to degradation. Further, microbes cannot use this compound as a sole carbon source, it is highly toxic to microbes, and finally its predominant crystalline form is less bioavailable. Nevertheless, there are a number of degradation pathways described for bacteria which are able to convert TNT under aerobic and even anaerobic conditions (Nishino et al. 2000, Ahmad and Hughes 2000). However, one bacterial species is mostly responsible for only one or two reaction steps and none of the species alone can degrade TNT completely. Fungi interestingly first reduce the nitro groups of TNT. The reduction enables the attack to the aromatic structure. Especially wood-rotting and litter-decomposing basidiomycetes (white-rot fungi) produce highly reactive oxidoreductases such as manganese peroxidase (MnP) and laccase. These extracellular enzymes break the aromatic structure of hydroxylamino-DNT and amino-DNT, metabolites of the prior reduction of TNT and DNT, under the formation of radicals. These subsequently are able to "*crack*" the aromatic structure and at best completely mineralize the compound (Fritsche et al. 2000, Scheibner et al. 1997).

Fungal treatment methods could provide new sustainable ways as such to treat soil contaminated by TNT. Both, white-rot and litter-decomposing fungi, are known to be able to degrade recalcitrant aromatic compounds, also TNT, with their non-specific oxidizing enzymes (Tuomela and Hatakka 2011). The idea to use litter-decomposing fungi derives from the fact that they are accustomed to soil and soil microflora and are easily able to penetrate soil. As far as the toxicity allows these fungi grow close to TNT residues and degrade them with their enzymatic system.

In this work we studied the capability of selected fungi to grow in TNT contaminated soil, to produce lignin modifying enzymes and to degrade TNT in soil. A scale up from laboratory to field trial was conducted.

Material and Methods

We used soil originating from a military storage area provided by the Construction Establishment of Finnish Defence Administration and six fungal strains obtained from the Fungal Biotechnology Culture Collection (FBCC) of the Department of Food and Environmental Sciences, University of Helsinki, Finland, namely *Gymnopilus luteofolius* FBCC466 (X9), *Kuehneromyces mutabilis* FBCC508 (K22), *Mycena galericulata* FBCC598 (K175), *Phanerochaete velutina* FBCC941 (T244i), *Physisporinus rivulosus* FBCC 939 (T241i) and *Stropharia rugosoannulata* FBCC475 (11372). In the first screening, fungi were inoculated to Petri dishes containing 50 g non-sterile TNT soil (dry mass 90.7 % and organic matter content 5.1 %) or a soil compost mixture. The substrate and carrier material for the fungus was 2.5 g pieces of Scots pine bark (*Pinus sylvestris*). As the original TNT concentration of sieved soil (1 mm mesh) was as high as 12 g kg^{-1} and non-sieved soil 30 g kg^{-1}, it was too toxic for fungi. More specifically, no fungal growth was observed in soil, although some fungi maintained good growth on bark. Consequently, soil had to be diluted with garden waste compost (dry mass 55.6 % and organic matter content 16 %). Three dilution ratios was tested: 1:1, 1:20 and 1:40 (soil:compost). Four fungal species, namely *G. luteofolius*, *K. mutabilis*, *P. velutina* and *S. rugosoannulata*, were able to grow well in the 1:20 diluted soil, in which the TNT concentration was approximately 1 000 mg kg^{-1}. The soil with ratio 1:1 was still too toxic, and the ratio 1:40 was discarded because lower dilution already worked well for the most tolerant fungi.

The selected fungi were incubated in non-sterile TNT contaminated soil in 500 ml glass bottles (Schott Duran laboratory glassware, Mainz, Germany) in the next experiment where degradation of TNT was studied. First, 100 g of vermiculite was placed at the bottom of the bottle followed by a plastic net to minimize mixing of vermiculite with soil, and perforated inoculum tube in the middle of the bottle containing 10 g of fungal inoculum on pine bark. Finally the tube was surrounded with 350 g of non-sterile contaminated soil diluted by garden waste compost (1:20). The bottles were properly sealed and continuously aerated with moist air. The incubation period for *K. mutabilis* and *P. velutina* were 77 days, and for *S. rugosoannulata* and *G. luteofolius* 70 days. All the incubations were performed at room temperature.

Enzyme activities were measured from soil bottles five times during incubation: 10 g of soil was extracted with 20 ml of 25 mmol l^{-1} sodium phosphate buffer (pH 7.0) by shaking at 120 rpm on a rotary shaker (Innova 5000 laboratory shaker, New Brunswick scientific, Edison, NJ, USA). After sedimentation, the extracts were centrifuged 13 000 rpm at 4°C for 15 minutes and the enzyme activity was determined. Manganese peroxidase (MnP) activity was measured by monitoring the formation of Mn^{2+}-malonate complexes at 270 nm and laccase activity by the oxidation of ABTS at 420 nm. The measured activities were expressed in units (U), defined as 1 μmol of substrate reacted at 25°C in 1 min. UV spectrophotometer (UV-170 Pharmaspec, Shimadzu, Tokyo, Japan) was used to detect the absorbance of the liquid.

A pilot scale experiment with 285 kg of diluted TNT contaminated soil (1:20) was performed. 10 kg of fungal inoculum growing on pine bark was added in six plastic mesh tubes (diameter of approximately 15 cm; Fig. 1). Soil was placed in a box supplied with moisturized aeration from bottom. Fungal tubes were placed in three levels inside the soil. Carbon dioxide production was measured during incubation and TNT concentration of soil was analysed before incubation, once during incubation (49 d) and at the end of incubation (107 d).

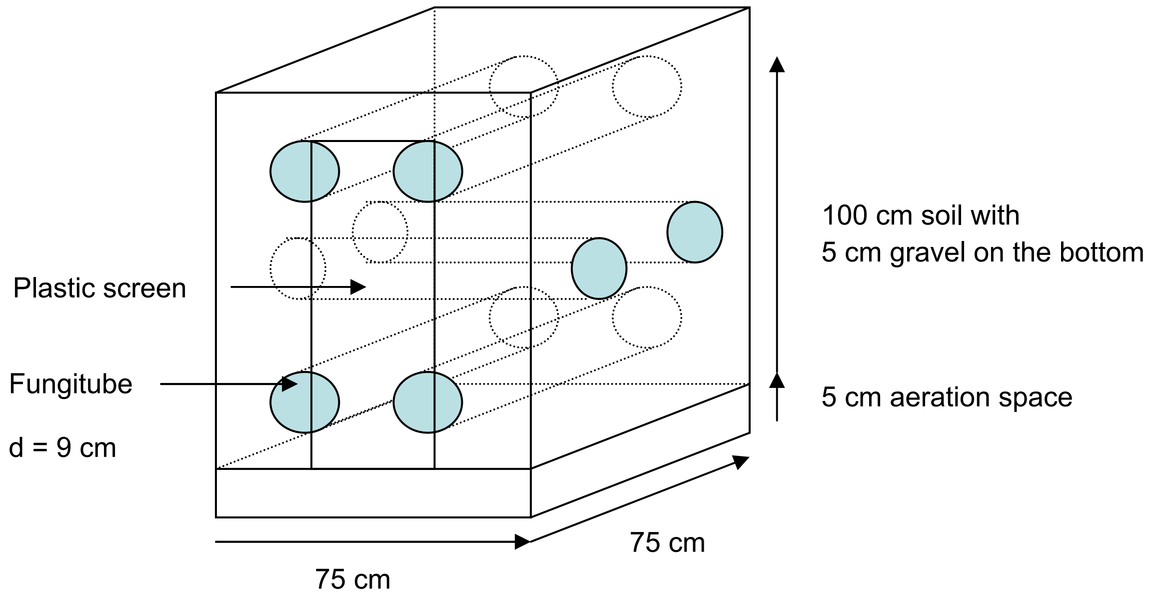

Figure 1. Schematic drawing of the pilot scale experiment

At the end of the experiments, each soil sample (3 g) was extracted with 15 ml of acetonitrile. The supernatant was filtered and TNT and its degradation products were analyzed with HPLC (Agilent 1290 infinity, Agilent Technologies, Santa Clara, USA) isocratically with acetonitrile-water 20:80 (v/v) as a mobile phase at a flow rate of 1.6 ml min^{-1} with UV-detection at 254 nm. Sample volume was 1 µl. A Agilent Zorbax C-18 HPLC column 2.1 mm x 5 cm (1.8 µm particles) was used.

Finally a field trial was set up with 4 t of TNT contaminated soil and fungal tubes containing in total 80 kg of pregrown pine bark (Figure 2). Due to the size only one pile with fungi was set up and one other without fungal addition served as control. For this setup no compost was used to dilute the toxicity.

Figure 2. Application of pregrown fungal tubes on TNT contaminated soil

Results

In the screening test, *M. galericulata* grew and survived well in soil, but growth was too slow even in uncontaminated control soil and consequently it was not selected for further experiments. Interestingly, *K. mutabilis*, which could not grow and survive at all in non-contaminated soil and grew poorly in TNT-soil with dilution 1:40, grew and survived well in more toxic TNT contaminated soil with dilution 1:20.

All of the four selected fungi (*G. luteofolius*, *K. mutabilis*, *P. velutina* and *S. rugosoannulata*) produced high amounts of MnP enzyme (max. activities were between 800 and 1 300 mU g^{-1} dry soil) in TNT contaminated soil. In general MnP activity was higher in contaminated soil than in control soil. Laccase was not detected either in TNT soil or control soil.

The most efficient fungus, *P. velutina*, degraded 80 % of TNT in 70 days in the laboratory scale experiment. This fungus was selected for a further pilot scale experiment. Degradation of TNT correlated with the fungal growth in laboratory bottles.

In pilot experiment *P. velutina* grew well in soil (Fig. 3), which was also confirmed by microscopic examination, and degraded 70 % of TNT in 49 days. No further degradation occurred the following 58 days of incubation. Harmful fungal metabolites from TNT, namely 4-amino-2,6-diaminotoluene and 2-amino-4,6-diaminotoluene, accounted for less than 0.5 % of the original TNT concentration at the end of the incubation. Carbon dioxide production remained high until the end of incubation.

The field trial was not successful due to the high amount of TNT and its subsequent toxicity. However, valuable information was gathered for large scale handling of TNT contaminated soil as well as the application of fungal tubes to larger soil volumes.

Figure 3. Viable mycelium was found throughout the soil in the pilot scale experiment after 107 days

Discussion

Fungal remediation of TNT contaminated soils is a promising biological treatment. The high degradation yield in the small scale experiments underlines the potential. A possible drawback could be extremely high TNT concentrations, which requires dilution prior to the remediation process. Here organic amendments are favoured, which not only dilute toxicity but also possibly enhance growth into soil. The tested garden waste compost proved to be ideal for the purpose. It is easy to obtain, inexpensive and safe to be left in the cleaned soil.

Large scale clean up in field scale is possible. Field trials with PAH contaminated soil in the size of 12 t have been successful, and a Finnish company has successfully cleaned as big volumes as 150 t (unpublished results). In case of TNT contaminations the size of the dilution will be a challenge. But if the soil contamination would be reasonable the fungal clean-up technique could be even applied in-situ either by drilling holes for deeper contamination or by applying mats for surface contamination.

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HEAVY WEAPONS SHOOTING RANGE NOISE IN FINLAND

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Noise has many negative effects on human health, well-being and comfort. Some 900 000 – 1 000 000 Finns live in areas where daytime noise levels (L_{Aeq}) exceed 55 dB. The number of residents, around 6500 people, exposed to military noise is rather small compared to road transport noise, for example.

Noise from heavy weapons may have direct physiological effects like causing damage to inner ear and hearing impairment. On the other hand, based on adverse characteristics of noise experienced by those exposed to it, effects may appear stress, which in the long term may increase the risk of cardiac and respiratory disease. Noise also impairs the quality and comfort of the living environment. The impacts are not dependent on the physical or physiological attributes of the sound alone, but also its source, the time of its occurrence, how it is experienced (activity of the exposed), its meaning content and other features relating to the individual or the community. Individual psycho-physiological factors influence what kind of sounds a person finds annoying.

National RAME working group (considering environmental hazards and special regulation) has prepared a proposal how the environmental protection will be ensured in future by regulating extensively of the environmental protection requirements and the related actions of heavy weapon shooting ranges.

The effects of environmental noise

Noise is sound that human beings consider unpleasant or that in some other way is harmful to the human health or well-being. Noise is also environmental pollutant, which influence to the quality and comfort of the living environment, land using, building and the value of the real estate. Public health experts agree that environmental risks constitute 24% of the burden of disease and harmful impacts of noise to public health are the second largest after particles in air.

Economic impacts of noise may be as large as 0,2 – 2% from GDP (gross domestic product) and in the area of EC (European Community) that means approximately 13 - 38 billion euros [1,2].

Noise policy and regulatory basis for noise requirements

Definitions of environmental noise policy in Finland are based on Government Resolution on Noise Abatement (2006/05/31), Commission Green Paper on Future Noise Policy 1996 (COM(96) 540) and Assessment and Management of Environmental Noise (2002/49/EC). Noise abatement must be taken into consideration across the board in all planning and implementation of activities that generate noise. Common approach for the EU policy on noise is supported in order to avoid, prevent or reduce the harmful effects due to exposure to environmental noise, particularly for limiting emissions from noise sources.

In addition to the principal piece of legislation on the abatement of environmental noise, Environmental Protection Act and Land Use and Building Act, legal provisions can be found of several other Finnish acts concerning health, neighbour relations, transport and industry.

General principles of Environmental Protection Act are preventing and minimizing harmful impacts, caution and care, BAT, BEP and the 'polluter pays' principle. Operators must have sufficient knowledge of their operations' and local authorities are required to see the necessary monitoring of the state of the local environment. Environmental permission is needed for any activity that poses a threat of environmental pollution. Permission is required from shooting ranges and also in certain cases from heavy weapons shooting ranges.

Land Use and Building Act (132/1999) ensures that land use and construction create preconditions for a favorable living environment and they promote ecologically, ecologically, economically, socially and culturally sustainable development. The Act calls for an adequate assessment of the environmental impact, including noise, when plans are being drawn up.

Legal provisions on noise abatement exist in several other Finnish acts like Health Protection Act (763/1994), Neighbour Relations Act (20/1920), the Aviation Act (1242/2005), the Road Transport Act (267/1981), ect.

Mitigation of heavy weapons ranges noise

Mitigation acts are allocated in generally to noise emission (noise source), noise transmission (propagation path of noise) as well as noise disturbance (shielding of disturbed target) based on reduction of noise level according to Figure 1. Sound can be defined as noise, however, only partly on the basis of its level; on the one hand on the basis of its physical or physiological effects (Frequency, time and energy content) and on the other hand, on the basis of the adverse characteristics experienced by those exposed to it. Thus quality of the sound, its source, the time of its occurrence, how it its experiences (activity of the listener), its meaning content and other features relating to the individual or the community are important factors related to noise experience.

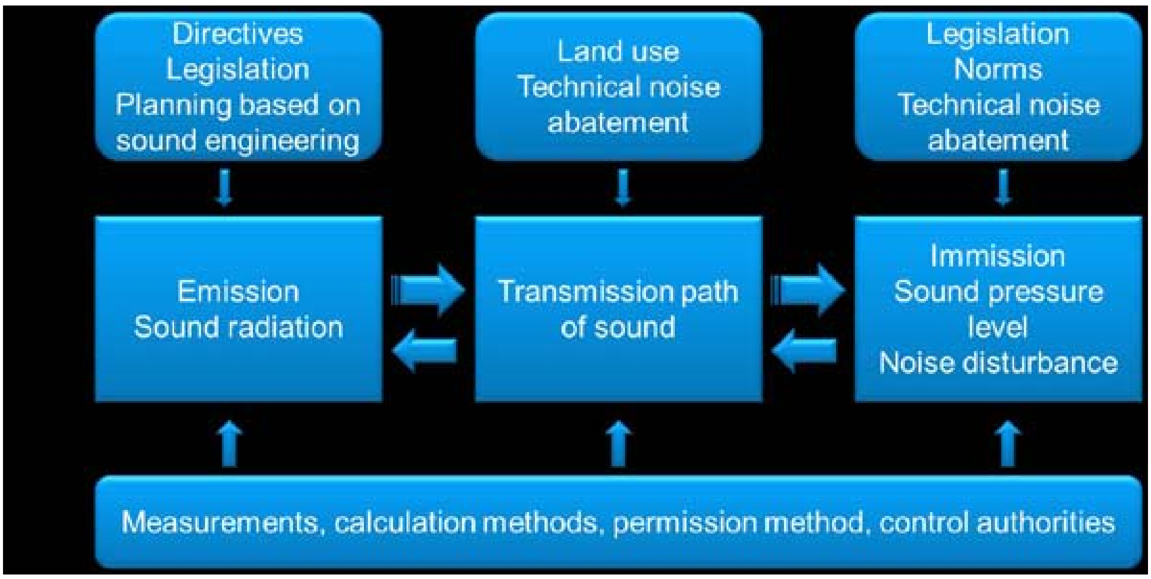

Figure 1. Mitigation of environmental noise

Often other noise abatement alternatives, like land use planning (distance to disturbed target), restrictions in utilization and influence to noise experience (annoyance) may be more suitable procedures that technical mitigation acts. The annoyance models, however, may be complex as illustrated in Figure 2 [3].

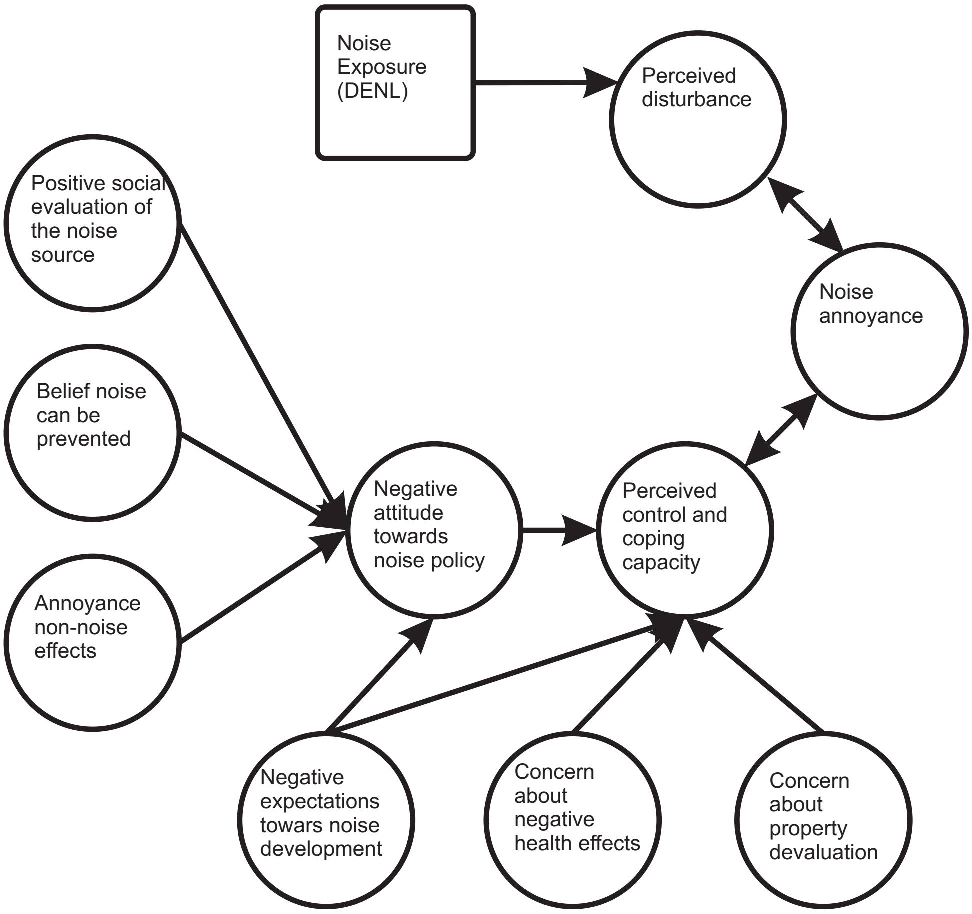

Figure 2. Simplified aircraft noise annoyance model

Heavy weapons ranges of Defense Forces and environment

Finnish Ministry of the Environment delivered a working group report at 2012 considering environmental hazards and special regulation of heavy weapons shooting ranges of Defense Forces. The report considers the possibilities to regulate more accurately about the environmental responsibilities of National Defense Forces. Environmental protection should be ensured in future by regulating extensively of the environmental protection requirements and the related actions of heavy weapon shooting ranges. Acts and decrees should regulate things like the reports concerning the environmental protection of shooting ranges, technical actions surveillance, operation control and reporting, relevant information and feedback system to fulfill the needed standard. Preparations for the Government Decision on the Noise Level Guide Values caused by heavy weapons shooting ranges should be started.

Conclusion

Noise problems are often difficult to eliminate because noise-generating activities and noise-sensitive activities, such as habitation, are an integral part of the basic structure of societies. Noise abatement development requires comprehensive goals, planning and programmes.

Noise problem includes contradictionary values and point of interests and the noise abatement call for comparison of interests, co-operation and interaction. As a starting point of noise abatement there should be an evaluation how the plans coming true change the impacts and what is the incidence and occurrence of impacts after abatement.

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ABATEMENT OF SHOOTING RANGE NOISE IN FINLAND

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During the last five years the Finnish Defence Forces have made environmental noise surveys of all of the small arms shooting ranges. The surveys included not only the calculation of noise level zones but also counting the number of houses and inhabitants in the zones. In 2012 the Finnish defence administration started a program of technical improvements of the environmental conditions of the military shooting ranges. Noise abatement forms a main part of the program, which includes the design of noise control measures and the actual building phase. The first large-scale improvements were made in Parolannummi shooting range in autumn 2012 (Fig. 1).

Simultaneously with the technical improvement program, the Finnish defence administration is hosting a project for preparing national guidelines on best available techniques (BAT) and guidance on best environmental practices (BEP) for small arms shooting ranges. Environmental noise is one of the two issues involved. The guideline project covers both military and civilian ranges. The project is nearing completion this spring.

BAT guidelines for noise control

The noise section of the BAT/BEP guidelines describes available noise control techniques, gives recommendations on implementation, states achievable attenuations and also treats briefly costs.

Figure 1. Parolannummi shooting range: an acoustically improved firing shed and heightened noise berms; an additional noise wall is erected on top of the dividing berm between two 150 m rifle ranges

The BAT concept and procedures do not, as such, introduce anything new to controlling the noise of a shooting range. The primary noise abatement techniques to be applied are standard and familiar ones: improving the firing sheds acoustically and erecting noise screens, earth berms or wall type noise barriers, high enough to provide sufficient attenuation of noise.

The guideline report states that the possibilities of controlling the noise of a shooting range depend on the starting situation. If abatement measures are to be applied on a range without sheds, noise berms or other noise reducing structures, new shed and earthwork constructions may bring considerable attenuations, say, 5 to 15 dB. If on the other hand there are already relatively good sheds and side embankments in the range, and possibly also some other control solutions, it may be difficult to reach an additional attenuation of even 5 dB.

Some of the main pieces of guidance given are as follows: In the frontal sector, the solution conforming to the BAT principle is a sufficiently high backstop berm. On a rifle or pistol range, to obliquely forward, BAT is implemented by an external side berm or a noise barrier. The noise screens are to be dimensioned so that the noise level at the receiver locations will not exceed the guideline or limit values of noise, and yet so that the additional attenuation is at least some 5 dB. If the locations to be shielded are inside the sector exposed to bullet noise (the sound produced by a supersonic projectile), it is necessary to extend the screen to cover the entire length of the field.

Backwards the BAT solution is a noise attenuating firing shed. In this respect, the most important property of the shed is that the back and side walls are tight. If ventilation is needed, the air passages need to be designed such as to attenuate sound.

On shotgun fields, side embankments or barriers can be erected only with certain restrictions, e.g. given by the flight path of the disks. Nevertheless, earth berms and barriers are the best noise abatement means on shotgun ranges. A skeet field cannot have a shed but on a trap field it is possible to have one.

An ordinary shed does not attenuate noise into frontal directions (–90°...0°...+90°). Towards greater angles in oblique frontal directions (ca. ± 45…90°, or approximately outside the bullet noise sector) and partially also into backward directions, BAT type of approach may also include the following structures. The attenuation is increased by equipping the shed with extended partition walls and roof which project forward from the shed. The extended walls and ceiling should be lined with sound absorbing material. If there are only a few firing points in the range, such extensions may alone form a sufficient solution.

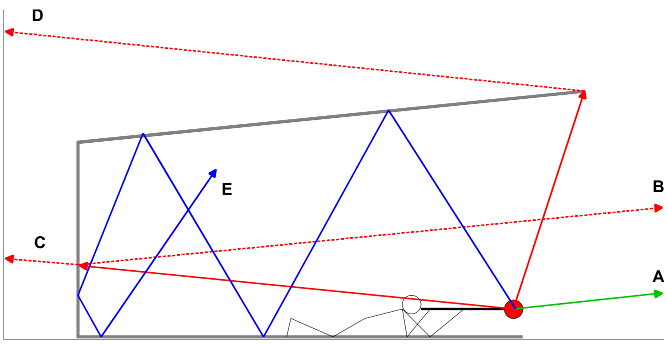

Figure 2. A schematic cross section of a firing shed and some sound rays from the muzzle blast

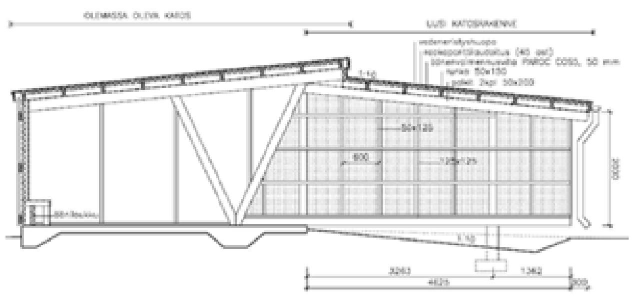

Figure 3. Cross-section of the prototype of a "noise control" shed. The new structure [uusi katosrakenne]starts from the front edge of the old shed [olemassa oleva katos], i.e. the position of the weapon muzzle

Other BAT type of techniques may be the following. Baffles are used for safety reasons, but they may also be used to attenuate noise if dimensioned correctly acoustically. Into frontal directions normal (transverse) baffles may improve the noise situation. And on a wide shooting field into directions more to the side longitudinal baffles or intermediate noise barriers may be used. Equipping the weapon with a silencer is a rather effective means to attenuate the muzzle blast into almost all directions. A good silencer attenuates noise ca. 8…12 dB to frontal directions and even more than 20 dB to the side. In many cases the use of a silencer is, however, not possible. For instance many sports rules forbid its use. In military training silencers are not used.

Acoustics and noise control in a shed

A shooting shed or shelter which has back and side walls attenuates noise directed to the sides and backwards to a certain extent. Some paths of the sound rays from the muzzle blast propagating inside and out of a shed are shown in Fig. 2. The sound reduction of a closed back wall is typically at least of the order of 15…20 dB. Sparse boarding with gaps in the back wall, or large ventilation openings, may on the other hand render the sound isolation of the wall almost negligible.

When the sound reduction of the walls is at least moderate, a larger part of the total noise propagating behind a shed, or obliquely to the sides of a shed, is actually diffracted around and over the front edge of the roof (path "*D*" in Fig. 2.). Less noise travels through the back wall (path "*C*"). As a result of the diffraction the sound ray bending over the roof backwards becomes attenuated by some 20 dB. However, sound directed up from the muzzle is considerably stronger than sound going straight backwards, due to the directivity of the muzzle blast of the weapon. For instance, with an assault rifle the difference is approximately +15 dB.

The diffracted sound amplifies the noise heard behind the shed so that the overall attenuation observed is clearly less than the noise reduction of the back wall alone, when compared with a situation without a shed. The overall attenuation of an ordinary shed into back directions is typically between 5…10 dB. The noise control obtained with a closed-wall shed can be improved not only by improving the sound reduction of the back wall but especially by extending side and top structures in the shed towards the front, to increase the attenuation induced by the diffraction (Fig. 3).

Figure 4. The Parolannummi "noise control" shed. The interior surfaces of the shed and the partition walls were lined with sound absorbing mineral wool covered with protective steel mesh

The Parolannummi shooting range has two standard 150 m rifle ranges. In autumn 2012, the old sheds of the ranges were improved in the described manner (Fig. 4). The sheds were equipped with extended 4.6 m long partition walls and extended roof, projecting forward from the original sheds. Partition walls were placed between every two firing points, i.e. with 3.5 m intervals. The inner surfaces of the sheds were covered with sound absorbing material. In addition to suppressing environmental noise, the acoustically treated interior of the sheds reduces the noise exposure of the shooters and instructors.

The renewed "*noise abatement*" sheds were checked by measurements both at near and far positions. The measures were found to be very effective in reducing environmental noise into side and back directions. Also into oblique frontal directions the attenuation proved to be considerable. The effect of the new shed is shown in Fig. 5. The attenuation is backwards slightly less than 10 dB, to the sides 15 dB and obliquely forward approximately 10 dB. Straight ahead the shed has no effect.

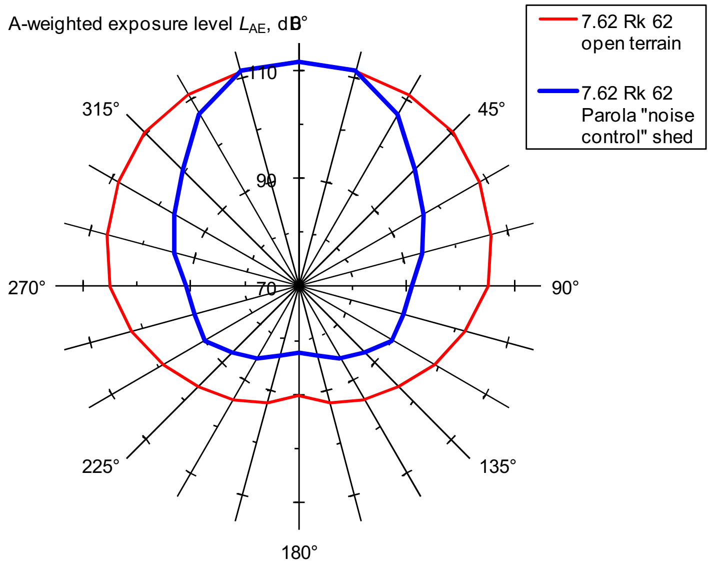

Figure 5. The directivity of the noise emission of the muzzle blast from the Finnish assault rifle 7.62 Rk 62 in open terrain and including the effect of the new improved shed in Parolannummi

Noise screens

Backstop and side berms

Often the environmental noise from a shooting range is a bigger problem to the front than to the back. Straight ahead and obliquely forward the most important factor affecting noise propagation is formed by the berms. There is always a backstop berm and often some sort of side berms because of safety. However, berms dimensioned only for safety are usually too low for noise. There are two explanations: Part of the noise is bent over the top of the berm down to the other side due to diffraction. And if the noise propagates downwind the sound rays become refracted, i.e. curved downward; noise which radiates gently obliquely upwards crosses over the berm and curves down on the ground again further away.

The attenuation of noise screens (i.e. earth berms as well as barriers) can be estimated using a noise calculation model. In Fig. 6, the attenuations obtained with screens of different heights and at various distances are shown. The curves are calculated using the joint-Nordic prediction method [1] which is a close relative to the general method of ISO 9613-2.

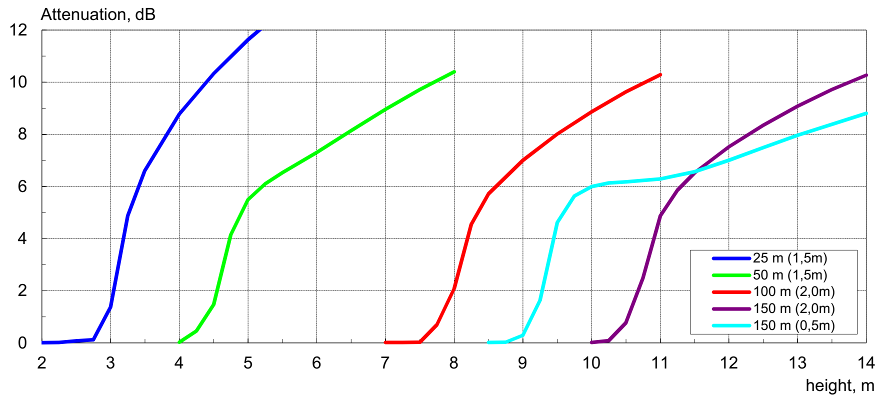

Figure 6. The screen attenuation [dB] of a backstop berm as a function of height in five different ranges; parametres: distance to berm foot & height of muzzle (blue/green: pistol, standing position; red/violet: shotgun; turquoise: rifle, prone position). Assumptions: receiver at 1 km distance, level terrain outside berm

In addition to improving sheds, the originally quite high backstop and side berms of the Parolannummi ranges were further heightened to 8…20 m from the firing point floor levels. The internal berm between the two ranges was also heightened with a wooden 2.5 m high barrier on top of the berm. The berms and the barrier attenuate not only the muzzle blast but also the bullet noise which was significant into some directions. The bullet noise also rose in relative importance when the muzzle blast became attenuated by the improved shed.

Check measurements supported by model calculations suggest that the effects of the heightened berms and barrier are in the range 2…9 dB depending on direction, distance and terrain shapes. At various receiving positions the attenuation is on an average 3…5 dB in average weather conditions.

Baffles

Some ranges have transversal baffles primarily for enhancing safety. The baffles may in some cases also augment the propagation of noise, both forward and backward. In the ranges to be improved, there may be need to optimise also the acoustical effect of the baffles.

Baffles dimensioned only for safety are usually not optimal for attenuating noise. The sound rays from the muzzle blast may diffract under the lower edge or over the top edge of a baffle and continue to the top of a backstop or side berm, so that the bending angles en route are relatively gentle.

In this case the screen attenuation due to diffraction loss is small. If a transverse baffle has an acoustically hard surface, meaning that it reflects sound, the baffle usually makes noise situation considerably worse in backward directions. In order to prevent these phenomena at least the side facing the firing shed must be made sound absorbing (Fig. 7).

Figure 7. The original baffles at the Vekaranjärvi rifle range are lined with absorbing surface to prevent reflections backwards. Also the lower edges of some baffles will be lowered further

Reference

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VIBRATION AND NOISE FROM HEAVY WEAPONS AND EXPLOSIONS

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Shooting with large weapons and blasting explosions generate impulsive and low-frequency sound waves which can propagate over long distances in the atmosphere. The energy carried by the waves may induce loud noise and perceivable vibration in residential or leisure buildings in the surroundings of heavy-weapon shooting areas, at distances of great many kilometres. The vibration and noise form one of the most significant environmental impacts caused by shooting areas.

The annoyance (and complaints) are an outcome of a combination of different phenomena and reactions including not only vibration and noise but also rattle and fear of building damage. Between 2007 and 2009 the Finnish Defence Forces (FDF) commissioned a research project on building vibration caused by heavy weapons and explosions. The project comprised of a literature survey and a series of vibration measurements [1]. From 2010 to 2012 several more on-site measurements were made, and a draft version of a vibration assessment guide was prepared, in order to deal with the issue. This year, the first large-scale vibration survey, covering the surroundings of a whole large artillery shooting area is being made at Pohjankangas.

The vibration of a building is induced by the passing sound wave. In simple terms first the overpressure portion of the incoming wave squeezes the house in and then the following underpressure expands it outwards. With heavy weapons and large explosions the wave length is roughly similar in size of a typical one-family house. The effects and motions are visualised in Figs. 1 and 2.

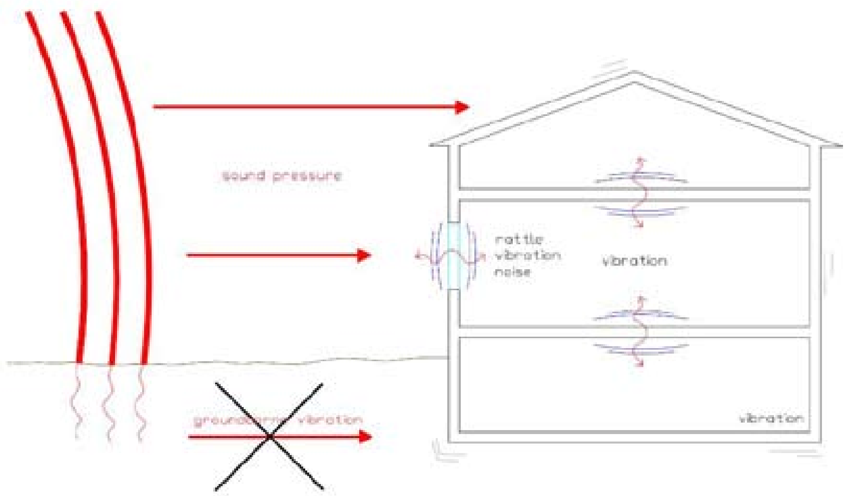


Figure 1. Heavy weapons and explosions generate sound (pressure) waves that are incident on the outer surface of a building and induce vibration of the building structures, as well as noise and rattle inside the building. The primary excitation is airborne; ground-borne vibration is generally negligible

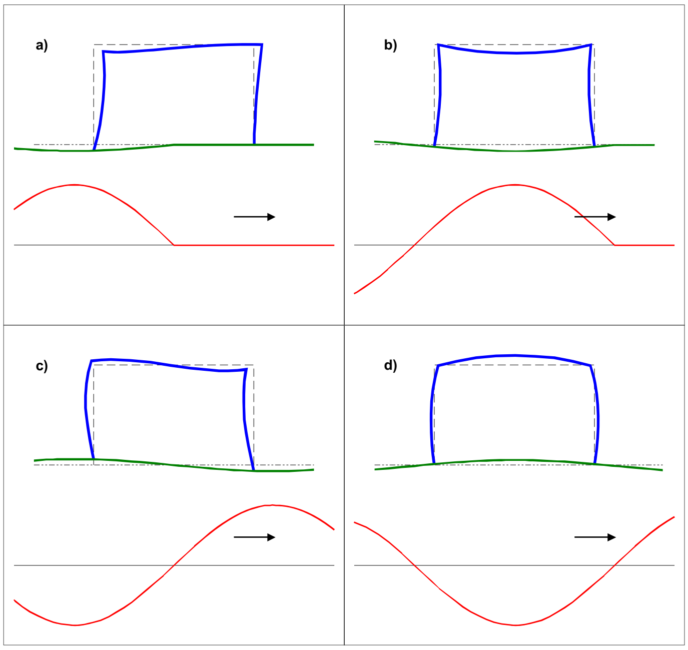


Figure 2. Schematic visualization of the motions of a house (and the ground) when a sound wave passes the house from left to right. The amplitudes of motion are strongly exaggerated

Perhaps contrary to common belief, in this case the building vibration is not induced by vibration waves propagating in the ground. Ground-borne vibrations from the muzzle blast of a heavy weapon or detonating an open-air explosion do not propagate farther than some tens or hundreds of metres. The phenomenon is thus quite different from the vibrations caused by mining or other underground explosions.

Vibration response of a building

In the measurements, information was collected on the vibration response of typical buildings to the sound wave excitation. Most of the measured buildings were wooden 1½- or 2-storey onefamily houses which are typical in the Nordic countries (Fig. 3).

The range of the measured vibration responses is summarized in Fig. 4, together with a typical spectrum of the incident sound wave of artillery (155 mm cannon). The vibration response of a structure is characterised by the ratio of vibration velocity to sound pressure. The ratio is defined so that a 0 dB response corresponds to the situation when the structure vibrates at the same velocity as the sound wave, meaning that the coupling of energy from the sound wave to structure is perfect. If the ratio is 0 dB, a sound pressure of 86 dB induces a vibration velocity of 1 mm/s.

The response of the buildings was the most sensitive at frequencies around 20–50 Hz, when the measurements were taken from large surfaces: walls, ceilings and light-weight floors. The responses were much weaker when measured from foundations and supporting structures. The vibration velocity of foundations was typically smaller than 1/10 of the velocity of large surfaces.

It is also relevant to note that the sound reduction of building façades is small for low-frequency noise. The sound insulation at frequencies below 100 Hz is on an average only approximately 10…15 dB.

Figure 3. Measured sources: (top left) 155 mm cannon, (top right) over 20 tons mass explosion, (bottom left) 108 kg explosive, and (bottom right) a typical Finnish wooden one-family house

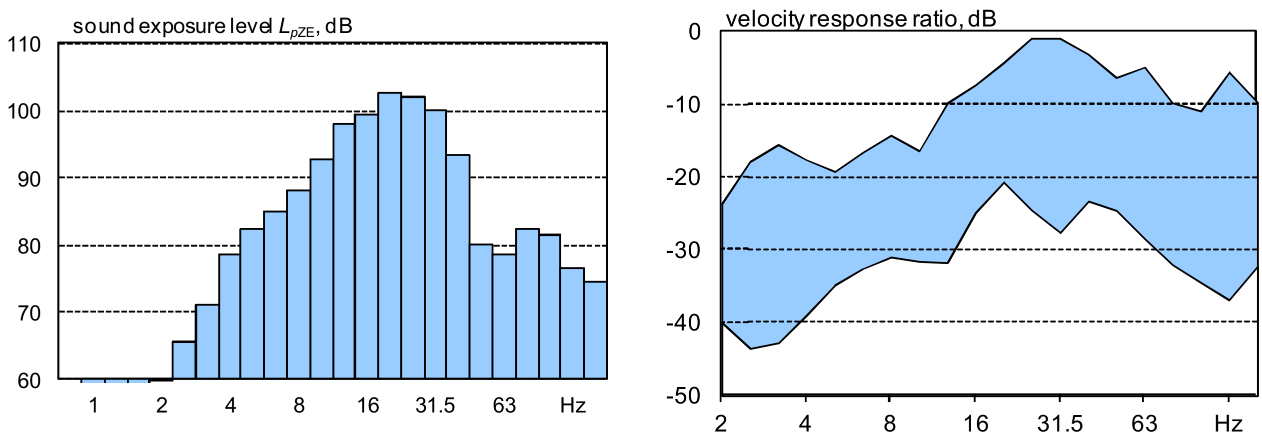


Figure 4. (left) Typical noise spectrum of an artillery muzzle blast at a distance of a few kilometres. (right) The range of response ratios of typical wooden one-family houses; the response is highest at roughly the same frequencies where the artillery noise has maximum energy

Table 1. The used guideline values for noise and the proposed guideline values for vibration

Building damage	quantity	value
Noise, outdoors	peak sound pressure level L_{Zpeak}	140 dB
Vibration, foundations/supporting structures	peak vibration velocity v_{peak}	5 mm/s
Annoyance		
Noise, single event	C-weighted sound exposure level L_{CE}	100 dB
Noise, average active day	A-weighted equivalent sound level L_{Aeq,r^*}	55 dB
Vibration, single event	W_m-weighted vibration velocity v_W	0.3 mm/s

* includes +10 dB impulse correction

Guideline values for vibration and noise

The proposed guideline values for vibration-induced building damage and human annoyance are summarized in Table 1 together with the guideline values for noise used by the FDF [2]. The proposed guideline values for vibration and building damage were synthesized from literature. Very little research or few standards are available which could be directly applied to vibration-induced building damage, when caused by shooting with heavy weapons. Most references on damage criteria, possibly applicable also to shooting, dealt with sonic booms, quarries or underground explosions. These vibration sources resemble to some extent heavy-weapon shooting but the similarity is not complete. There seems to be a reasonable agreement in the literature about the damage criteria. The criterion values are mostly given for peak vibration velocity vpeak, measured at supporting structures and foundations, and for peak sound pressure level L_{Zpeak} outdoors.

Literature on annoyance is even more scattered than that on damage. Guideline values for annoyance caused by vibration from shooting and explosions are almost non-existent. Impulsive shooting vibration differs from the more common traffic-induced vibration in many ways. The startle effect increases annoyance compared to steadier traffic vibration. On the other hand, event duration in shooting is much shorter than in a pass-by of truck or train, and there may be fewer events per day. For now guideline values for traffic vibration [3] are suggested as preliminary values for shooting vibration assessment. The used quantity is Wm –weighted vibration velocity v_W [4].

It is often mentioned that the rattle (= vibratory movement which creates new noise) of windows, light objects on walls or shelves etc. is a key factor increasing annoyance. No clear rattle threshold limits exist. Individual structural elements and objects may react much differently in this regard. Nevertheless, the rattle is indirectly taken into account in the noise guideline value of L_{CE} 100 dB.

Measurement and assessment of vibration and noise

Vibration measurement methods

In the draft assessment guide three vibration measurement methods were suggested:

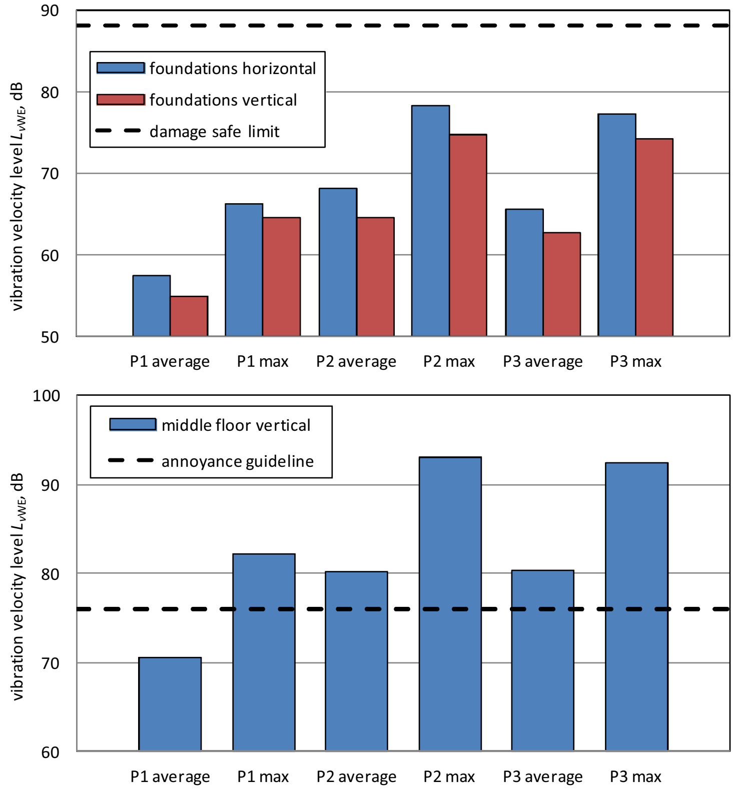
- Survey method: only noise is measured and the sound level guideline values are used for assessing also vibration.
- Engineering method: primary method where noise and vibration at a single position are measured, either from the foundation (damage) or from the walls/floors (annoyance).
- Advanced method: multichannel measurement with noise and multiple vibration positions.Used when the situation is tensed or vibration can be assumed to be close to the limit values.

Measurement results

As the sound (pressure) wave passing over the building is the cause of building vibration, the vibration assessment can be made using both vibration and noise measurements. In Finland such combined measurements have been made in the surroundings of five different shooting areas and explosion sites in about 20 buildings, most of which were wooden one-family houses.

In none of the one-family houses the damage criterion was exceeded. The vibration velocities measured from the foundations and the supporting structures were in all houses at least ten times smaller than the limit 5 mm/s. Also the sound pressure levels were not higher than approximately 125 dB, thus clearly lower than the limit 140 dB. The measured vibration levels were near the damage criterion only in non-residential buildings owned by the FDF, which were well inside the shooting areas and close to the sources (less than ~1 km).

Figure 5. An example of vibration measurement results in three different houses (P1…P3) having concrete



or stone foundations and wooden base floors

The annoyance criterion of 0.3 mm/s was exceeded in some of the houses when measured from the light-weight wooden floors with rather long spans. The levels, when measured from heavyweight concrete floors, were usually, but not always, below the threshold of sensation of 0.1 mm/s. As a conclusion, the vibration sensed by the residents is not necessarily the primary cause of annoyance.

The noise guideline value, single-event sound exposure level L_{CE} 100 dB, was exceeded in some of the houses when the weather conditions were favourable to sound propagation from the source to the house.

Noise surveys

The noise surveys of the FDF heavy-weapon shooting and practice areas are being made using both calculations and measurements side-by-side. The surveys are conducted according to the Finnish noise assessment method [2]. The noise maps are calculated for the overall shooting activity including both muzzle blast and impact noise. The projectile flight noise is generally negligible.

The primary method is calculation using the Nordic general prediction method [5]. The sound emission data were measured at the shooting sites during the surveys in recent years. Immission measurements are used in verifying the modelling results, especially in situations where the calculations are considered demanding and the results perhaps less reliable. As the final result of the survey, the noise zones around the shooting areas are determined. An example of this is shown in Fig. 6.

Abatement

Currently a pilot project on a vibration survey of a whole artillery shooting area is in progress. The aim is to cover the entire surroundings of the area and create vibration zones similar to the noise zones in Fig. 6. Another goal is to determine "*damage–safe*" zones in and around the shooting area in order to help the planning of shooting activities.

Abatement of noise and vibration would be the most effective by taking noise and vibration issues in consideration when planning the shootings. However, the shooting sites and the buildings around the area have in most cases been there for decades and the distance between them cannot be increased.

The reduction of the noise emission of the weapons themselves, or that of the shooting site in general, is very difficult and practically impossible with heavy weapons. There are either no generally applicable techniques for improving the sound insulation of buildings at low frequencies. The reduction of building vibration by making structural changes is not feasible on a large scale, but such changes might reduce rattle in some cases.

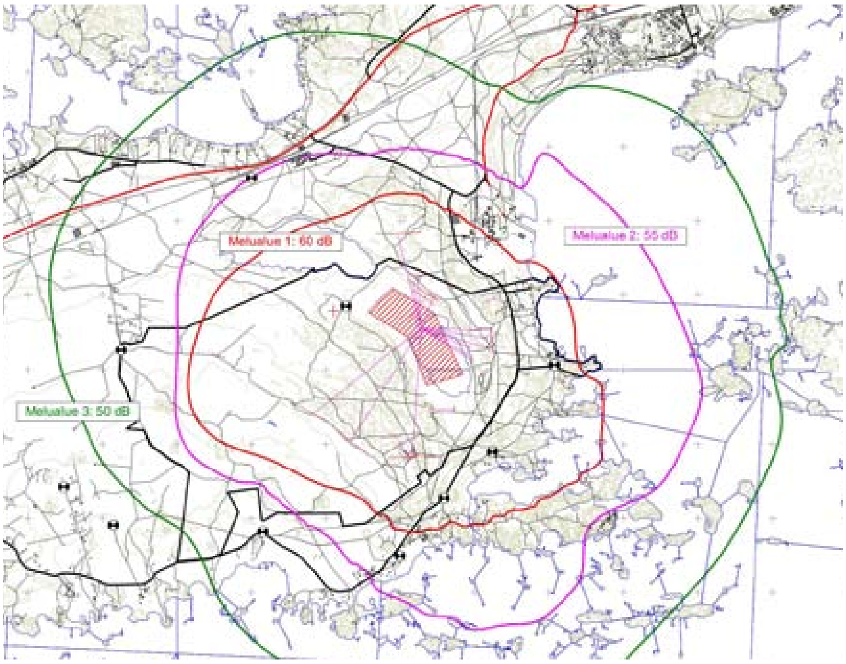


Figure 6. An example of noise zones: Syndalen shooting area with mortars, rocket launchers and explosions. The map covers approximately an area of 10 x10 km²

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EUROPEAN UNION NON-MILITARY MATTERS AS MILITARY MATTERS

Ronald de Rooij[1]

1 Netherlands Ministry of Defence.

The Common belief is, that when the EEC was founded, the founders only had in mind an economic community. In a sense, that is true. But we should not forget, that in these days (roughly from 1948 to 1958) there was also a vivid movement trying to get off the ground European armed forces. In the end, this was not feasible, but one of the ancient remnants of that can be found in art. 346 of the treaty of the functioning of the EU (consolidated version). Many, even most people still believe that this is the exemption article because of which the military are immune to all non-military legislation coming from Brussels. The military issue is a national competence and cannot, therefore, be influenced in any way by non-military (for example environmental) EU directives or regulations. Wrong. Art. 346 is only an exemption for giving information to the EU and only in exceptional cases when national security is at stake. As for exempting Defence from the single market it only concerns some forms of equipment, not defence activities as such and only when pertaining to national security in exceptional cases. Even better (or worse), the EU Commission may judge the use of the article and may even go to Court about its use. As far as I can see, for environmental matters, it has never been used.

It is my belief that, because of the political will to reach some form of military integration after the horrors of the second world war, the article has a limited scope. It was the time of the start of the Cold War, the time of a future European Army, the time of the signing of the NATO treaty, the time of "*never again war in Europe*". That is why the article has never been a defence exemption from the EU treaty.

Politically even more interesting is what is written down in the other European Treaty, the Treaty on European Union. Art. 42 begins with telling us that the common security and defence policy shall be an integral part of the common foreign and security policy. So, let us look at that too. Art. 40 states that the implementation of the common foreign and security policy shall not affect the application of the procedures and the extent of the powers of the institutions laid down by the Treaties for the exercise of the Union competences referred to in articles 3 to 6 of the Treaty of the Functioning of the EU. This means that defence is bound by all EU competences, shared or exclusive, unless otherwise provided in the Treaties (art. 346 TFEU) and/or EU law. It is therefore necessary to at least be aware as a defence community, that for many non-military issues, our capital is Brussels, and not Helsinki, Stockholm, Copenhagen, Rome, Paris, Berlin, etcetera. As the for military matters these capitals are truly still real capitals. The fact that they are not anymore on issues that could directly have military operational consequences, is slow to sink in at Ministries of Defence. For some of them, it is a cultural (sometimes even a political) shock. Also for military matters, the TEU provides "*an ever closer union*" by stating in art. 24 that the Union's competence in matters of common foreign and security policy shall cover (….) including the progressive framing of a common defence policy that might lead to a common defence.

The Netherlands' Ministry of Defence got aware of it's implications in 2000 and even then very slowly. Even today 90% of foreign desk functions is NATO related and only 10% is EU related, all in the second (military) pillar of the EU. Foreign affairs in the Dutch MOD is still largely NATO, not EU. Outside the Ministry of Defence Building in The Hague, the situation in other Ministries is drastically different. I dare to say that for the Ministry of Environment, Economic Affairs and Social Affairs (all doing some environmental tasks) the number of NATO posted, or even related officials is zero. That is not necessarily a disaster, if the two international bodies in Brussels (NATO and EU) would communicate if necessary. But they don't. That has political reasons that I will not go into. For now it is sufficient to note that they don't communicate if necessary. So, something is amiss and that is bound to go wrong sometime. It did, with the Habitats Directive.

I will spare you the details of it. Who is interested in the internal discussions in such a small and insignificant country? But thanks to a very realistic Ministry of Economic Affairs, the Habitats Directive is now manageable for the MOD, but at a financial and operational cost. Remember that this issue plays within a very densely populated country. Our freedom to move or change locations for military activities was therefore very limited. The pressure from outside high. Had we seen the Habitats Directive coming in 1996, I think we would have acted with a lobby to change it. But we did not see it coming until it was too late. This prompted the same reaction inside the MOD as in Europe after World War 2: This may never happen again!

And it went wrong again, with the ozone depleting substances regulation (first edition), where somebody forgot first to exempt defence and later to put our F-16 fighters in the exemptions list. (The first was solved before publication, the latter was repaired by the EU Commission, afterwards). In the recast edition the ministries of defence were involved from the beginning by the EU Commission through the informal network of MOD environmentalists, called DEFNET. That this in itself is not a guarantee for a satisfying outcome became apparent later. If it had been for the MOD's the second (recast) edition would not have made it through the Council, but the Ministries of Environment are the leading Ministries on behalf of their country and they won the debate in just enough countries to see the recast Ozone Regulation through. In my country that was in particular a close call, as the MOD was initially internally divided, then against, and then the MOE wanted a ministerial intervention during the weekend. As the vote of the Netherlands on Monday in Brussels would be crucial for the outcome, it was a heated debate indeed. Well, losing is OK, you win some, you lose some. We just were reinforced with the belief that we needed to do something to limit the chances of losing again in the future. At least the decision on ozone depletion was taken knowing the consequences and giving us just enough time to adapt. That was not the case with the Habitats (and Birds-) Directive. So, you might conclude, we improved our act. But was it enough? That depends on what is enough. What should be enough? In short what is the future we want on EU non-military parts vis à vis member states Ministries of Defence?

One thing is now clear. Art 346 was not even mentioned in the process. It was not relevant. Not for the Commission, not for most member states and it was particularly irrelevant for the outcome. The Commission set (de facto) end dates for use of certain types of military equipment containing ozone depleting substances and the Council agreed (if only just). Mind you that this was about equipment certainly relevant for national security.

The future we want for the relationship between the EU and Defence therefore, is a future of structured dialogue between Member States' ministries of defence and the EU Commission on all non-military issues. The goal is to know of each other's plans and priorities, difficulties and possibilities, in short dilemma-sharing in the earliest phases of policymaking. This will enhance the quality of the EU as a whole a little bit too. The old "*second pillar*" as the military pillar of the EU was called, will then be a tiny little bit more integrated in the body of the EU proper. The means to do it could be very modest to be effective. Why not put a compulsory defence paragraph, or a paragraph on common defence and security policies in every impact assessment the Commission makes before writing a new (legislative) proposal? Let us take in from there, shall we?

TOWARDS SUSTAINABLE DEFENCE - THE STRATEGIC ENVIRONMENTAL PROTECTION PLAN OF THE FINNISH DEFENCE FORCES

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To sustain the mission, the FDF has developed a long term plan to develop environmental protection (EP) systematically between 2012 and 2025. The plan defines the FDF's environmental policy and sets the strategic goals for EP which are:

- To sustain the mission and provide sufficient training facilities by taking environment into consideration
- Continuing development of EP
- Reaching set goals economically efficiently
- Active cooperation with other stakeholders and the rest of the society
- Taking EP into consideration in international cooperation and military crisis management

However, the EP plan goes far beyond of just stating policies and strategic goals. It determines a route map that will lead to set targets. These are specified for each area of interest. The plan includes 177 individual tasks that are split into short, mid and long term categories. For example for training areas the plan foresees prioritizing of use, environmental base-line studies, risk assessments, monitoring and reporting procedures, noise mappings, land use planning and outreach plans.

In addition to tasks from grass root levels to strategic planning, emphasis has been given to enhanced situation awareness throughout the defence administration and the comprehensive management of EP. Most of the development issues will be executed as programs that will be centrally project managed.

The Finnish Defence Forces (FDF) employs over 16,000 people, trains about 25,000 conscripts, and as of 2008 about 25,000 reservists annually. A maximum of 1,000 people at a time serve in crisis management operations. The wartime strength of the FDF is 350,000 men and women. For training of these troops the FDF needs facilities. All in all, the FDF has around 8 000 buildings and ca. 265 000 ha of land and water areas. Of land areas 29 300 ha are included in European Union's Natura 2000 conservation regime.

The Finnish Ministry of Defence's strategy includes a part on the defence administration's environmental policy. This policy document is more detailed than many declaration type strategies based on some of the best known standards such as the ISO 14001. Still, the strategy basically states the aim and the vision but not the path how it actually will be implemented. Until now the mid-term planning has been solely based on four-year span framework planning and yearly planning. The defence administration acknowledged that there was a need for longer term planning that would concretize environmental policy into an action plan or road map that would lead to set goals.

The vision: Managing environmental protection with a comprehensive road map

How the strategic EP plan was born?

In document hierarchy the plan is part of implementation of the Defence Forces' Logistics Strategy. Therefore the first step was that the need for such a plan was stated in the Logistics Strategy. As already mentioned the plan is also tightly bound to the MoD policy document which was renewed shortly before the creation of the implementation plan started.

The long term plan was under development for several years. It seemed difficult to find the right balance to at the same time stay on a strategic level but still split the tasks into comprehensive executable items. The first drafts were too abstract and the experts did not feel it would have brought the sought additional value in comparison to the existing policy documents.

The plan started to find its form after the Defence Command conducted a process evaluation on environmental protection. The evaluation project included visits to all major commands. During these visits interviews were conducted with both environmental specialists and the leadership of all levels of the chain of command. This evaluation made it possible to clarify what working methods have proven efficient, what challenges the current managing practices have, and how well processes have been defined and followed. The evaluation also gave insight how the professional skills compared to the actual needs and sparked ideas how to better maintain and further develop the personnel's knowhow.

The most important challenges the strategic EP plan tries to tackle

In Finnish military culture the unit level commander has traditionally had significant room for maneuver in making decisions and leading his troops. As part of this basic principle also a lot of EP tasks have been the (sole) responsibility of the units. A decade ago it was also seen that the only way to include EP into everyday routines was to maintain these responsibilities as close to the operator as possible. Due to this thinking environmental specialists have been hired during the years on a case by case basis to different command posts. This has led to a bottom-up structure and a scattered specialist network. Usually one command has had no more than one person working with EP issues, which has meant that the specialist must have mastered the whole scale of EP. This has meant that the personnel have remained on a generalist's professional level. Another difficulty has resulted in coherence as independent units, branches etc. may have adopted differing operating procedures and their EP skills have not developed evenly. From the top-down perspective it has been difficult to get an overall situational awareness, develop guidance, and install global reporting and monitoring practices.

One of the most important challenges has been the difficulty to address material needs. For example the shooting ranges need environmental permits and the authorities have set strict requirements for the EP infrastructure. In the bottom-up management model this lead to reactive work-flow where development starts haphazardly where ever the administrative dead line would come first and usually too late to make the investment processes possible.

Goals of the strategic plan

To answer the challenges, the plan was designed to completely rethink the management of EP in the Defence Forces. The basic idea is the following:

1. you have to have situational awareness (otherwise you do not know what is wrong; prerequisites from legislation, surrounding society's expectations, current emissions)
2. after you know where you are, you can define where you want to be (realism, how the

policies and legislation is evolving, how the defence forces are developing, how weapons systems are changing)

3. when you know where you want to be, you have to define a plan how to get there (milestones).

Basically, to take these three steps, it was foreseen that the plan should define following aspects:

- To describe the role and duties of EP in the FDF (including legal requirements and how they will develop)
- To describe the processes of EP
- To define the environmental policy of the FDF (this policy is the type meant by EMS standards, much more compact than the MoD policy document)
- To define the goals of EP (where we want to be)
- To define on a strategic level tasks that will pave the way to set goals
- To create a platform of necessary reporting and monitoring

Components of the strategic environmental plan

The strategic environmental plan consists of six chapters (see figure 1). It starts with describes briefly the base line situation, the general reasons why such a plan is needed and states briefly the environmental policy of the organization. The plan continues to discuss EP development and scenarios: it presents main content of important environmental policy documents (EU and Finland), forecasts changes in environmental law both on national and EU level, goes on to analyze predictions on weapons systems development and how they affect EP needs, and finally provides information on foreseen structural changes in the organization of the Defence Forces.

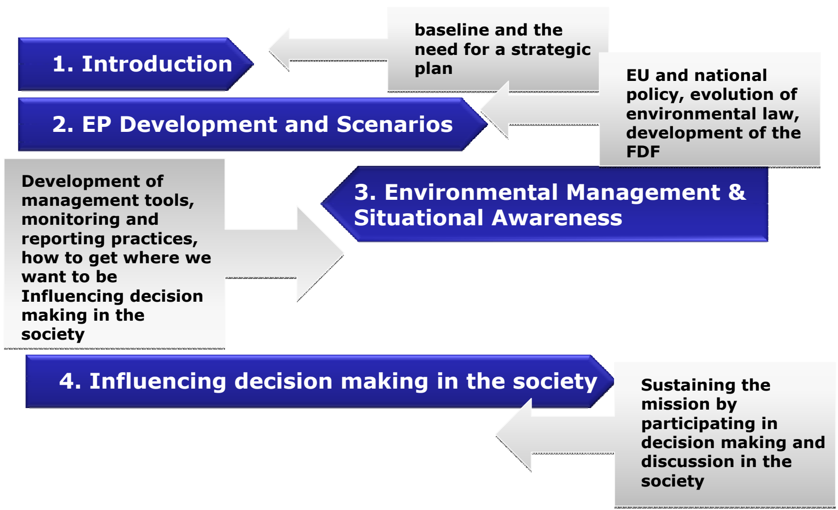

Figure 1. The structure of the strategic plan

The third chapter of the EP plan is about situational awareness: what should be monitored and reported, how information flow should be organized, how information is distilled to fit different needs (unit level, specialists, and executive management). The fourth chapter underlines the importance of sustaining the mission by taking part in public discussion. It talks about encroachment planning, participation in land use planning and community strategies.

The fifth chapter includes the core task areas of managing the environmental effects. It describes legal requirements, planning of project entities and goals (milestones) of all areas of special interest.

The sixth and final chapter concludes the rest of the plan by trying to systemize all needs into comprehensible programs, projects, career tracks, guidance documents and general decision making.

Environmental policy of the Defence Forces and strategic goals of EP

The environmental policy of the Defence Forces is included in the EP plan but it was introduced to and signed by the managing directors separately. The Chief of Defence Command and the Army Command, the Navy Command, and the Air Force Command all reviewed and accepted the policy before it was accepted. The policy follows the guidance of the ISO 14001 standard (see figure 2). The basic principle is that modern and efficient FDF takes environment into consideration in all its actions. Every one of us, but especially those in leading positions, have responsibility for the environmental quality of current and future generations. The environmental concerns are always taken into account but the security situation determines the level of EP achievable. In international operations host nation legislations is respected and, if Finnish legislation is stricter, it is strived for that its obligations could be followed. The goal is to maintain continuous improvement of EP.

The FDF has three main tasks: 1) the military defence of Finland, 2) supporting other authorities and 3) participating in international crisis management. EP is a supporting function but it is tightly interconnected to FDF's main tasks. Most important task of EP is to sustain afore mentioned missions. This is achieved by following legislation, cooperating with all stakeholders and actively developing EP measures. The EP tasks are prioritized as follows: protecting defence interests, noise control, protection of soil and groundwater, hazmat handling, protection of water environment, material efficiency, energy efficiency and protection of biodiversity.

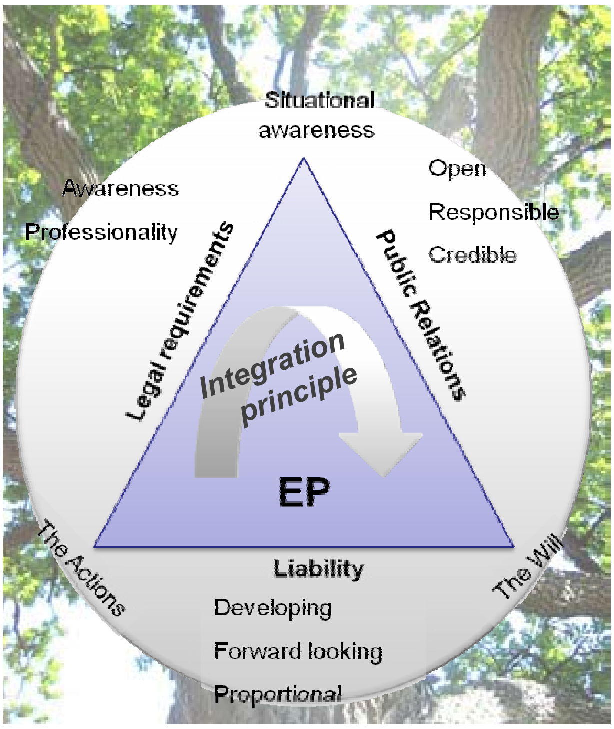

Figure 2. Key aspects of environmental policy of the FDF

Scenarios of development of policy, legislation, weapons systems and the Defence Forces

What comes to environmental policy and legislation, the basic situation is that megatrends such as climate change, declining biodiversity, scarcity of natural resources and chemicalization of the environment influence also the defence sector in all nations. Environmental consciousness of citizens has raised the bar of expectations in the eyes of our society. Environmental effects such as noise are much more widely acknowledged as detriment factors to our living conditions. Thus, there is a continuing pressure to minimize all harmful impacts. Especially the EU white papers, road maps and other policy documents show that future environmental legislation will become more particular and stricter. The deregulation efforts of EU do not seem to bring any relief in this area. Last years' experience has also shown that even if the law itself would remain unchanged, the interpretation of it evolves and becomes more and more demanding.

Weapons systems are also developing. For example new military aircraft seem to become louder than ever. Also range of weapons is increasing which is a challenge to shooting and training area management. Then again, growth of ammunition or explosives is not foreseen. Use of mechanized troops will grow.

The renewal of the Defence Forces will mean scaling down of the overall defence branch. Some properties will be decommissioned. Because garrisons will be closed, at least part of the activities will be relocated and may cause increased environmental impacts at the expanded site.

Knowing where we stand – situational awareness

To increase situational awareness processes and guidance have to be developed and organization structure simplified. The basic idea is to point out processes that are not tightly bound to the chain of command and therefore not necessary to maintain side-by-side with core activities. Many of the EP measures support facility management and are by their nature supportive. The FDF plans to centralize the production of such services which gives a possibility to link the EP personnel closely to those support processes. In practice this means that environmental specialist will form a team that is located in the new Logistics centre that will provide services to all branches (army, navy, air force). This new set-up will make it possible for environmental specialists to concentrate on certain specific areas such as noise management or EMS.

Other important measures include development of data management systems, monitoring, reporting and a comprehensive corporate-wide environmental management system. Special focus will be given to increase information flow to the executive levels. This is secured by locating the environmental manager of the FDF in the Defence Command. Data management is arranged in cooperation with the Construction Establishment of Defence Administration. The FDF SAP solution is used only if the information need is linked to other than EP processes, which is the case i.e. with material consumption.

Situational awareness can be enhanced with simple means. The EP branch has taken into use monthly situational reports by video conferencing. Each specialist will provide information on most important happenings using a simple power point slide (a one-slide situational report with traffic-light signalization). This information will be collected together and is posted in concise format to all relevant commands.

Situational awareness part of the plan includes also preparedness which means taking different security situations as a central part of the planning.

Managing the public partnership and environmental risks to core-processes

Many of the environmental challenges are not based solely on legal requirements but rather on the expectations of the surrounding society. High level of environmental protection is imperative to maintain good relations to our neighbors. That alone is not sufficient: it is important to continuously and systematically work on outreach programs and partnerships with surrounding communities.

Risks that environmental issues may cause are, among others, that

- Environmental conditions of a location turn out to be unsuitable for training i.e. due to ground water or soil conditions such as water permeability, low pH or a tendency for erosion.
- Special Nature values, i.e. presence of rare ecosystems or species restrict the development of an area.
- Site has cultural historic values that prevent development (especially buildings).
- Increasing density of surrounding settlement near FDF areas cause encroachment issues or stakeholder support is lost.
- Activity or EP is arranged insufficiently causing legal problems or weakening of stakeholder relations.
- Legal or administrative requirements are unbearable or
- Legislation does not sufficiently take national defence into consideration

In the worst case, the environmental risks may lead to unbearable encroachment issues which in turn may result in negative training. Encroachment means real or perceived threat to reasonably develop a defence facility to its purpose. By negative training we refer to a situation where training routines have to be adjusted in a way that differs from war time procedures.

Influencing EU and national environmental policies and legislation, participating in land use planning, taking positions on permit and court cases, outreach programs, effective communications and feedback processing, and of course, high level of environmental protection are the means to sustain the mission.

Participating land use planning processes is the only way to systematically influence the land use around FDF training areas. There are no efficient mechanisms to reduce noise levels from heavy weapons systems or fighter planes. Distance is the best preventing method. Municipalities are often keen to plan settlements too near of FDF training areas. Following of planning procedures and making statements on plans that threat our possibilities of training is perhaps the most important task of EP. Our goal is that all regional plans would include noise areas around FDF training areas It is important to supervise the more detailed planning also.

Reducing the Environmental impacts

Reducing the environmental impacts –chapter forms the core of EP in the FDF. The strategic goals are set to all areas of special interest that include 1) shooting and training activities, 2) life-cycle management of military materials, navy vessels, air force flight operations, garrisons' energy and material efficiency (including use of water, waste water) and remediation of contaminated sites (figure 1).

Example: Training areas

Training areas have been prioritized as to their essentiality to the FDF, their environmental vulnerability (noise, ground water, encroachment issues). New more extensive environmental base-line studies are currently being developed (in prioritized order starting from the sensitive ground water areas). On the basis of the base-line studies risk assessments are conducted and monitoring plus reporting practices enhanced (see figure 3). All shooting and training areas are noise mapped and noise curves will be given to planning authorities to have an impact on land use planning of the surrounding society. The army has developed a new outreach plan to reduce encroachment issues.

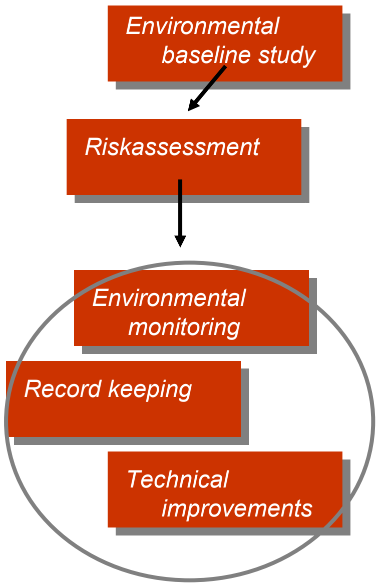

Figure 3. Systematically and coherently managed training areas

Example: Building comprehensive programs

The FDF has acknowledged that many environmental challenges can be most effectively tackled with comprehensive programs that systematically go through similar installations or procedures. Areas that have been recognized as suitable for such plans include shooting and training areas, shooting ranges, petrol stations, garrison land use plans, R&D EP plans, environmental reporting, Climate change and energy efficiency program, program to reduce naval impacts to Baltic Sea and Environmental protection education plan.

Conclusion

The strategic EP plan of the FDF has filled an important planning gap between environmental policy and grass root level EP actions. Already after two years of existence the plan has significantly helped to secure sufficient financing for EP and added cost efficiency and overall efficiency of the branch. Systematic approach to improving installations by renewal programs has standardized procedures and accelerated steps forward in making the defence sector more sustainable.

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CLIMATE CHANGE IMPACTS AND ADAPTATION OF DEFENCE INSTALLATION AND FACILITIES - DEVELOPMENT OF A STRATEGIC PLANNING DECISION-MAKING TOOL FOR THE SWEDISH FORTIFICATIONS AGENCY

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The Swedish Fortifications Agency (FortV) manages property comprising defense installations, buildings and land all over Sweden, also including those of cultural historical value. Defense installations and facilities need to be managed and geographically located in such a way that disturbances are minimized and all types of military activities can be securely performed all days year-round. In addition, interactions with the surrounding communities and environment also need to be taken into account where neither defense activities are to harm the surroundings or vice versa. Thus ensuring sustainability should be in focus when continuous procedures in the long-term are coupled with resilience for maintaining operations in the case of short-term shocks and disturbances. Considering climate change impacts on the natural and built environment requirements of knowledgeable adaptation planning should then naturally be a priority. For defense facilities, sustainability then becomes the ability to function well for today's assignments as well as those that may be assigned in the future. It also includes the ability to maintain and enhance those natural resources and the built environment that are the sources of the capability to operate today, as well as 100 or more years into the future. However, as the effects of climate change increase the risk for damage and reduced abilities to function the needs for investments and strategic planning thus poses great challenges and possibly costly threats to defense facilities.

In order to prepare for these changes the Swedish Fortifications Agency has made it a priority to understand the effects of climate change on both fixed installations and land as changes to environmental resources and man-made infrastructure intensify. Naturally there are relationships among climate adaptation and mitigation strategies, energy management, greenhouse gas (GHG) reduction, energy efficiency for built infrastructure, resource conservation, community interactions, and environmental stewardship all acting together at an installation. This paper however focuses on the work being done on climate change impacts for adaptation planning.

For the FortV the goal is to become resilient to the potential impacts of climate change. Accordingly the Swedish Defence Research Agency (FOI) has been tasked with the development of a strategic framework and planning tool to identify critical climate change related issues in various geographical locations that need to be considered in FortV's adaptation planning. This paper briefly summarizes the ongoing work being carried out by that aims to increase FortV's adaptive capacity through developing a decision-support model or tool that identifies critical climate-related issues, sensitive to the type of defense installation and geographical location.

The Såtenäs area where the Skaraborg Wing, F 7, is based is used as a pilot study area. The issues of concern here include for example future changes in; flooding and landslides, thawing and pollution, wind and precipitation patterns, disturbances in technical infrastructure and damages and subsequent impacts on buildings. These issues are also coupled with other natural and socio-economic changes occurring in the surrounding region which the tool aims to include and take into consideration.

Climate change effects and climate adaptation

Are identified land planning options, strategic investments and liquidations still valid alternatives in a future with a changing climate? Climate change effects can lead to alterations in natural systems with direct effects on infrastructure, buildings and installations as well as societies and human behaviour. Differences between Swedish regions with respect to climate change impacts and the consequences of these impacts for local communities are expected to be significant (Juhola et al. 2012). Also, the scientific knowledge is limited in regard to interactions and critical levels, especially regarding the specificities of defense installations and facilities. However, assuming certain climate scenarios, predictions could be developed and assessments made with a varying degree of accuracy.

Climate adaptation research

Considering the description of the problem above, climate adaptation options are clearly important to develop but in regard to this issue the literature is very limited. Most climate adaptation research has so far focused on sectors, municipalities, regions and countries but when it comes to the military and the defense sector it is mainly aspects of climate change coupled to national security that has been investigated. Also, adaptation research and policy has typically been organized by economic sector: agriculture, water resources, transportation, health, tourism, and so on (Simonsson et al. 2011). In for example Såtenäs, all these and other sectors interact in a relatively small area, made up of heterogeneous units, to create a system that cannot be understood and managed by analyzing and addressing sector processes alone.

There are a few studies that have been carried out on climate adaptation of military installations and facilities (see e.g. Smith et al. 2010). However there seems to be a knowledge gap on climate change impacts on defense activities and adaptation processes within the military sector, and especially the interactions with the civil society.

Adaptive capacity and climate change adaptation

Climate adaptation is seen as interrelated with adaptive capacity and vulnerability, where vulnerability is the function of a system's exposure, sensitivity and adaptive capacity (IPCC 2007). Adaptive capacity refers to "*the ability or potential of a system to respond successfully to climate variability and change*". Similar to many developed countries, Sweden is assessed as having a high adaptive capacity to climate change; in fact, the Scandinavian countries rank highest in a global comparison (O'Brien et al. 2004; Yohe et al. 2006). However these types of indices are often based on only a few measurable parameters intended to represent socio-economy, access to education and information, and technological development. As is often the case with such indices they mask differences and local conditions within nations. In practice, the options for implementing adaptation measures depends on technical and organizational capacity, which defines the availability of adaptation options (Berkhout et al. 2006), as well as legal, economic, cultural and knowledge factors (Arnell & Delaney 2006).

Adaptation therefore takes place at a number of scales from the local and individual to the global level and can be driven and initiated top-down by public agencies or bottom-up by private actors, or in combination of both (Adger et al. 2009; Berkhout 2012; Füssel 2007; Patt 2009). Adaptation may thus also be constrained both by perceived and actual adaptive capacity (Grothmann & Patt 2005). The Intergovernmental Panel on Climate Change (IPCC) and other studies point to a number of barriers to implementing adaptation, including inabilities of natural systems to adapt to the rate and magnitude to of climate change, as well as environmental, economic, informational, social, attitudinal and behavioural constraints (see e.g. Simonsson et al. 2011, André & Simonsson 2013, IPCC 2007).

Climate change adaptation in the Swedish society

The aftermath of the storm Gudrun in southern Sweden in 2005 led to the initiation of the Swedish Commission on Climate and Vulnerability (hereafter referred to as the "*Commission*"). Together with other national and international events and publications on climate change and climate risk (e.g. the Fourth Assessment Report by IPCC and the Stern Review), the Commission introduced and emphasized the need for adaptation to occur alongside mitigation, the latter of which hitherto had been the main focus for Sweden's climate debate. The Commission consulted with a wide range of different actors within Swedish society to produce the comprehensive report Sweden facing climate change – threats and opportunities (SOU 2007:60).

The main conclusion from the Commission was that "*It is necessary to make a start on adapting to climate changes in Sweden. The principal features of the climate scenarios, despite uncertainties, are sufficiently robust to be used as a basis*". (SOU 2007:60, p. 11) The Commission placed particular emphasis on the increased risks of flooding and landslides with severe implications for the built environment and infrastructure. It also suggested that municipalities and County Administrative Boards take on additional responsibilities. Accordingly the County Administrative Boards, the supervisory authority at the regional level, are now responsible for coordination and reporting on the progress of climate adaptation within each county, both at the regional and local level (Prop. 2008/09:162).

The legislation relevant to adaptation among actors in Sweden primarily concerns spatial planning and analyzing risks and vulnerabilities and preparing for accidents and extreme events. There is no single overarching national authority responsible for climate change but a number of national authorities have supporting functions for adaptation. The orientation of the work by national agencies in relation to adaptation is determined by the instructions issued by the government.

How does climate change adaptation come about?

Adaptation processes are not straightforward as for example the reasoning that climate adaptation is reasoned to become realized through first awareness, then concern which then leads to the formulation of an adaptation policy (c.f. Berkhout 2012). Adger et al. (2009) states: "*Adaptation is an imperfect process driven by our limited understanding and ability to act*". Organizations and individuals may therefore be limited by factors such as variations in risk perceptions, the long-term and distant nature of climate change, problems of linking current and past experiences with future events, lack of knowledge of climate change impacts, and difficulty in assessing and implementing adaptation options. Also, as noted in Rudberg et al. (2012), there will be options that are more or less feasible and attractive than others. This is very pronounced in the defense context as already mentioned, there are severe safety, security, political, economic and practical issues to consider when it comes to defense installations and facilities.

It is therefore crucial that the understanding of climate change impacts and adaptation options is specific enough to allow for decisions to be made. Although a certain level of uncertainty always will persist, planners and managers should be equipped with actionable information in a form they can readily access and use if they are to be able to respond appropriately and in a timely manner to climate change challenges.

Methods and approaches to assessments for climate adaptation planning

Climate change impact assessment characteristically poses the question: *"If the climate changes what will its impacts be on a given exposure unit?"* It presumes some kind of causal relationship between climate and the system exposed. Several broad categories of climate change impact assessment can be identified, each involving the deployment of methods and tools drawn from a formidable and ever-expanding range of options.

In order to make the assessment useful for adaptation and decision-making it is however important to start by discussing and decide upon the following issues:

Delimitations and goals

- What will the work lead to?
- What types of decisions will the work act as a basis for?
- What quality requirements are needed for the analysis?
- What interfaces and limits need to be taken into account for end-users and connected systems?
- What endpoints or perspectives are to be taken into consideration (e.g. humans, environment, economy, property owner, national security)?
- What are the time horizons of interest?
- What phases of the productive activities need to be considered?
- Who are the stakeholders and who are suitable participants in the work?
- What criteria should the identified risks be assessed according to?
- What levels of details, methods and limitations should be chosen so that the results of the analysis can be related to the chosen criteria?

Ambition and aim for climate assessments and identification of related risks

- Completeness
- Knowledge-based (earlier experiences and scientific results are considered)
- Multi-disciplinary
- Transparent and easy to examine (well-documented process)
- Structured
- Effective (should focus on the important and critical issues)

The concept of risk requires that we know of an event that has not yet occurred, and that we more or less have to predict future events. Climate risks are inter- and multidisciplinary by nature, and depending on what scientific discipline or approach that is interpreting the risk it can be assessed and valued differently. Facts and assessments are therefore often intimately intertwined which does not mean that we cannot, or should not, make the distinction. It rather implies that valuing and assessments should be made explicit to increase transparency and allow for an opening of the discussion of who should use it and how weighting can be applied. It is therefore important to try to avoid misinterpretations and difficulties in communication why collaboration between scientists and end-users is crucial.

Development of a climate adaptation decision-making tool for the FortV

In 2010 FortV tasked the consultancy firm Tyréns with the work to develop a model that identifies what municipalities are better suited for defense installations in the future which could act as a basis for strategic decisions on primarily ministerial level. The model includes components such as access to housing and commercial buildings, available land, real estate market, labour market, infrastructure development, and regional and local development planning. These components are analyzed departing from background statistics and information. Thus it not very future-oriented but gives a good indication on critical aspects of the situation today and in the very near future. Moreover, three different perspectives can be applied; property owner (FortV), user (Swedish Armed Forces) and societal (municipalities).

The structure of the resulting model has been applied also in this work as we see the two as complementing each other and as a suitable interface that can be connected to the end-users systems. In addition, the original model provides an important wider socio-economic context to the climate impact assessment and adaptation tool presented here. This tool is focusing on expected future climate changes, and the effects and impacts that need to be considered from the property owner's perspective (however, it would be possible to apply the other perspectives too). But it is of course difficult, and not wanted to a certain degree, to disregard the user perspective here as the facilities and installations serve very specific (military) purposes.

The ideas presented here are work in progress but we have structured the 'climate assessment tool' as shown in figure 1 where the ten components capture the main issues of most critical importance for the FortV in its adaptation planning. The identification of these ten components are based on knowledge on climate change and its expected impacts departing from a property owner's and defense installation angle.

Analyses and information of some components (colored green in the figure 1) are a prerequisite to allow for assessments of impacts on installations and facilities and supporting systems (colored lilac in the figure 1). As indicated in the figure 1, hazard maps (boxes with red borders) using geographical information systems (GIS) could be developed for certain components.

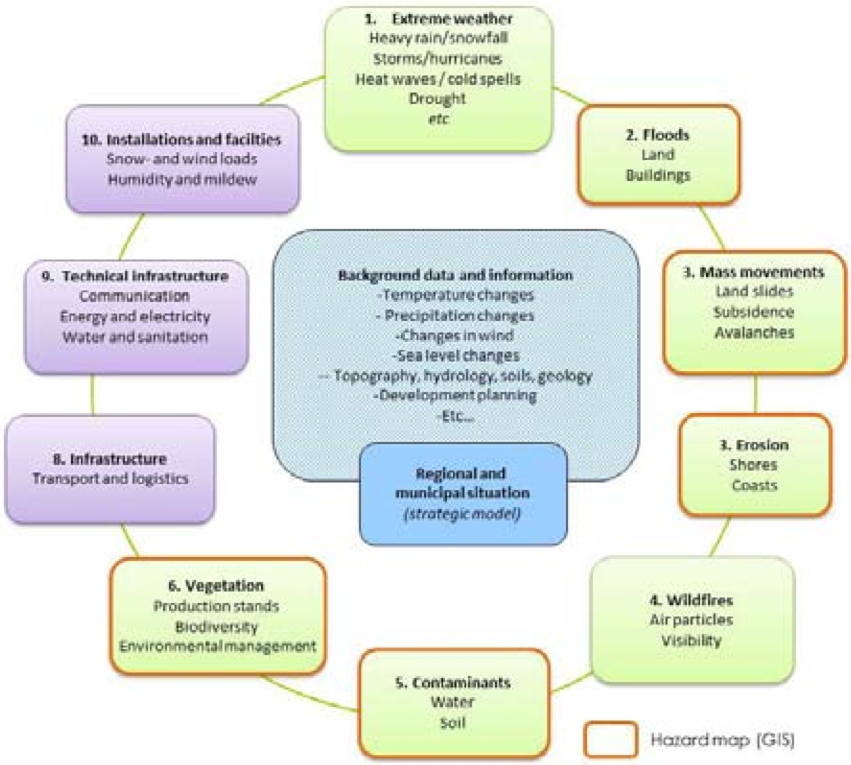

Figure 1. Framework and tool for identification and assessment of critical climate related issues to consider in strategic planning and climate adaptation for property owners of defense installations and facilities

Each box has an underlying excel file that explains what main factors need to be considered in order to assess the component as '*very critical*', '*critical*', or '*not so critical*'. In order to reach that final assessment the factors are analyzed departing from existing scientific knowledge and the experience of end-users that result in a score. Different time intervals and climate scenarios are applied which is importance to adaptation planning and prioritization. The scores are weighted to allow for specific circumstances at the various locations. The tool is made transparent in this manner where it is easy to see the sources of the information and how the weighting has been performed. There is also a short clarification of why and how the issue matters and comments to the results are provided.

The section below present an example of some preliminary work related to the pilot study.

Skaraborg Wing at Såtenäs as a pilot case study

Såtenäs is a small community in the southwestern part of Sweden (see figure 2) where the Skaraborg Wing, F 7, is located, and where about 1,000 people are employed (military and civilian personnel). The Wing is responsible for the production of three Gripen divisions and for the training of all the Air Force's Gripen pilots. The Wing is also the home base for all of the Air Force's eight TP 84 Hercules transport aircraft, often used for international missions.

Figure 2. (a) Location of the pilot case study area, (b) Jas Gripen taking off from Såtenäs (From the Swedish Armed Forces media photos archive)

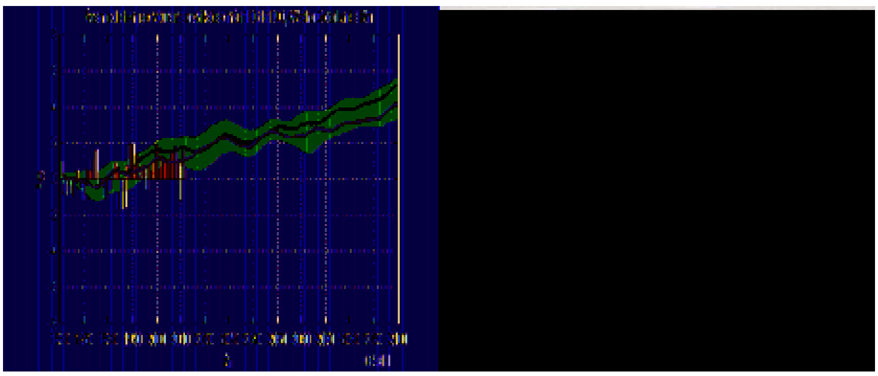

Figure 3. Estimated change (°C) of the yearly mean temperature 1961-2100 in the Västra Götaland County compared to the normal (mean value for the years 1961-1990). The bars shows historical data where red indicate temperatures above the normal and blue lower than the normal. The lines show neutralized 10- year-man values from climate scenarios. The pink line corresponds to emission scenario B2 and the turquoise corresponds to emission scenario A2. (From SMHI)

Figure 2 shows the location of Såtenäs which is situated in Västra Götaland County on the shore of Sweden's largest lake, Lake Vänern, which has been identified as very prone to floodings in the future due to climate change. The Swedish Meteorological and Hydrological Institute (SMHI 2011) has performed climate modeling of the area. It shows a successive increase of yearly mean temperatures during this century (about 4-6 °C higher towards 2100 compared to today's climate) (see figure 3) with the greatest changes expected during wintertime. Consequently snow will decline substantially, and the length of time when the ground has a snow cover will decrease with about one month at around 2050. The depth of ground frost will also become reduced. The yearly mean precipitation will increase with about 10-30 % at the end of the century, also with the greatest increase during wintertime. Moreover, heavy rainfall events are expected to intensify in the future. Accordingly, water flows will become altered, including groundwater flows.

Assessment of Contaminants in a future climate for Såtenäs (component 5)

In areas of military activities there are often a great deal of contaminants in both ground and water. Contaminant behavior such as transport and degradation is of crucial concern for development planning and management of land. But assessments of the pollution levels and behavior of today will probably not be valid in the future.

Based on existing research the following assumptions can be made for Såtenäs:

- Differences between the highest and lowest groundwater levels are in most cases small which is due to the prognosis of more rain than snow in the future
- Changes in the unsaturated/saturated zones is not expected to affect groundwater quality
- Higher flows could affect ground water quality negatively
- More precipitation and more intensive rains will lead to larger volumes of water that is to be drained away from manmade hard surfaces
- This implies a higher risk of flooding and overflow of sewage
- This in turn leads to an increased risk of chemical and biological contamination, for example in wells with drinking water.

In short it has been shown that climate models and scenarios regarding seasonal variation in groundwater levels demonstrate small but clear changes (Aastrup et al. 2012). The same is true for the greater part of chemical parameters: dilution of decomposition compounds at rising groundwater levels; alkalinity; mercury (Hg) and copper (Cu) increases and decreases at rising and diminishing ground water levels respectively.

This leads to a more detailed analysis of crucial factors as shown in table 1. This analysis will then be used for the final risk assessment.

Concluding remarks

- The climate impact assessment tool presented here could be used as an effective basis for discussions and well-informed adaptation decisions to avoid costly and unwise investments and localizations of defense installations and facilities.
- This work still needs to be complemented with end-user perspectives and in-depth knowledge on the systems they are managing.
- If climate adaptation planning and action is taken serious and prioritized the Swedish Fortifications Agency and the Swedish Armed Forces will become more resilient to climate change impacts and effects.

Table 1. Distribution of contaminants in water and soil in a future climate

(↑ =increase, ↓ =decrease, –=unaltered)

	Assessed change	Contaminant transportation	Mobilization of metals	Corrosion
Fluctuation of groundwater surface	↑	↑	↑	↑
Depth of groundwater surface Jan-April	↓	n/a	HgCu ↓	n/a
Depth of groundwater surface May-Oct	↑	n/a	HgCu ↑	n/a
Depth of groundwater surface Nov-Dec	-	n/a	n/a	n/a
Infiltration	↑	↑	n/a	n/a
Period of ground frost	↓	n/a	n/a	n/a
Depth of ground frost	↓	n/a	n/a	n/a
Surface drainage/floodings	↑	↑	↑	
Soil temperature	↑	n/a	n/a	n/a
Soil moisture	↓	n/a	n/a	n/a

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This book summarises the outcomes of the first European Conference of Defence and the Environment. It includes useful information for anyone working with environmental issues of defence: the authorities, stakeholders and policy planners.

The book is divided into thematic chapters that help to find relevant information intresting to the reader.

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