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"DEF*NET* and European Union Law – a road towards defence sustainability?"

2015 is an appropriate year to take stock of the European Union (EU) environmental policy. Indeed, there is a new Commission in place, a new State of environment report (SOER) - a report published every five years by the European Environment Agency - and possibly a new climate agreement at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC). Besides, 2015 will also be the year of the 20th Plenary meeting of the DEF*NET* (Copenhagen, 28-29 October).

The DEF*NET* is an informal network of environmental and energy focal-points and specialists from the Ministries of Defence (MoD's) of the EU which exists since 2001. Therefore for the DEF*NET*, it is interesting to try and assess the evolution of EU law in domains where the state of environment is particularly worrying according to SOER and to discuss possible impacts on Defence.

I. Defence and EU environmental law – benefits of the DEF*NET*

Since 1972 and especially since 1986, the global trend is that all EU policies are more and more involved with environment. This issue is integrated at the highest legal level, in the Treaty on the functioning of the European Union (TFEU) at the article 11: *"Environmental protection requirements must be integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development"*. This "horizontal clause" means that all EU laws have to take account of their impact on environment. The provision of article 11 TFEU about environmental protection « *emphasizes the fundamental nature of that objective and its extension across the range of [the Community] policies and activities* »[1].

Moreover, a European Commissioner for Climate Action was created in 2010, which is a signal of the importance of the environment policy in the EU. The first commissioner was Connie Hedegaard and the actual commissioner for Climate Action and Energy is Miguel Arias Cañete.

History of EU environmental law – short overview	
1972	1st Environment Action Programme;
1986	Single European Act: Environment becomes a community policy;
1992	Maastricht Treaty: Environment policy moves to co-decision process;
1997	Amsterdam Treaty: Sustainability development principle is integrated to objectives of the Communities;
2009	Lisbon Treaty new objective: Promotion of measures at international level (especially climate change).

In this context, defence activities have to take environmental protection issues into account. That is why the DEF*NET* was created. It represents a channel between EU law and defence administrations.

[1] Court of Justice of the European Communities, case C-320/03, Commission vs. Austria, 2005: point 73.

What is the DEF*NET?*

The DEF*NET* network helps MoD's to ensure that defence activities are taken into account during the EU environmental and energy law making process and implementation. This is achieved through exchange of technical information to share solutions to environmental and energy problems, so as to improve MoD's performance on that topics.

It contributes to improve the implementability of EU legislation through exchanges between EU institutions and MoD's. The DEF*NET* also acts as a defence stakeholder, developing and working to develop close contacts with EU institutions, especially with the European Commission.

How does the DEF*NET* work?

First, the specificity of defence activities leads the network to discuss Commission proposals on many environmental topics and to adopt a DEF*NET* consensual position. If the position is to ask for changes in a Commission's proposal, then each MoD would try to back the DEF*NET* position at its national level so that the Council of the EU takes the request into account and convinces the European Parliament that the changes are necessary.

Some contributions of the DEFNET

The DEF*NET* has managed to obtain some defence adaptations or exemptions in specific EU regulations. It was the case for instance in the ship recycling regulation, which translates the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships into EU law. Another example is the action of the network in the elaboration of an ozone regulation modification: the DEF*NET*, acting as a direct interlocutor to the Commission, negotiated deadlines for all EU Member States MoD's with regards to the critical uses of halons, in order to better fit the regulation with the possibilities of the defence sector.

Examples of EU law where DEF*NET has been involved*

SUBSTANCES:	REACH regulation (1907/2006/EC)
WATER:	Marine Strategy Framework directive (2008/56/EC)
AIR:	Ozone regulation - critical uses of halons (744/2010/EU)
ENERGY:	Energy efficiency directive (2012/27/EU)
WASTES:	Ship recycling regulation (1257/2013/EU)

II. Framework for the future of EU environmental law

The general legal framework of future EU environmental law is determined by the 7th Environment Action Program (EAP)[2]. It sets priority objectives for 2020 and establishes a vision for the year 2050. The first three priority objectives are as follows:

- « *to protect, conserve and enhance the Union's natural capital;*
- *to turn the Union into a resource-efficient, green and competitive low-carbon economy;*

[2] Decision n° 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet'.

- *to safeguard the Union's citizens from environment-related pressures and risks to health and well-being;* »

The annex of the decision details thematic priorities. For instance about horizontal chemicals legislation, it states that « *efforts need to be stepped up to ensure that, by 2020, all relevant substances of very high concern, including substances with endocrine-disrupting properties, are placed on the REACH candidate list*. ». This list contains candidates to an authorization regime of the REACH regulation.

Beyond this general legal framework, two other elements should contribute to the future legislative proposals of the Commission about environmental protection.

From the political area, the European Council conclusions on environmental matter are likely to play a great role, such as for the energy/climate policy and the legal objective for greenhouse gas (GHG) emissions which will be mentioned below. These conclusions establish an EU position based on important communications from the Commission. They are a political impulse that is very important to be considered because it sets political goals, sometimes legally binding.

From the scientific domain, the 2015 State of Environment Report (SOER 2015) from the European Environment Agency (EEA) should contribute to determine the action of the new environment commissioner. It is also an obligation of the Commission to monitor the implementation of 7th EAP in link with EEA's indicators on the state of environment (art. 4 of 7th EAP decision). According to SOER 2015, the actions needed should be focused on the three following key domains[3]:

- Natural capital: where « *loss of soil functions, land degradation and climate change remain major concerns* ».
- Resource efficiency and low carbon society, where it "*remains to be seen whether all improvements will be sustained*"; (the improvements have been on GHG emissions, fossil fuel use, pollutant emissions and quantity and recycling of wastes).
- Environmental risks to health where despite some improvements on drinking, bathing water and air quality, « *air and noise pollution continue to cause serious health impacts [...]"* as does also the growing use of chemicals.

[3] SOER 2015 suggests a different management of environmental issues : implementation, integration and coherence of existing policies, investments, strategic innovation, improvement of the knowledge base.

	5–10 year trends	20+ years outlook	Progress to policy targets	Read more in Section ...
Protecting, conserving and enhancing natural capital				
Terrestrial and freshwater biodiversity			☐	3.3
Land use and soil functions			No target	3.4
Ecological status of freshwater bodies			☒	3.5
Water quality and nutrient loading			☐	3.6
Air pollution and its ecosystem impacts			☐	3.7
Marine and coastal biodiversity			☒	3.8
Climate change impacts on ecosystems			No target	3.9
Resource efficiency and the low-carbon economy				
Material resource efficiency and material use			No target	4.3
Waste management			☐	4.4
Greenhouse gas emissions and climate change mitigation			☑/☒	4.5
Energy consumption and fossil fuel use			☑	4.6
Transport demand and related environmental impacts			☐	4.7
Industrial pollution to air, soil and water			☐	4.8
Water use and water quantity stress			☒	4.9
Safeguarding from environmental risks to health				
Water pollution and related environmental health risks			☑/☐	5.4
Air pollution and related environmental health risks			☐	5.5
Noise pollution (especially in urban areas)		N.A.	☐	5.6
Urban systems and grey infrastructure			No target	5.7
Climate change and related environmental health risks			No target	5.8
Chemicals and related environmental health risks			☐/☒	5.9

An indicative summary of environmental trends
Source: SOER 2015[4].

The trends that are underlined in the SOER table above show that some themes will have a serious concern in a twenty year horizon. Three themes have been selected because of their possible impact on defence activities, but of course some other trends will continue to have an impact on defence, such as in the area of chemicals with the consequences of the REACH regulation, notably.

III. Focus on some environmental challenges that may impact defence

1) Climate change and energy

2015 is the year when the EU aims to reach a new international agreement on climate change at the COP21 in Paris. This agreement should be legally binding, applicable to all Parties, and implemented from 2020. "*The EU's contribution to the new agreement will be a binding, economy-wide, domestic greenhouse gas emissions reduction target of at least 40% by 2030*"[5]. This European commitment is based on the new EU climate and energy policy framework, adopted at the end of 2014.

[4] European Environment Agency, *The European Environment State and Outlook 2015 – Synthesis Report*, Copenhagen, 2015, p. 11.
[5] European Commission website, consulted in June 2015. (http://ec.europa.eu/clima/policies/international/negotiations/future/index_en.htm)

The Climate and energy policy framework

The EU's contribution on the upcoming UNFCCC's agreement is based on the climate and energy policy framework. The framework has been endorsed by the European Council as follows in October 2014[6]:

The threefold objective proposed by the Commission in the framework[7] has been maintained: greenhouse gases reduction, renewable energy sources share, energy efficiency improvement. The European Council has decided to make the EU level GHG objective legally binding and has indeed set the objective to 40% reduction compared to 1990 level. As a reminder, the EU commitment for 2020 is 20% reduction. For energy efficiency, the 27% improvement target is indicative, but it will be reviewed in 2020 at the latest, with the aim to set it to 30%. The Commission will propose priority sectors where important energy efficiency improvements can be obtained.

Energy Union

Besides the climate and energy policy framework, another framework has been proposed by the Commission and is being discussed by EU Member States and the European Parliament: namely the Energy Union. The Commission's proposal[8] contains five pillars, endorsed by the 19-20 March 2015 European Council conclusions: (i) energy security, solidarity and trust, (ii) a fully-integrated internal energy market, (iii) energy efficiency, (iv) decarbonisation of the economy and (v) research, innovation and competitiveness.

The Energy Union's communication contains a roadmap with different proposals, which will have concrete impacts on EU legislations.

Extract from the Roadmap for the Energy Union

- Energy efficiency directive review in 2016;
- Directive on Energy Performance of Buildings review in 2016;
- MRV for heavy duty vehicles in 2016-2017;
- Communication on decarbonizing the transport sector in 2017.

How could defence be impacted?

The impact on defence will of course notably depend on the content of the reviews envisaged, but the pressure should increase on defence activity[9]. The July 2014 communication on energy efficiency[10] proposed a more ambitious target of energy savings (30% for 2030) than in the framework for climate and energy policies communication (the Commission's proposal was 25%), with a view to improve energy security of the EU. Consequently, and even if the

[6] European Council, *Conclusions - 23/24 October 2014*.
[7] European Commission, *A policy framework for climate and energy in the period from 2020 to 2030*, COM(2014) 15 final, 22 January 2014.
[8] European Commission, *A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy*, COM(2015) 80 final, 25 February 2015.
[9] Defence activities are already impacted by current energy/climate policy at least at home, even if to a certain extent only (energy efficiency, renewables, fluorinated gases, etc.), but should be more and more impacted by these stronger objectives in the future.
[10] European Commission, *Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy*, COM(2014) 520 final, 23 July 2014.

30% objective was not endorsed by the European Council, energy efficiency is seen as a key topic for energy/climate policies. A review of the energy efficiency directive should be performed next year. Since energy efficiency concerns buildings of MoD's, the review could have consequences on defence.

However, the higher defence impacts should possibly be, in the end, on the mandatory decrease of GHG emissions of vehicles and on the use of more renewables in oil. Indeed, the armed forces heavily use fossil fuels for their activities and the transport sector is more and more under pressure for GHG emissions reduction. On this matter, the Energy Union roadmap provides that the communication on decarbonising the transport sector should include an "*action plan on second and third generation biofuels and other alternative, sustainable fuels*".

2) Biodiversity

The current state of biodiversity is reported to be poor: the 7th EAP recalls that "*only 17 % of species and habitats assessed under the Habitats Directive have favourable conservation status*". The future state is also worrying, according to SOER 2015: "*5–10 year trends: High proportion of protected species and habitats is in unfavorable Conditions*".

For the time being, a fitness check of the Nature directives[11] is being performed. According to the mission letter[12] of Mr. Vella, commissioner for Environment, Maritime Affairs and Fisheries, the purpose of this fitness check is "*to carry out an in-depth evaluation of the Birds and Habitats directives and assess the potential for merging them into a more modern piece of legislation*". This fitness check is managed by a consortium of consulting companies. The Commission has selected ten Member States, with which they run a detailed evaluation of the implementation of the directives. A presentation about the first outcomes of the fitness check should happen at the end of October.

The fitness check could result in a review of the Nature directives, while the level of ambition should stay the same: in case of a review, Frans Timmermans – the European Commission's First-Vice President in charge of "Better Regulation" – committed *"that any changes to the Birds and Habitats Directives would not lower environmental standards*"[13], while speaking at the European Green Week conference in Brussels in June 2015.

How defence is impacted?

The ongoing extension of Natura 2000 beyond territorial waters raises the questions of how it can be done without being a problem for defence activities, and which compensatory measures should and could be implemented in case of negative impact assessment of a plan or project with regards to nature conservation objectives (article 6 of 92/43/EEC directive).

[11] The so-called Nature directives are the 92/43/EEC directive on the conservation of natural habitats and of wild fauna and flora and the 2009/147/EC directive on the conservation of wild birds.

[12] Jean-Claude Juncker, President of the European Commission, *Mission letter – Karmenu Vella, Commissioner for Environment, Maritime Affairs and Fisheries*, 1 November 2014.

[13] EurActiv.com, 4 June 2015. (http://www.euractiv.com/sections/sustainable-dev/better-regulation-wont-hurt-environment-vows-timmermans-315114).

Moreover, if the Nature directives are merged into a new text, an easier implementation could derive, amongst other things, from the use of a single notion for sites. On the actual texts, there are special protected areas (2009/147/EC directive) and special areas of conservation (92/43/EEC directive). The Member States approximation could be simpler and so would be the appropriation by defence stakeholders.

3) <u>Soils</u>

The topic of soils is a global challenge ahead, not directly managed by EU law. 2015 was proclaimed as the "International Year of Soils" (IYS) at the 68th United Nations General Assembly. Indeed, soils provide ecosystemic services such as food, genetic resources and wood. There is a shared view that soils are being more and more degraded.

The area of soils is the last environmental aspect which does not have a specific legislative framework at the EU level yet. It is only covered by the 2004/35/EC directive on environmental responsibility and a thematic strategy[14]. The 2006 directive proposal[15] has not reached an agreement at the Council, and consequently the Commission withdrew its proposal in May 2014.

However, the 7th EAP provides that the question of soils should be addressed by the EU and its Member States. What is interesting is that the action on soils "*could be through a targeted and proportionate risk-based approach, within a binding legal framework*"[16]. A too much comprehensive approach could be avoided thanks to the target and proportion criteria. Therefore the Commission should concentrate on most important degradation processes, such as soil sealing, erosion, loss of organic matter, acidification, landslides and pollution.

<u>What's next?</u>
A cartography exercise of national legislations was started by the Commission in 2014, with a view to revise the strategy on soils. If a new directive is proposed, it could set common EU risk reduction targets, but let Member States the choice of the means to reach the targets. In parallel, the Commission is working on a communication on lands.

<u>What would be the impact on defence?</u>
The new directive proposal should probably contain objectives about polluted sites and soils. This could of course impact the defence sector with regards to military areas within the EU. But the possible impacts will depend on the strength and nature of the targets compared to already existing national legislations on that topic.

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The examples described here show that obviously, due to the current and future challenges of environment, the EU law should be reinforced in some areas, and completed in others, such as soil degradation.

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[14] Commission of the European Communities, *Thematic Strategy for Soil Protection*, COM(2006)231 final, 22 September 2006.
[15] Commission of the European Communities, *Proposal for a directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC*, COM(2006) 232 final, 22 September 2006.
[16] Decision n° 1386/2013/EU, annex, point 25.

For Ministries of Defence, it means that the monitoring of the upcoming EU law should continue in the coming years to assess their possibility to adapt. The DEF*NET* network should help in doing so. It is the core of its mission.

ENVIRONMENTAL NOISE AND RECONCILIATION OF INTERESTS

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Abstract

Environmental noise is one of the main local environmental problems in Europe. The number of residents exposed to military noise is rather small compared to transport noise, for example, and hereby the harmful effects of noise on human health and well-being are probably minor. However, the negative effects on comfort and constrains on land using and construction are prominent.

Noise reduction at the source is generally approved to be the most preferred abatement method. Limiting noise propagation by placing barriers between the source and people affected and protective measures at the receiver like superior sound insulation of building envelopes are common noise abatement means. These practises are, however, seldom technically appropriate and/or cost-efficient for heavy weapon shooting ranges.

Sufficient protection zones in land use plans are focal part of noise abatement of heavy weapon shooting ranges. Also the various economic and social measures aiming at reducing the impacts of shooting noise may be notable. The aim of this presentation is to provide an overview of the environmental noise and reconciliation of interests within heavy weapon shooting ranges.

1. Introduction

Sound is defined as noise on the basis of the adverse characteristics experienced by those exposed to it. The direct effects could be related to sleep, relaxation, performance and communication. Noise from heavy weapons, in the vicinity of the sound source, may also have direct physiological effects like causing damage to inner ear and hearing impairment. The direct impacts increase the level of annoyance causing stress, which in the long term may increase the risk of cardiac and respiratory disease [1]. Noise impairs the quality and comfort of the living environment and restricts land using and building and may reduce the value of real estate [2]. 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.

There are, generally speaking, several noise abatement instruments available in reducing detrimental effects of environmental noise such as:

- Noise reduction at the source by actions to noise source;
- Limiting noise propagation;
- Protecting the receiver by shielding of disturbed target;
- Sufficient protection zones in land use plans;

- Noise management controlling training activities;
- Social measures like management or treatment of the noise impacts; and
- Economic measures.

Only a few of these are technically appropriate and/or cost-efficient for heavy weapon shooting ranges. The reduction of noise emission of heavy weapons is usually inappropriate. The barriers, earth mounds or screens alongside the weapon should be sufficiently absorptive, massive, high and long enough to provide a reasonable vertical and horizontal overlap with the line of sight of the weapon and the exposed receiver points. At greater distances the screening potential may be low. The diffracted part of the emitted low frequency sound over the barrier may still propagate far and cause harm in noise sensitive areas. A noise screen of glass combined with gallery-type of structure where the screen forms the outer facades of the building is capable for substantial sound reduction. Construction costs may, however, be disappointing and the acoustic quality of the outside living areas stay most often still unsatisfactory.

Land use planning with sufficient protection zones, control of the training activities producing noise, management or treatment of noise impacts and economic and social measures are key means in mitigation of negative effects of heavy weapon shooting range noise.

Noise issues are often difficult to handle, because on the one hand, noise is often caused by important activities, but on the other hand, the detrimental impacts may be substantial. Also almost anyone can at times cause noise and be the one exposed to it. "Polluter pays" principle is notable starting point for noise abatement but will not necessarily lead in all cases to a most cost-effective outcome. Reconciliation of interests is essential when reducing the harmful impacts cost-effectively.

2. Land use planning and community development

Land use planning and community development work is often interdependent between each other's and therefore, the local authorities responsible for these tasks should work in close co-operation. The starting point for all these measures is that spatial separation is given full consideration at the local administration when imposing zoning policy. Land zoning and spatial separation should contain clearly defined noise abatement targets. Such a policy should contain at least following elements:

- Placing as much distance as possible between the noise source and the noise-sensitive activity;
- Placing noise-compatible activities such as parking space, open spaces and possibly commercial facilities between the noise source and the noise sensitive areas;
- Using the natural land and built form as barriers to screen sensitive areas;
- No housing is allowed within certain distance from the shooting range; and
- Apartments within adjacent zone have to have working sound insulation of building facade.

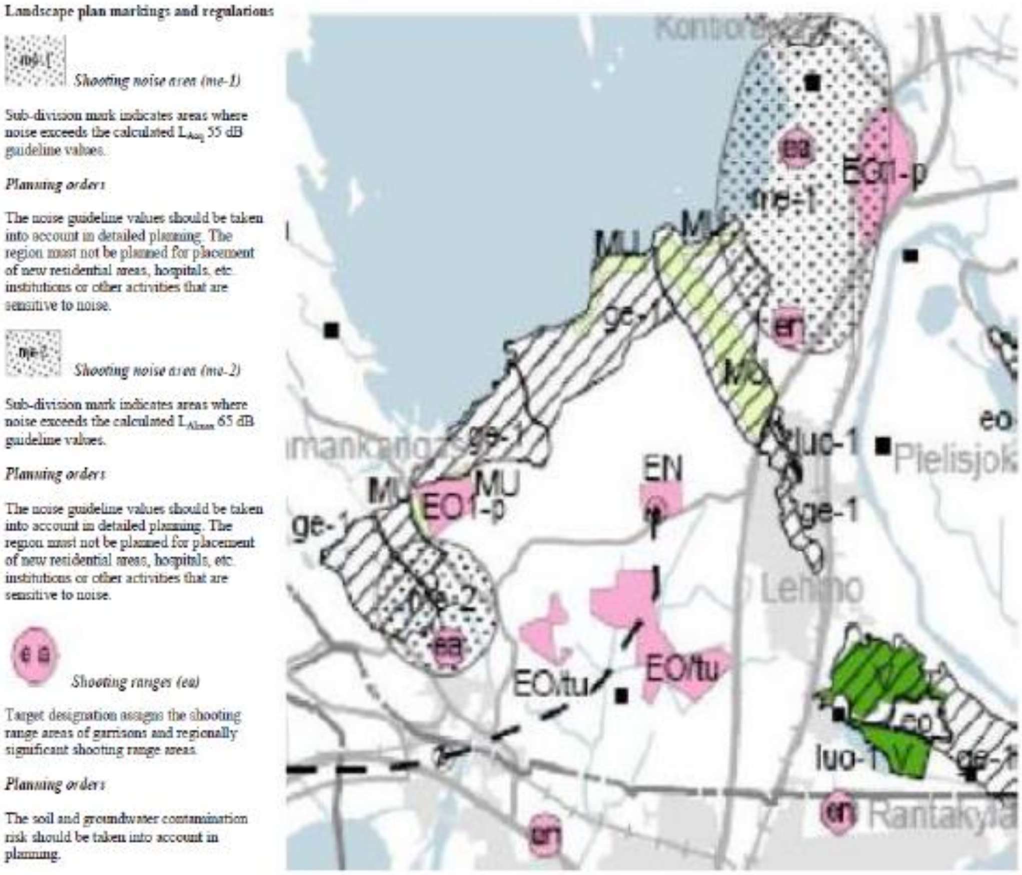

Figure 1. Example of the landscape plan markings and regulations for shooting range

Even though there is zoning policy with clearly defined noise abatement targets, the problem is often that there is not enough demand for noise compatible land use to afford adequate protection for every community. Moreover, the existing community structure and transport infrastructure set the limits for the spatial separation. The strip zoning may also not be compatible with other plans for the growth and development of the community.

3. Noise management controlling training activities

Development of training activities by taking into account the noise impacts can prove to be cost-effective noise management measure. In training activities noise may be taken into account at least the following ways paying attention to:

- Weather conditions - direction of wind, vertical velocity distribution of wind and vertical temperature distribution of air;
- Firing direction - taking into account sound radiation pattern of the weapon if available;
- Number of shots fired;
- Maximum noise level of single shot; and
- Trainings date and duration.

Weather conditions which are favourable to sound propagation should be avoided in shooting activities, if possible.

4. Social measures like management or treatment of the noise impacts

Social measures as non-economic incentives or measures are primarily used in connection with promoting awareness of the noise issue and providing information and training. Their function is to provide information, make regulations acceptable or to be an adjunct to policy implementation and enforcement of regulation. The aim is to reduce the noise nuisance. Such social measures are e.g. the following:

- Training and education of technical staff responsible for training activities;
- Training administrative people responsible for urban planning and zoning;
- Increasing public awareness, e.g. with the help of information and education, noise surveys, information of sound insulation; and
- Interaction.

Residents could be informed about the extent of the noise nuisance based on the emission (weapons used in training) and immission (weather conditions). Also about possible exceptional situations could be informed afterwards.

5. Economic measures

Economic and social measures rarely replace regulation or other measures. More often they supplement the other measures. The economic measures are decided and used at the national level, such as taxes or incentives. Some of the economic acts can be also introduced at the local level, e.g. noise compensations.

The adoption of various economic measures is in line with polluter-pays-principle when aiming at evaluating also the external costs what the environmental costs are. Economic instruments are also intended to provide funds needed to finance environmental protection measures, improve the application of direct regulations to which they are linked and stimulate technical innovation. There are several types of incentives and economic instruments used in connection with noise abatement:

- Economic incentives, such as grants and subsidies to promote development and use of quiet equipment;
- Charges on noise sources;
- Special taxes on noisy equipment; and
- Noise compensations, which are more like a financial penalty on those responsible for noise and re-addressing it to those suffering from noise.

In Denmark, for example, an erector of a wind turbine has a duty to pay compensation for loss of value of real property following the erection of the wind turbine. The size of the loss of value is determined by an appraisal authority. If a property loses more than 1 per cent in value due to the erection of new wind turbines, the owner is ensured full compensation for his loss. The owner of the property must notify his claim for compensation for loss of value [3].

6. Preparation of normative noise values for heavy weapons in Finland

Finnish Government resolution on environmental noise abatement from 2007 sets out the general objectives, targets and methods to reduce noise emission and the harmful effects they cause [4]. The resolution emphasises the importance of integrating noise abatement measures into the planning and implementation activities that cause noise in order to prevent noise problems and reduce existing disruptions and disturbances from noise emissions.

National working group (considering environmental hazards and special regulation, RAME) prepared 2012 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 [5]. One of the recommendations is a preparation of proposal for the Government Decision on the noise level values caused by heavy weapons. The work would be carried out by the end of 2016 and the Government Decision on the noise level values caused by heavy weapons could come into force in the beginning of 2017. The aim of the work is to draw up heavy weapons noise values taking into account their effects on health, the pleasantness of the living environment, the statutory duties of the Defense Forces and the economy.

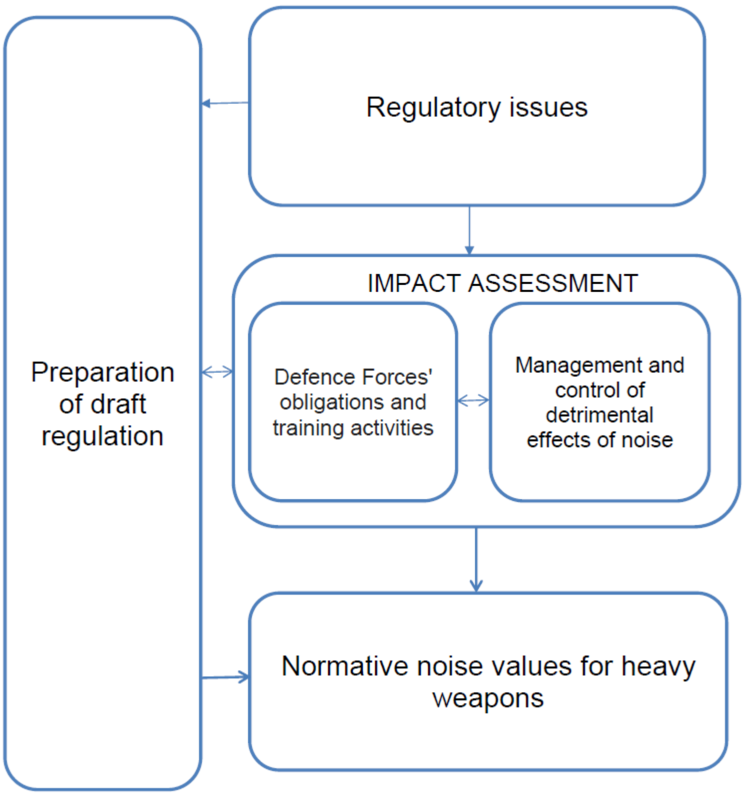

Figure 2. A block diagram of the work content

Table 1. Description (partial) of detailed work content

Regulatory issues	
Comparison of legislation in reference countries	Noise indicators Noise values and binding nature of them Planning systems (especially land use)
Legal Status	Fundamental rights, such as concerning the property and equality
Defence Forces' obligations and training activities	
Impacts of the noise regulation to the implementation of obligations	Exercises at day and night time Issues related to land use
Impacts of the noise regulation to cost-effectiveness	Line of actions Supervision
Management and control of detrimental effects of noise	
Noise abatement and noise impacts	Health, comfort Land use and building (Sound insulation of building envelope)
The noise dose-response relationships and special features of noise	Research results concerning dose-response relationships Identify the amount of sanction associated with the specific characteristics of noise
The noise calculation and measurement guidance	Calculation methods and its guidance Measurement guidelines
Noise zone configuration in land using	Land use planning Overall planning

7. Concluding remarks

In most practical situations the overall effect of controlling heavy weapon shooting range noise at source or limiting its propagation are not possible methods of control. One limited mean is the improved building design and sound insulation of property to minimise disturbance within buildings. The shape, orientation and location of the building and the arrangement of the internal spaces as well as appropriate sound insulation of construction parts should be chosen to reduce potential noise problems.

Noise abatement should be an integrated and focal part of land use planning of heavy weapon shooting ranges. Land use planning is generally a long process. It is aiming at solution lasting a long time, several decades. Time scale of land using means also uncertainties and difficulties concerning exact information on noise levels.

Because usual environmental noise abatement practises are seldom technically appropriate and/or cost-efficient for heavy weapon shooting ranges noise impact management actions must be taken into consideration across the board in all planning and implementation of training activities that generate noise. In addition to that social measures like management or treatment of the noise impacts are important. Interaction with the residents exposed to noise is important element in reducing adverse effects of noise. This would mean implementation of reconciliation of interests in practise.

Finnish Government resolution on environmental noise abatement sets out the general objectives, targets and methods to reduce noise emission and the harmful effects they cause. According to that resolution and the working group RAME proposals the aim of the civil service is to prepare a proposal for the Government Decision on the noise level values caused by heavy weapons by the end of 2016.

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FORSVARSMINISTERIETS EJENDOMSSTYRELSE

Noise Emission Data of Danish Heavy Weapons

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Abstract

Environmental noise caused by heavy weapons and explosives is an important parameter for the communities situated near the shooting areas. Weapons with caliber ≥12.7 mm and explosives are considered as heavy weapons in Denmark. The use of shooting areas is legislated by Executive Act 468 of 13 June 2002 of Danish Ministry of Environment about noise control of Defence Forces training and shooting areas. The objective is to ensure that new population centres are not built in noisy areas and that noise-sensitive activities are not situated in such areas.

In order to calculate the noise exposure around shooting areas, noise emission data should be provided as free field sound exposure level at a distance of 10 meter. These noise calculations are carried out using calculation software Milstøy ver. 2.5., which is the noise analysis tool used by Danish Defence to estimate the noise level near these areas. This tool takes as input an emission database, containing the source level relatively close to the weapon.

This paper presents the method used in measurement of sound exposure levels for the heavy weapons and how the noise emission data are used in Milstøy in order to calculate the noise exposure around the military training and shooting areas.

1. Introduction

This project is a part of work being conducted at the Danish Defence Estates and Infrastructure Organisation (FES) to recalculate the noise zones around the Danish shooting and training areas in order to revise Executive Act 468 of 13 June 2002 of Danish Ministry of Environment about noise control of Defence Forces training and shooting areas.

The work conducted by FES in cooperation with Grontmij A/S. The shootings are conducted by the Army Battle School, Artillery School, Engineer Regiment and Navy Center for Weapons.

Currently FES uses the calculation software MILSTØY to calculate the noise propagation in the linear zone. Milstøy is developed by SINTEF IKT for FES and the Norwegian Defence Estates Agency (FB). Milstøy use an emission database as input, giving source data at the start of the linear zone. This database is based on results of measurements. The Danish heavy weapons, which are included in the Milstøy emission database, are relatively small and most of them are currently phased out. Therefore the Danish Defence has the need to measure the source data for the heavy weapons used in the shooting and training areas.

This paper describes the method used in the measurements, and data analysis. Today there is no standard method to measure the sound exposure levels from heavy weapons. An attempt to do a standard method is described in [1].

Noise propagation codes often take free field source data as input to calculate the effect of different types of ground conditions along the propagation path. For the heavy weapons it is not possible to measure the free field sound pressure. This means that free field source data have to be calculated from the sound pressure measured to the ground. In this project this is done by first measuring a reference source to estimate the influence of the ground and weather for different frequencies. The reference source is different charges of TNT depending on the size of weapon caliber, in order to have data describing a free field detonation. Finally the resulting ground correction is added to the measured data for the heavy weapons to produce the free field emission data.

2. Weapon and Ammunition

The measured weapons with their ammunitions are shown in Figure 1Figure **14**.

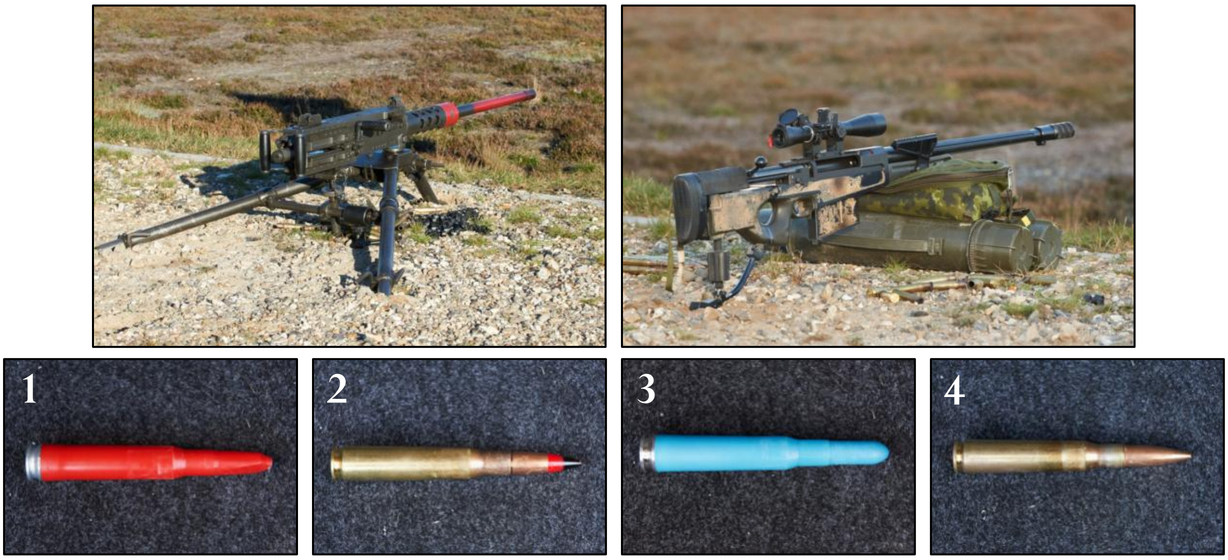


Figure 1: 12.7 mm Machine Gun and 12.7 mm Anti-material Rifle with different ammunitions. (1) 12.7 mm Cartridge, Blank, (2) 12.7 mm Cartridge, Armor-Piercing, Tracer, (3) 12.7 mm Cartridge, Blue, (4) 12.7 mm Cartridge, ball.

**Figure 2: 35 mm Bushmaster Cannon on Combat Vehicle CV9035 with different ammunitions.
(1) 35 mm X 228 APDS, (2) 35 mm X 228 HEI-T, (3) 35 mm X 228 KETF,
(4) 35 mm X 228 TP-T (DM18), (5) 35 mm X 228 TPFDS-T.**

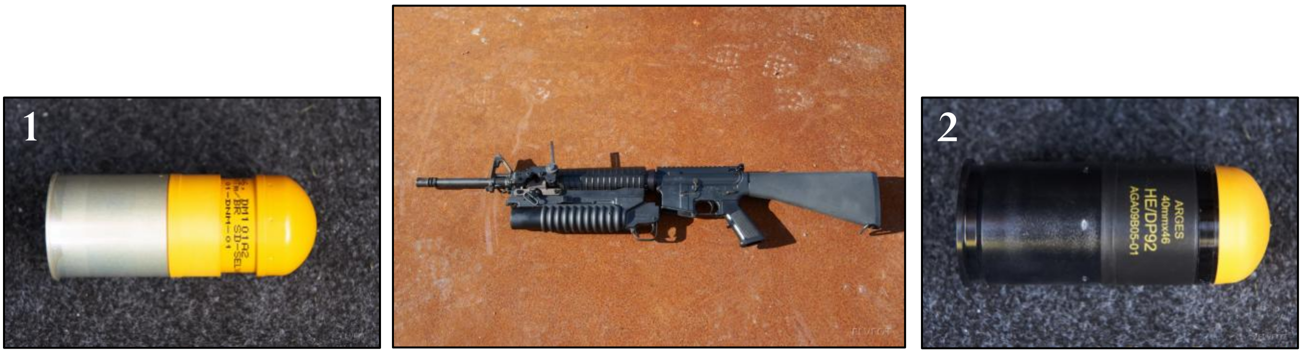


**Figure 3: 40 mm Grenade Launcher with different ammunitions.
(1) 40 mm High Explosive (HE), (2) 40 mm High Explosive Dual Purpose (HEDP).**

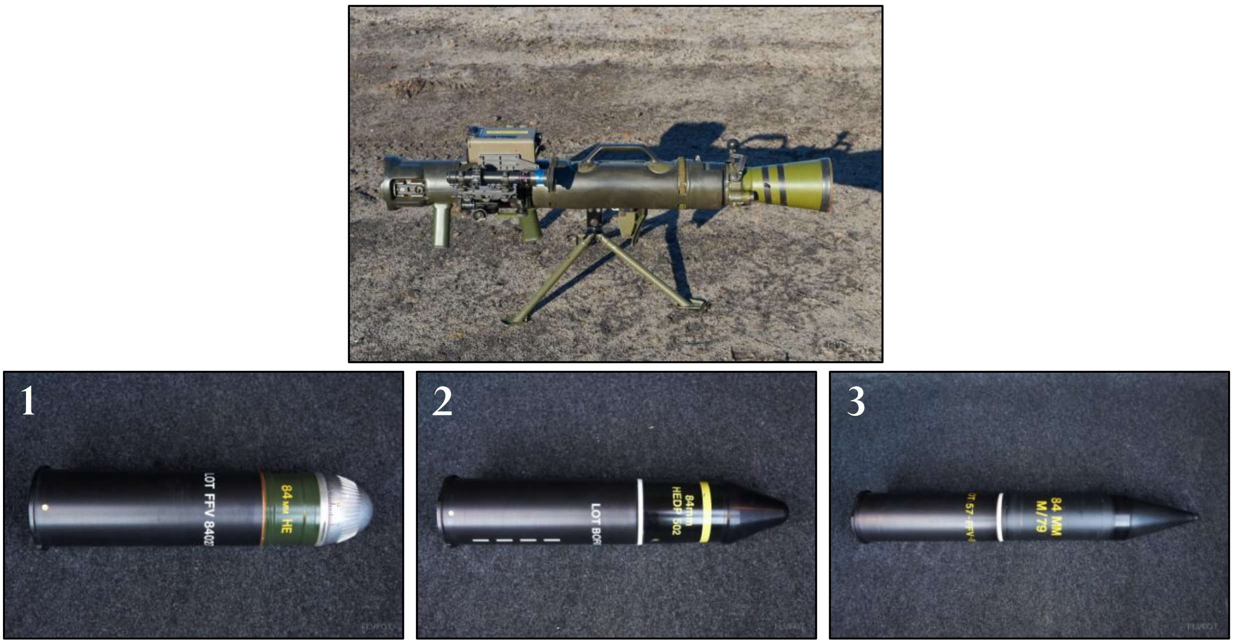


**Figure 4: 84 mm Carl Gustav Recoilless Rifle with different ammunitions.
(1) 84 mm High Explosive (HE), (2) 84 mm High Explosive Dual Purpose (HEDP),
(3) 84 mm Tandem-warhead HEAT.**

Figure 5: 84 mm AT4.

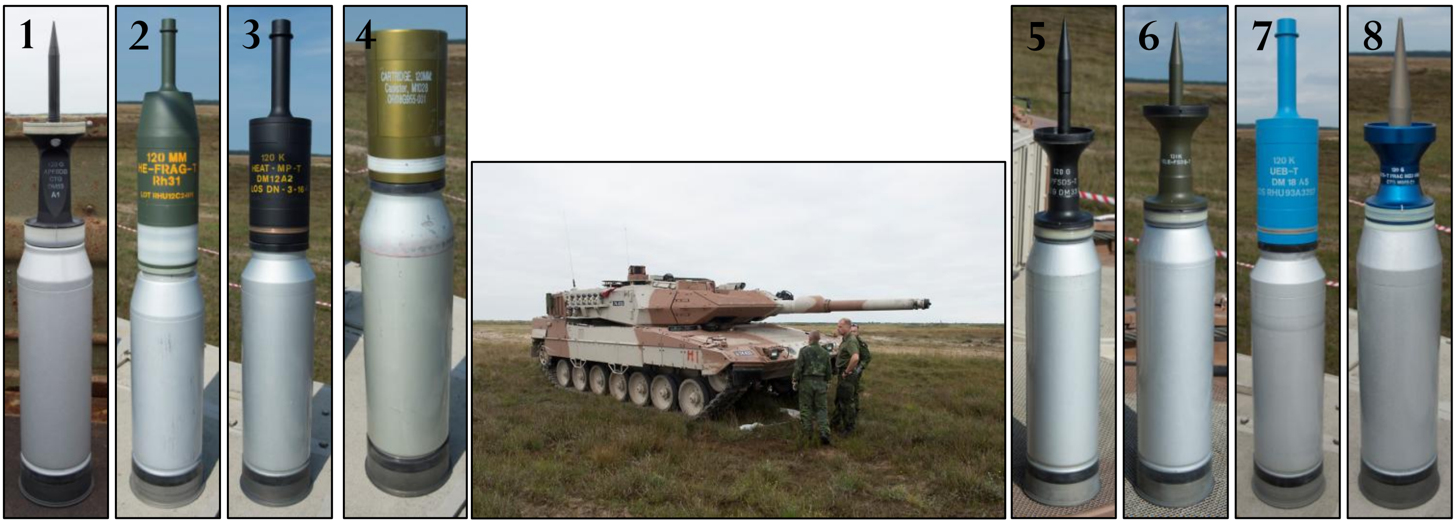


Figure 6: 120 mm Rheinmetall L55 Smoothbore Gun on Leopard 2 A5 with different ammunitions.
(1) 120 mm DM53A1, (2) 120 mm HE-FRAG-T, (3) 120 mm HEAT-T DM12A2,
(4) 120 mm M1028 CANISTER, (5) 120 mm PPT FS DM33 LS, (6) 120 mm PPT FS DM33 PELE,
(7) 120 mm ØGRPT DM18, (8) 120 mm ØPT CS M865 C1.

Figure 7: 60 mm Lightweight and Commando Mortar with different ammunitions.
(1) 60 mm High Explosive (HE), (2) 60 mm High Explosive, PF IM, (3) 60 mm Illumination, H,
(4) 60 mm Smoke Cartridge, (5) 60 mm Infrared Illumination.

Figure 8: 81 mm Mediumweight Mortar with 81 mm High Explosive (HE).

Figure 9: 120 mm Heavyweight Mortar with 120 mm High Explosive (HE).

Figure 10: 155 mm Selv-propelled Howitzer M109A3 with 155 mm High Explosive (HE).

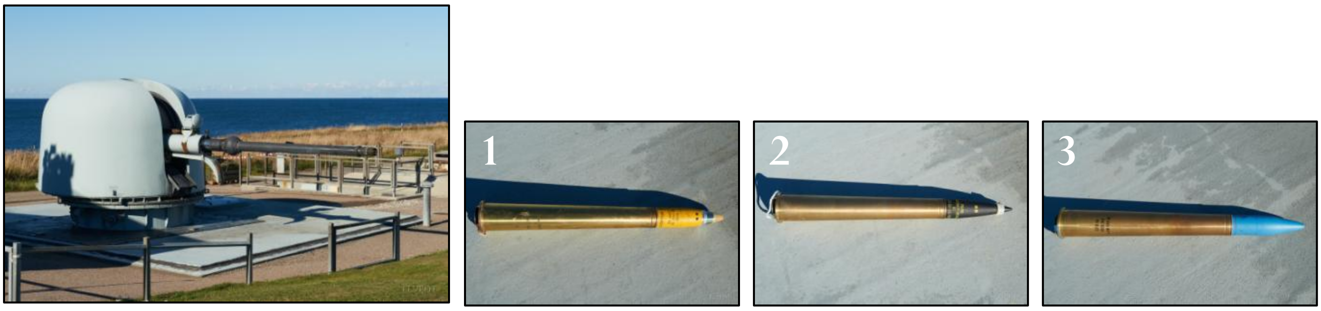


Figure 11: 76 mm OTO Melara with different ammunitions.
(1) 76 mm High Explosive (HE), (2) 76 mm Sapomer, (3) 76 mm Training Projectile.

Figure 12: Signal, Lightning and Smoke Ammunitions.

Figure 13: Hand Grenades.
(1) Sharp Hand Grenade, (2) Training Hand Grenade, (3) 6 bang,
(4) 7 bang, (5) Smoke Hand Grenade (Phosphor).

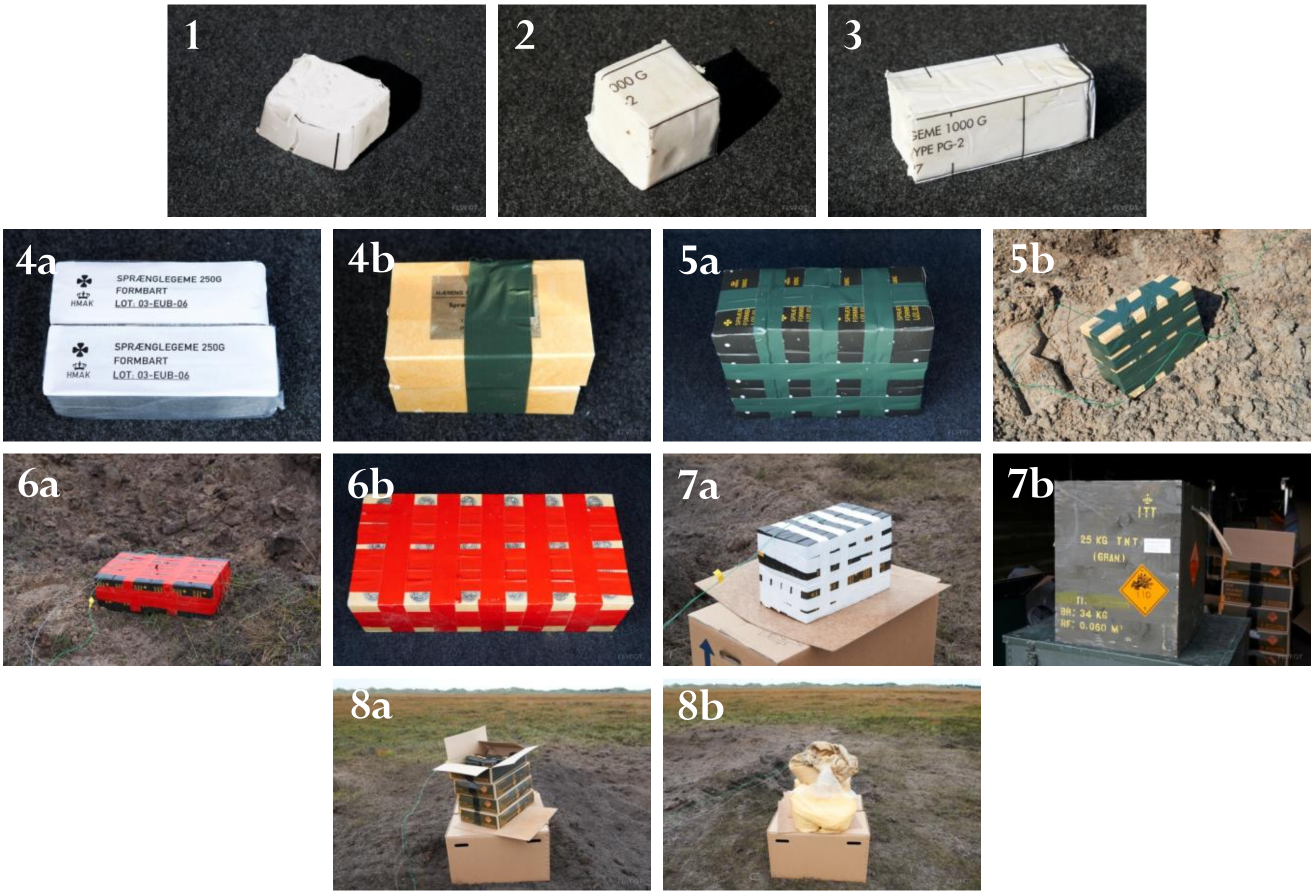


Figure 14: Different amounts of TNT and Pentrit Explosives.
(1) 100 g Pentrit, (2) 200 g Pentrit, (3) 500 g Pentrit, (4a) 1 kg Pentrit, (4b) 1 kg TNT, (5a) 10 kg Pentrit, (5b) 10 kg TNT, (6a) 15 kg Pentrit, (6b) 15 kg TNT, (7a) 25 kg Pentrit, (7b) 25 kg TNT, (8a) 75 kg Pentrit, (8b) 75 kg TNT.

3. Facility

The measurements are carried out in the period from August to October 2013 at Oksbøl and Borris shooting areas, which are located in the western part of Jutland, Denmark.

4. Measurement Setup

The muzzle noise is measured with 5 microphones, which are placed in a half circle with the weapon in the centre, as shown in Figure 15, The microphone positions relative to the muzzle (firing direction (0°)) are 45°, 90°, 135° and 180°. The distance between the microphone and the firing line depends on the weapon caliber. The recommended distances for different heavy weapons are shown in Table 1. The height of the microphone is 1.4 m.

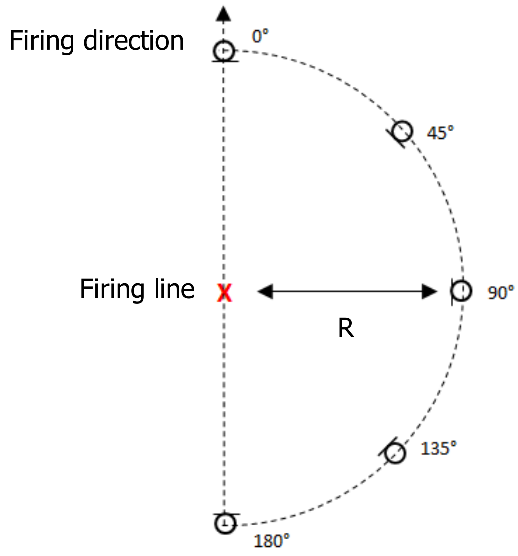


Figure 15: Measurement setup for the muzzle noise.

Table 1: The recommended distance between the microphone and the firing line for different heavy weapons.

Weapon Type	Distance between the microphone and the firing line (R)
12.7 mm machine gun	20 m
35 mm Bushmaster Cannon on Combat Vehicle CV9035	50 m
40 mm Grenade Launcher	20 m
84 mm Carl Gustav Recoilless Rifle	100 m
84 mm AT4	100 m
120 mm Rheinmetall L55 Smoothbore Gun on Leopard 2 A5	100 m
60 mm Lightweight and Commando Mortar	30 m
81 mm Mediumweight Mortar	80 m
120 mm Heavyweight Mortar	80 m
155 mm Selv-propelled Howitzer M109A3	100 - 150 m
76 mm OTO Melara	50 m
Signal, Lightning and Smoke Ammunition	10 - 20 m
Hand Grenade	25 - 50 m
Explosives (1 – 75 kg)	150 - 300 m

In order to simulate the target hitting the ground, noise from detonating HE cartridges (e.g. 81 mm HE, 120 mm HE and 155 mm HE) are measured with 3 microphones placed at different positions at a controlled space. The distance between the microphone and the detonation point is 150 m. The measurement setup is shown in Figure 16.

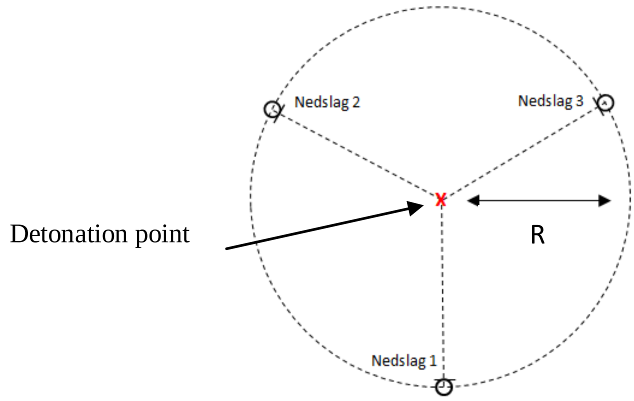


Figure 16: Measurement setup for the noise from detonating HE cartridges.

Table 2 shows an overview over the measurement devices that used in the measurements.

Table 2: Measurement devices.

Measurement device	Manufacture	Type
¼" Condenser Microphone	BSWA	MP 411
¼" Microphone Preamplifier	BSWA	MA 401
½" Microphone Preamplifier	BSWA	MA 231
Data Collection Unit	National Instruments	NI 9234
Pistonphone	Brüel & Kjær	4231
LabView Sound & Vibration Toolkit, version 2011	-	-
LabView Sound & Vibration Measurement Suite, version 2011	-	-

5. Measurement Method

The method used in the measurements is based on [1, 2] with some modifications.

5.1 Calibration with different charges

In order to be able to remove the effect of the ground and the meteorology conditions from the measurements, calculating of the ground correction is needed. This is done by detonating different charges of TNT depending on the weapon type. Detonation shall be done at the same place and height as the measured weapon is placed. Table 3 shows the used charge for each measured heavy weapon.

Table 3: Used charge size in the measurements.

Weapon Type	Charge size
35 mm Bushmaster Cannon on Combat Vehicle CV9035	200 g
40 mm Grenade Launcher	100 g
84 mm Carl Gustav Recoilless Rifle	200 g
84 mm AT4	200 g
120 mm Rheinmetall L55 Smoothbore Gun on Leopard 2 A5	500 g
60 mm Lightweight and Commando Mortar	100 g
81 mm Mediumweight Mortar	200 g
120 mm Heavyweight Mortar	200 g
155 mm Selv-propelled Howitzer M109A3	1 kg
76 mm OTO Melara	50 g

At a given distance from the source, the ground correction (L_{ground}) is the difference between a measured value (L_m) over the ground and a free field value (L_{ff}).

$$L_{ground} = L_m - L_{ff}$$

The ground correction term (L_{ground}) reflects the change in sound level caused by the presence of the ground. This ground correction mainly consists of the linear sound reflected from the ground. There is also a non-linear interaction with the ground near the source (weapon). Depending on the height of the source, non-linear interaction typically leads to higher amplitudes and a shift to slightly lower frequencies than in the linear case. There are also contributions from the meteorological conditions due to a variation in the wind direction.

5.2 Analysis Method

For each combination of weapon and ammunition, it is fired 3-5 shots. The equivalent sound pressure level at each angle is calculated by averaging the number of shots at each microphone.

$$L_{eq,t} = 10\ log\left(\frac{1}{N}\sum_{i=1}^{N} 10^{\left(\frac{L_i}{10}\right)}\right)$$

where L_i is the sound pressure level at each frequency range (one octave band),
N is the number of shots.

The noise emission data in Milstøy database is based on Sound Exposure Level, which is defined as the total sound energy integrated over reference duration of 1 sec. Sound Exposure Level is denoted as L_E. The relationship between L_{eq} and L_E is:

$$L_E = L_{eq,t} + 10\ log\left(\frac{t}{T}\right)$$

where t is the measurement period,
T is the reference time of 1 s.

Sound Exposure Level can be computed for C-weighted levels (appropriate for impulsive sounds) and therefore is denoted as L_{CE}.

By subtracting the measured value $L_{E,m}$ from the ground correction, the free field value $L_{E,ff}$ can be calculated using

$$L_{E,ff} = L_{E,m} - L_{ground}$$

Milstøy takes noise emission data as input at a reference position at 10 m in order to calculate the sound back out to the position, where the sound level was measured. Obviously the sound propagation is not linear at 10 m from the source. The sound exposure level ($L_{E,10m}$) is calculated as follows:

$$L_{E,10m} = L_{E,ff} + 10\,log\left(\frac{r}{R}\right)$$

where r is the distance from the source (weapon),
R is the reference distance of 10 m.

Table 4 shows $L_{E,10m}$ values for 84 mm AT4, whereas Figure 17 shows the directivity.

Table 4: Linear sound pressure level (dB re 20 µPa) pr. one octave band and the linear free field sound exposure level at 10 m corrected for ground and meteorological conditions.

Direction*	One octave band [Hz]										$L_{E,10m}$
	16	31.5	63	125	250	500	1000	2000	4000	8000	
0°	99.9	109.0	115.0	112.3	114.3	106.3	103.6	104.6	102.0	101.0	119.8
45°	98.8	110.6	117.5	119.2	109.0	102.1	100.9	99.5	99.9	95.9	122.2
90°	102.6	112.0	119.4	119.7	114.5	110.4	100.4	99.8	97.5	94.1	123.8
135°	111.5	120.5	126.7	126.3	116.5	119.7	114.6	108.3	105.2	102.9	130.8
180°	115.2	125.3	131.0	126.1	122.3	118.6	116.4	111.9	109.0	106.4	133.7

* Direction is relative to the firing direction.

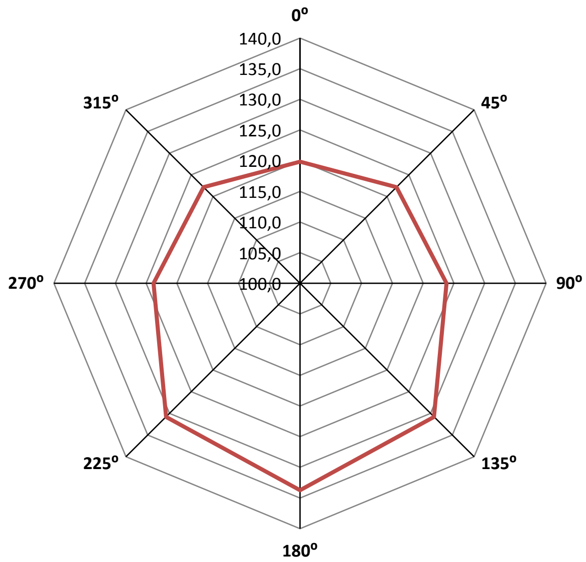


Figure 17: Directivity of 84 mm AT4.

6. Use of noise emission data in noise propagation model

Milstøy uses the noise emission data, as in Table 4. These data depends on the characteristics of the noise source. In order to calculate the noise around the training and shooting areas, the following input data should be available:

- Weapon type and the used ammunition,
- Coordinates of the firing lines,
- Height of the weapon,
- Direction of firing,
- Number of shots distributed over day and weekends (07-18, 18-22 and 22-07).

The results of noise calculation for one of the biggest shooting areas in Denmark are shown in Figure 18.

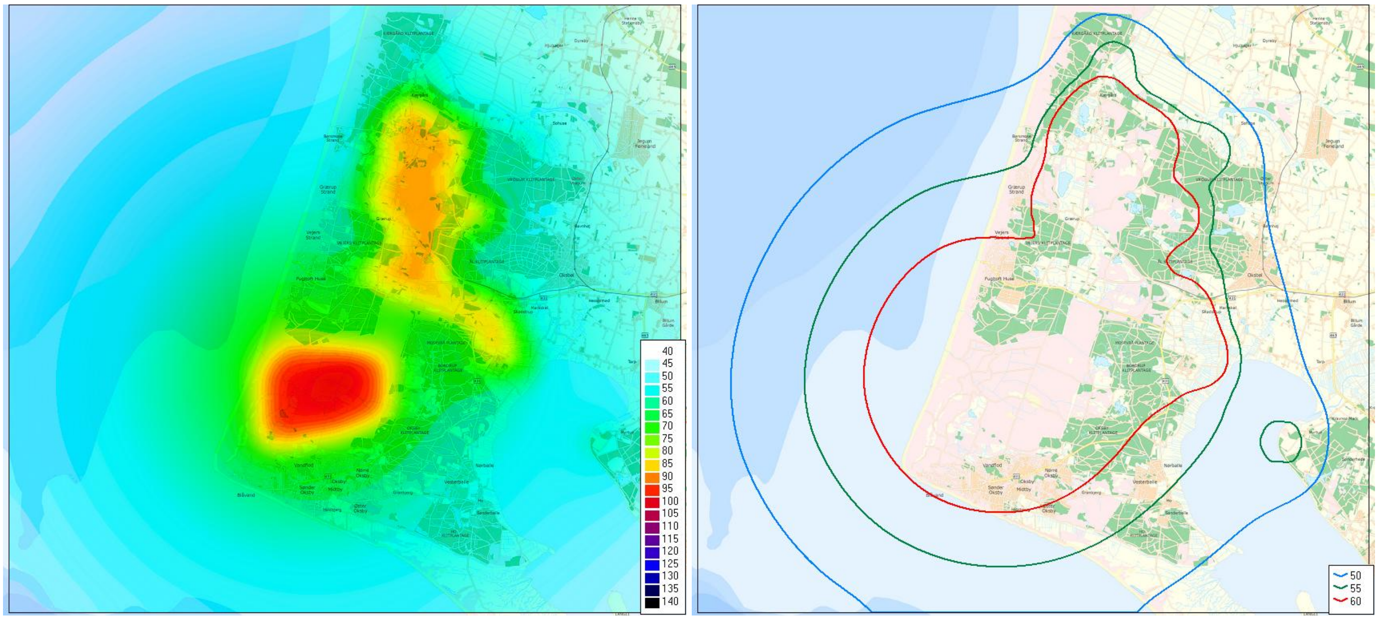


Figure 18: Noise map with 50, 55 and 60 dB noise contours.

7. Conclusions

This work demonstrates the method used to measure the noise emission data for weapons with caliber ≥12.7 mm and explosives. The measured noise data is used by Milstøy in order to calculate the noise around the shooting and training areas.

The following parameters have big influence on the noise data from the measurements and should be investigated.

- Ground reflections,
- Weather conditions (e.g. temperature, relative humidity, wind speed and direction),
- Separation of near-field/nonlinear effects,
- Height of the microphone,
- Distance between the firing line and the microphone.

8. References

[1] Dr.-Ing Edmund Buchta: "Standard method to measure the sound exposure emissions and imissions from large weapons", no. 559.

[2] Norwegian Defence Research Establishment (FFI): "Noise emission data for M109, 155 mm field howitzer", FFI-rapport 2007/02530, December 2007.

Noise Management at Major Training Areas in Germany

Author:Werner Ax

Introduction

Up to the end of their training for operations within the extended spectrum of tasks like International Security Assistance Force (ISAF), Kosovo Force (KFOR), United Nations Interim Force in Lebanon (UNIFIL), Operation Atalanta (Somali coast) and United Nations Mission in Sudan (UNMIS), German military personnel spend time at major training areas, too. Major training areas are large-area firing ranges where firing and demolition operations can also be carried out with heavy weapons (i.e. 20-mm and above). To that aim, the training areas have different characteristics of use to entirely meet the armed forces' training requirement. Those facilities offer firing ranges for armoured combat vehicles and small arms, firing positions and target areas for artillery firing, demolition ranges for live demolition familiarization training as well as for the disposal of munitions.

The Federal Immission Control Act formulates two essential principles for noise management during the operation of facilities: Installations shall be operated in such a way that "harmful effects on the environment, (…), and significant nuisance to the public and the neighbourhood are avoided" and that "precautions are taken to prevent any harmful effects on the environment (…) or significant nuisance, in particular by such measures as are appropriate according to the best available techniques". Accordingly, firing ranges with their operations are installations within the meaning of the Federal Immission Control Act, which must, as a rule, comply with its protection objectives.

Due to the particularities of firing noise (low frequencies, varying impulses, high acoustic energies), the Noise Management Directive for Noise Management at Firing Ranges (Lärmmanagementrichtlinie - LMR) prepared by the German Federal Ministry of Defence as a self-imposed obligation provides for immission control at the major training areas. The Noise Management Directive stipulates noise management on a daily basis. On the one hand, certain noise criteria are to be met (protection against considerable noise nuisance), on the other – fulfilling the second requirement of the Federal Immission Control Act – daily firing is to be planned in such a way that the neighbourhood is subject to the lowest possible noise level (minimization of noise load), and that firing operations do not have to be restricted or only to a small, inevitable degree.

Concept of the Noise Management Directive

Noise Management does not follow the traditional rules of noise acoustics which is based on an approval procedure to be followed just once. The precondition for such an approval procedure is the ability to deliver a static description of the operation producing the loudest noise as it is possible and customary for many industrial installations. Owing to the employment of a multitude of weapons and ammunitions and to the variable sequence of firing and training projects, operations at a training area are of an extremely dynamic nature. Operations do not repeat themselves every day but depend on the user's current training requirements. In the Noise Management Directive this concept is referred to as cooperative noise management.

Noise management verifies the adherence to certain noise criteria on a daily basis and throughout the neighbourhood to ensure that protection objectives are met. These noise criteria include the continuous sound level during day and night, respectively, which increases proportionately with the number of shots fired. They also include the single-event maximum noise level to ensure that single shots will not become too loud. These levels may be exceeded on five per cent of all days of any one year (to be precise: of the 365 days previous to the day of assessment).

Noise management is already integrated into daily operations. On the ground, decision-making must be minimized since technical competence in the field of noise acoustics cannot be expected. To carry out noise management, the facility operator must be provided with an IT tool that will assist the operations planner in making management decisions on training activities in a largely automated way and tailored to the planning process.

Since 2010, noise management in accordance with the Noise Management Directive has been in effect for firing large-calibre weapons at Bundeswehr training areas. This daily noise management can only be carried out if the facility operator is provided with computer-aided tools (*WinLarm*) that integrate noise management into overall range management. Such tools must replicate the planning process for firing exercises in a practice-oriented way and supply the planner with relevant and timely information about the effects of current planning on noise load.

WinLarm also uses the information about the topography, the location of residential areas in the vicinity and the degree at which they need to be protected to calculate noise criteria and to graphically illustrate the consequences of these criteria for firing operations in order to calculate and assess firing noise.

Firing Planning

Training areas are assigned in accordance with the forces' requirements approximately two years in advance prior to the period of use. It must be ensured that – irrespective of the occupancy times - the individual user has access to the entire range of services of the training area, not least with a view to the noise load caused by the use of the training estate. Structural measures at training areas may be necessary to achieve best possible noise protection.

Before its stay at the training area and prior to the range conference, the exercising unit will submit initial information on the type and number of weapons and weapon systems to be used.

Based on these returns, the technical information system *WinLarm* will verify whether the unit’s intentions can be realized or what changes will be needed.

Prior to firing at the training area, a range conference will be held. On this occasion, members of the range headquarters will coordinate wishes, requirements and details regarding the use of the training area. Following this range conference, the use of the estate and its individual facilities is determined for the firing period concerned (usually for two weeks). In principle, users are now entitled to use the area as agreed.

In the time to follow, users will specify the course of the exercises. Range headquarters will take range safety into special consideration and complete its planning by issuing the safety order. It determines what weapons and types of ammunition may be fired from which position of the allocated range. Any change of occupancy will be accompanied by a new evaluation of the noise situation and other aspects.

The actual use cannot be determined until the end of a day of firing. For a multitude of different reasons, there may be changes to firing operations. These changes must be compatible with range safety and the noise contingent.

After the firing exercise, the actual process is documented and entered into *WinLarm*. A concrete noise calculation (real calculation), taking into account the actual weather conditions on the day of firing, will replace the noise prediction (estimate) that was based on average weather conditions. As far as noise management is concerned, this is of particular importance. The Noise Management Directive permits 18 days day of violation of the limit values for each immission location per marked period day/night over a period of one year prior to the firing day.

When the values are exceeded, the planner has the option to:

- move firing operations to another range,
- relocate firing positions on the same range,
- stipulate the use of ammunition causing less noise,
- limit the number of rounds,
- accept this firing day as a day of violation of the limit values,
- or, if the exercises must absolutely be conducted,

direct a request for exemption to the supervisory authority (the responsible supervisory authority under public law for occupational safety and technical environmental protection of the Bundeswehr).

It is crucial to the *WinLarm* program to be fast and user-friendly to find practical solutions for the management of training projects. It is the responsibility of the commandant of the training area to decide how the estate should be used.

Occupancy comprises information on the firing day, the exercise facility, the start and the end of the exercise and a list of firing configurations (weapon systems, weapons and ammunition). Initially, the colours of a traffic light are used to give a simple indication of the status of the firing day to know whether it is in line with the regulations:

- green: in line with the regulations, values are not exceeded,
- amber: in line with the regulations but values are exceeded,
- red: not in line with the regulations because values are exceeded.

As long as "green” is indicated, the planner will give priority to military aspects. When the value is exceeded, there are tools for the planner to find out about the concrete and detailed reasons.

Outlook

Routine operation of the programme has been in progress at all Bundeswehr training areas since 2010. During this period, noise management revealed noise-related problems that merely needed some organizational measures to be resolved. Furthermore, structural and organizational measures were taken to reduce the noise load while still ensuring the indispensable firing operations and exercises as part of pre-deployment training.

Emission of toxic fumes and metals from weapons and ammunition

Johnsen, I.V., Johnsen, A. and Voie, Ø.A.

When weapons are fired toxic fumes such as carbon monoxide (CO), copper (Cu) and lead (Pb) are emitted. These fumes can accumulate and pose a threat to the shooter if shots are fired inside a confined area without adequate ventilation.

1 Introduction

When weapons are fired fumes containing gases and metals are emitted. Some of the components in these fumes can potentially pose a threat to the user (Strømseng et al. 2009). The exposure of gunners to these fumes is most severe when shots are fired in a confined area without adequate ventilation. These areas can for instance be inside armoured vehicles or indoor shooting ranges (Strømseng et al. 2009; Voie et al. 2011).

After the Norwegian Defence switched to a new weapon (HK416) and unleaded ammunition, soldiers have from time to time complained about health problems such as coughing, fever, chills, headache, nausea, myalgia and sore throat. The Norwegian Defence Research Establishment (FFI) has quantified the emission of gases and metals from a large number of weapons and ammunitions (Strømseng et al. 2009). In addition, field measurements of gases and metals have been made in the breathing zone of the gunners during firing exercises.

1.1 Toxicity

Carbon monoxide (CO) is the gas that is emitted in the largest amount, during firing of most weapons. CO is a colourless, flavourless, odourless and non-irritating gas. Long exposure or exposure to high concentrations can lead to collapse, spasms, loss of consciousness and eventually death in the most severe cases (Goldstein, 2008; Strømseng et al. 2009). In Norway the limit for CO in the working environment is 25 ppm over an 8 hour day, and there is a short term limit of 100 ppm average over 15 minutes (Arbeids-og sosialdepartementet, 2014).

Lead poisoning can occur after long term exposure on shooting ranges (Graeme et al., 1998). Symptoms are often vague and can occur suddenly although the poisoning is chronic. In adults symptoms of severe lead poisoning can include kidney failure, high blood pressure, joint pains and impotence. Early symptoms are irritability, drowsiness, headache, shivering, fatigue, hallucinations and memory loss (Graeme et al., 1998; Strømseng et al. 2009). The Norwegian limit of lead in the breathing zone is 0.05 mg/m3 over a working day of 8 hours, the short term exposure limit over 15 minutes cannot exceed 0.15 mg/m3 (Arbeids-og sosialdepartementet, 2014).

Exposure to copper (Cu) and zinc (Zn) fumes can lead to metal fume fever. Metal fume fever gives flue like symptoms such as fever chills, malaise, nausea, lead and muscle pain, headache, cough and sore throat (Strømseng et al. 2009; Graeme et al. 1998). The Norwegian working environment limit for copper is set to 0.15 mg/m^3 and cannot exceed 0.3 mg/m^3 averaged over 15 minutes (Arbeids-og sosialdepartementet, 2014).

2 Materials and methods

When FFI measures fumes from weapons and ammunitions, different kinds of equipment are used. PAC7000 (Dräger) is an electrochemical sensor that measures CO in the range from 0-2000 ppm. This is a small sensor that is placed on a person's shoulder, near the breathing zone. Multiwarn II (Dräger) is also an electrochemical sensor which measures CO, ammonia (NH_3) and Hydrogen cyanide (HCN). A detector using a FTIR technique, called Gasmet, is sometimes used if there are other gases that need to be monitored, such as Cl_2 and HCl. To measure the amount of metal dust in the breathing zone the dust has to be collected on a filter, because there are no methods to analyse metal dust continuously. Particulate matter in air from the breathing zone is collected on a HTTP filter (0.40 µm) mounted in an aerosol analysis monitor from Millipore. The air is filtered at a flow rate of 2 L/min, generated by an air pump (SKC). The metal contained on the filters are later digested and then analysed by ICP-MS (Thermo Xseries 2). The digestion is performed by adding aqua regia (1:3 ultrapure 67 % HNO_3: ultrapure 30% HCl) to the filters and heating to 190°C in a microwave (UltraWave from Milestone).

3 Emission from semi-enclosed shooting ranges with noise cancelling

3.1 Theory and test setup

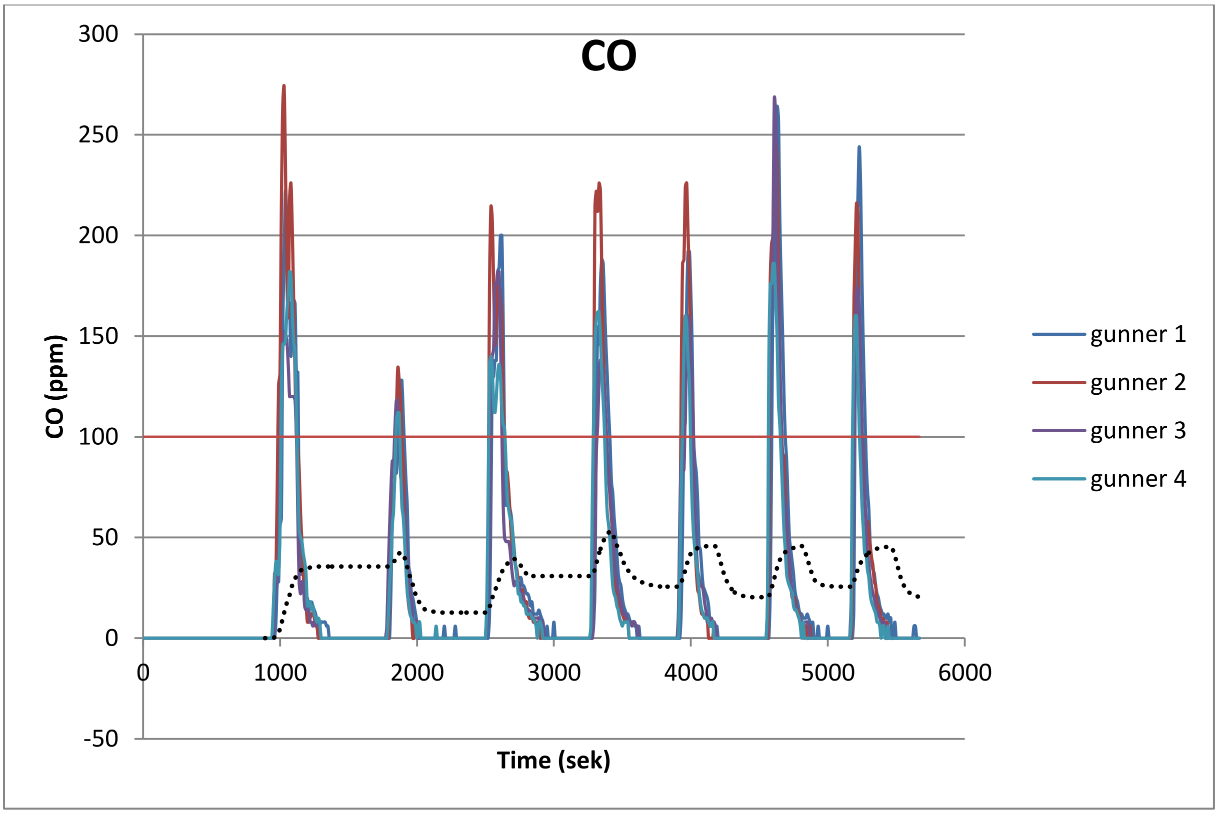
Semi-enclosed shooting ranges with noise cancelling has a roof and soundproof walls 5-6 meters in front of the firing point, like a funnel (Picture 3.1). The soundproofing can make ventilation on such lanes challenging because the layout provides very limited natural ventilation.

Picture 3.1. Semi-enclosed shooting range with noise cancelling. Picture from Råvatn shooting range.

One such lane is Frigården shooting range for small arms. This lane has a mechanical ventilation system. The system was installed with a ventilation apparatus behind the shooters (system 1) and one right in front of the doors (system 2) that aimed to drive the fumes out into the open and prevent turbulent airflow behind shooters. To test the conditions around the gunner four shooters were equipped with a CO monitor (PAC7000) and three shooters were equipped with filters and pumps for collection of metals in the breathing zone. The weapon used was a HK416 with unleaded ammunition (NM255). The four shooters fired 7 sets of 60 shots each. Each set was done with different ventilation settings; 1 set with all ventilation off, 1 set with system 1 on full speed, 1 set with system 1 and 2 on half speed, 1 set with system 1 on full speed and 2 on half speed, 1 set with system 1 on half speed and 2 on full speed and 2 sets with system 1 and 2 on full speed. Personnel used masks with fresh air supply to prevent exposure of toxic concentration of fumes.

3.2 Results and discussion

CO measurements done with personal sensors (PAC7000) showed that the ventilation system had little or no effect on the CO concentration around the gunner (Picture 3.2). All the gunners were exposed to the same level of CO concentration. During firing, the CO concentrations were quite elevated, but decreased rapidly when fire ceased. This was true with every setting of the ventilation system. The moving average over 15 minutes did not at any occasion exceed the short term limit for CO exposure (100 ppm).



Picture 3.2. CO-concentration of all gunners during the seven sets of firing.

No significant difference in metal emission could be observed with any of the ventilation settings. The copper concentration was generally high and exceeded the short term exposure limit for copper (0.3 mg/m^3) (Arbeids-og sosialdepartementet, 2014). The copper concentrations were at a level, which can induce symptoms in exposed personnel (Voie et al., 2013). The zinc concentration was under the national regulation limit.

Table 3.1. The metal concentration in the gunners breathing zone. The concentration is an average of the measurements of three filters from different gunners. The metal on the filter was averaged over the amount of air that passed the filter during the exposure period. The national regulation limits are from Arbeids-og sosialdepartementet, 2014.

	Averaged over volume of air through the filter	
	Cu mg/m^3	Zn mg/m^3
All ventilation off	3.3	0.34
System 1 on full speed	1.7	<lod
System 1 and 2 on half speed	4.4	0.77
System 1 on full and system 2 on half speed	3.4	0.16
System 1 on half and system 2 on full speed	4.2	0.31
System 1 and 2 on full speed	9.4	0.87
System 1 and 2 on full speed	1.5	<lod
National regulation		
8-hour limit	0.1	5*
Short-time limit (15 min)	0.3	10*

*Refers to zinc oxide

4 Emissions from CV90

4.1 Theory and test setup

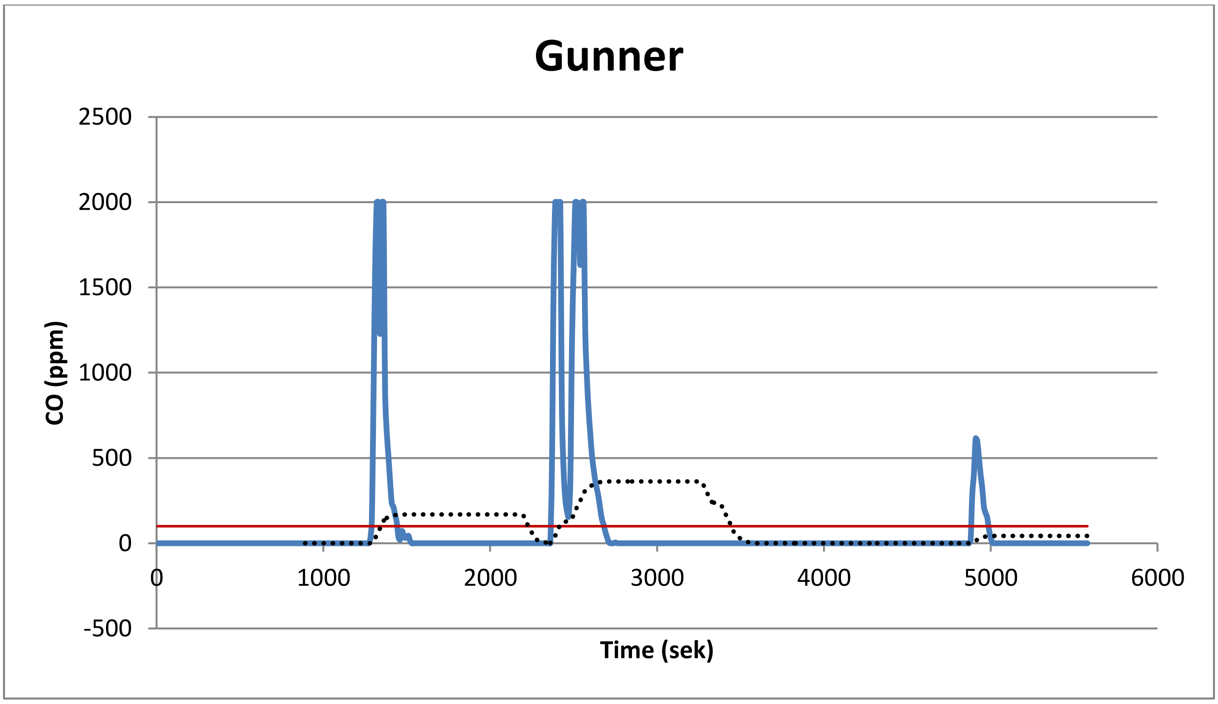
FFI has measured the emission from the firing of 30 mm plastic ammunition from Combat Vehicle 90 (CV90) (Picture 4.1). The measurements focused on the gas exposure of the operators/gunner during firing, in order to evaluate the need for protective measures.

The firing exercise consisted of three separated firings where 30 rounds were fired in series of 5-7 shots. For each of the three firings the concentration of CO, NH_3 and HCN were measured. Both the gunner and the driver had PAC7000 and filters mounted on the shoulder to monitor CO and metals in the breathing zone.

Picture 4.1. Combat Vehicle 90 (CV90).

4.2 Results and discussion

The results showed that especially the gunner was exposed to a very high concentration (> 2000 ppm) of CO (Picture 4.2) during the firing exercise. The average level of CO over 15 minutes exceeded the Norwegian short-term limit for a working atmosphere (100 ppm). The maximum concentration of HCN was well below the 8-hour national limit for HCN in a working atmosphere (5 ppm). Ammonia was not detected above the detection limit of 1 ppm.



Picture 4.2. Concentration of CO in gunners breathing zone. The peaks indicate the measurements done during the three firings. The dotted lines indicate the moving average over

15 minutes. The red line indicates the Norwegian threshold limit for short-time exposure (15 minutes).

The air concentration of lead in the gunners breathing zone was high and exceeded the Norwegian short-term limit for working atmosphere (0.15 mg/m^3, 15 minutes) by a factor of six (Table 4.1). Copper was also measured in the gunners breathing zone. The concentration exceeded the threshold value for an 8-hour working day (0.1 mg/m^3), but not the limit for short-term exposure (0.3 mg/m^3, 15 minutes).

Table 4.1. Concentration of metals in the gunner and drivers breathing zone in CV90 during firing of 30 rounds of ammunition. The concentration is an average of the three rounds fired. The national regulation limits is from Arbeids-og sosialdepartementet, 2014.

	Average over 15 minutes			
	Copper mg/m^3	Zink mg/m^3	Antimony mg/m^3	Lead mg/m^3
Gunner	0.12	0.02	0.07	0.94
Driver	0.04	0.01	0.00	0.02
National regulation				
8-hour limit	0.1	5*	0.5	0.05
Short-time limit (15 min)	0.3	10*		0.15

*Refers to zinc oxide

5 Emissions from Leopard 2

5.1 Theory and test setup

From a combat vehicle, Leopard 2, (Picture 5.1) FFI tested the fume emission when shots were fired with machine guns through the coax. Measurements were performed with closed hatches for a “worst-case-scenario”. Two different machine guns were used in the test; FN Mag original and KSP 58. Both weapons were fired with leaded (M80/M62, 1:4) and unleaded (NM231/232, 1:4) ammunition. Two sets of 200 shots were fired in rounds of 3-6 shots with each combination of weapon and ammunition.

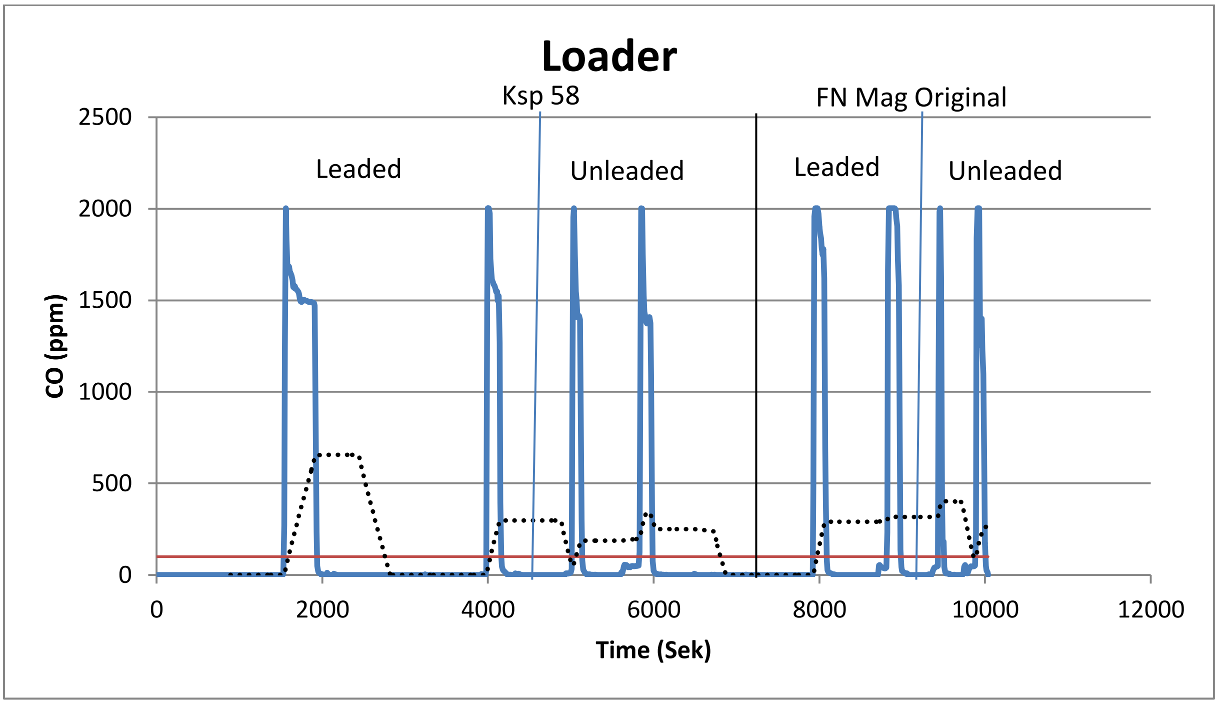
Detectors for monitoring CO, NH_3 and HCN (Multiwarn II) were placed inside the vehicle on the roof over the loader. This was the area we expected the fumes to accumulate. On the gunner and the loader PAC7000’s was mounted on the shoulder for CO measurement, a PAC7000 was also placed at head level were the driver is sitting. The gunner and the loader were also equipped with filters and pumps for collecting metal dust. The personnel used filter-/gas masks to avoid exposure to high concentrations of metals.

Picture 5.1. Leopard 2.

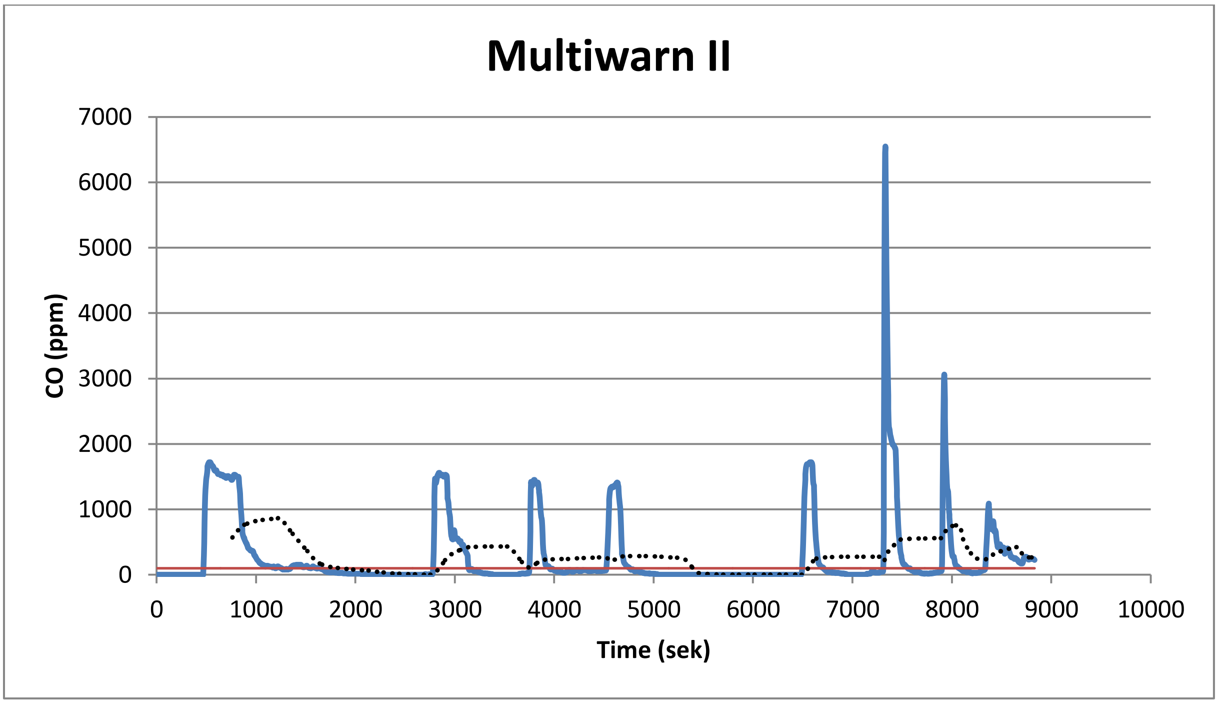
5.2 Results and discussion

The CO concentration was high and saturated the PAC7000 detectors (2000 ppm) during each firing-set (Picture 5.2). The ventilation system showed poor ventilation ability and the CO concentration remained high until the hatches were opened. Even with the hatches open it took some time to get the concentration down to under 50 ppm. The gunner and loader left the vehicle between each firing, hence the sharp decline in the CO concentration for the gunner right after shooting (Picture 5.2). Under normal circumstances this would hardly be the case, and the exposure to the personnel would be higher than this test showed. A sharp decrease in the CO concentration was when the hatches were opened, but even with the hatches open and ventilation on full speed, the CO concentration inside the vehicle used 1.5 minutes to reach 100 ppm (Picture 5.3). The measurements of the fumes emitted from the two types of weapon and ammunition showed that the emission of CO was fairly similar. However, one set shot with FN Mag and leaded ammunition differed from the other series of shots, of which there was measured particularly high CO concentrations in the vehicle. (max. 6550 ppm).

In this experiment the vehicle was thoroughly aired out between each set of shooting and the exposure of the personnel can, therefore, be considered as short term (< 15 min). A moving average of CO over 15 minutes was calculated throughout the entire test. This value was somewhat underestimated since the PAC7000 detector was saturated in each set. Even though the loader left the vehicle between every set, the moving average was above 100 ppm for all the sets which is the short term limit for exposure. To avoid this, breaks between tests would have to be longer and the hatches would need to be open during firing.



Picture 5.2. The concentration of CO in the loaders breathing zone. The peaks indicate the measurements done during the eight firings. The dotted lines indicate moving average over 15 minutes. The red line indicates the Norwegian threshold limit for short-time exposure (15 minutes).



Picture 5.3. The concentration of CO under the hatch over the loaders head. The peaks indicate the measurements done during the eight firings. The dotted lines indicate moving average over 15 minutes. The red line indicates the Norwegian threshold limit for short-time exposure (15 minutes).

The concentration of metal in the gunner and loaders breathing zone is showed in Table 5.1. The values are an average of the two sets with the same weapons and ammunition, and were averaged over the air that passes the filter during 15 minutes. The exposure time was for most sets shorter, and the actual concentration in the air will therefore have been somewhat higher.

When leaded ammunition was fired, the concentration of lead in the breathing zone of the gunner and the loader was high with both guns. The highest concentration was registered after firing Ksp 58 and leaded ammunition (0.78 mg/m^3). This was probably because the exposure period was longer on this set (about 15 minutes) compared to the exposure period when FN Mag was fired (6 minutes). The results do not indicate a significant difference in lead exposure between the weapons or between the loader and the gunner. The lead concentration was well above what is considered the short term limit for lead exposure.

High concentrations of copper in the breathing zone of both gunner and loader were measured with both weapons and both types of ammunition. For leaded ammunition there seemed to be no significant difference in copper emission between the weapons (when different exposure time was taken into account). For unleaded ammunition however, it seemed as though the emission of copper was higher from FN Mag than from Ksp 58. Unleaded ammunition and Ksp 58 was the only combination that did not exceed the work day limit (0.1 mg/m^3) for copper exposure.

Table 5.1. Average metal concentration in the gunner and loaders breathing zone. The metal concentration is the mean over 15 minutes.. The national regulation limits for short time exposure over 15 minutes is from Arbeids-og sosialdepartementet, 2014.

Weapon	Ammunition		Averaged over 15 minutes		
			Cu mg/m^3	Zn mg/m^3	Pb mg/m^3
Ksp 58	Leaded	Loader	0.78	0.43	0.64
		Gunner	0.31	0.17	0.24
	Unleaded	Loader	0.16	0.11	0.01
		Gunner	0.07	0.13	0.01
FN MAG	Leaded	Loader	0.25	0.05	0.08
		Gunner	0.62	0.13	0.27
	Unleaded	Loader	3.29	0.77	0.02
		Gunner	0.27	0.04	0.02
National regulations					
8-hour limit			0.1	5*	0.05
Short-term limit (15 min)			0.3	10*	0.15

*Refers to zinc oxide.

6 Discussion and conclusion

The CO concentrations measured around the gunners varied between the three tests discussed in this report. CO concentration in Frigården shooting range was considerably lower than the CO measured both in CV90 and Leopard2. The moving average of CO concentration at Frigården over 15 minutes did not at any occasion exceed the national short term limit of 100 ppm. For each set the exposure of the personnel at Frigården could be considered short term, but because the breaks between sets were short, the moving average of CO concentration never reached zero. This means that if many sets are fired successively, the exposure could be considered long term, and the national limit for long term exposure (25 ppm) would have to be considered. The CO exposure of the personnel in CV90 was greater than at Frigården and at two out of three sets, the detector (PAC7000) was saturated (>2000 ppm). The moving average of CO over 15 minutes was also over 100 ppm and could hence pose a health threat to the exposed personnel. This was also the case for the tests in Leopard2, where the CO sensors were saturated (<2000 ppm) during each set.

High CO concentrations could pose a threat if personnel are exposed over longer periods. There is also a risk of symptoms similar to those of smokers if the exposure is chronic. There is no filter or gas mask that can capture CO, thus the only way to prevent high exposure is to have good ventilation and monitoring. CO monitors are therefore installed on many Norwegian shooting ranges.

Exposure of gunners to copper fumes was generally very high at Frigården shooting range. All measurements from all firing sets were well above the national short term limit of 0.3 mg/m3. Firing with this combination of weapon and ammunition on this range could and would probably in many cases lead to metal fume fever. Copper exposure of the personnel in CV90 was not as high and only exceeded the long term limit (0.1 mg/m^3). Because the exposure period was short term this should do no harm to the personnel. The lead exposure in CV90 was somewhat higher than the copper exposure. The concentration measured on the gunner exceeded the short term limit for lead exposure (0.15 mg/m^3). Copper exposure in Leopard2 was lower than the exposure of the personnel at Frigården, but it still exceeded the short term exposure limit for many firing sets and could hence cause metal fume fever. The lead concentration measured around both the gunner and the loader also exceeded the short term limit at three firings.

To prevent exposure to high metal concentrations in confined areas such as these, personnel should consider using gas-/filtering masks. Ventilation systems should also be installed or rectified on confined places were shots are fired.

7 Summary

Measurements of mainly CO and metals were done at three different confined spaces to test personnel exposure to these during firing. Different settings on the ventilation system on Frigården small arms shooting range was tested during firing of unleaded ammunition using HK416. Two different guns were fired from the coax of a Leopard2 using both leaded and unleaded ammunition. In CV90 exposure was measured from the firing of 30 mm plastic ammunition.

In both combat vehicles the moving average (15 minutes) of CO concentration in the air after shooting exceeded the national short term exposure limit (100 ppm). The CO concentration was lower on Frigården shooting range after shooting with HK416 and the national limit was not exceeded. The copper concentration in the air did in some cases, both in Leopard2 and at Frigården shooting range, exceed the national short term limit of 0.3 mg Cu/m^3. This might imply a risk of metal fume fever in exposed personnel. In CV90 and Leopard2 lead concentration did in some cases exceed the national limit for short term exposure of lead (0.15 mg/m^3).

Better ventilation, protection masks and CO surveillance should be considered used to avoid exposure to high concentrations of toxic fumes from weapons.

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Implementing Best Available Techniques at Small Arms Ranges

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The Finnish National Best Available Techniques -guidance for Small Arms Ranges

The compilation of Finnish national Best Available Techniques (BAT) guidance for small arms range operations started in 2010 in co-operation between operators, including the Finnish Defence Administration, authorities and other stakeholders. The work was completed in 2014 with the publishing of the report "Best Available Techniques (BAT). Management of the Environmental Impact of Shooting Ranges" (Sara Kajander and Asko Parri (ed.), The Finnish Environment 4/2014)

The report presents the results of the analysis of technical and practical methods for managing pollutant and noise emissions of shooting ranges, the assessment of their effectiveness, their availability and costs in Finland. Sample specifications and structural drawings that are indicative in nature or show the principles have been prepared of the techniques assessed to be the best. The report covers rifle, pistol and shotgun ranges located outside. The report should be considered to be a guideline, and it is intended for shooting range operators, permit and supervisory authorities, and shooting range designers.

As a rule, Best Available Techniques reports have been prepared for industrial operations, the environmental protection techniques of which are already rather advanced. The controlled circumstances of industrial processes and the long-term monitoring results enable the description of the minimum and maximum emission levels and the techniques required to achieve them. The basic premises of the specification of best available techniques for shooting ranges with regard to pollutant emissions are exceptional in the sense that instead of determining minimum and maximum emission levels, the goal in the shooting range BAT-project was to determine the need for environmental risk management. The project also included assessing management methods some of which are still experimental. With regard to noise, existing techniques and practices were examined and a procedure for assessing the need for noise abatement and targeting it in the most purposeful way possible from the perspective of BAT was recommended.

Management of pollutant emissions

The pollutant management methods suitable for pistol and rifle ranges can be divided into three main categories:

- Reduction of pollutant load
    - renovation of the backstop berm
    - bullet traps
- Prevention of pollutant migration
    - covering the backstop berm

    - liners placed inside the backstop berm (sand trap)
- Water management and, if necessary, treatment.

The remediation of impact areas using either the screening or mass replacement technique is, in principle, suitable for use at all ranges where shooting is targeted at a backstop berm. The method is particularly suited to new shooting ranges, where the accumulation of easily soluble metal dust from fragmented and eroded bullets in the impact areas can be prevented through the regular removal of the bullets.

Bullet traps with a filler material that makes a bullet lose its energy and stop upon impact are suitable for use at most shooting ranges. Rubber grindings are often used as the filler material, and the structure can be, for example, a layer lined with a rubber membrane and installed on the surface of the backstop berm, or a wall or box structure. The solution is effective for pollutant management. Metal bullet traps, where the bullet's kinetic energy is reduced by redirecting it, for example with metal plates, are particularly recommended for use with smallest calibre firearms; there are various reasonably simple implementations. Bullet fragmentation often causes metal dust that must be taken into consideration when planning environmental protection. There is no experience in Finland in the use of metal bullet traps with rifle calibre firearms (and equivalent) but in the USA, for example, commercial metal traps are used in rifle-calibre shooting with good results.

Covering the backstop berm and the target area prevents the formation of water with pollutant content and the migration of metals effectively. Covering is particularly well suited for biathlon, where the risk caused by bullets fragmented in front of the targets is otherwise difficult to manage.

Lining installed within the backstop berm (bentonite, film or asphalt,) or a sand trap, prevents water with pollutant content from migrating to the soil. The benefit of this structure is that the usage and safety characteristics of the shooting range do not differ from a normal backstop berm structure. The structure is suitable for use at all shooting range where firing is directed at a backstop berm. In connection with the sand trap structure, infiltration water must be collected from the top of the lining via underground drains and treated if necessary.

If the structural solution of the shooting range causes pollutant content in water, the polluted water can be collected depending on the water permeability and structure of the soil either with ditches or with lining and underground drains. Water with pollutant content can be cleaned in a treatment well by filtration or in basins or ditch systems by sedimentation.

Management of pollutant emissions at shotgun ranges is more challenging due to the larger target area, and more expensive than at pistol and rifle ranges. The spreading area of pollutants can be limited and reduced by landscaping or other physical obstacles. In practice, this means building extensive earthen berms or mesh or wall structures, or their combinations, in the firing sector. This solution does not eliminate the possibility of pollutant migration, but focuses the risk and need for measures to a smaller area. Pollutant migration can be prevented by surfacing the primary shot fall areas and shot removal, or by managing water with pollutant content in the same way as on pistol and rifle ranges.

Assessment of the need for pollutant management

The pollutant management need and the site-specific best available techniques for shooting range operations are determined based on the long-term environmental risk caused by the operations. The BAT report includes instructions for the assessment of the need for pollutant management at a shooting range. The assessment procedure of the environmental risk management need involves the investigation and description of the site's operating history, soil, groundwater and other environmental conditions, and the emissions caused by the operations and their possible long-term impact. The goal is to determine how the operations burden the environment and what effects they have. The emission level acceptable with regard to the environmental conditions is determined and the environmental risk caused by the operations assessed site-specifically. Depending on the site's characteristics and the already available source data, the survey can be carried out either as a desk study, or it can include terrain surveys and environmental sampling, if necessary.

Based on the results of the risk management need assessment procedure, the site's risk management goals are determined. In the survey, shooting ranges are divided into four categories according to risk level:

- Level 1 – low environmental risk
- Level 2a – elevated surface water contamination risk, impact wider than local
- Level 2b – elevated groundwater contamination risk that is targeted at a classified groundwater area or an aquifer used for household water supply.
- Level 3 – high environmental risk or detected environmental impact.

An indicative risk management requirement level has been defined for each risk level. Techniques or practices to be used have not been separately defined for the different requirement levels or shooting range types; risk management can usually be implemented in several different ways. The operator plans and presents the site-specifically most suitable and feasible solution that meets the requirements for the risk level in question to the authorities for assessment. The choice of best available techniques and practices are also guided by their suitability for the site, cost-effectiveness, and implementation schedule. Should there not be any particular reason for urgent measures, the operator can be granted a sufficient amount of time to complete the implementation, if this facilitates, for instance, arranging financing. At sites with a low environmental risk, monitoring the burden caused by the operations through monitoring of shots fired and the possible observation of the impact are sufficient risk management measures.

Noise management

The management of shooting noise is divided into noise abatement and the reduction of harmful impacts. Noise abatement is commonly divided into reduction of the source emission, reduction of transmission, and receiver protection. In the case of shooting range noise, receiver protection is not used as a means of abatement. Most commonly, noise is abated with noise barriers and other noise control structures.

Planning the operations and the usage times of the range aim at reducing the harmful impact. During the designing stage of the shooting range, the noise caused by the shooting range can be influenced effectively and the generation of harm prevented. The design should pay attention to the range's location, elevation, range structures, and changes in the terrain and stands of trees. The arrangements of the range area, the positioning of the ranges and the direction of firing can affect the noise spreading to the environment. Early in the design stage, we recommend contacting the municipal land use planner and the building and environmental protection authority in order to determine the prerequisites for range placement. With regard to noise, the distance between the shooting range and the areas subjected to the noise should be sufficient. Usually, 3.5 km or template review is enough. At ranges where only .22 calibre firearms are used, the sufficient distance is clearly shorter. If the above-mentioned condition is not met, the design must be more detailed, using a prediction method for shooting range noise.

Techniques for reducing noise emission include reducing the calibre and using silencers, taking into consideration the limitations set by competition rules, etc.

The best techniques for controlling the propagation of noise include correctly designed and dimensioned firing line enclosure structures and noise berms and screens. In the rear directions, the best available technique is considered to be a noise-attenuating, tight enclosure. The ventilation of the firing line enclosure must be planned to attenuate the noise. At shotgun ranges, an enclosure can be used only at a trap range. An earthen berm is often the most natural choice for a noise barrier at shooting ranges. The noise berm, constructed from natural soil, is affordable, does not allow noise to be transmitted through it, nor does it reflect it. A noise barrier in its basic form has a hard surface, reflecting sound to the opposite direction. If this direction is also problematic, the barrier's surface on the side of the noise source must be sound-absorbing. In the firing direction and the frontal sector, a sufficiently high backstop berm should be used as noise protection. At a pistol and rifle range, noise obliquely and directly to the sides, is abated using a noise berm, noise barrier, or a combination of the two. The barriers should be dimensioned so that the noise level at the receiver to be protected does not exceed the guideline or limit values, however so that the barrier attenuation is at least 5 dB. At a shotgun range, side barriers or berms can only be used with certain limitations, for example, taking the clay pigeon's flight trajectory into consideration. The barriers should always be placed as close to the firing stands as possible for performing the sports. If other means are insufficient, overhead baffles can be used, if their noise attenuation can be reliably anticipated.

The ground in front of the firing line enclosure or the firing stand should be soft to reduce ground reflection. Retaining vegetation in the vicinity of the shooting range is important, particularly if the vegetation is dense and high between the shooting range and the area subjected to noise. Particularly, the zone closest to the range, to a distance of around 100 m, is important.

Planning of the usage times of the shooting range can reduce the disturbance caused by noise. The usage times of the shooting range should be planned specifically for the ranges of all different sports in co-operation with the shooters, authorities, residents in the area, and other operators. The planning should take into consideration the special characteristics, operational requirements and noise emissions of the different shooting sports. For instance, the environmental permit limits the use of the shooting range in the evenings of certain weekdays at the shotgun and rifle ranges, while the usage of small .22-calibre firearms that have low noise emissions is allowed without limitations.

Procedures related to the use of the shooting range can affect the effectiveness of the implemented noise abatement measures. At rifle and pistol ranges, for instance, shooting should be carried out from the firing points located closest to the side berm; this allows the berm to best attenuate the propagation of noise. Such procedures should be put into writing, all range users made aware of them, and effective practices established to monitor compliance.

Communications form an important part of noise abatement measures at shooting ranges. The better the residents in the vicinity are aware of the usage times of the shooting range, the easier it is for them to prepare for and feel positive about the operations. In addition to communications, other stakeholder activities also increase acceptance to the operations, therefore reducing the experienced harm. For example, the residents in the vicinity could be offered a visit to the shooting range in order to familiarise themselves with the operations; they could also be informed of the operations at the shooting range being responsible and goal-oriented.

Monitoring ensures that the operations follow the rules; it can also have an effect on how the noise caused by the operations is experienced. It will be good for the residents to know that the operations at the range are pre-approved, in compliance with the regulations, and monitored. The range usage times must be monitored and off-hours usage prevented, if necessary. The range structures and their condition must be monitored and reviewed regularly. The operations at the shooting range must be monitored systematically.

Assessment of the disturbance and need of noise abatement

Studies on shooting range noise have found that the disturbance depends not only on the sound level but also the number of shots. The scope of the required noise abatement also depends on the number of people exposed. A small number of shots and the timing of the shooting activities so that they cause only minor disturbance in the vicinity could be considered to be justifiable reasons for deviating from the guideline values; on the other hand, a large number of people exposed and extensive range operations could be considered as reasons to deviate from the guideline values to the other direction.

Based on the above, the BAT-report recommends that the need for noise reduction at an existing shooting range could be assessed, and the noise control measures targeted, in the most purposeful way from the perspective of BAT. Table 1 provides a tool for the assessment, based on the noise zones and the numbers of shots and people exposed. The measures are divided into three categories marked in different colors. The number of exposed people includes people living in a residential building and a building location used as a holiday home.

Table 1. Recommendation for the assessment procedure for the need of noise abatement at a shooting range.

Area usage 1	**Area usage 2**	**Annual number of shots ***				
		less than 10,000 shots/a	10,000–100,000 shots/a		over 100,000 shots/a	
Noise zone [LAImax]	Noise zone [LAImax]		Number of people exposed within the noise zone			
			1-10	over 10	1-10	over 10
Over 75 dB	Over 70 dB					
70–75 dB	65-70 dB					
65-70 dB	60-65 dB					
60-65 dB	55-60 dB					
under 60 dB	under 55 dB					

	Situation unacceptable. Extensive noise control measures are required.
	The noise control structures are designed in such a manner that the sound level does not exceed the target or limit value specified in the environmental permit and/or the noise load is reduced with the help of usage times **
	Noise disturbance is minor, usually no need for noise prevention measures. Special usage time limits in exceptional cases only

Area usage 1: Residential areas, areas in service of educational institutions

Area usage 2: Recreational areas in population centres or in the immediate vicinity of population centres, areas in service of healthcare institutions, holiday home areas, natural conservation areas

* Shots from .22-calibre firearms are taken into consideration only in cases where the exposed site is very close to the shooting range.
** Noise abatement at small shooting ranges (less than 10,000 shots/a) is implemented mainly through usage times; noise control structures would be required in exceptional cases only.

Assessment of the viability of the implementation of measures

The assessment of the benefits of environmental protection measures at shooting ranges is based on the assumption that the benefits at a minimum level can be considered to be sufficient, when the acceptable emission or maximum risk level is not exceeded using the chosen solution. Acceptable level can be considered to be, for instance, noise or pollutant emissions that even in the long term do not cause health hazards; contamination of the environment or the risk thereof; deterioration of special natural conditions; endangering of water supply or other use important of groundwater in the impact area of operations; or undue burden to the neighbors referred to in the Adjoining Properties Act.

The environmental protection legislation also requires that the operations strive to minimize the harmful environmental impact and prevent any harm. During the selection of the best available techniques, one must thus also assess the degree of additional benefit relative to cost of measures exceeding the minimum level the implementation of which requires investments that can be considered reasonable. If the benefit achievable by further measures is assessed to be significant while the overall cost remains at a level deemed reasonable, the application of a requirement level higher than minimum can be considered justified.

Economical viability considerations are based on the premise that it must be possible to continue operations on a hobby basis in such a manner that the end users' costs are comparable to the costs of other corresponding hobbies. The assessment of the operating costs should include the planning and implementation of the measures, maintenance of the structures, and the measures related to the termination of the operations. The analysis may also take into consideration the possibilities of receiving various subsidies and the effect of the schedule on the viability.

Project: Improving the environmental protection of small arms ranges

In 2011, the Finnish Defence Forces made a decision to upgrade all small arms ranges to meet current environmental protection requirements, in accordance with the results of the on-going BAT study. A 7-year project aiming at improving the noise and pollutant management at 50 shooting ranges, and, at the same time, piloting and perfecting techniques studied in the BAT-study, was planned.

The project “Improving the environmental protection of small arms ranges” was started in 2012. The shooting ranges were prioritized with regard to environmental protection challenges and importance for training, and the work started from the ranges with highest priority. To the end of 2014, measures have been completed on six ranges, and partly carried out on five ranges. In addition, the survey, permit and planning processes in different stages are ongoing on more than 10 ranges.

About half of the 22,5 million euro project budget had been used, the cost distribution being approximately 70% to noise abatement measures and 30% to pollutant management measures. The costs and cost estimates per range vary from 10 000 euros to 3,4 million euros, depending on the size of the range area and the number and type of individual lanes, and the different environmental protection needs and demands. As an indicator for the environmental protection costs, the figure €/shot/10 years has been used. The variation is wide, the indicative cost being between 0,01 - 1,50 €/shot/10 years for the different ranges. It cannot, however, be concluded that the smaller the cost, the better the cost-benefit ratio, as the cost should be evaluated against the environmental benefits gained and the user needs for the range. A summary of the project is presented below in Table 2.

Table 2. A summary of the "Improving the environmental protection of small arms ranges" – project: the ranges, their environmental protection needs and measures to meet these, the overall costs for each range and an estimate of the cost of environmental protection per shot per 10 years.

Range area	Shots/ year, 1000	Noise management need	Noise management measures	Pollutant management need	Pollutant management measures	Cost, in all 1000 €	Cost/€ shot/ 10 yrs
Completed							
Parolannummi	400	Major	Closing down range parts, noise-attenuating shooting stalls, noise berms and baffles	Major	Remediation, sand traps with asphalt and plastic liners, water treatment wells	1150	0,31
Hätilä	300	Minor	Closing down of range parts, new shooting stalls	Minor	Remediation, detention ponds for run-off waters	1350	0,44
Vekaranjärvi	1 500	Major	Closing down range parts, noise-attenuating shooting stalls, noise berms	Major	Remediation, sand traps with bentonite and plastic liners, detention pond	2800	0,18
Säkylä	800	Minor	Noise-attenuating shooting stalls	Major	Remediation, sand traps with asphalt and plastic liners	1500	0,18
Pirkkala	400	Major	Noise-attenuating shooting stalls, noise berms	Minor	Detention ponds for run-off waters	700	0,18
Hoikanportti	1 000	Minor	Noise-attenuating shooting stalls	Minor	Detention ponds for run-off waters	300	0,03
						7800	
Partly completed						**Cost estimate**	
Upinniemi	700	Major	Noise-attenuating shooting stalls, noise berms	Intermediate	Remediation, detention ponds for run-off waters	800	0,11
Tyrri	900	Major	Noise-attenuating shooting stalls, noise berms	Major; groundwater protection	Remediation, sand traps with bentonite and plastic liners	1250	0,14
Lupinmäki	400	Major	Closing down	Minor	Detention	1500	0,38

			range parts, noise-attenuating shooting stalls, noise berms		ponds for run-off waters		
Santahamina	950	Major	Relocation of range parts, noise-attenuating shooting stalls, noise berms	Intermediate	Remediation, sand traps with plastic liners, detention pond	3400	0,36
Luonetjärvi	500	Intermediate	Noise-attenuating shooting stalls	Intermediate/ minor	Remediation, sand traps with plastic liners, detention pond	700	0,14
						7650	
Planned 2015-2018						**Cost estimate**	
Kyrönpelto	500	Intermediate		Minor		950	0,19
Taipalsaari	200	Intermediate		Intermediate		500	0,25
Vuosanka	100	Minor		Minor		10	0,01
Skinnarvik	20	Intermediate		Minor		20	0,10
Rissala	200	Minor		Minor		30	0,02
Pansio	50	Minor		Minor		20	0,04
Pohjankangas	250	Minor		Intermediate/ minor		1000	0,40
Baggby	300	Intermediate		Intermediate		850	0,28
Raasi	650	Intermediate		Minor		1100	0,17
Syndalen	350	Minor		Major		400	0,11
Sodankylä	500	Minor		Minor		550	0,11
Pahkamaa	30	Minor		Minor		300	0,10
Padasjoki	100	Intermediate		Major		500	0,50
Tammela	10	Minor		Major		150	1,50
Hiukkavaara	300	Intermediate		Minor		150	0,05
Lakiala	5	Minor		Minor		10	0,20
Haapajärvi	30	Minor		Minor		100	0,33
Gyltö	50	Minor		Minor		100	0,20
Russarö	50	Minor		Minor		100	0,20
Heinuvaara	10	Minor		Minor		20	0,20
Niskavaara	10	Minor		Minor		20	0,20
						6880	
All 32 ranges	**11 535 shots/ year**					**22 330 €**	**0,01–1,5 €/shot /10yrs**

The project continues until the end of 2018. The amount of shooting ranges at which the measures are targeted has decreased in number to 32, due to fulfilled and planned closing of ranges. The increased environmental protection costs of shooting ranges have played an important part in the decisions.

Challenges in implementing the BAT-report

During the project, several challenges have been encountered. Some of them have been expected, some have come as a surprise. Most of the challenges are connected to the environmental permit process, which also was the starting point and motive for the BAT-survey.

Environmental permit process

- The long duration of the environmental permit processes has led to situations where environmental protection measures have had to be carried without a permit decision or with an appeal process going on.
- The long duration of the environmental permit process has also led to situations, where technical development has passed the solutions proposed in the application, but the permit regulations require the use of the specific technique suggested in the application.
- The incongruence of the permit regulations, sometimes also over-dimensioned requirements. The BAT-study aimed at providing guidance for uniform environmental protection demands and solutions to meet these. Draft versions of the BAT-report have been available to permit authorities since the year 2013, but it is unclear what guidance effect the draft has had. After the publication of the BAT-survey, only three environmental permits have been issued to the Finnish Defence Forces. Two of these are subject to appeal. The main deviation from the BAT-guidance in the permits issued during the BAT-draft period and after the publication of the report are:
    - The implementation of guidance values for noise as limit values
    - Over-dimensioned noise abatement demands
    - The use of Environmental Quality Standards (EQS) as limit values for run-off or seepage waters from the range area. This is incongruent with the definition of EQS's in the Government Decree 1022/2006. According to the Decree, pollutant concentration in surface waters may not exceed the environmental quality norm set for it. In this context, surface waters refer to a body of water as defined in the Water Act (587/2011), or a pond, river, brook, or other natural waterway, and a reservoir, channel or other corresponding artificial waterway. A rivulet is not considered to be a body of water; it refers to a watercourse that is smaller than a brook, has a drainage basin that is less than ten square kilometers in size, and in which water does not constantly flow and fish passage is not possible to any significant extent, or a ditch. The environmental quality norm is set as an annual average (= the arithmetic mean of the measured results of each individual, representative monitoring point over one year).
    - Monitoring requirements based on single samples instead of the annual average, and in general, more intense monitoring than proposed in the BAT-survey.
    - Over dimensioned or overlapping pollutant management demands
    - Obligations to use specified structural solutions, instead of setting the emission standard and leaving the operator with freedom of choice when it comes to methods

A summary of the environmental permit situation and challenges in connection to the permits is presented in Table 3 below.

Table 3. A summary of the environmental permit situation of the ranges included in the project

Range area	**Environmental permit, year**	**Appeal Yes/No**	**Reason for appeal (FDF)**	**Comments**
Before the publication of the BAT-study				
Parolannummi	2009	No		
Hätilä	2009	No		Environmental permit regulations for pollutant management are over-dimensioned compared to BAT-guidance
Vekaranjärvi	2011, into force 2013	Yes	Usage times; contaminant limit values in run-off waters set at surface body quality norm level; frequent	Neighbors also appealed: noise control requirements; usage times; pollutant control requirements

			removal of bullets required even with water control structures; monitoring program	
Pirkkala	2008, into force 2010	Yes	Usage times	
Upinniemi	2014	No		The surface water monitoring program and limit values for contaminants in surface waters were not set according to application and BAT-report. Decision not to appeal due to schedule limitations.
Kyrönpelto	2013	No		
Vuosanka	2009/2011	No		Neighbors appealed: noise
Rissala	2008	No		
Pansio	1994	No		Permit renewal process required
Baggby	2008/2011/2012	Yes	Implementation schedule; noise and pollutant management requirements	Neighbors also appealed: noise
Syndalen	2010	Yes	Permit included environmental permit demand for heavy weapons shooting in the same area	
Sodankylä	2012	No		
Pahkamaa	2009	No		
Padasjoki	2009	No		
Tammela	2009	No		
Hiukkavaara	2014	No		
Lakiala	2014	No		
Haapajärvi	2006	No		
After the publication of the BAT-study				
Tyrri	2014, not in force	Yes	Restrictions of number of shots fired per year; over-dimensioned noise abatement demands, would require massive investments with little benefits; limit for pollutant levels in seepage waters not set according to BAT-report.	Building in process, measures partly carried out as planned
Lupinmäki	2015, not in force	Yes	Guidance values for noise set as limit, would require massive investments; allowed weapon types; usage times; unnecessary soil remediation requirements; required water control structures	Building discontinued, measures partly carried out as planned, which does not fulfil the permit regulations.
Luonetjärvi	2015	No		
No permit yet				
Säkylä	Application 2012, no decision yet			Measures carried out as planned in the application; discussed with authorities
Hoikanportti	Application 2013, no decision yet			Measures carried out as planned in the application; discussed with authorities
Santahamina	Application 2012, additions 2014, no decision yet			Measures partly carried out as planned in the application; discussed with authorities

Taipalsaari	Application 2013, no decision yet			Measures partly carried out as planned in the application; discussed with authorities.
Pohjankangas	Application 2014, no decision yet			Planning in process
Raasi	Application 2012, no decision yet			
Skinnarvik	Application in 2015			
Gyltö	Not applied yet			
Russarö	Not applied yet			
Heinuvaara	Not applied yet			
Niskavaara	Not applied yet			

The impact of disruption of contaminated soil on pollutant emissions

- The excavation and disruption of contaminated soil may increase the pollutant emissions manyfold over a short period of time. This must be considered when assessing the benefits of environmental protection structures. The work should also be planned in such a way, that possible pollutant pulses can, as far as possible, be controlled and monitored.

The use of unsuitable building materials causing pollutant emissions

- In two separate cases, filter materials (rock aggregate) containing sulphide ore minerals have been used. The rock aggregate itself is clean, but the rapid corrosion of the sulphide minerals has caused the pH of the water to decrease. The acidic pH of the water dissolves metals from the soil. Interestingly, this has caused emissions that cannot be linked to shooting activity, but nevertheless have to be dealt with.

Effects of the improvement of the environmental protection of small arms ranges

Due to noise abatement measures carried out within the project, the number of people exposed to shooting noise from the Defence Forces' small arms ranges has decreased with 572. The number of holiday homes exposed to the noise has decreased with 190. The cost of the noise management measures so far has been around 6,9 million euros. A more detailed analysis of the situation is presented in Table 4.

Table 4. The effects and costs of noise abatement on Defence Forces' small arms ranges

	1.1.2012		**1.1.2015**				
Range area	**Number of people within >65 dB noise zone**	**Number of holiday homes within >60 dB noise zone**	**Number of people within >65 dB noise zone**	**Number of holiday homes within >60 dB noise zone**	**Change due to project, People**	**Change due to project, Holiday homes**	**Cost of noise abatement, 1000 €**
Completed							
Parolannummi	205	108	0	3	- 205	-105	656
Hätilä	0	1	0	0	0	-1	557
Vekaranjärvi	0	34	0	13	0	-21	1 047
Säkylä	4	1	0	0	-4	-1	165
Pirkkala	28	78	28	78	*	*	355
Hoikanportti	0	1	0	0	0	-1	150
Partly completed							
Upinniemi	30	112	0	57	-30	-55	400
Tyrri	101	5	26	2	-75	-3	500
Lupinmäki	73	26	73	26	*	*	972

Santahamina	258	46	0	0	-258	-46	1 759
Luonetjärvi	4	11	4	11	*	*	400
All together	**703**	**423**	**131**	**190**	**-572**	**-243**	**6 961**

In addition, the comfort and noise protection of the shooters has increased significantly. This has been one main reason for building noise-attenuating shooting stall constructions also on ranges where noise abatement measures have not been required by the environmental noise situation.

The effects of the pollutant management measures on the Defence Forces' small arms ranges cannot be quantified in a similar way as those for noise, since there has, in most cases, not been any systematic monitoring of pollutants emissions, their migration and impacts. It should also be noted that the aim of the measures is risk management at long term, that is, to prevent impacts that may have risen in tens or hundreds of years. Because of this, the effects of the project can only be assessed qualitatively. An evaluation of the benefits and the costs of the pollutant management measures is presented in Table 5. Based on the evaluation, it seems that at least on the high-priority ranges, where measures have already been completed or partly completed, the effects are mostly strong and positive. The cost of the pollutant management measures so far is around 4,2 million euros.

Table 5. An evaluation of the effects of pollutant management measures in the project and the costs of these.

Range area	Pollutant risk 1.1.2012	Pollutant risk 1.1.2015	Comments	Costs of pollutant management, 1000 €
Completed				
Parolannummi	High. Situated in important groundwater area used for water supply, elevated levels of Ni measured in GW on range	Risk management significantly improved. Contaminant load reduced due to extensive remediation. Pollutant spreading from back-berm and front of firing line prevented. Minor risk of contamination from other range parts.	Use of unsuitable building material has caused elevated emission levels. Water purification necessary.	310
Hätilä	Minor risk of pollutant spreading to surface waters.	Risk management improved Contaminant load reduced due to extensive remediation. Control of run-off waters from the whole range area.	Over-dimensioned environmental permit regulations. Use of unsuitable building materials has caused elevated emission levels.	300
Vekaranjärvi	Risk of pollutant spreading to surface waters.	Risk management significantly improved. Contaminant load reduced due to extensive remediation. Control of run-off waters from the whole range area.		450
Säkylä	Situated in important groundwater area, but area not in use due to contamination by solvents.	Risk management significantly improved. Contaminant load reduced due to extensive remediation. Pollutant spreading from back-berm and front of firing line prevented. Minor risk of contamination from other range parts.	Measures do not affect the current quality of the aquifer, but may have effect on long-term usability.	1 155

Pirkkala	Minor risk of pollutant spreading to surface waters.	Risk management improved.		50
Hoikanportti	Minor risk of pollutant spreading to surface waters.	Risk management improved.		60
Partly completed				
Upinniemi	Risk of pollutant spreading to surface waters.	Risk management significantly improved. Contaminant load reduced due to extensive remediation. Control of run-off waters from the whole range area.		250
Tyrri	High. Situated in important groundwater area used for water supply.	Risk management significantly improved. Contaminant load reduced due to extensive remediation. Pollutant spreading from back-berm and front of firing line prevented. Minor risk of contamination from other range parts.		750
Lupinmäki	Minor risk of pollutant spreading to surface waters.	Risk management improved. Control of run-off waters from the whole range area.	Over-dimensioned environmental permit regulations.	150
Santahamina	Situated by the sea, risk of pollutant spreading to the sea with run-off waters.	Risk management significantly improved. Contaminant load reduced due to remediation.		550
Luonetjärvi	Intermediate risk to groundwater.	Risk management significantly improved. Contaminant load reduced due to remediation.		140
All together				**4165**

Parallel with the environmental protection planning and implementation, monitoring programs have been drawn up for each range, and systematic monitoring has been started. This significantly improves the situation overview on the impact of small arms ranges on the environment.

Conclusions

The desired consistency in the environmental protection demands for small arms ranges has not yet been achieved. From applicant point of view, one mean to promote this is further developing the content of environmental permit applications. The noise situation and pollutant risk, assessed according to the BAT-guidance, and the environmental protection needs concluded from these, should be clearly presented. To avoid too detailed regulations, the Defence Forces could actively suggest regulation contents and formats.

Based on the Finnish Defence Forces' experiences, improving the environmental protection of small arms ranges according to the BAT-principles can be considered effective with regard to costs and impacts on the environment.

As experience is gained about the usability and efficiency of the noise and pollutant management methods and techniques presented in the BAT-study, the practical and structural solutions evolve. This should be complemented by studies in areas, where more information proves necessary. These include the impacts of contaminated soil disruption on pollutant emissions and the possibilities to manage these, and the efficiency of water control and purification methods. The BAT-report should be updated in about five years' time.

Environmental impacts of small calibre weapons in marine environment - An Example from two Swedish firing ranges.

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Abstract

The military training and firing ranges, deployed by the Swedish Armed Forces are used mainly for shooting with small and large calibre weapons, detonating explosives and demining exercises. However, these activities create an accumulation of scrap metal and unexploded ordnance, which are both of security and environmental concern. Some Swedish firing ranges are located adjacent to the sea. This will result in that a certain amount of both small and large calibre bullets will enter the water and the sediments. In the present study, environmental impact from lead deposited in the sea (Hanöbukten) from shootings at the Rinkaby and Ravlunda firing ranges are evaluated.

As a first step in estimating the potential impact on Hanöbukten from the nearby firing ranges, an impact area has to be defined. The small calibre ammunition, which reaches Hanöbukten, is assumed to be evenly distributed outside each of the two firing ranges. For Rinkaby firing range, the sea impact area is estimated to cover 400 ha, and for Ravlunda the corresponding area is 900 ha. The theoretical amount of lead deposited in Hanöbukten will be 80 tonnes from Rinkaby and 400 tonnes from Ravlunda. The data is based on historical investigations on the amount of small calibre ammunition used.

The question if ammunition may have an environmental impact on Hanöbukten is related to conditions, which involves the ammunition's corrosion in water, as well as the position of the bullets as to the sediment layer. The copper sheath that partially covers the projectiles implies that there is a less exposed lead surface during the transition period. The main part of sediments in Hanöbukten consists of sand and clay, which in turn are overlain by sand and gravel. This means that exposed metals are likely not in contact with the fine-grained sediments as they are situated upon the sand and gravel exposed directly to the water phase.

When a maximum corrosion rate of 0,05 % for lead in water during a 114-year period, about 2 tonnes soluble lead compounds have been formed outside Rinkaby, and correspondingly about 7 tonnes soluble lead compounds outside Ravlunda during 70 years. Considering that the amount of lead from the small calibre is distributed on each impact area, the total load of metallic lead to the sea from Rinkaby will become 5 kg/ha, and for Ravlunda 8 kg/ha in during a 114-year and 70 year time period, respectively. In the absence of accumulation bottoms, the main part of the soluble lead contaminations will, however, in the course of time successively pass over to the water phase and be transported further. It is therefore not probable that levels of lead in the sediments above the target value (<25 mg/kg TS)[1] will be achieved.

[1] Estimation basis for environmental quality. Coast and Sea. NV report 4914.

Content

Introduction

The military training and firing ranges, deployed by the Swedish Armed Forces are used mainly for shooting with small and large calibre weapons, detonating explosives and demining exercises. However, these activities create an accumulation of scrap metal and unexploded ordnance, which are both of security and environmental concern. Some Swedish firing ranges are located adjacent to the sea. This will result in that a certain amount of both small and large calibre bullets will enter the water and the sediments.

In the present study, environmental impact from small calibre lead deposited in the sea (Hanöbukten) from shootings at the Rinkaby and Ravlunda firing ranges are evaluated. The study is mainly based on historical data on the ammunition used and on lead weathering data. It was not possibly to get any sampling according to condition presented below. In the study the environmental effects are focused mainly on lead.

The sediments in Hanöbukten mainly consist of sand or clay, which in turn are overlain with sand and gravel. When there is a lack of accumulation on the sea floor, the main portion of added ammunition is estimated to be deposited within the sediment's top surface. No sampling has been reported in the relevant sediment area in Hanöbukten, likely due to the lack of accumulation floors. A documented organic content in the sediment from a sampling station in the area north the firing ranges, shows a loss on ignition of 0,3 %[2]. A marine geological map of Hanöbukten is shown in figure 1.

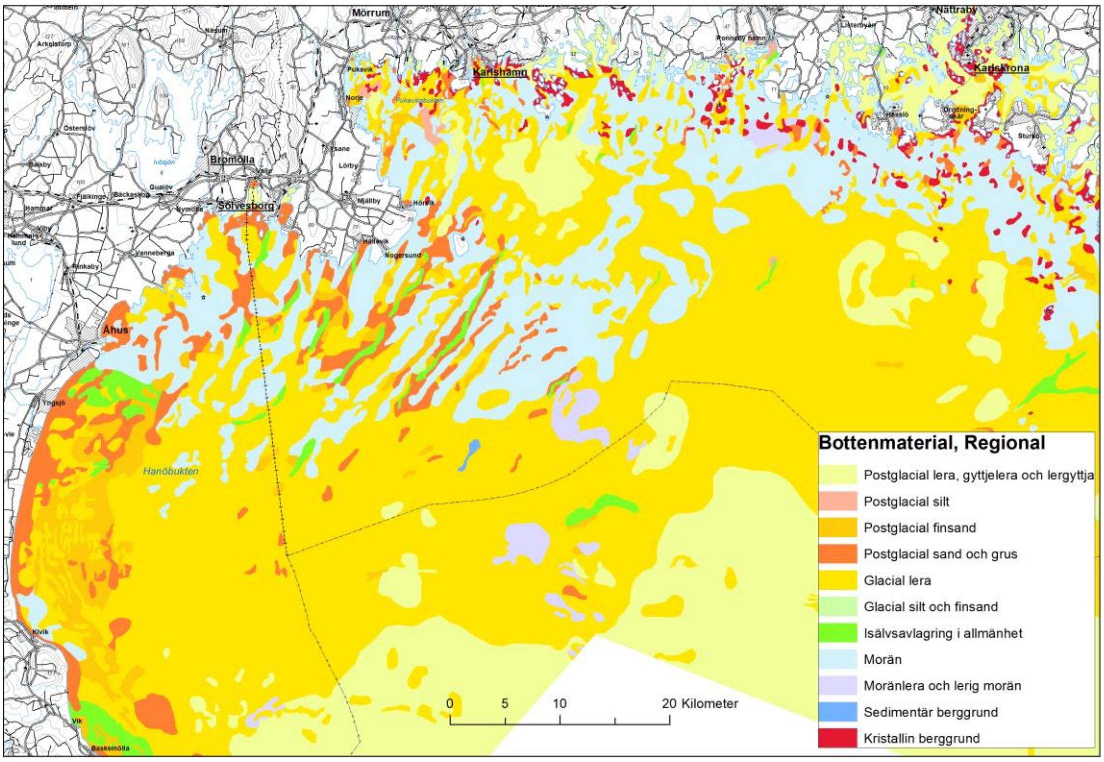


Figure 1. Marine geological map of Hanöbukten. Geological Survey of Sweden. K415.

[2] Hanöbuktens costal waters environment 2012. Swedish Agency for Marine and Water management 2012.

Rinkaby training and firing range has been in use for about 114 years. A part of the ammunition fired within the range has reached Hanöbukten. About 20 % of the small calibre ammunition used has been estimated to reach the bay. Ravlunda firing range has been in use for about 70 years. Also here, a part of the ammunition fired during the years is considered to have been deposited in Hanöbukten, approximately 50%.

To estimate the impact from the firing ranges on Hanöbukten, an impact area has to be defined. As a starting point, the potential impact area in Hanöbukten for each firing range has to be defined, i.e. probable striking areas as to the used ammunition types. For Rinkaby, the area has been estimated to be about 2 km wide reaching 2 km out into the bay, which gives an extent of 400 ha. For Ravlunda, the corresponding area is 4,5 km x 2 km, i.e. covering 900 ha.

Figure 2. A map of the estimated impact areas in Hanöbukten, corresponding to the Ravlunda and Rinkaby firing ranges.

Small calibre ammunition

For some reason there is a common misconception that metallic ammunition bullets, which reaches an aquatic environment, will more or less instantaneously dissolve, and thereby inducing an impact on its surrounding. The question whether ammunition will have an environmental impact on Hanöbukten is dependent on the corrositivity of the metallic lead bullets in brackish sea water (0.7-0.8 % salinity), in combination with the physical exposure of the bullet as it reaches the sediment's top surface. Parts of the lead bullet projectile are also covered by a thin brass sheath, which results in a reduced available lead surface during a transition period. The main part of sediments in Hanöbukten consists of sand and clay, which in turn are overlain by sand and gravel, i.e. accumulation floors are missing. From this one may conclude that metallic bullets will more likely be exposed to the water phase than bound into the sediments but are instead transported to the water phase.

Corrosion of lead in water

Scientific studies on the dissolution of metallic lead in water are scarce; the authors could not find any relevant data.. In fact, metallic lead is considered to be very stable in aquatic environments, which can be exemplified by the long-time use of lead in cables on the bottoms of lakes or at the seabed. Due to the lack of direct investigations, one has to use the results from indirect studies.

However, despite the lack of verified data on lead dissolution in water, an often used corrosion rate for lead in water is 1% per year. This rate is probably adapted from studies on lead in impact zones or shotgun ranges on land. Environmental risk assessments for ammunition in aquatic systems (such as in Hanöbukten) should instead be based on a more relevant corrosion rate for metallic lead. A more realistic corrosion rate for metallic lead bullets in water can be calculated by using observations of musket shots from the warship Vasa, i.e. lead shots that have been lying in brackish water (0,5 % salinity)for 333 years. From such studies an annual corrosion rate appears to range 0,02- 0,06 %.[3,4]

The conditions for lead are also partly conditional for copper, which constitutes a part of the bullet shield. SKB[5] has conducted some studies in oxygen free water (dissolution on copper plates of between 0,003 – 20 µm/year). These results are, however, not entirely comparable with the conditions in Hanöbukten. Studies on water pipes of copper has for example shown a corrosion rate of 2,5 µm/year for a 0,7 mm pipe. This means that it will take 280 years before the pipe has rusted through. A conclusion is that the corrosion of metallic copper in brackish water is generally low and should therefore not constitute an environmental risk.

Impact area.

The small calibre ammunition reaching Hanöbukten, is assumed to be distributed outside respective shooting range. For Rinkaby, the location is estimated to cover an area of 400 ha, and for Ravlunda the corresponding area is 900 ha. This is based on the shooting ranges border against Hanöbukten, as well as a probable impact zone for the projectiles.

Table 1 below shows the amount of metals estimated by the Swedish Armed Forces (P7), which has been deposited in Hanöbukten. The data is based on investigations[6],

Table1. Estimated amount of metals deposited in Hanöbukten during the period of activity.

Shooting range/ active period	Lead tonnes	Copper tonnes ton	Zinc tonnes	Antimony tonnes
Rinkaby/114 year	80 = 701 kg/year	60 = 526 kg/year	2 = 17,5 kg/year	0,2 = 1,8 kg/year
Ravlunda/70 year	400=5710 kg/year	200 = 2857 kg/year	10 = 143 kg/year	1 = 14 kg/year

In order to estimate the environmental impact in a long-term perspective, the amount of deposited ammunition lead during the period of activity is assumed to be 701 resp. 5170 kg/year. To estimate the amount of soluble lead contamination which might have been formed, one has to consider the total deposited amount of metallic lead , and the annual "loss" of soluble lead

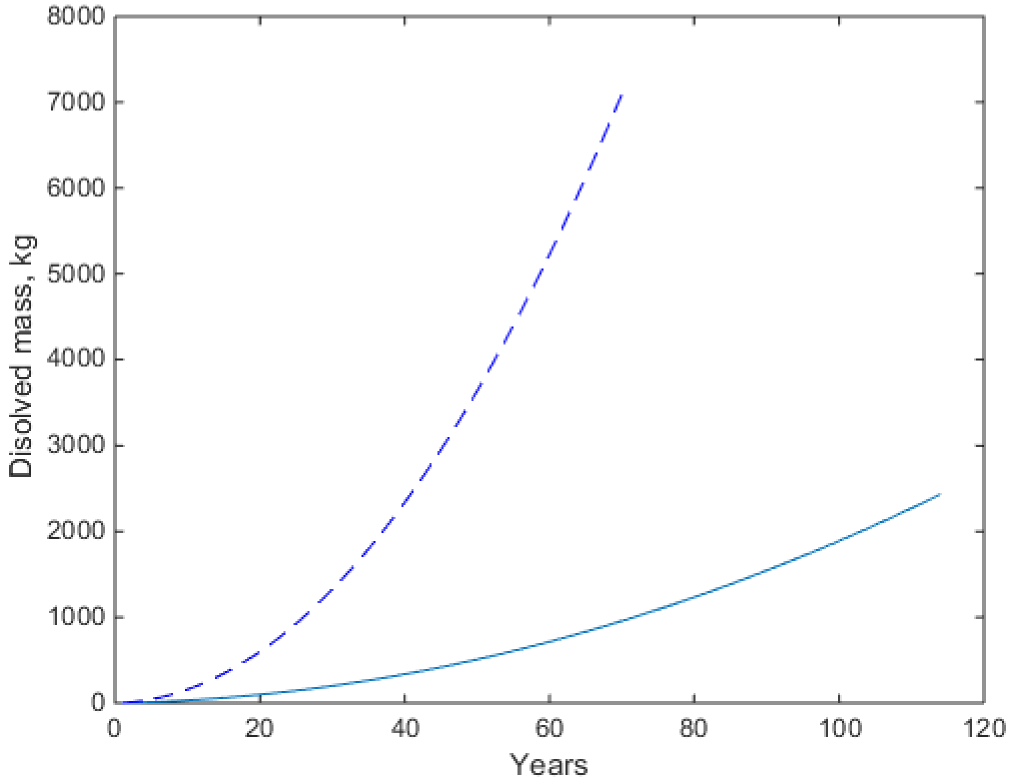
[3] Qvarfort, U 2015.Weathering studies of musket bullet from the warship Vasa. Report from a on-going investigation.

[4] Arrhenius, O. 1967: Corrosion on the warship Wasa. Rapport Korrosionsinstitutet.

[5] Swedish nuclear waste management.

[6] Investigations of the contamination situation around Ravlunda and Rinkaby. SWECO 2009

compounds. The ammunition lead deposited in year 1 will "produce" soluble lead during 70 resp. 114 years, i.e. up to the current date. The ammunition lead deposited year 2 will "produce" soluble lead during 69 resp. 113 years etc. This means that the amount of metallic lead deposited in Hanöbukten as well as the load of soluble lead will increase successively. To calculate the amount of soluble lead contamination from the built up amount of metallic lead within the impact area, the following equation can be applied[7]. It should be pointed out that this calculation is a rough approximation and reflect a theoretical worst case scenario as to the load of soluble lead, i.e. all deposited ammunition lead is considered to be available for corrosion and the corrosion rate is assumed to be constant over the years.



$$msol = M_0\left(1-e^{-kt}\right)+k\frac{At}{2}$$

$$M_0 = \frac{kA}{2\left(1-e^{-k}\right)}$$

k= 0,0005 (i.e. annual corrosion rate, 0,05%)
<u>Rinkaby case:</u>
A= 701 kg/year
Tf=114 year: dissolved mass (*msol)* = 2297 kg
<u>Ravlunda case:</u>
A=5710 kg/year
Tf=70 year: dissolved mass (*msol)* = 7093 kg

The calculation made above is based on the used amount presented in Table 1. This means that during a 114-year period, about 2,3 tonnes soluble lead compounds has been formed outside Rinkaby and about 7,1 tonnes soluble lead compounds outside Ravlunda during 70 years. If the amount of lead from the small calibre is considered to be evenly distributed within each impact area, the total load of lead from Rinkaby will become 5,8 kg/ha (0,05 kg/ha/year), and for Ravlunda 7,9 kg/ha (0,11 kg/ha/year) in total during a 114-year and 70 year time period, respectively. When there are no accumulation floors, the main part of the soluble lead contaminations will, however, in the course of time successively pass over to the water phase and be transported further by bottom currents.

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[7] Background report to government commission on lead in ammunition. NV report 5624

From the results above is evident that the load of soluble lead caused by small calibre ammunition in Hanöbukten is highly marginal. In reality the projectiles are initially shielded off by a brass case, which will limit the available weather able surface for lead. Since no extensive accumulation floors are present within the studied area, there will be minimal binding to the sediments. The sediment samples taken outside Ravlunda range close to the beach showing low levels of lead and copper are probably representative also for the more distant sediments [8]. Based on the calculations above, it seems unlikely that lead concentrations in sediments will reach nor exceed the target value for lead indicating none or small impact
(<25 mg/kg TS).[9] The same conditions will apply to copper, zinc and antimony.

Summary.

The sediments in Hanöbukten mainly consist of sand or clay, which in turn are overlain by sand and gravel. Accumulation floors are generally not found within the relevant area. . This type of hard sea floors makes it difficult to take meaningful sediment samples. Another consequence is that the main part of small calibre ammunition will deposit upon or within the sediment's top surface. From this position, released/dissolved metal compounds will directly be introduced into the water phase and be transported further by bottom currents. If the amount of small calibre ammunition is considered to be distributed evenly within each defined impact area, the total load of metallic ammunition lead from Rinkaby will become 200 kg/ha and for Ravlunda, 440 kg/ha during active time periods. From this successively built up amount of metallic lead, a total of 2,3 tonnes soluble lead compounds may be formed outside Rinkaby and about 7,1 tonnes outside Ravlunda. During the years, the amount of soluble lead compounds has been transported away by bottom currents. It is therefore not probable to find lead concentrations in the sediments exceeding the target value denoted by the Swedish EPA (<25 mg/kg T).

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[8] Sample time investigation SWECO 2008-2009.
[9] Estimation basis for environmental quality. Coast and Sea. NV report 4914.

Development of Guidance Values for Explosive Residues

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Abstract
Screening values of harmful substances are commonly used to regulate and manage contaminated sites. In Finland, soil screening values are risk-based and regulated by Government Decree 214/2007 and its Guidance document (Environmental Administration Guidelines 6/2014). Those values have been determined through a risk assessment framework for different land use options. If site-specific soil concentrations exceed the set guidelines, quantitative risk assessment and/or risk management measures are to be applied.

No official guideline values have been assessed for energetic materials. Therefore, adapting the risk-based framework used in the Guidance document, generic health based Maximum Acceptable Concentrations (MAC_h) were assessed for the most common explosive substances (TNT, RDX, HMX) as well as some of their degradation products and impurities (2,4-DNT, 2,6-DNT, TNB, and 2- and 4-amino-DNT). In the exposure assessment, health risks when exposed to surface soil were calculated for “Military Site” land use option. For each substance, an individual MAC_h was assessed using back calculation from surface soil concentrations. For “Military Site”, MAC_h -guidance values for TNT, RDX and HMX were 496 mg/kg, 182 mg/kg and 30 000 mg/kg, respectively. These values can be used for range management, keeping in mind that they are not valid when other exposure routes, such as drinking and eating site-specifically contaminated water and food, are present. Also, if the site is located in a classified groundwater area, quantitative risk assessment including fate and transport modelling should be applied.

1. Introduction

The use of heavy weapons and explosives is practiced in numerous operational military ranges in Finland. Artillery, mortars, tanks, multiple launch rocket systems, shoulder-fired anti-tank rockets, grenade shooting machine guns as well as hand grenades are known to cause energetic residues to the top soil. Also, detonation and demolition training, explosive ordnance disposal and open burning of the excess propellants can cause emissions that may be accumulated into the surface soils. Several ranges have been used for training for decades, and therefore it is possible that in some sites concentrations of energetic compounds may have reached levels which are unacceptable for human health and environment.

Screening values of harmful substances are commonly used to regulate and manage contaminated sites. In Finland, soil screening values are risk-based and regulated by Government Decree 214/2007 and its Guidance document (Environmental Administration Guidelines 6/2014). Those values are determined through a risk assessment framework for different land use options. In that framework, three levels of soil screening values are derived: The threshold value indicates insignificant risk, lower and upper guideline values denote risks that are unacceptably high either for residential or industrial land use. If site-specific soil concentrations exceed the set guidelines, quantitative risk assessment and/or risk management measures are to be applied.

To be defensible in decision making process, the soil screening values have to be scientifically sound and transparent. Also, to be used as national standard values and for regulatory purposes these guidelines have to take in consideration a variety of exposure and transport scenarios considering both health and ecological aspects. Because the amount of work and data behind each screening value is extensive, values have been derived only for the most toxic, persistent and accumulating chemicals, as well as for the harmful substances most commonly found in the environmental compartments.

Consequently, no official soil screening values have been assessed for energetic materials in Finland. Noticing the importance of improving the level of environmental protection concerning the environmental impact of energetic residues, the Defence Command of Finland has launched a multi-national, three-year-project on the technical and practical solutions for environmental protection of heavy weapons ranges. One part of the project is to determine the guidance values for explosives.

As a first step on the screening value project, generic health based Maximum Acceptable Concentrations (MAC_h) for surface soil were assessed for the most common explosive substances as well as for some of their degradation products and impurities.

2. Materials and methods

Human health risk assessment can be defined as the characterization of the potential adverse effects on human life or health. According to US EPA’s Risk Assessment Guidance for Superfunds, RAGS-manual (US EPA 1989), risk assessment process is divided into four basic steps:

1) Data collection and evaluation
2) Exposure assessment
3) Toxicity assessment
4) Risk characterization

2.1 Data collection and evaluation

At the first stage of risk assessment, the existing environmental data from heavy weapons operations and explosives training sites in Finland was collected. Also, some of the environmental investigations from heavy weapons ranges from other countries (Walsh et al. 1993; Hewitt et al. 2003; Pennington et al. 2006) were referred to identify the potential chemicals of concern (CoC). The most abundant energetic compounds, their degradation products and impurities that were most commonly found in the soil samples from heavy weapons ranges are listed in Table 1.

Table 1. The Chemicals of Concern (CoC) at heavy weapons ranges

Energetic substance	Formula	Abbreviation	CAS-number
2,4,6-trinitrotoluene	$C_7H_5N_3O_8$	TNT	118-96-7
2-amino-4,6-dinitrotoluene	$C_7H_7N_3O_4$	2-AT / 2-ADNT	35572-78-2
4-amino-2,6-dinitrotoluene	$C_7H_7N_3O_4$	4-AT / 4-ADNT	19406-51-0

2,4-dinitrotoluene	C_7-H_6-N_2-O_4	2,4-DNT	121-14-2
2,6-dinitrotoluene	C_7-H_6-N_2-O_4	2,6-DNT	606-20-2
octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	$C_4H_8N_8O_8$	Octogen, HMX	2691-41-0
1,3,5-trinitro-hexahydro-1,3,5-triazine	$C_3H_6N_6O_6$	Hexogen, RDX	121-82-4
1,3,5-trinitrobenzene	$C_6H_3N_3O_6$	TNB	99-35-4

2.2 Exposure assessment

At the second stage, the exposure media, exposure pathways and also the potential receptors were chosen. The main focus for this study was to determine the Maximum Acceptable Concentrations of energetic compounds for surface soil. Therefore, transport to and exposure from surface water and groundwater were excluded from further assessment. It must be stressed out that this exclusion was not based on chemical characteristics and behavior of CoC, hence many of them are capable of leaching into deeper soil layers and eventually into groundwater. On the other hand, CoC are not volatile, so volatilization from soil or water is not considered to be a significant exposure pathway. Moreover, the scope of the assessment was to focus to health effects and therefore no ecological effects are considered in this assessment.

The main users of training ranges are military personnel, maintenance staff and conscripts that work, train and/or exercise at the site (henceforth “Receptor”). Consequently, the chosen land use option, where the Receptor is exposed to CoC is called “Military Site”. The final composition for the human health risk assessment is shown in Table 2.

Table 2. Conceptual exposure scenario for the Receptor on direct exposure to surface soil at Military Site

Exposure Media: Military Site	Exposure Pathway: DIRECT	Exposure Receptor:
Surface soil	Inhalation of dust	Lungs → blood → organs → excretion
	Ingestion of particles	GI-track → blood → organs → excretion
	Dermal contact	Blood → organs → excretion

Human health risk assessment can be defined as the characterization of the potential adverse effects on human life or health. Calculating risk is sometimes called the “forward calculation” whereas calculating clean-up levels is called the “back calculation”. In this risk assessment the back calculation was used to determine the Maximum Acceptable Concentration on the surface soil for each CoC listed in Table 1. In order to calculate the exposure and descriptive risk levels for CoC, exposure parameters suitable for the “Military Site” and for the Receptor were selected. The default parameters recommended by US EPA were used where applicable (US EPA 2011). Exposure parameters are shown in Table 3.

Table 3. Exposure parameters used in health risk assessment

Exposure Parameters	Units	Value	Definition
Exposure duration	a	20	Approximated working years at the Military Site
		70	Averaging time for carcinogens (US EPA)
Exposure frequency for soil	events/a	200	Approximated number of days when

			surface soil is not covered of snow/ice
Body weight	kg	70	default for adult Receptor (US EPA)
Skin surface area exposed to soil	cm^2	5300	Approximated surface area of the skin that can be directly exposed (about 25 % of the whole skin area of adult Receptor)
Soil/skin adherence factor	mg/ cm^2	0,2	default for adult Receptor (US EPA)
Ingestion rate for soil	mg/d	200	approximated according to the type of work/training at Military Sites
Absorption factor	-	1	Worst case (everything is absorbed)

For obvious reasons it was assumed that the Receptor is an adult, whose approximated working years at the Military Site was set to 20 years. The exposure frequency for soil (200 events/a) is the mean number of days when the temperature is above the zero C in Finland.

Some energetic residues may be absorbed through the skin into the bloodstream. Absorption depends upon the amount of soil contact with the skin, concentration of CoC in soil, the absorption potential of particular substance, as well as the exposed area of the skin surface. Receptor who is working at Military Site is supposed to wear long sleeved outfit or overalls. Therefore the reasonable maximum for skin surface area that could be exposed to soil particles was thought to be less than default used by US EPA. In this risk assessment, a quarter of the whole skin was supposed to be exposed. Soil to skin adherence factor is the one that is used by EPA (US EPA 2004) for landscapers and rockery workers (95^{th} percentile).

Adult Receptor working outdoors may ingest soil through incidental contact of the mouth with hands and clothing. Also, particularly in open sands soil particles and dust carried by the wind may enter the mouth. The ingestion rate at the Military Site is supposed to be higher than that recommended for general population by US EPA (central tendency = 50 mg/d). Therefore, the ingestion rate of 200 mg/d (95^{th} percentile, general population) which is also including the ingestion of dust, was selected for exposure estimation. Since there was limited amount of scientifically sound data available about the absorption of the CoC into the body, the absorption factor was conservatively set to 1 (full absorption).

It must be noted that in exposure calculations the soil concentration of the CoC was assumed to be constant with time.

2.3 Toxicity assessment

A substance can have either carcinogenic or non-carcinogenic toxicity. While carcinogenicity has no threshold for toxic effects, non-carcinogenic effects often appear above certain limit value or after particular exposure time. For non-carcinogens, there is supposed to be a substance-specific reference dose (RfD), below which no harmful effects are supposed to appear even for the most sensitive individuals. For carcinogens there is no safe dose; it is assumed that exposure to any amount of a carcinogenic substance will increase the risk of cancer. Thus, substance-specific Slope Factor (SF) is used in estimating the carcinogenic toxicity of the chemicals. Reference doses (RfD) and Slope Factors (SF) for CoC are show in Table 4.

Table 4. Carcinogenic and non-carcinogenic toxicity of CoC

Energetic substance	Cancer Classification	Oral RfD	UF***	Oral SF
	US EPA (1986)	(mg/kg-d)	-	$(mg/kg\text{-}d)^{-1}$
TNT	C	0,0005	1000	0,03
RDX	C	0,003	100	0,11
HMX	D	0,05	1000	-
2,4-DNT	B2	0,002	100	0,31**
2,6-DNT	B2	0,0003	nd	-
TNB	nd	0,03	100	-
2-AT	nd	0,002 *	100	-
4-AT	nd	0,002 *	100	-

* No reference dose available. US EPA is using the RfD of 2,4-DNT (0,002) for 2-AT and 4-AT.
** No reference dose. For calculation oral SF given to 2,4,-DNT by Californian EPA was used.
*** UF = Uncertainty Factor.
US EPA= United States Environmental Protection Agency (1986)

Uncertainty factors are usually 10-fold default factors that are used in deriving the RfD-values from experimental data. The factors account for variation in human population, extrapolation from animal data to humans, extrapolation from subchronic to chronic exposure, extrapolation from LOAEL (Lowest Observed Adverse Effect Level) instead of NOAEL (No Observed Adverse Effect Level) data, and uncertainty associated with extrapolation when the database is incomplete.

Chemicals in the environment assessed by US EPA are classified in five groups based on the existing scientific evidence for carcinogenicity. No energetic substances are classified into Group A: "Human Carcinogen" neither into Group B1: "Probable Human Carcinogen". Dinitrotoluene (DNT) has been classified into Group B2: “Probable Human Carcinogen". The B2-category is for chemicals for which there is "sufficient" evidence from animal studies and for which there is "inadequate evidence" or "no data" from epidemiologic studies. Group C: “Possible Human Carcinogen” is for chemicals (TNT, RDX, HMX) with limited evidence of carcinogenicity in animals in the absence of human data. The rest of the substances in this study were not categorized by US EPA for their carcinogenicity. Even though TNT and RDX are Group C chemicals, they have been given Slope Factors and thus in this study, they were assessed also for their carcinogenic potential together with DNT.

2.4 Risk characterization

Carcinogenic risk is estimated as the probability of an individual to develop a cancer over a lifetime:

$$IELCR = SF \times LADD$$

where:

IELCR = Individual excess lifetime cancer risk for chemical (-)
SF = Slope Factor for chemical (mg/kg-day)-1
LADD = Lifetime average daily dose (mg/kg-day)

Acceptable excess lifetime cancer risk caused by exposure to a chemical is conservatively set to 1×10^{-6} (one in a million).

Non-carcinogenic risk is evaluated by comparing an exposure level with a reference dose in a similar exposure period. This ratio is called Hazard Quotient (HQ):

HQ = CADD / RfD

where:

HQ = Hazard quotient for chemical (-)
CADD = Chronic average daily dose (mg/kg-day)
RfD = Reference dose for chemical (mg/kg-day)

Acceptable non-carcinogenic risk level is achieved when Hazard quotient is less than 1 (HQ < 1).

Intake of energetic residues in soil by ingestion was estimated as follows:

$$CADD = \frac{C_{\max} \times IR \times AAF \times EF \times BIO}{BW \times 365 \frac{d}{yr}} \times 10^{-6} \frac{kg}{mg}$$

$$LADD = \frac{C_{ave} \times IR \times AAF \times EF \times ED \times BIO}{LT \times BW \times 365 \frac{d}{yr}} \times 10^{-6} \frac{kg}{mg}$$

where:

C_{max} = Maximum 7-year average concentration of chemical in soil (mg/kg)
C_{ave} = time-averaged concentration of chemical in soil over the exposure duration (mg/kg)
IR = Soil ingestion rate (mg/day)
AAF = Chemical-specific oral-soil absorption adjustment factor (mg/mg)
BIO = Bioavailability of chemical in soil (mg/mg)
EF = Exposure frequency
ED = Exposure duration (years)
BW = Body weight (kg)

Intake of energetic residues in soil by dermal contact with soil was estimated as follows:

$$CADD = \frac{C_{\max} \times SA \times AAF \times AF \times EF \times BIO}{BW \times 365 \frac{d}{yr}} \times 10^{-6} \frac{kg}{mg}$$

$$LADD = \frac{C_{ave} \times SA \times AAF \times AF \times EF \times ED \times BIO}{LT \times BW \times 365 \frac{d}{yr}} \times 10^{-6} \frac{kg}{mg}$$

where:

SA = Skin surface area exposed to soil (cm^2)
AAF = Chemical specific dermal-soil absorption adjustment factor (mg/mg)
AF = soil-to-skin adherence factor (mg/cm^2/event)

To back calculate the Maximum Acceptable Concentrations (MAC) for each energetic compound, the soil concentration was set chemical-specifically to the value, where either the carcinogenic risk equaled acceptable excess lifetime cancer risk (for TNT, RDX, and DNTs) or the chronic average daily dose equaled to chemical-specific reference dose (for HMX, TNB, and ATs).

When risk limits for widespread contaminants are assessed, a specific contribution factor is usually set for each chemical to estimate the portion of the background exposure that should be added into the site-specific exposure load. In the case of energetic substances it is assumed that the exposure is site specific only with no background exposure. Resulting health-based MAC_h for CoC in surface soil of the Military Site are presented in Table 5.

Table 5. Health based Maximum Acceptable Concentrations (MAC_h) for energetic residues in surface soil of the Military Site (mg/kg)

Energetic substance	Abbreviation	MAC_h (mg/kg)
2,4,6-trinitrotoluene	TNT	496
2-amino-4,6-dinitrotoluene	2-AT / 2-ADNT	1470
4-amino-2,6-dinitrotoluene	4-AT / 4-ADNT	1450
2,4-dinitrotoluene	2,4-DNT	97
2,6-dinitrotoluene	2,6-DNT	45
octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	Octogen, HMX	30 000
1,3,5-trinitro-hexahydro-1,3,5-triazine	Hexogen, RDX	182
1,3,5-trinitrobenzene	TNB	18 000

There is limited amount of screening values for energetic substances available. US EPA has calculated an industrial soil screening level of 79 mg/kg for TNT and 24 mg/kg for RDX (US EPA 2014). Norwegian Defence Research Establishment FFI has evaluated risk based screening values for different land uses. In that study, an industrial soil screening levels of 100 – 200 mg/kg for TNT and RDX, 500 – 1000 mg/kg for HMX, and 100 – 170 mg/kg for 2,6-DNT were calculated. Other screening values calculated for military land use were not found. Therefore, comparison to other guidelines is not appropriate since the land use options and selected exposure pathways are different.

In recent years, energetic residue concentrations at the surface soils of different heavy weapons training sites have been studied in Finland. Results indicate that energetic residue levels at artillery, mortar and antitank rocket firing points, as well as at the hand grenade training sites and explosives demolition pockets have mainly been below the MACs calculated in this study.

3. Discussion

This study describes the evaluation of the health based Maximum Acceptable Concentrations of energetic residues in the surface soils of military sites. The MAC_hs are the first step in the process towards the defendable guidelines for energetic substances. These screening values are valid to be used site-specifically by site managers for first phase decision making and for health and safety evaluations.

It must be kept in mind, however, that these screening values should only be used when assessing the applicability of the site for military use. Importantly, MACs assessed here are not valid when other exposure routes, such as drinking and eating site-specifically contaminated water and food are present. Also, if the site is located in a classified groundwater area, quantitative risk assessment including fate and transport modelling should be applied. For environmental conservation, ecotoxicological studies should be referred when assessing the ecologically sound screening values.

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Full text article

Precautionary soil and water protection by the German Ministry of Defence (MOD) - Vulnerability assessments on military training areas

In 2014 the German MoD celebrated the 25th anniversary of its Site Remediation Program. The essence of the program's success is a systematic, consecutive approach for the identification, investigation and remediation of contaminated sites. The program consists of three main phases. Phase I covers the identification and initial evaluation of potential contaminated sites based on available data and information. Field investigations to either confirm or disprove a potential contamination of soil and water are conducted in Phase II. If proved necessary, remediation measures apply in Phase III. This standardized Remediation Program of the German MoD has been realized on German military sites since 1995 and applies to all harmful soil alterations and water pollutions.

However, the program has in general not been applied at military training ranges in use, such as artillery target areas and demolition training ranges. Remediation measures are ineffective when training activities cause an ongoing release of contaminants after a successful soil remediation. In order to address contaminations on these sites the German MoD initiated a new program in 2014. The main objective of this new program is to establish a future-oriented and precautionary soil and water protection program dealing with training ranges in use to prepare the German MoD's environmental protection measures for prospective challenges. Furthermore, the new program is not only implemented to ensure environmentally safe military exercises, but also to provide support for the organization of military training areas from an environmental perspective. Therefore the program involves military staff on all levels to achieve a widespread acceptance and to address concerns of both military use and environmental laws.

The new program is based on a three-year pilot study to examine five demolition training ranges in different geologic and morphologic settings in Germany. The results of the study showed in several cases significant concentrations of energetic compounds in the soil. Other contaminants such as polycyclic aromatic hydrocarbons and heavy metals were of minor importance. The results of the pilot study lead to the development of a general concept to evaluate potential soil and water contaminations due to the current use of demolition training ranges. The concept combines standardized geologic and hydrologic settings with information on the military usage (e.g., the amount of explosives) to assess locally the potential risk for the environment. However, the concept encounters its limits evaluating larger training ranges or even entire military training areas. Therefore the Federal Institute of Geosciences and Natural Resources (BGR) applied vulnerability mapping and assessments to military training areas and ranges as an extension of Phase I of the traditional Site Remediation Program of the German MoD. Thus the Program is now able to cover potential risks of military training ranges in use.

The general concept of groundwater vulnerability assessments has been commonly used in the field of hydrogeology since the late sixties. Today several different methods exist, such as the DRASTIC (Aller et al., 1987), EPIK (Doerfliger & Zwahlen, 1998) or COP (Vías et al., 2002). The current study is based on the German GLA-Method (Hölting et al., 1995) developed by the German State Geological Surveys (GLA) and the Federal Institute of Geosciences and Natural Resources (BGR). Until today the German State Geological Surveys implement the GLA-Method as part of the EU Water Framework Directive. The GLA-method assesses the natural environment (e.g., geology, pedology, hydrology) with respect to its protective function above the groundwater table. This concept is referred to as intrinsic vulnerability. The controlling factor of the intrinsic vulnerability is, according to the GLA-Method, the time taken by the infiltrating water to reach the groundwater surface (travel time). Therefore the method takes the property and thickness of the top soil and each geological layer between the ground surface and the piezometric level of an aquifer into account. Intrinsic vulnerability maps are generated with the use of geographic information systems and show the spatial pattern of low to highly vulnerable areas. The maps simply represent the natural protective function without considering the properties of a contaminant (or contaminant group).

In contrast, specific vulnerability combines the properties of a contaminant (or contaminant group) with the intrinsic vulnerability of a project area. Thus, physicochemical, mechanical as well as microbiological processes are considered during the transport of any pollutant through the unsaturated zone. The specific vulnerability of military training ranges of the current project is based on the final report of the European COST Action 620 “Vulnerability and Risk mapping for the Protection of Carbonate (Karst) Aquifer” (2004).

During a first project phase, the GLA-Method and the results of the COST Action 630 were combined and the vulnerability concept was modified to the needs of environmental protection on military training areas by the BGR. Simultaneously, a comprehensive database was developed containing not only type and quantity of the ammunition used on various training ranges, but also the important chemical components of each ammunition type. The military database was furthermore supplemented by a geodatabase providing geoinformation relevant to vulnerability assessments. Eventually the concept was applied on two training areas in Germany (military training area Oberlausitz, Saxony; military training area Baumholder, Rhineland-Palatinate). The project areas differed greatly in topography, vegetation and geology. The results showed that the concept can generally be applied independent of the natural environment. However, the results, as in any theoretical model, depend greatly on the quantity and quality of the data available.

As previously described, the new vulnerability assessment is an extension of Phase I of the existing Remediation Program. The results of the analysis are classified into three priority levels. Priority 1 excludes training ranges from any further evaluation, since the contamination potential appears negligible. Military training ranges categorized as Priority 2 require further information and data analyses (e.g., contamination due to activities during prior years) in Phase I to confirm or disprove the contamination potential. Training ranges of Priority 3 are directly transferred to Phase II of the Remediation Program. In total 21 training ranges and target areas of the military training areas Oberlausitz und Baumholder were evaluated. Five target areas were classified as Priority 3 and directly transferred to Phase II. The contamination potential of five training ranges could not yet bet conclusively defined (Priority 2). The remaining training ranges were classified as Priority I and therefore excluded from the Program.

After the successful implementation of the vulnerability concept in 2014, ten additional military training areas across Germany will be assessed in future. Depending on the data and information availability the workload is estimated to two military training areas per year. Phase II and III action will be taken subsequently according to the Site Remediation Program as results from the vulnerability assessments evolve.

In conclusion, vulnerability assessments prove to be a flexible tool to meet the expectation of modern environmental protection. Moreover it is a practical complement to the traditional Remediation Program of the German MoD, which is primarily an aftercare program. Finally, vulnerability maps enable the responsible entities to establish an environmentally sustainable organization of military training areas to ensure long term military use.

Towards Environmentally Sustainable, High Performance Ammunition

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ABSTRACT

Ranges and training area (RTAs) are a key aspect to the training of military forces around the world. However, the use of ammunitions was shown to lead to the dispersion of Energetic Materials (EM) residues in RTAs. The use of sustainable ammunitions constitute a promising mitigation process by solving the issue directly at the source, thus reducing the unexploded ordnances production, the need for expensive RTAs cleaning or remediating as well as the necessity to develop site-specific range attenuation designs. A cost benefit analysis indicated that it is cost-effective to consider the long-term effects of the munitions on the environment right at the beginning of the weapon system development cycle.

Canada has initiated the development of environmentally sustainable ammunition in 2008 with a project aiming to prove that the environmental pressure on RTAs can be decreased and the health hazards for the users be minimized without reducing the ammunition performance. This was accomplished by performing significant improvements to a 105-mm army artillery munition (HE M1) currently using a M1 single-base propellant and Composition B as the main charge explosive. A near-zero dud rate was achieved by developing a self-destruct device for the fuse system. The potential of RDX contamination was eliminated by replacing Composition B with a melt-cast recyclable formulation made of an energetic thermoplastic elastomer, TNT and HMX, which meets the current performance criteria of in-use munitions, has better IM properties than Composition B and can be processed with conventional melt-cast equipment. The use of toxic and carcinogenic compounds in the propellant formulation was avoided by replacing the M1 propellant charges with a modular HMX-based formulation greener than M1, which is suitable for extended range applications and has better IM properties than current propellant formulations. A matrix of criteria was built to help select the appropriate candidates. The main selection criteria considered were the environmental and IM properties, the technical feasibility, the life cycle cost and the performance. The project was completed with a gun-firing demonstration.

The aim of this communication is to provide an overview of the project and to describe the properties of the chosen propellant and explosive formulations. This will help sustain military training while preserving our resources, as well as shaping the future of weapon system development.

1. INTRODUCTION

Ranges and training area (RTAs) are a key aspect for the military forces around the world. However, the use of ammunition was shown to lead to the dispersion of Energetic Materials (EM) residues both in impact areas and at firing positions (Walsh *et al*, 2011 and 2013a, and references therein). Normally functioning munitions only spread a small amount of energetic residues in the environment. Most of the contamination in impact areas comes from unexploded ordnances (UXOs) that are cracked open by the detonation of an incoming round, by incomplete (low-order) detonations, by the destruction of duds and insensitive munitions (IM) and by the corrosion of UXOs. In fact, a single round which detonates incompletely (low order) spreads as much unburned explosives as 10,000 to 100,000 high-order rounds. In addition, UXOs pose safety problems for the troops, both in domestic training and in operations, and have to be removed from RTAs with a regular surface clearance. Unexploded or deflagrated RDX does not degrade in soil and, because of its solubility in water, migrates easily to groundwater and off military property. This may trigger a serious environmental problem and becomes a public health concern if the groundwater is used for drinking. Another health hazard arises from the incomplete combustion of gun propellant and from burning of excess gun propellant bags at firing positions. Propellants contain significant amounts of carcinogenic and toxic components, recently forbidden in Europe (EU, REACH), which could have a health impact on soldiers. Many RTAs firing points were contaminated with concentrations of energetic residues above the preliminary guidelines, sometimes by many orders of magnitude. This is an important issue because military personnel have to train to keep their state of readiness. Therefore protecting sensitive receptors of the fauna, flora and human populations by preventing contamination and hazards is essential to keep RTAs operational.

Range remediation and mitigation have been found beneficial to avoid unnecessary dispersion of EM outside range boundaries. Sustainable ammunitions constitute a promising mitigation process by solving the issue directly at the source, thus reducing the unexploded ordnances production, the need for expensive RTAs cleaning or remediating as well as the necessity to develop site-specific range attenuation designs. Canada initiated a Technology Demonstration Program (TDP) in 2008, aiming to prove that green and insensitive munitions (IM) will decrease the environmental pressure on RTAs and minimize the health hazards for the users without decreasing the performance of the munition. This five-year project, entitled Revolutionary Insensitive, Green and Healthier Training Technology with Reduced Adverse Contamination (RIGHTTRAC) was mainly funded by Director General Environment (DGE) of Canada's Department of National Defence (DND), led by Defence Research and Development Canada (DRDC), and performed with the collaboration of General Dynamics – Ordnance and Tactical Systems (GD-OTS) Canada, the *Institute national de la recherche scientifique – Centre eau, terre environnement* (INRS-ETE), the National Research Council (NRC) and the *Centre de recherche industriellle du Québec* (CRIQ). The goals of this TDP were to reach a near-zero dud rate and eliminate the potential for RDX contamination as well as the use of toxic and carcinogenic compounds. This was done by performing significant improvements to the fuzing system, the main explosive charge and the gun propellant. Once demonstrated, the technologies developed during this project are expected to be easily transferable to other types of medium and large calibres for the energetic formulations, and to other types of large calibre ammunition for fuzes.

A cost-efficiency analysis (CEA) was used to estimate the sustainable munitions' incremental economic costs, based on cost differences between green and conventional munitions (Sokri, 2011). This methodology was preferred to a full cost-benefit analysis because the feasibility of measuring all of the project's benefits (e.g., the value of training) was deemed low. In collaboration with subject matter experts, relevant cost categories were identified during the whole life-cycle of the munition, from its manufacture to its disposal either by live-fire or by demilitarization. Obtaining all the necessary data proved to be a huge challenge, because the information was often missing, partial, or very complex. For example, the RTA maintenance scenario may be as simple as performing a surface clearance to avoid UXOs, and cutting the bushes on a flat area, or as complex as performing an in-depth clearance, discarding the UXOs by blow-in-place, and cutting trees in a wooded steep area. Despite intensive research efforts, it was not achievable to obtain data for some cost categories. Therefore, simulated data obtained from a hypothetical training installation and a realistic baseline scenario were used for liability, remediation of impact areas, munitions conception, unit manufacturing cost, demilitarization and initial investment (e.g., PBX plant).

Results demonstrated that, on a 10-year basis, mean potential savings of several millions of dollars per artillery range could be reached by using sustainable ammunition in artillery impact areas. The status quo would thus be more expensive due to environmental hazard.

The aim of this communication is to provide an overview of the project and to describe the performance, IM and environmental properties of the chosen propellant and explosive formulations. A description of the selection criteria used to choose the final propellant and explosive formulations is also provided. Modifications to the fuzing system and the recycling process have already been previously reported (Brochu *et al*, 2011, 2014) and will not be further described in this communication.

2. RIGHTTRAC

As shown in Figure 1, the vehicle used for this demonstration was a 105-mm army artillery munition (HE M1), currently filled with Comp B and using a single base gun propellant (M1) formulation. The project tackled the three main components: the fuze, to add an independent self-destruct capacity to existing fuzes in order to significantly reduce or eliminate the UXOs; the gun propellant, to replace toxic or carcinogenic ingredients, to improve the IM characteristics of the propellant and to explore the concept of modular charges; and the explosives to replace the RDX in the main charge and to obtain an IM formulation. IM was a safety prerequisite, and a requirement to comply with international agreements. The development work on the fuze, main explosive charge and gun propellant ran concurrently during the first two years. Two explosives and six gun propellants candidates were evaluated by performing material characterization, sub-scale IM testing, and sub-calibre ballistic assessment. Work was also planned for the booster and primer, to ensure that both would effectively ignite the IM explosive/propellant charge (Brochu *et al*, 2011, 2014).

The final selection of an explosive and a propellant formulation was performed in fall 2011. A Green Insensitive (GIM) explosive, melt-cast, RDX-free formulation that was chosen to replace Composition B (Comp B) met the current performance criteria of in-use munitions, had a lower vulnerability than Comp B and was recyclable. Likewise, toxic components in the gun propellants (e.g., nitroglycerin, 2,4- and 2,6-dinitrotoluene, phthalates derivatives and diphenylamine) were replaced by more environmentally friendly products that resulted in a HMX-based Low Vulnerability (L320) recyclable formulation characterized by better Insensitive Munition (IM) properties than the current M1. Moreover, the charges were conceived as modular increments to avoid burning excess propellant artillery that would have resulted in significant contamination. Substantial enhancements were also planned for the

C32A1 Multi-Option Fuze for Artillery (MOFA), currently in use by the Canadian Armed Forces (CAF), in which a self-destruct device (SDD) was to be added. The SDD was planned as an independent fuze that would initiate the detonation in case of malfunction of the primary fuze, which can happen due to operator handling, impact on soft ground or age-related failures.

The technologies developed during this project are expected to be easily transferable to other types of medium and large calibres for the energetic formulations, and to other types of large calibre ammunition for fuzes.

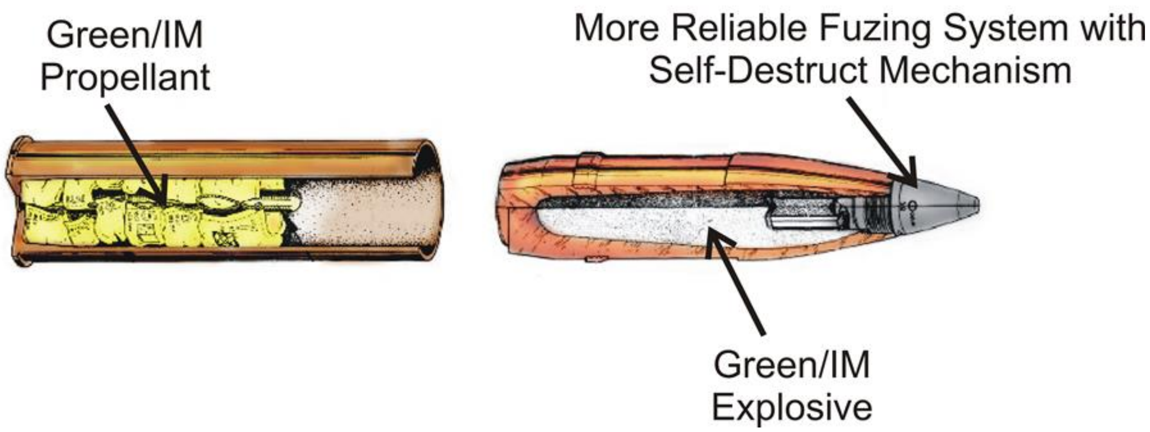

Figure 1: RIGHTTRAC concept

3. Results

3.1 Explosive Formulation

GIM, the selected candidate that was developed and patented by DRDC, is a melt-cast formulation made of TNT, HMX and an Energetic Thermoplastic Elastomer (ETPE) (Ampleman *et al*, 2002, 2003; Ampleman, 2011). Because of the existing large industrial base for the processing of melt-cast formulations, those are more common in North America than cast-cured formulations. Early in the project, the conformity of GIM to the performance prerequisite was verified using detonation pressures and velocities, as well as plate dent tests (Brousseau *et al*, 2010). As indicated in Table 2, the performance GIM was within 5% of Comp B’s. GIM was thus judged qualified for further testing in RIGHTTRAC.

3.1.1 Performance – Gun Testing

The performance test and demonstration was conducted by GD-OTS Canada. The goals of this demonstration consisted in (1) testing the velocity uniformity by firing ten 105-mm M1 cartridges filled with High-Explosive Simulator (HES) and ten additional cartridges filled with GIM (XC179); and (2) testing the functionality of the GIM explosive by firing five XC179 cartridges. As the self-destruct device was not available for this demonstration, the GIM was tested with the current C32A1 fuze. Figure 2 shows the instrumented LG1 MKII

105 mm Howitzer employed by the CAF for direct and indirect fire that was used for the demonstration.

The velocity of the projectile was measured with an Infinition Radar using microwaves to track the projectile. The pressures were measured with piezo electric tranducer Kistler 6215 fitted with a 10 kHz filter. Results indicate that the velocity and pressure were as expected, and similar to that of current 105-mm M1 cartridges. In addition, as shown in Figure 3, all XC179 projectiles were successfully ignited by the C32A1 fuse.

Fragmentation testing was also conducted to determine the number and weight distribution, as well as the velocity and spatial distribution of fragments produced upon detonation. Results will be available soon.

Table 2. Performance of GIM Relative to Comp B.

Formulation	Density g/cm^3	Relative VoD % Comp B	Relative P % Comp B	Plate Dent % Comp B
GIM	1.67	97	94	96
Comp B	1.68	100	100	100

VoD: Velocity of Detonation; P: Pressure

Figure 2. Howitzer LG1 MkII Weapon

Figure 3. XC179 GIM explosion

3.1.2 Insensitive Munitions Testing (IM)

In preparation for the final selection of the explosive formulations, preliminary small- and full-scale IM tests were performed on GIM and Comp B, namely Shaped-Charge Jet (SCJ) attack, Bullet Impact (BI), Slow Cook-Off (SCO) and Sympathetic Reaction (SR) (Brousseau *et al*, 2010b). The goal of these IM tests was to compare the candidate energetic formulations to the reference formulations M1, and to discriminate between the candidates. Results are summarized in Table 3 for GIM and Comp B.

The reaction of GIM to BI was much better than Comp B's: GIM did not detonate upon bullet impact, but rather burned slowly, in contrast to Comp B, which detonated. Both Comp B and GIM exploded (Type III) during the SR but nonetheless they passed the test. GIM performed as well as than Comp B for the SCJ test. This level of reaction was not surprising, considering the severity of the threat. To our best knowledge, it is extremely difficult to obtain a milder reaction to the 84-mm shaped charge jet test with the military energetic formulations commercially available. Lastly, GIM performed as well as Comp B in SCO and passed the test.

Table 3. IM Tests Results for GIM and Comp B.

Formulation	BI	SCJ	SR	SCO
Comp B	I or II	I	III	V
GIM	V	I	III	V

NR: No reaction; NA: Not available.
Red: fail; green: pass

3.1.3 Detonation Residues

GIM explosive residues produced during live-fire and blow-in-place (BIP) operations were assessed by detonating six GIM-filled 105-mm projectiles on ice blocks at DRDC Valcartier experimental test site and collecting the residues on snow. Results, provided in Table 4, were compared to those of Comp-B filled 105-mm.

Table 4. Detonation Residues of Live-fire and Blow-in-place of GIM- and Comp B-filled 105-mm Rounds.

	Live-Fire		BIP	
	Munition outcome (%)	Residue	Munition outcome (%)	Residue
Comp B[1]	0.000007	RDX	0.0003	RDX
GIM[2]	0.0003	HMX	0.1	HMX

[1]Hewitt *et al*, 2003; [2]Walsh *et al*, 2013a

As expected for IM munitions (Walsh *et al*, 2010, 2013b, 2013c, 2014), the detonation residues of GIM-filled rounds are one to two orders of magnitude higher than Comp B's. However, GIM-filled rounds performed extremely well compared to other commercially available IM formulations, such as IMX-104, PAX-48 and PAX-21, for which deposition rates were one to two orders of magnitude higher (Walsh *et al*, 2010, 2013b, 2013c, 2014).

The laboratory dripping water tests as well as outdoor weathering tests performed on the explosive formulations candidates before the final selection indicate that GIM was much more resistant to dissolution than Comp B (Hawari *et al*, 2009, 2011; Côté *et al*, 2011). Comp B completely dissolves in a few months on contact with dripping water, releasing RDX and TNT. Under the same conditions, GIM did not fully dissolved in one year; it is not even expected to dissolve completely, as suggested by the dissolution kinetics. TNT was released from both formulations. In addition, HMX was released from GIM, and RDX from CX-85.

HMX is known to have a low toxicity (Sunahara *et al*, 2009) as well as a fairly low solubility in water (6 mg/L), almost one order of magnitude below that of RDX (40 to 60 mg/L) and TNT (130 mg/L). The toxicity of TNT is known to be below that of RDX, albeit above that of HMX. However, TNT decomposes rapidly to amino derivatives that bind to the organic material of the top soil. As a result, both HMX and TNT generally do not migrate into the groundwater. Their transport in sand was governed solely by dissolution, while both dissolution and sorption were observed in a more organic soil. TNT and HMX are considered environmentally friendly because of their low bioavailability and/or low toxicity. The K_{ow} data indicate that both HMX and TNT can potentially bioaccumulate in terrestrial and aquatic organisms.

An ecotoxicological assessment was built on each formulation under study by conducting terrestrial, aquatic, and benthic ecotoxicity assays (Refs 48-55). Three tests were included in the terrestrial ecotoxicity assays: ryegrass seedling emergence and growth inhibition, earthworm lethality, and earthworm avoidance behaviour. For the explosive formulations, the benthic assays were performed using amended artificial sediments and included four tests: mussel lethality and sub-lethal immunologic assays, as well as amphipod crustacean Hyallelaazteca lethality and growth inhibition tests. Microtox assays, as well as growth inhibition of algae and duckweed were also performed for aquatic receptors. Results reported in Table 6 indicate that GIM is as toxic as Comp B. The toxicity seems related to the concentrations of bioavailable TNT (Hawari *et al*, 2009, 2011).

3.2 Main Propellant Charge

The propellant charge of a 105-mm artillery munition is currently made of seven different types of bags, each containing a different charge weight and some using lead as a de-coppering agent. In addition, the shape, size and web dimension of the formulation of the first bag is different than the one of the six other bags. The range of the munition is fine-tuned in the field by removing the appropriate number of bags from the cartridge. The excess propellant bags used to be burned on the ground immediately after artillery exercises, which produced a significant amount of toxic and carcinogenic contaminants.

The concept of modular charges evaluated within this project consists in building identical charge weights bags for the 105-mm cartridge, which would be incorporated in the 105-mm cartridge during the firing event. The range would then be fine-tuned using an appropriate number of bags. The net advantage of this concept is a significant reduction in excess propellant bags burning, which can be retained for a future use. Similar modular charges already exist for the 155-mm artillery munition (M777), and are under study for the 105-mm calibre, albeit with the M1 propellant.

To be considered in the project, propellant candidates had to meet the current performance criteria of current artillery 105-mm propellant (M1). In addition, the potential candidates had to be free of NG, 2,4-DNT, 2,6-DNT, phthalates derivatives and DPA. The mechanical and ballistic performance, environmental and IM properties of L320, the selected candidate, will be discussed here.

3.2.1 Performance

3.2.1.1. Small-Scale Testing

The conformity and L320 to the performance prerequisite was verified using formulation ballistic properties (quickness, force and linear burning rate) (Richer, 2013). The performance of a propellant is measured by its burning rate as well as its quickness, which is defined in STANAG 4115 as the pressurisation rate, by its force, which corresponds to the maximum pressure applied at a specific loading charge, and by its vivacity, which is the ratio of quickness to force.

The quickness and force L320 are provided in Table 5 relative to that of M1-0.025. To find a suitable balance between pressure, burning rate, ignition delay and firing residues, several shape, size and web dimensions were tested (Petre *et al*, 2012). At the end of those tests, L320 was considered acceptable for an application in a 105-mm artillery munitions.

Table 5. Gun Propellant Performance at 21 ˚C and Mechanical Properties, Relative to Reference Formulation M1-0.025.

Formulation	Relative Young's Modulus %	Relative Quickness %	Relative Force %	Vivacity %
M1	100	100	100	100
L320	98	117	104	112

3.2.1.2 Gun Testing

The same instrumented LG1 MKII 105 mm Howitzer used for explosive testing was employed for this part of the demonstration. A total of 66 shots were fired by GD-OTS Canada to: 1) assess the best configuration; 2) optimize the low pressures zones; 3) verify the zones 1 and 7 characteristics; 4) the temperature sensitivity; 5) the uniformity; 6) the reduction or elimination of unburned residues at lower zones; and 7) test the modular charges concept.

The results clearly demonstrated that L320 was superior to the current propellant formulation and that modular charges could be very easily developed and implemented with the 105 mm munition.

3.2.2 IM Properties

As for explosive formulations, preliminary small- and full-scale IM tests were performed on propellant formulations to discriminate the candidates and compare them to M1, the reference formulation (Brousseau *et al*, 2010b). However, it has to be noted that BI, SCJ and SCO were performed on early batches of propellant formulations with a somewhat different composition than the final one, and that L320 is expected to better react than Modified L320 to IM testing, due to its composition. Results are summarized in Table 6.

Table 6. IM Tests Results for Modified L320 and M1.

Formulation	BI	SCJ	SCO
M1	V	II	IV-V
Modified L320	V	II	IV-V

NR: No reaction; NA: Not available.
Red: fail; green: pass

All formulations passed the BI test, but Modified L320 demonstrated a less violent reaction than M1. For the SCJ test, the gun propellants reacted similarly with a partial detonation (Type II). As for the IM explosive tests, this level of reaction was expected, considering the severity of the threat. No propellant formulations passed the SCO test: all the propellants candidates produced violent burning reactions similar to that of M1 at comparable temperatures (Type IV-V). The only exception was modified L320 that seems to be able to resist slightly higher temperatures.

3.2.3 Detonation Residues

The amount and distribution of unburned propellant residues produced by the firing of XC179 and M1 cartridges was evaluated by collecting the deposits in front of the gun using collection plates that were filled with water. High Performance Liquid Chromatography did not allow the detection of any residues, indicating that the deposition rate of XC179 was at least one to two orders of magnitude lower than that of M1 (0.08%).

As for explosive formulations, laboratory dripping water tests as well as outdoor weathering tests (Martel and Côté, 2009; Coté and Martel, 2010; Martel *et al*, 2010), were performed on the propellant formulations candidates before the final selection. M1 and L320 are very resistant to dissolution and were not expected to completely dissolve (Hawari *et al*, 2010, 2012). The order of dissolution seems to be related to the proportion of NC in the formulation, a higher NC content leading to a lower lixiviation. It was hypothesized that NC may swell in water and hence slow down the diffusion of the chemicals or act as potential adsorbent for the soluble components.

The ingredients leaching from the propellant formulations were DNT and DPA from M1, and HMX and a plasticiser from L320. As a matter of fact, up to 15% DNT and 1% DPA were released from M1 after 56 days of contact with water with dripping water, as compared with a little more than one third of the HMX content. The plasticiser is very soluble in water and tends to leach easily from the formulation.

The M1 reference propellant formulation was found to inhibit ryegrass and benthic amphipod growth. This formulation was expected to be toxic to earthworms because of 2,4-DNT. It was hypothesized that the low toxicity of 2,4-DNT to earthworms was due to its low bioavailability in the soil interstitial water, which can be explained by the presence of NC on which 2,4-DNT may be imbedded. L320 was not toxic to any of the receptors.

3.2.4 Combustion Residues

The particulate and gaseous residues were collected directly at the muzzle of the gun during a live firing event for M1 and L320 only. For M1 (Savard, 2009), the main combustion gases of the reference formulation were carbon monoxide (CO), carbon dioxide (CO_2), methane, ammoniac, sulphur dioxide and hydrogen sulphide. In addition, more than 100 Volatile Organic Compounds (VOC) were detected, most of them aromatic (benzene, toluene, etc); carbonyl sulphide, methyl isocyanade and ethane dinitrile were also detected in significant concentrations, as well as Semi-Volatile Organic Compounds (SVOC). In addition, particulate matter mainly composed of lead, potassium, sulphur, iron and copper, characterized by a mean particle size of 0.93 µm, were detected.

The combustion gases of L320 (Savard, 2014) were identical to those of M1, except for a slightly higher CO_2/CO ratio and smaller methane production. The firing of L320 also led to the production of less VOC and SVOC, although the main products were identical. The particulate matter was also identical in the two formulations, although the lead concentration was sensibly lower in L320.

3.0 CONCLUSION

This project has proven that it is possible to develop IM and green munitions that perform better than current munitions and that will help to ease the environmental pressures on RTAs. The test vehicle was a 105-mm M1 artillery round, but the technology aimed to be transferable to other calibres. The main outcomes of this project consist of a green and IM main explosive charge, and a greener, modular, extended-range and IM main propellant charge. Each of these outcomes can be exploited separately or as a whole, either for Army, Air Force or Navy munitions.

In contrast to the traditional approach, which consists in evaluating the environmental and health impacts at the end of the development cycle of a formulation, the candidate formulations were simultaneously tested for their environmental impacts as well as their ballistic, IM and mechanical properties. This approach had the benefit to avoid dedicating considerable efforts on the development of formulations that could be discarded at the end of the development cycle due to noxious environmental impacts (Brochu *et al*, 2013).

The end result is that military personnel will be able to train and fight with ammunition having comparable or better properties than current munitions, with the added benefit of decreasing the environmental pressure and the health hazards on soldiers, sailors or airmen. The technology developed under RIGHTTRAC will contribute to sustain military training and maintain troop readiness by minimizing long-term environmental impacts.

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Life-Cycle Assessment methodology: a tool for the evaluation of environmental and toxicological impacts of ammunitions

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1. Introduction

Over the last ten years the environmental concerns associated with the military activities have increased due to legislation pressure and an increasing awareness to the environmental issues. Such situation has leaded the defence industry and the Armed Forces to seek for a tool to evaluate the environmental burdens associated with ammunitions. Some methodologies have been applied to evaluate the environmental impacts and rank the different alternatives from an environmental point of view. Examples of those methodologies are the POEMS methodology (UK) and the MIDAS (USA), although the results delivered by these methodologies are very broad and the assessment of eventual environmental benefits from different production, use or disposal alternatives are difficult to evaluate.

One of the suitable solutions to overcome this problem is the implantation of a life-cycle approach, based in the Life-Cycle Assessment (LCA) methodology, to assess the environmental and toxicological impacts of ammunitions. The Life-Cycle Assessment (LCA) is a methodology for assessing the potential environmental and toxicological impacts of a product system throughout its life-cycle (ISO 14040, 2006). The application of the LCA methodology to military system can assist in i) which are the hotspots and how do they contribute to the impacts associated with the production of ammunitions; ii) the comparison of the impacts from different formulations and production solutions to assess which one presents lower impact and why; iii) the assessment of impacts resulting from the use of ammunitions and the consequences for human health and ecosystems; iv) in the comparison and analysis of the advantages and disadvantages of different pathways of demilitarization techniques.

To show the field of possibilities just described the results of two LCA studies will be presented. Those studies are: *i)* the comparative assessment for production and use of four different 9 mm ammunitions with two types of projectiles (steel-lead versus composite) and two types of primers (lead versus non-lead) and *ii)* and a quantitative assessment of the environmental and toxicological impacts associated with two different demilitarisation paths - open detonation and incineration with gas treatment.

2. Life-Cycle Assessment Methodology

Life-Cycle Assessment (LCA) methodology assesses the potential environmental impacts of a product system throughout its Life-Cycle (LC). LCA is based on system analysis and handles the process as a chain of subsystems which exchange inputs and outputs (Malça and Freire, 2006). The Life-Cycle includes the extraction of materials, production, use and disposal (cradle-to-grave). The results obtained by an LCA study can be used to identify environmentally preferable solutions and opportunities to improve products or processes.

According to the ISO standards (ISO 14040, 2006), an LCA has four interrelated phases: goal and scope definition, Life-Cycle Inventory (LCI), Life-Cycle Impact Assessment (LCIA) and interpretation. The first phase of the LCA includes the definition of the goal and scope of the study, including the product system boundaries and a functional unit. The functional unit is a reference that relates the system inputs and outputs and is required to ensure comparability of results between different LCA studies. In the inventory analysis, the inputs and outputs of the system are collected and compiled. In the LCIA, inventory data is characterized into specific environmental impact categories according to selected LCIA methods. It should be noted that different LCIA methods will lead to distinct results (values, impact categories and units). Interpretation is the final phase of the LCA procedure, in which the results are summarized and discussed as a basis for conclusions, recommendations and decision making in accordance with the goal and scope definition phase (ISO 14040).

3. Case studies

This section presents the life-cycle model and inventory developed and respective results for two case studies to demonstrate the capabilities of LCA studies.

3.1 Comparative assessment of four small calibre ammunitions

A detailed Life-Cycle Inventory (LCI) was implemented, in which primary data referent to the ammunition production was collected from a Romanian company and may be considered as representative of the production process of this type of ammunitions. The 9 mm ammunitions assessed were:

#1) Ammunition with steel-lead bullet (projectile) and with leaded primer (TNR-Pb - Lead trinitroresorcinate);

#2) Ammunition with steel-lead bullet (projectile) and with non-leaded primer (DDNP – Diazodinitrophenol);

#3) Ammunition with composite (nylon-copper) bullet (projectile) and with leaded primer (TNR-Pb - Lead trinitroresorcinate);

#4) Ammunition with composite (nylon-copper) bullet (projectile) and with non-leaded primer (DDNP – Diazodinitrophenol).

Table 1 presents the energy and water requirements associated with 9 mm ammunitions production. Table 2 presents the emissions associated with the firing of the four types of ammunitions. The gaseous emissions (CO_2, CO, HCN, NO, NO_2, NH_3 and CH_4) and metal quantity in solid residues (Pb, Cu, Zn and Sb) were quantified by an experimental set-up and techniques described in Rotariu and Petre (2014).

Table 1. Data for energy and water requirement for production of 9 mm ammunitions

Electricity	0.046 kWh/bullet
Natural gas	0.240 MJ/bullet
Water	2.042 kg/bullet

Table 2. Emissions associated with use of 9 mm ammunitions in study

Substance	**Emissions (mg/bullet)**			
	#1	**#2**	**#3**	**#4**
CO	198.65	184.75	119.21	118.76
CO_2	**101.79**	**96.79**	58.56	57.93
NO	3.80	3.22	3.85	4.41
NO_2	0.64	0.62	0.49	0.52
NH_3	**3.10**	**2.46**	1.67	1.84
HCN	**1.77**	**1.22**	0.18	0.13
CH_4	**1.10**	**0.96**	0.61	0.59
Pb	**3.14**	**1.04**	0.81	0.04
Cu	0.55	0.41	**4.85**	**5.21**
Zn	**0.12**	**0.11**	**0.19**	0.03
Sb	**0.37**	**0.20**	0.15	-

3.1.2 Results

Figure 1 presents the life-cycle environmental impact comparison referent to the production and use for the four 9 mm ammunitions. It is observed that the production phase have a higher contribution to the environmental impact categories, whilst the use phase shows a higher contribution to the toxicity categories (due to the emissions associated with the ammunition firing). Ammunition #1 is the one presenting the highest impact for seven out of nine impact categories, but mainly for the Human Toxicity categories due to the emissions of lead in the use phase. The composite ammunitions (#3 and #4) present higher impacts for the categories Eutrophication (due to the copper and nylon production) and Ecotoxicity (associated with the emissions of cooper). For the Human Toxicity categories the presence of lead, either in the projectile or in the primer, is relevant and its substitution leads to unequivocal toxicological benefits.

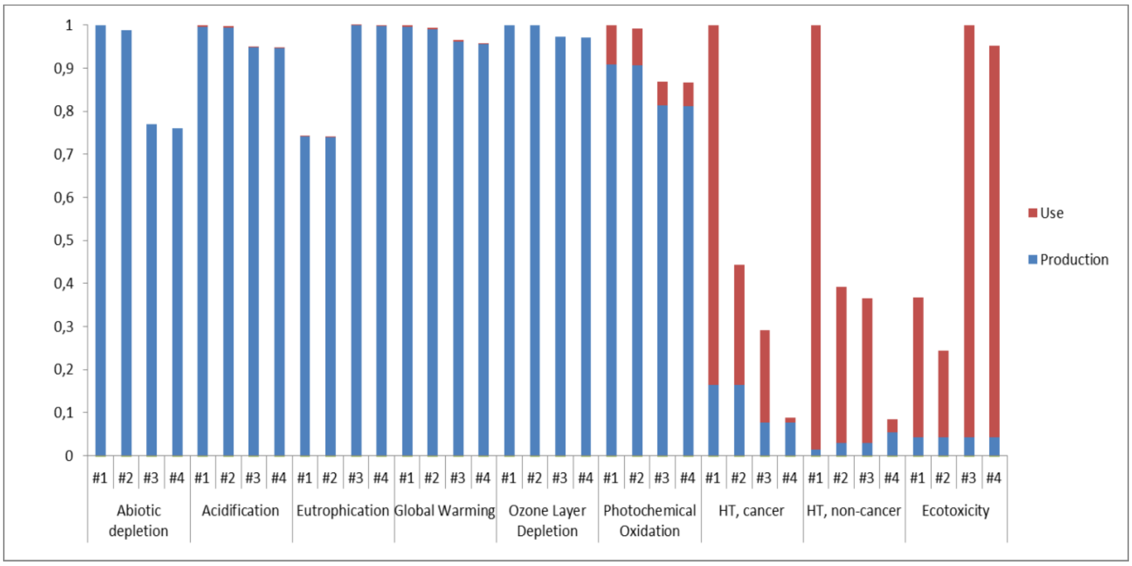

Figure 1. Life-Cycle impact comparison between the four 9 mm ammunitions: #1 – steel-lead projectile with lead primer; #2 – steel-lead projectile with non-lead primer; #3 – composite projectile with lead primer; #4 – composite projectile with non-lead primer

Since the production phase presents the higher significance to the environmental impact categories it is shown in detail the contribution to each one of the impact associated with 9 mm ammunition production (Figure 2). For ammunitions #1 and #2, it is observed that energy requirement presents the highest impact contribution for Abiotic Depletion (46%), Global Warming (55%) and Ozone Layer Depletion (65%), whilst brass (used for the cartridge) have the highest contribution for the categories Acidification (43%), Eutrophication (76%), Photochemical Oxidation (39%) and non-cancer Human Toxicity (76%). Projectile of ammunitions #1 and #2 also presents a significant impact for categories Abiotic Depletion (37%), Photochemical Oxidation (30%) and, in fact being the highest impact contributor, to cancer Human Toxicity (58%), mainly due to the emissions associated with the production of steel and lead.

For ammunitions #3 and #4 the contribution to the impacts arising from energy requirement and cartridge production, when compared with ammunitions #1 and #2, are higher once the composite projectile presents a lower influence. Therefore, it is observed that brass becomes a higher contributor to cancer Human Toxicity (increasing to 54%), in which the projectile contributes with only 5% (decreasing 53% compared with the steel-lead projectile). However, the composite projectile presents an increase of 20% for the non-cancer Human Toxicity, mainly due to the emissions associated with production of copper. Regarding the Ecotoxicity, the highest contribution to the impacts for all the four ammunitions is associated with the propellant, mainly due to the cultivation phase of cotton that is used for production of the single base powder.

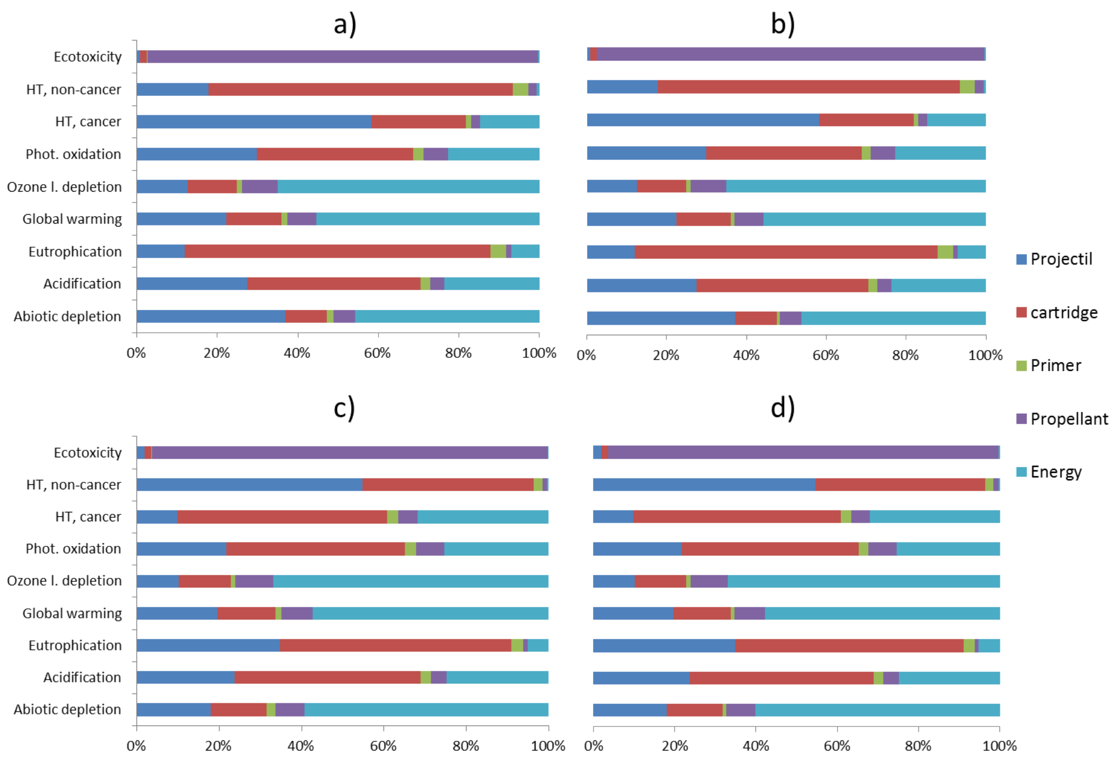

Figure 2. Representation of the main contribution to the total impacts associated with the four 9 mm ammunitions production: a) #1 - steel and lead projectile with lead primer; b) #2 - steel and lead projectile with non-lead primer; c) #3 - composite projectile with lead primer; d) #4 - composite projectile with non-lead primer

3.2 Comparative assessment of two demilitarisation techniques

This subsection presents the comparison between two ways to disposal a large calibre munition (Open Detonation vs Incineration with Gas Treatment) in an environmental perspective. For both demilitarisation techniques was considered a 155 mm generic large calibre ammunition with a charge of 4.5 kg of composition B in the projectile, which corresponds to around 10 kg TNT equivalent of energetic material.

The Incineration with Gas Treatment process is based on data from Ferreira *et al.* (2013), in which the model and inventory was developed based on the idD operations covering the following processes: dismantling of ammunition, unloading of energetic material, incineration in static kiln and consequent gas treatment. Life-Cycle Inventory included the consumption of energy (electricity and propane), consumables for the gas treatment, transport of materials, equipment and emissions from combustion. For Open Detonation it was compiled data from literature regarding the materials used for detonation (Bellow *et al.*, 2008) and air emissions associated with detonation (US army Environmental command, 2009). Table 3 and 4 presents the energy and materials associated with the Incineration and Gas Treatment process, while Table 5 and 6 shows the emissions from Open Detonation and the materials used in the detonation.

Table 3. Energy and water consumption associate with the dismantling process

Electricity	1.369 kWh
Propane	0.479 kg
Water	6.161 kg

Table 4. Energy, consumables and emissions associated with the incineration and gas treatment process

Inputs	*Energy*				
	Electricity			7.860	*kWh*
	Propane			1.320	*kg*
	Materials				
	Water			15.31	kg
	Urea			0.280	kg
	Hydrochloric acid			0.078	kg
	Sodium Hydroxide			0.060	kg
	Hydrogen Peroxide			0.004	kg
	Zeolite			0.050	kg
Outputs	*Materials*				
	Sludge			0.008	kg
	Fly ashes			0.032	kg
	Ash and Slag			0.040	kg
	Emissions to air				
	2,3,7,8 TCDD	8.65E-13 kg	NO_x	4.06E-03	kg
	1,2,3,4,7,8 HxCDD	1.73E-12 kg	SO_2	3.98E-04	kg
	1,2,3,7,8,9 HxCDD	8.65E-13 kg	Hg	1.71E-06	kg
	1,2,3,4,6,7,8 HpCDD	8.65E-13 kg	Cd	1.54E-06	kg
	OCDD	8.65E-15 kg	As	3.33E-06	kg
	Furan	9.52E-12 kg	Ni	2.47E-06	kg
	HF	8.36E-05 kg	Pb	2.05E-06	kg
	HCl	8.36E-05 kg	Cu	2.05E-06	kg
	VOC	6.55E-04 kg	Cr	2.05E-06	kg
	CO	1.28E-03 kg	CO_2	6.24E+00	kg
	H_2S	2.81E-04 kg	PM	4.20E-04	kg

Table 5. Emissions associated with the open detonation of a generic 155 mm ammunition (US army Environmental command, 2009)

Emissions (g/ammunition)					
carbon dioxide	9.35E+02	chromium	3.91E-02	acetylene	1.45E+01
carbon monoxide	2.21E+01	cobalt	1.36E-02	benzaldehyde	4.08E-02
lead	1.62E-02	copper	3.15E-02	2-butenal	1.19E-02
oxides of nitrogen	6.55E+01	total dioxin	3.40E-08	1-butene	1.87E-02
PM2.5	57E+02	ethylbenzene	1.19E-02	cis-2-butene	5.44E-03
PM10	7.99E+02	ethylene	4.85E-01	trans-2-butene	6.12E-03
sulphur dioxide	1.70E+00	formaldehyde	7.06E-02	diethylphthalate	4.76E-03
acetaldehyde	1.53E-01	manganese	3.06E-01	dodecane	9.35E-03
acetonitrile	1.36E-02	methylene chloride	8.16E-02	ethane	1.53E-01
acetophenone	5.36E-03	2-methylnaphthalene	1.53E-03	hexaldehyde	2.81E-02
ammonia	7.31E-02	naphthalene	1.36E-02	magnesium	5.53E+02
antimony	7.40E-02	nitroglycerin	2.64E-02	methyl ethyl ketone	2.38E-02
arsenic	1.70E-03	phenol	2.04E-03	1-propyne	7.48E-02
barium	6.38E-02	phosphorus	1.87E-01	valeraldehyde	3.91E-02
benzene	1.70E-01	propinaldehyde	7.31E-02	furan	3.57E-02
beryllium	4.68E-04	propylene	9.35E-02		
cadmium	1.11E+00	toluene	5.19E-02		
carbon disulphide	1.79E-02	xylene	4.51E-03		
chloromethane	1.11E-02	zinc	5.78E-01		

Table 6. Donor and gravel used for detonation of a generic large calibre ammunition (Bellow *et al.*, 2008)

Materials for detonation	Amount (kg/ammunition)
C4 donor	0.6
Gravel	1138.5

3.2.2 Results

Picture 3 presents the environmental and toxicological comparison between Open Detonation and Incineration with Gas Treatment. It can be seen that Incineration presents high impact for the six environmental categories. The reason for this impact is associated with the high energy requirements for the kiln and the gas treatment process, which represents more than 80% of the total impact. For Global Warming, the emissions, mainly resulting from the propane combustion, also represents a significant impact (46%). On the other hand, Open Detonation dominates the impacts for Human

Health and Ecosystems due to emissions resulting from the detonation. The detonation emissions represent 35% of the total impacts for cancer Human Toxicity; 98% for non-cancer Human Toxicity; and 72% for Ecotoxicity.

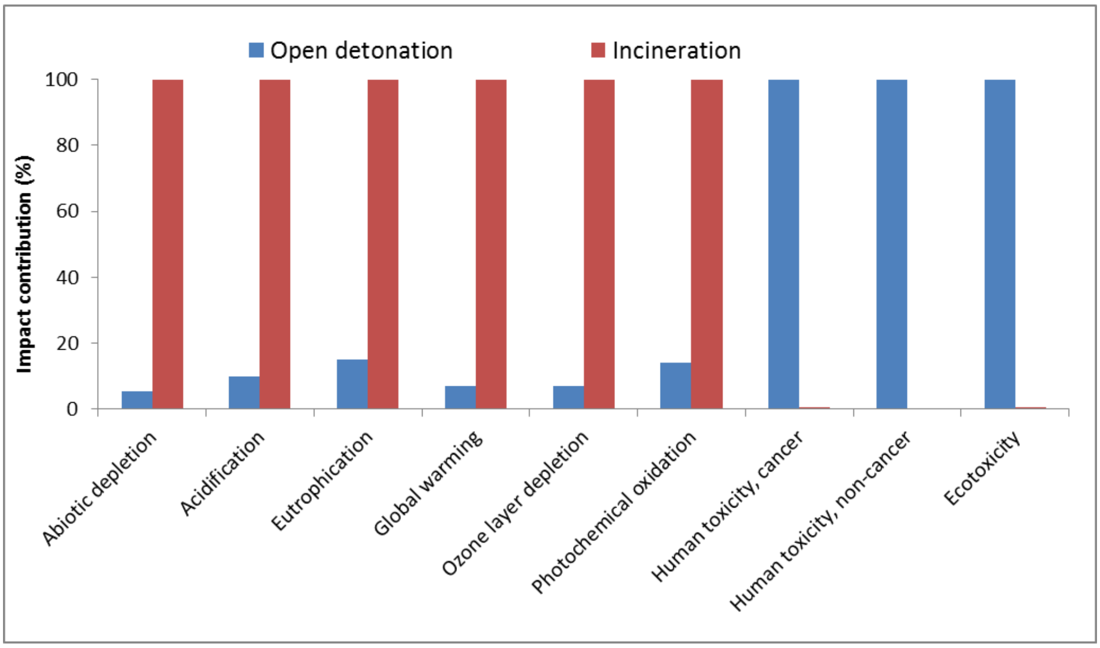

Figure 3. Environmental and toxicological impact comparison between Open Detonation and Incineration with Gas Treatment

4. Conclusion

This article presented the application of the Life-Cycle assessment methodology to assess the environmental and toxicological impacts associated with military products or systems. It was presented two case studies to demonstrate the feasibility of the LCA. The first case study applied a eco-design approach in which was carried out a comparative assessment for production and use of four different 9 mm ammunitions with two types of projectiles (steel-lead versus composite) and two types of primers (lead versus non-lead). It was concluded that the substitution of lead in the primer decreased the toxicity impacts for human health, and the production of a projectile with a lighter material (composite) also decreased the total environmental impact. However, the composite projectile increased the impact for Ecosystems due to emissions of copper. Therefore, it is needed to continue to search of different alternatives to decrease the environmental and toxicological impacts of bullets.

For the second case study was carried out a comparative assessment of the environmental and toxicological impacts associated with two different demilitarisation paths - open detonation and incineration with gas treatment. It was observed that the incineration in static kiln presented higher impacts for the six environmental impact categories mainly due to the high energy requirements; while Open Detonation dominates completely the toxicological impacts due to emissions resulting from the detonation.

Summary

Over the last ten years the environmental concerns associated with the military activities have increased due to legislation pressure and an increasing awareness to the environmental issues. Such situation has leaded the defence industry and the Armed Forces to seek for a tool to evaluate the environmental burdens associated with ammunitions. Some methodologies have been applied to evaluate the environmental impacts and rank the different alternatives from an environmental point of view. Examples of those methodologies are the POEMS methodology (UK) and the MIDAS (USA), although the results delivered by these methodologies are very broad and the assessment of eventual environmental benefits from different production, use or disposal alternatives are difficult to evaluate.

One of the suitable solutions to overcome this problem is the implantation of a life-cycle approach, based in the Life-Cycle Assessment (LCA) methodology, to assess the environmental and toxicological impacts of ammunitions. The Life-Cycle Assessment (LCA) is a methodology for assessing the potential environmental and toxicological impacts of a product system throughout its life-cycle (ISO 14040, 2006; ISO 14044, 2006). The application of the LCA methodology to military system can assist in i) which are the hotspots and how do they contribute to the impacts associated with the production of ammunitions; ii) the comparison of the impacts from different formulations and production solutions to assess which one presents lower impact and why; iii) the assessment of impacts resulting from the use of ammunitions and the consequences for human health and ecosystems; iv) in the comparison and analysis of the advantages and disadvantages of different pathways of demilitarization techniques.

To show the field of possibilities just described the results of two LCA studies will be presented. Those studies are: i) the comparative assessment for production and use of four different 9 mm ammunitions with two types of projectiles (steel-lead versus composite) and two types of primers (lead versus non-lead) and ii) and a quantitative assessment of the environmental and toxicological impacts associated with two different demil paths - open detonation and incineration with gas treatment.

Acknowledge

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Energetics Residues Deposition from Training with Large Caliber Weapon Systems

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ABSTRACT

Training with large caliber weapon systems will result in the deposition of energetic materials on military training ranges. Deposition can occur at several locations. These include firing points, impact points, propellant disposal areas, demolitions training ranges, and munitions disposal areas. The potential quantity, composition, and concentration of energetics in each of these areas is directly linked to the activities that occur there. During live-fire training, propellant residues are generated at firing points and propellant disposal locations. Explosives residues will be found down range in the impact area. Activities by engineers and explosive ordnance disposal units in demolitions training ranges will involve expedient demilitarization of munitions and practice conducting blow-in-place (BIP) of munitions. BIP operations may also occur on impact ranges with rounds that fail to detonate properly or do not detonate at all (dudded rounds). Munitions disposal areas are locations where damaged or outdated munitions may be destroyed on a military base.

The mass of residues associated with these activities is contingent upon the efficiency of each operation. The US Army Cold Regions Research and Engineering Laboratory has developed methods to determine residues mass deposition rates on a per-round basis for most heavy weapon systems and activities associated with training with large caliber rounds. Research conducted since 2002 on various heavy weapon systems has given us useful insights into sources of contamination, efficiency of munitions and weapon systems, and munitions constituents that will be problematic on training ranges.

This paper presents results of research for standard US weapon systems from 60-mm to 204-cm. Energetics residues deposition rates vary from 72% at the firing point for the 84-mm AT-4 shoulder-fired weapon system to non-detectable residues mass at 155-mm howitzer impact points. Examples are given for various weapon systems and an example of a residues database for military training ranges is presented. This database is being used in the US to determine impacts on various training ranges and was instrumental in having one family of munitions reclassified and restricted from training range use.

INTRODUCTION

Live-fire exercises on military training ranges will result in the deposition of munitions residues in the environment (Jenkins et al. 2006, Thiboutot et al. 2012). There are several sources of contamination, including propellants, explosives, and chemical munitions constituents (Pichtel 2012). The causes of this contamination are inefficient consumption of gun propellants (ME Walsh et al. 2011, MR Walsh et al. 2012), improper field disposal of excess artillery propellants (MR Walsh et al. (MR Walsh et al. 2010), incomplete detonation of high explosive rounds (Hewitt et al. 2005, MR Walsh et al. 2011), and extinguishment of chemical smoke and flare munitions particles (ME Walsh et al. 1996, MR Walsh et al. 2014). Even when munitions seem to be functioning properly, residues will still remain.

In the United States, monitoring of ground and surface waters on and near military bases has revealed concentrations of energetic compounds above drinking water standards (Martel et al. 2009, Clausen et al. 2009). On one range, persistent white phosphorus contamination in a wetland killed tens of thousands of ducks, thousands of swans, and scores of eagles over the years (Racine et al. 1992, ME Walsh et al 2014). Range use has been restricted on several facilities and some ranges closed to further training while attempts have been made at great cost to address or confine the contamination. At Camp Edwards, an Army National Guard base in the northeaster US, over $1.5B has been spent with little significant effect on the spread of the contaminants off base (Clausen et al. 2009). It has been estimated that the cleanup will be a 50-year effort.

This paper describes research conducted over the last 15 years in the US to quantify the environmental impact from training with heavy weapon systems. The range of weapon systems covered is 60-mm to 204 mm and includes mortars, tanks, howitzers, and rockets. We concentrate on energetic materials, including white phosphorus, and consider typical training activities. Demolitions munitions such as shaped and cratering charges and Bangalore torpedoes, which can be a significant source of range contamination, are not discussed.

METHODS

Heavy weapons munitions testing needed to be conducted such that a mass deposition rate could be estimated on a per-round basis and yield values for the constituents of concern (COCs). This requirement was developed to enable an extrapolation of estimated residues based on range use. In many cases (munitions detonations, blow-in-place [BIP] of individual rounds, render-safe operations with shaped charges or explosively-formed projectiles [EFPs]) individual munitions were tested to enable an evaluation of the variability of the operation. For others, such as firing of rounds and some munitions detonations, data was collected on two to 100 individual events that occurred in the same location. The derived estimate was then divided by the number of rounds involved to get an estimated deposition rate on a per-round basis.

To derive and estimated per-round deposition rate for munitions, we conduct our tests on snow-covered ground, snow-covered ice, or an ice surface. For the first case, sample collection on ice, we simply record the edge of the deposition area, based on the distribution of the visible residues, and then sweep the areas with clean push brooms, collecting the piles of residues into labeled clean polyethylene (PE) bags. This is known as whole-population sampling. For sample collection on snow or snow-covered ice, the deposition area is visually demarcated based on the distribution of dark residues on the clean snow surface (Jenkins et al. 2002, Walsh et al. 2012 – Fig. 1). Samples are then collected with small (10 x 10 cm or 20 x 20 cm) polytetraflouroethylene (PTFE) lined aluminum scoops to a depth of 2 cm within the demarcated area or plume (ITP). We use a random systematic sampling method called Multi-Increment sampling (Ramsey et al 2013, Hadley et al. 2014). For the ITP areas, around 100 increments are collected in clean PE bags for each sample. Several quality assurance procedures are conducted, including replicate sampling, sampling outside the demarcated plume (OTP), and sampling below the original 2-cm sample depth (Figures 2, 3). Sample processing and analysis is covered in another paper at this conference (M.E. Walsh et al).

Figure 1: Preparing to sample a firing point

A database was then constructed using results from all the testing conducted on munitions deposition since 2002. The table is broken down into the type of activity (live-fire, BIP, etc), the weapon system, the munition, and the material analyzed, sometimes consisting of more than one component.

Figure 2. Series of detonation plumes being sampled

Figure 3. Sampled detonation

RESULTS

In Table 1, live-fire detonation data is presented. For some of these tests (PAX and IMX), the rounds were command detonated rather than actually fired (Figure 4a). Table 2 depicts the results for blow in place operations. These tests involved a single round per detonation and utilized a single block demolition charge (91% RDX) as an external donor charge. (Figure 4b). Table 3 contains results of the firing point tests. Multiple rounds were fired from a single firing position and the average resides per round calculated from the total deposition estimate (Figure 4c). Propellant burns were conducted on snow and soil (wet and dry) with a small amount of propellant (Figure 5a). Burn pan tests were conducted with a known mass of propellant burned in the pan (Figure 5b).



a. High-order setup (1) b. BIP setup (2) c. Rocket setup (3)


d. Burning a line of propellant on soil (4) e. Initiation of a burn pan test (5)

Figure 4. Test setups with corresponding table numbers in ( ).

Table 1: Live fire detonation results

Weapon System	Munition Caliber	Munition Tested	Number Tested	Plumes Sampled	Energetic Material	Energetic Compound	Mass / Round (g)	Residues / Round (mg)	Consumption Efficiency	Compound Remaining
Mortars										
	60-mm	M888 (HE)	7	7	Comp B	RDX / HMX	230	0.073	99.99997%	0.000032%
		M888 (HE)	5	5	Comp B	RDX / HMX	230	0.074	99.99997%	0.000032%
		M768 (IHE)[a]	7	7	PAX-21	RDX / HMX	130	9.2	99.9929%	0.0071%
						DNAN	120	7.1	99.9941%	0.0059%
						AP**	91	14,000	85%	15%
									96%	4.1%
		No DODIC (IHE)[a]	7	7	IMX-104	RDX/HMX	75	4.5	99.994%	0.0060%
						DNAN	110	5.3	99.995%	0.0048%
						NTO	180	2,200	98.8%	1.2%
										0.61%
	81-mm	M374 (HE)	14	14	Comp B	RDX / HMX	600	8.5	99.9986%	0.0014%
		M374 (HE)[a]	3	3	Comp B	RDX / HMX	600	10	99.9983%	0.0017%
		M821A2 (IHE)[a] 12 g C4 Booster	7	7	IMX-104	RDX/HMX	150	16	99.989%	0.011%
						DNAN	260	27	99.990%	0.010%
						NTO	430	1,900	99.56%	0.44%
									99.77%	0.23%
		M821A2 (IHE)[a] 18 g C4 Booster	5	5	IMX-104	RDX/HMX	160	7.6	99.995%	0.005%
						DNAN	260	7.8	99.997%	0.003%
						NTO	430	540	99.87%	0.13%
									99.93%	0.065%
		M821A2 (IHE)[a,b] 18 g C4 Booster	2	1	IMX-104	RDX/HMX	160	3.8	99.998%	0.002%
						DNAN	260	13	99.995%	0.005%
						NTO	430	1,150	99.73%	0.27%
									99.86%	0.137%
		M821A2 (IHE)[a,c] 18 g C4 Booster	2	2	IMX-104	RDX/HMX	160	4.1	99.997%	0.003%
						DNAN	260	17	99.993%	0.007%
						NTO	430	720	99.83%	0.17%
									99.91%	0.087%
	120-mm	M933 (HE)	8	7	Comp B	RDX / HMX	1,800	19	99.999%	0.0011%
									99.999%	0.00078%
									98.7%	1.3%
Howitzers										
	105-mm	M1 (HE)	13	9	Comp B	RDX / HMX	1,300	0.095	99.99999%	0.000007%
	155-mm	M107 (HE)	7	7	Comp B	RDX / HMX	4,200	0.30	99.99999%	0.000007%
		M107 (HE)	7	7	TNT	TNT	6,600	-ND-	—	—
	155-mm (Practice / Breaching)	M1122 (IHE-TP)[a] (40-g C4 Booster)	1	1	IMX-101	RDX / HMX	180	18	99.9900%	0.010%
						DNAN	480	5,900	98.8%	1.2%
						NTO	230	40,000	83%	17%
						NQ	430	170,000	60%	40%
									84%	16%
		M1122 (IHE-TP)[a] (50-g C4 Booster)	7	7	IMX-101	RDX / HMX	190	12	99.9937%	0.0063%
						DNAN	480	2,400	99.50%	0.50%
						NTO	230	15,000	93%	6.5%
						NQ	430	130,000	70%	30%
									89%	11%
		M1122 (IHE-TP)[a] (60-g C4 Booster)	1	1	IMX-101	RDX / HMX	200	10	99.9950%	0.0050%
						DNAN	480	660	99.86%	0.14%
						NTO	230	14,000	94%	6.1%
						NQ	430	120,000	72%	28%
									90%	10%
									99.999995%	0.000005%
									88%	12%
Tank										
	120-mm (Breaching)	Canadian Round (100 g C4 in fuze well)			PAX-48	RDX/HMX	740	-ND-	>99.998%	<0.002%
						DNAN	1,700	-ND-	>99.998%	<0.002%
						NTO	1,100	23	99.998%	0.0021%
Rockets										
	227-mm	M31 Unitary	6	1	PETN-109	RDX	15,000	-ND-	—	—

(a) Command detonated
(b) Co-located detonations
(c) Whole population sample (swept ice)
** For AP, the percent levels reported are for perchlorate

Table 2: BIP detonation results

Weapon System	Munition Caliber	Munition Tested	Number Tested	Plumes Sampled	Energetic Material	Energetic Compound	Mass / Round (g)	Results for Energetic Compound: Residues / Round (mg)	Consumption Efficiency	Compound Remaining
Mortars										
	60-mm	M888 (HE)	7	7	Comp B + C4	RDX / HMX	750	200	99.97%	0.027%
		M768 (IHE)	7	7	PAX-21+ C4	RDX / HMX	650	860	99.87%	0.13%
						DNAN	120	740	99.38%	0.62%
						AP**	91	35,000	62%	38%
									96%	4.3%
		No DODIC (IHE)	7	7	IMX-104 + C4	RDX/HMX	600	8,300	98.62%	1.38%
						DNAN	110	20,120	81.7%	18.3%
						NTO	180	89,000	51%	49%
									87%	13.2%
	81-mm	M374 (HE)	7	7	Comp B + C4	RDX / HMX	1,100	150	99.986%	0.014%
		M821A2 (IHE) (Flat block of C4)	7	7	IMX-104 + C4	RDX/HMX	680	20,000	97.1%	2.9%
						DNAN	260	45,000	83%	17%
						NTO	430	230,000	47%	53%
									78%	22%
		M821A2 (IHE) (Folded block of C4)	7	7	IMX-104 + C4	RDX/HMX	680	2,100	99.69%	0.31%
						DNAN	260	5,000	98.1%	1.9%
						NTO	430	45,000	90%	10%
									96%	3.8%
	120-mm	M933 (HE)	7	7	Comp B + C4	RDX / HMX	2,300	25	99.999%	0.0011%
									99.986%	0.014%
									93%	7.1%
Howitzers										
	105-mm	M1 (HE)	7	7	Comp B + C4	RDX / HMX	1,800	50	99.997%	0.0028%
	155-mm	M107 (HE)	7	7	Comp B + C4	RDX / HMX	4,700	15	99.9997%	0.00032%
		M107(HE)	7	7	TNT + C4	TNT	6,600	5.9	99.9999%	0.000089%
						RDX	520	5.9	99.9989%	0.0011%
	155-mm (Practice / Breaching)	M1122 (IHE) (1 Folded Block C4)	3	3	IMX-104 + C4	RDX / HMX	710	21	99.9970%	0.0030%
						DNAN	480	5,300	98.90%	1.1%
						NTO	230	15,000	93%	6.5%
						NQ	430	100,000	77%	23%
									93%	6.5%
	155-mm (Practice / Breaching)	M1122 (IHE) (2 Folded Blocks C4)	3	3	IMX-104 + C4	RDX / HMX	1,200	46	99.9962%	0.0038%
						DNAN	480	21,000	95.63%	4.4%
						NTO	230	24,000	90%	10%
						NQ	430	100,000	77%	23%
									94%	6.2%
									100%	0.0014%
									94%	6.4%
Tank										
	120-mm (Breaching)	Canadian Round (5 Blocks C4) (No fuze)	5	5	PAX-48 + C4	RDX/HMX	3,300	3,800	99.88%	0.12%
						DNAN	1,700	53,000	97%	3.1%
						NTO	1,100	410,000	63%	37%
									92%	7.7%
		Canadian Round (2 Blocks C4) (No fuze)	2	2	PAX-48 + C4	RDX/HMX	1,800	5,200	99.71%	0.29%
						DNAN	1,700	140,000	92%	8.2%
						NTO	1,100	690,000	37%	63%
									82%	18%

Table 3: Firing point results

Weapon System	Munition Caliber	Munition Tested	Number Tested	Plumes Sampled	Energetic Material	Energetic Compound	Mass / Round (g)	Results for Energetic Compound: Residues / Round (mg)	Consumption Efficiency	Compound Remaining
Mortars										
	60-mm	M888 / M702	25	1	M9 - Ign. Ctg.	NG	1.4	0.088	99.99%	0.0065%
	81-mm	M301A3 / M185	61	1	M9 - Charge 5	NG	30	1,000	96.7%	3.3%
	120-mm	M933 / M230	40	1	M45-Charge 2	NG	26	350	98.6%	1.4%
Howitzers										
	105-mm	M1 / M67	70	1	M1- Charge 5	DNT	42	34	99.9%	0.081%
	155-mm	M107 / M3	60	1	M1-Charge 7	DNT	250	1.2	99.99952%	0.000480%
	155-mm	L17 (British)	30	1	L8 - Charge 3	NQ	760	-ND-	—	—
						NG	260	-ND-	—	—
			30		L8 - Charge 5	NQ	1,900	-ND-	—	—
						NG	660	-ND-	—	—
			20	1	L10-Charge 8	NQ	6,700	-ND-	—	—
						NG	2,300	-ND-	—	—
Tanks										
	105-mm	C109A1(Canada)	90	1	M1	DNT	300	6.7	99.998%	0.0022%
Rockets										
	84-mm	M136 (AT4)	6	1	AKB 204	NG	130	95,000	27%	73%
	84-mm	Carl Gustav			AKB 204	NG	140	20,000	86%	14%
	66-mm	M72 LAW			M7	NG	22	42	99.8%	0.19%
	204-mm	M26 GMLRS	1	1	AR 360B	AP	57,000	<1.6	> 99.99999%	<0.000003%
	204-mm	M26 GMLRS	18	2	AR 360B	AP	57,000	ND	—	—

Table 4: Propellant burn points

Weapon System	Munition Caliber	Propellant used for Test	Charges Tested	Plumes Sampled	Energetic Material	Energetic Compound	Mass / Round (g)	Results for Energetic Compound		
								Residues / Round (mg)	Consumption Efficiency	Compound Remaining
Mortar -Snow										
	81-mm	M185	10	1	M9	NG	5.3	84	98.4%	1.6%
	120-mm	M230	11	1	M45	NG	13	2,273	82.5%	17%
Mortar-Frozen ground										
	120-mm	M230	11	1	M45	NG	13	664	94.9%	5.1%
Mortar-Pan										
	120-mm	M230	10	1	M45	NG	13	27	99.8%	0.21%
Howitzer-Dry Sand										
	105-mm	M67	10	1	M1: 5 Chrg 6 & 5 Chrg 7	DNT	65	620	99.0%	0.95%
Howitzer-Wet Sand										
	105-mm	M67	10	1	M1: 5 Chrg 6 & 5 Chrg 7	DNT	65	650	99.0%	1.0%
Howitzer-Dry Sand										
	155-mm	L8	6	2	Charge 4	NG	110	3	99.998%	0.0024%
						NQ	330	33	99.99%	0.010%
Howitzer-Dry Sand										
	155-mm	L8	4	2	Charge 7	NG	280	2.0	99.999%	0.0007%
						NQ	820	16	99.998%	0.0019%

*The initial energetics mass per round for the 105-mm burn point tests is the combined total of one charge 6 and one charge 7 propellant bag.

Table 5: Propellant burn pans

Weapon System	Munition Caliber	Propellant used for Test	Burns	Plumes Sampled	Energetic Material	Energetic Compound	Mass (g)	Results for Energetic Compound		
								Residues (mg)	Consumption Efficiency	Compound Remaining
CRREL Mk-1										
	Full-size Pan (1-x2-m)	Mixed propellant	3 burns	1	M1: Mixed (276 kg)	DNT	27.6 kg (total)	2300***	99.992%	0.008%
CRREL Mk-2										
	Full-size Pan (1-x2-m)	M67 (105-mm)	1 burn	1	M1: Chg 6&7 (65 kg)	DNT	6.5 kg (Total)	1600***	99.98%	0.020%
CRREL Mk-3										
	Full-size Pan (1-x2-m)	M67 (105-mm)	1 burn	1	M1: Chg 6&7 (90 kg)	DNT	9 kg (Total)	NDD	>99.999%	<0.001%

***Estimated mass ejected from pan

DISCUSSION

An examination of the tables presented above illustrates the wide range in residues deposition. Both mass and performance (percentage residues) must be considered when interpreting the results. Frequency of use, terrestrial distribution of the residues, concentration of the deposition events (scattered versus fixed location deposition), and mobility are all factors that need to be considered when assessing the impact of training with heavy weapons on ranges. Toxicity of the energetic components is a very important consideration.

It is vitally important that range managers know what is being used on their ranges as well as the possible contamination that will result from training with munitions (Walsh et al. 2014). In the US, we are developing and deploying a new generation of insensitive munitions, designed to protect materiel and personnel by greatly reducing the incidence of unintentional activation. We tested munitions containing two different insensitive high explosive formulations, PAX-21 and IMX-104. In both cases, abnormally high quantities and percentages of one of the components were found in the detonation residues (MR Walsh et al. 2013, 2014; ME Walsh et al. 2014). In the case of the PAX-21 rounds, 7 million liters of water would, on average, be contaminated above current drinking water standards after each high-order detonation. For a BIP operation, the volume would be over 15 million liters on average (Walsh et al. 2013). Environmental testing of these rounds prevented billions of Euros in cleanup liabilities when the rounds were reclassified for combat use only.

SUMMARY

Energetics residues mass and efficiency data has been derived through an extensive research program on the environmental effects of training with military munitions. These result demonstrate the importance of testing munitions for environmental impacts prior to certification and use on training ranges. The environmental impacts of live-fire training will differ greatly from round to round and may differ substantially between similar rounds with different explosive or propellant configurations. Large environmental cleanup liabilities and loss of training ranges may result from contamination caused by energetics residues from military munitions.

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Sample Collection, Processing, and Analytical Methods for the Measurement of Post-Detonation Residues from Large Caliber Ammunition

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1. Introduction

Post-detonation residue from any explosive formulation will contain at least some of the original energetic compounds. Reasons for measuring the residual energetics include the assessment of the potential for environmental contamination of training ranges and determination of the detonation efficiency of a munition. The mass of residual energetics can be infinitesimal to a significant percentage of the initial mass. Thus the collection method must not be susceptible to cross-contamination or matrix interferences and it must provide the ability to concentrate the residue if needed.

The US Army Cold Regions Research and Engineering Laboratory and Envirostat, Inc. developed and optimized a method that uses snow as the collection medium for post-detonation residues. The method has been used to measure residue from conventional and insensitive munitions. Recently, an alternative method that uses ice as the collection surface was tested. The objective of this paper is to give an overview of the snow and ice sampling methods and provide comparative results for high order detonations of one munition.

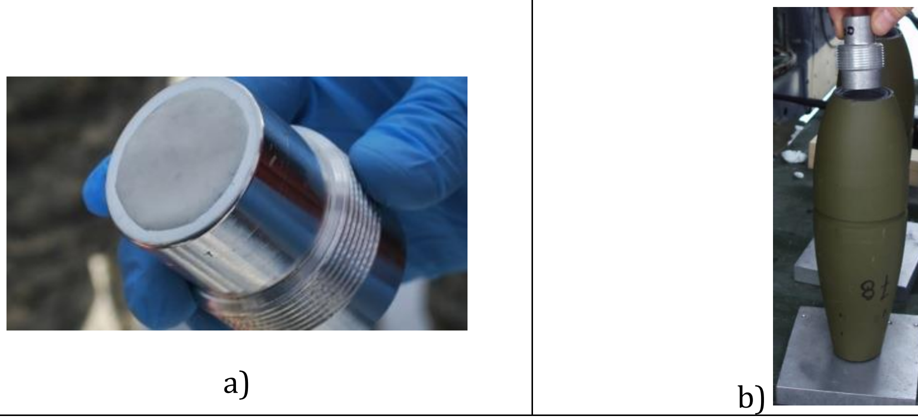
2. Methods

2.1 Detonations

Tests were conducted using mortar projectiles (DODIC CA16) that each contain 807 g of IMX-104 and 23 g of HMX in the supplemental charge.

Command high-order (HO) detonations were initiated using a fuze simulator (Figure 1) that was developed by CRREL (Walsh et al. 2011a). The simulator enables high-order detonation without the need for fuze activation by live firing of a projectile. The booster cup of the fuze simulator was filled with 18 g of C4 (91% RDX), and the detonation train was initiated using a blasting cap inserted through the simulator into the booster charge.

Figure 1. Fuze simulator a) packed with C4 and b) with 81-mm mortar projectile.



a) b)

2.2 Snow Sampling Procedures

Detonations are initiated on a snow-covered range that was underlain by ice (Walsh et al. 2012) in March 2014 and February 2015.

For each test, multiple rounds were detonated in the same manner. To measure the variability in the deposition masses, the detonations in 2014 were placed so that there was no overlap of the plumes and each plume was sampled individually. Up until recently, individual plumes were sampled to obtain mean deposition rates (Walsh et al. 2011b and 2012).

An alternative method was tested in February 2015 in which multiple detonations were performed at the same location and the cumulative residue from the overlying plumes was sampled. This procedure reduces the number of samples that need to be collected and it potentially increases the detection sensitivity for highly efficient detonations.

The plume sampling procedure was identical in 2014 and 2015. Following detonations, the plumes containing the residues were demarcated by walking the edge, which was determined qualitatively as the border between the area of soot deposition and clean snow. A geographical position system was used to record the outline of each plume, and the data were used to compute the area of deposition. To verify that the visually discernable plume on the snow surface contained the bulk of the residues (>95% goal), we demarcated a 3-m annulus around the main plume area and another annulus extending from 3- to 6-m outside the plume (OTP). To obtain the snow samples, we used 10- x 10-cm scoops to collect multi-increment (MI) samples in each plume. We sampled to a depth of 2 cm or deeper if residue was apparent below the surface. A systematic-random approach was used to collect triplicate samples from each plume. Each snow sample within the plume (ITP) consisted of approximately 100 increments that were combined in a special clean polyethylene (PE) lab-grade bag. For OTP units, we collected between 40 and 100 increments. One OTP sample was collected per plume, and triplicate OTPs were taken around randomly selected plumes for quality assurance.

In 2014, five individual plumes were sampled. In February 2015, residue from two co-located overlying detonations was sampled.

Figure 2. Sampling of snow inside and outside a detonation plume.

2.3 Ice Sampling Procedure

In March 2015, our test site had no snow. However, it did have a smooth ice surface. We had installed pans to collect some of the post-detonation residue for a related study of the physical properties of the detonation soot. After the first detonation, we observed that the detonation residue could be easily collected from the ice surface by sweeping. We realized that collection of residue from the entire plume (Figure 3) would minimize sampling uncertainty. We then established a second test area for a another detonation under the same conditions (but without collection pans) with the intent to compare the results obtained to those of the two previous snow-sampling events of residues from the same ammunition.

Figure 3. Sweeping of detonation residues from the ice surface.

The plume area was measured by walking the plume boundary with a GPS unit. The sample collection procedure simply involved the use of wide soft-bristled brooms to collect all the visible residue on the ice surface. The volume of the residue, which contained ice crystals and soot, filled six of the 38-cm by 76-cm bags sample collection bags.

2.4 Sample Treatment

The post detonation samples were each transferred to a clean bag (with an overbag) in our field lab. This procedure prevents loss of the sample as it melts if the bag is punctured and it minimizes cross-contamination. The bulk of each sample generally melted overnight, with some snow and ice remaining the following morning. Each sample that contained frozen material was immersed in a hot water bath to just complete the melting process; the sample was never allowed to warm.

Once the samples were melted, the solids separated from the aqueous fraction by vacuum filtration (Figure 4).

Figure 4. Separation of the solid and aqueous phases of the melted post detonation samples.

2.5 Analytical Methods

IMX-104 is composed of RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), DNAN (2,4-dinitroanisole), and NTO (3-nitro-1,2,4-triazol-5-one).

RDX was determined using reversed phase HPLC parameters in US EPA SW-846 Method 8330, the standard analytical method for explosives. DNAN is a nitroaromatic with properties (Log K_{ow}, aqueous solubility, vapor pressure) similar to other energetic nitroaromatics such as TNT, and it was determined using the same procedure. Solid phase extraction using Waters Sep-Pak Porapak RDX cartridges and elution with acetonitrile were used to pre-concentrate the RDX and DNAN residing in the melted snow. Solid residues from the filtration process were extracted with acetonitrile. All of the extracts were analyzed by high-performance liquid chromatography and some of the extracts were analyzed by gas chromatography to confirm the presence of DNAN.

NTO is too polar to be analyzed by the standard analytical method for explosives. Concentrations in the aqueous and solid phases were determined by methods based on those developed by Le Campion (1997). The aqueous samples were analyzed directly without preconcentration. Samples were injected using a matrix of 3/1 (v/v) acetonitrile/water. Determinations were made using a 15 cm x 4.6 mm (5 μm) Hypercarb (ThermoScientific) column eluted with 1.5 mL/min of 3/1 (v/v) acetonitrile/water with 0.1% trifluoroacetic acid (Fisher HB9813-4) at 28°C. The UV detector was set at 315 nm for NTO.

2.6 Estimation of Residual Energetic Mass

For the snow sampling method, mass deposition per round was estimated from the extrapolation of the mass derived from the analysis of the residues in both the aqueous and solid phases, the area sampled and the total area of the plume. The sequence of arithmetic calculations are as follows for each analyte.

Mass (mg) in Aqueous Fraction = Conc. (mg/L) x Volume (L) of Melted Snow

Mass (mg) in Solid Fraction = Conc. (mg/L) in Extract x Volume (L) of Solvent

Mass (mg) in Sample = Mass in Aqueous + Mass in Solids

Area (m^2) Sampled = Number of increments x Area per increment

Mass per Unit Area (mg/m^2) = Mass in Sample (mg)/Area (m^2) Sampled

Mass in Plume (mg) = Mass per Unit Area (mg/m^2) x Area of Plume (m^2)

In the case where multiple detonations took place in the same area, the mass in the plume is divided by the number of overlying detonations.

For the swept ice method, the sum of the masses of each analyte found in the aqueous and solid phases corresponds to the masses in the plume because all (or nearly all) of the residue was collected.

3. Results

The residual mass of energetics estimated by the three collection techniques for three classes of energetics are summarized in Table 1. The initial mass of NTO was 428 g and the mean residual masses determined ranged from 0.5 to 1 g, yielding detonation efficiencies between 99.7 and 99.9%. The masses of DNAN and the nitramines (RDX plus HMX) were considerably smaller (milligram quantities), yielding detonation efficiencies of greater than 99.99% for all three methods.

Table 1. Residual masses of energetics determined by three sample collection methods.

	NTO		DNAN		RDX plus HMX	
Matrix - Plume	Mass (g)	Detonation Efficiency	Mass (g)	Detonation Efficiency	Mass (g)	Detonation Efficiency
Snow - Individual	0.54	99.87%	0.008	99.997%	0.0077	99.995%
Snow - Overlying	1.15	99.73%	0.013	99.995%	0.0038	99.998%
Swept Ice Individual	0.72	99.83%	0.017	99.993%	0.0041	99.997%

Initial masses: NTO (427.7 g); DNAN (255.8 g); RDX plus HMX (162.7 g)

The overall efficiencies estimated by the three sample collection methods are summarized in Table 2. Given the total initial energetic mass (846 g) and the sum of the residual energetics, the detonation efficiencies were estimated to be 99.9% by all three methods.

Table 2. Detonation efficiencies estimated by three sample collection methods.

Matrix - Plume	Mean Efficiency
Snow -Individual	99.93%
Snow - Overlying	99.86%
Swept Ice - Individual	99.91%

Initial energetic mass = 807 g IMX-104 + 16 g RDX in Fuze Simulator + 23 g HMX in Supplemental Charge = 846 g Total

4. Discussion and Conclusions

The use of snow-covered training ranges as a collection media for post detonation residue has been optimized over many years. The method was used to develop a database for the most commonly used ordnance on training ranges in Canada and the USA (Walsh et al. 2011b). Advantages of the snow cover are many. It serves as a pristine collection medium, the plume is easily visualized on the white background, the sample processing method is straightforward, and replicate samples may be collected. Ideal conditions are ambient temperatures slightly below 0°C, cloud cover, no wind, and no precipitation.

The optimized method uses Multi Increment® sampling of individual plumes. Variations of the method were tested in February and March of 2015. The first variation involved sequential detonations in one location rather than well-spaced, non-overlapping detonations. Although co-locating the detonation plumes eliminates the ability to test variability between rounds, it reduces the number of samples that are collected and analyzed, and it could improve detection capability for some types of residues by the accumulation of trace amounts. The second variation tested in March 2015 used ice as the collection surface. The post detonation residue from the whole plume was swept from the ice surface and the entire residue was processed and analyzed. This later variation minimizes field sampling uncertainty. A test facility, where an ice surface is generated, could be constructed to take advantage of this procedure for studies of detonation efficiencies.

This paper summarizes the results from the three sample collection methods following high-order detonations of IMX-104 ammunition. High-order detonation is the most common mode of detonation for fired munitions. The detonations were initiated using a fuze simulator. Similar procedures are commonly used during life-cycle environmental assessments of new munitions to determine air emissions from detonations. Use of the fuze simulator has advantages over live fire. The detonation site is controlled and can be selected for a reduced danger zone. Detonations can be placed to allow complete overlap or no overlap of the plumes, depending on the objectives of the test. Duds are avoided through the command detonation process.

For the IMX-104 rounds, almost all of the residual energetic mass was NTO. The three sample collection methods yielded residual mass estimates of 0.5 to 1 g of the original 428 g of NTO. Estimates of residual DNAN and RDX plus HMX were also very similar between the three collection methods, yielding detonation efficiencies exceeding 99.99%.

5. Acknowledgments

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Introducing a project: Technical and practical solutions for environmental protection of Heavy Weapons Ranges

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Background

Military training on heavy weapons ranges has effects on the environment. It causes noise and leaves traces of explosives in the soil. Training areas are usually large and have often significant nature values and important groundwater resources.

Training in real surroundings with real weapons is indispensable and cannot be completely replaced with simulations. On the other hand the guidelines for heavy weapons noise and munition concentrations are often ambiguous or non-existent. At the same time general requirements of environmental legislation have tightened. Some legal exemptions are unavoidable in order to maintain effective military training.

Over the last few years a lot of background research has been conducted on these issues. The studies have increased knowledge about the environmental impacts but also they have shown that there is a lack of coherent knowledge on the possibilities to reduce the environmental impacts of heavy weapons. On some areas there is an abundance of information whereas on some topics there would be a need for more in-deep studies. Most of the knowledge is scattered and cannot be easily found at one, collected source.

These factors have caused a need to understand the environmental impacts even further and to create effective and feasible technical solutions and management practices on shooting and training areas.

Although legislation and practical requirements vary from country to country, there is a global trend that expectations towards defence authorities are rising in the area of environmental protection. Also Nordic nations have similarities in their geology, weather, training practices and culture. Common understanding has been that there is a growing need to develop management practices for heavy weapons ranges as problems with i.e. explosive residues in groundwater have emerged and are forming a severe threat for mission sustainability. Budgetary constraints could be partly compensated by greater cooperation and more efficient use of resources. Joining forces to develop common solutions is beneficial to all the Nordic nations.

To respond to this need Finland proposed a Nordic joint project, which will officially start in the kickoff meeting in Helsinki on the June 8th 2015. Project has participants from Finland, Sweden, Norway, Denmark and USA.

The project will run for three years and will have 2 workshops held annually to check and advance the progress of the project and achievement of milestones. The final report will be ready by the end of the year 2017.

Aim and Purpose of the Project

Aim and purpose of the project is to collect and assess good practices and technical solutions for environmental risk management of heavy weapons ranges and explosion platforms.

The history of research on the environmental impacts of heavy weapons is fairly short, which is why there is a need to summarize a description of environmental properties of substances used in energetic materials of heavy weapons systems. This part of the proposed project is limited mostly to collecting existing data that has been published during the last couple of decades. The NATO-AVT group on explosives has produced significant proportions of this work and also its follow-up project will be tightly linked with the project.

An important aim is to collect and produce the best possible information of the environmental behavior and health risks of munition constituents, which can then be used to create and harmonize environmental guideline values. Guidelines help the work of environmental authorities and diminish unnecessarily immoderate environmental requirements for the military training.

The main target of the project is to collect existing information on physical structures and management practices, and review it critically. In some areas additional research projects may be necessary to reach a sufficient level of knowledge; also recommendations for further studies can be made. The aim is to collect and compare knowledge on the efficiency of physical structures that are designed to reduce the environmental impact of the use of heavy weapons systems. It is already known that experiences in this particular field are limited and often pilot-scale trials. This means that a Best Available Technology Reference Document is not possible in strict sense since the solutions are not tested and proven in the way meant by the definition.

Also an important area is to assess how far existing solutions used in other business areas such as road building, chemical industry can be transferred into heavy weapons ranges and evaluate their cost-effectiveness and proportionality in this use. It is important to note that a wide range of controlling methods and technical solutions exist to protect soil and groundwater and to manage environmental noise in general but there often is no or very limited application of these technologies in military training areas. Thus, one of the goals of the proposed project is to "validate" or examine the possibilities to use these solutions to reduce the impacts of military training.

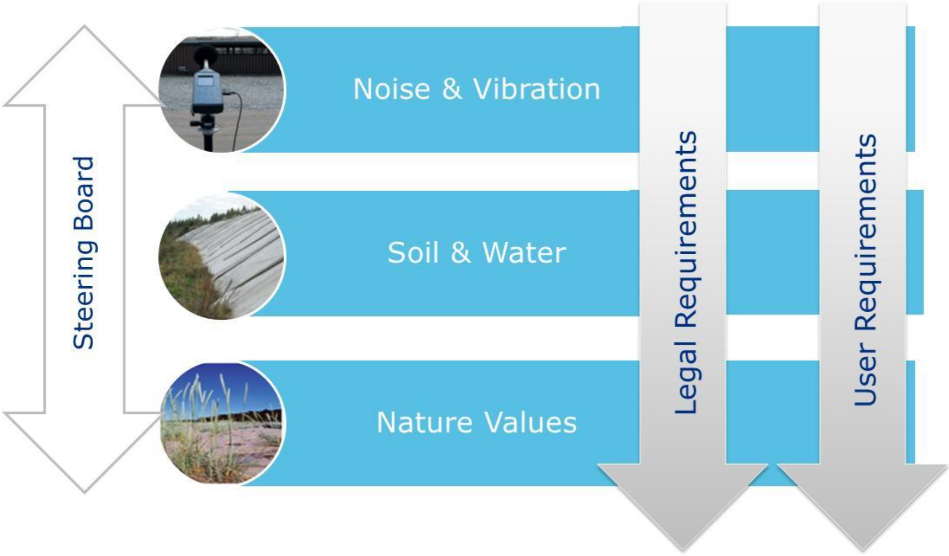
Because both physical structures and environmental practices must meet the legal requirements in all interested nations, a legal comparison is needed. There may also be a need to further develop and harmonize the legislation and in some cases exemptions may be unavoidable. A recommendation of development needs of legislation will be part of the outcome.

Organization of the Project

The environmental impacts can be divided in three groups: noise & vibration, soil & water and nature values. These groups will work independently in workshops and produce representative chapters to the report.

To project will cover all the aspects of using heavy weapons as part of the military training. This means that possibilities and limitations to development of training practices must be understood. Also legal requirements will be covered parallel to the three groups concerning environmental aspects. These two specialist groups will have their own workshops, but also participate in the work of the environment groups.

Steering board sees that the entity stays within the given target frame and time schedule. Steering board will have participants from environmental authorities to provide genuine possibility to create an executable guidance document.



Goals and products

In the desired outcome the following areas have been addressed:

- Summary of pre-existing knowledge of environmental impacts, effects on nature values, munition constituents and noise.
- Physical technology solutions for heavy weapons shooting ranges and explosion platforms
- Best Environmental Practices
- Sampling and monitoring practices of environment at heavy weapons ranges
- Monitoring and management of use of training areas and consumed ammunition,
- Models to calculate or simulate environmental impacts of training,
- Other management practices.
- Legal comparison and a recommendation of development needs of legislation.

The result of this work will be a report "*Technical and practical solutions for environmental protection of Heavy Weapons Ranges (guidance document)"*. This guidance will help to define case-specific measures needed to address environmental protection of shooting and training areas.

Investigating Environmental Consciousness within Hellenic Armed Forces - Part I:
Hellenic MoD's route on developing Sustainability Standards for Manpower Factor:
The Questionnaire Tool

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Introduction

The implementation of Sustainability in Defence within the Hellenic Armed Forces will be discussed. In this context, the investigation of the environmental consciousness as high determinant of the proper materialisation of environmental policies will be presented.

About Sustainable Development

The Sustainable Development, as known, is based on three pillars: economy, society and environment and their mutual interaction.

However, the latest international experience has shown that a fourth pillar, the one of politics, is necessary for the successful implementation of sustainability principles into countries' national policies. This pillar, also applicable in Greece and in our MoD, acts as a link between the other three ones to produce the desired result.

Another emerging pillar in all the above is Consciousness (European Environment Agency, 2013). Investing on human factor will play a significant role in order to employ more effective solutions towards sustainability.

Hellenic MoD's Environmental Policy

Our Environmental Policy is based on the vision of sustainable Armed Forces and is reflected by the triptych "Accomplishment of the Mission - Togetherness with Society - Protection of the Environment". The accomplishment of the mission is always on top of our priorities.

The main Components of our Ministry's Environmental Policy are:

1. Climate change
2. Energy
3. Soil
4. Air
5. Sea
6. Water Resources
7. Nature and biodiversity
8. Acoustic noise - Vibrations
9. Hazardous materials and substances
10. Waste management
11. Cultural heritage
12. Environmental issues interaction.

They are all interacting with each other, and serve all fundamental fields of sustainability.

Implementation of HMoD Environmental Policy

At this point, it is useful to introduce our course-of-actions on completing, last year, reviewing and revising our Environmental Policy.

- The cornerstone is the Compliance with National legislation, the EU Regulations & NATO Standards, coupled with Wide-spectrum Co-operations.
- The continuous review of our Environmental Policy is based on the "Plan-Do-Check-Act" circle.
- A detailed briefing to the pertinent Committee of the Hellenic Parliament was provided in December 2012, to ensure the governmental support to our efforts.
- Our MoD "Integrated Strategic Sustainability Plan" was issued in January 2013, where all relevant activities were associated with measurable performance indicators.
- The first phase of our Armed Forces Regulation on "Integrating Sustainable Development Principles in Military Activities" was completed in August 2013. The respective directions refer (among others) to the following elements: contribution to the society, green procurement procedures, environmental assessment in operations, and relative must-do actions.
- A "green" web page was also launched in September 2013, to serve as a central information point for the environmental activities and initiatives of our MoD.
- The annual edition of the "Green Paper", reporting environmental & social activities of our Armed Forces was issued for the 1st time in October 2013.
- A major reforming of our MoD's environmental organisational structure was approved in February 2014. As indicative reforms, let me refer to the establishment of a brand-new "Directorate of Sustainability" in the Hellenic National Defence General Staff, and of a dedicated Environmental Office in each and every Military Unit.
- The establishment of an environmental web Forum was approved in February 2014, in order to enhance diffusion of knowledge and experience; and to optimize, through online cooperation, the existing procedures and assessments to environmental aspects. There will be an internal CLOSED section of the Forum for the environmental officials; and an OPEN section as well, for all environmentally concerned people of the Armed Forces.
- After all, the Revision of our MoD Environmental Policy was completed and approved in February 2014. This revision has also taken into account all relevant EU and NATO Documents.

This step-by-step thorough Revision actually reflects my personal vision, which is "FROM MITIGATION TO ADAPTATION" and it closes a successful circle of the aforementioned actions completed.

For those who wish to have a further look to the English versions of our MoD GREEN PAPER and ENVIRONMENTAL POLICY, they can have direct access to the following URL http://www.greenarmedforces.mil.gr.

"Sustainability in Defence" Initiative

The Hellenic MoD is consistently making efforts to transform its Environmental Policy to Sustainable Development values.

In June 2014, the Hellenic MoD organised an International Conference on "Sustainability in Defence", as a part of the "Sustainability in Defence" Initiative, based on the "Sustainability in Defence" Concept. The Conference made part of the Hellenic Presidency of EU Council of the first Semester of 2014. The outcome and the material of the Conference can be found at the following path: www.greenarmedforces.mil.gr > SiD > Presentations**.**

A relevant presentation was also given in the recent NATO Conference IESMA 2014 at the Energy Efficiency Centre of Excellence.

A previous presentation of the Hellenic MoD dealt with the subject of Climate Change and Energy, in a senior level meeting at EDA in December 2013.

Last, but not least, after recent approval, the Hellenic MoD is examining the establishment of a Centre of Excellence focused on "Sustainable Development"

The key factors of incorporating Sustainability in Defence, namely **Manpower, Infrastructure** and **Financing** were explored during the aforementioned SiD Conference.

At first, environmental consciousness and awareness, of the personnel engaged in Defence, established and upgraded through the continuous provided respective training and education, is the major factor that determines the actual implementation of environmental policies and actions. Thus, the Manpower Factor is the basis of all further measures taken to apply sustainability in defence.

The development of appropriate Infrastructure is the key tool required to materialize the pillars of Sustainability in the defence sector. This includes both the sustainable transformation of existing installations and the development of modern, energy saving and smart new installations, that will serve the multiple actions required to operate in a sustainable manner, in total.

Last, but of crucial importance, is the proper Financing of projects. The recent cutbacks in defence budgets and investments have turned the situation critical for the defence sector.

Therefore, a thorough investigation of all possible funding is of outmost importance in order to employ the proper combination of national, European or Allied funding sources. EU offers a wide range of funding opportunities, such as the European Structural Funds, the Horizon 2020 for Research and Development, and others, while NATO is supporting projects through the "Science for Peace and Security" program. This is highly interesting for the MoD's but also for the defence industry, including SME's, to promote production of sustainable and at the same time innovative products.

Assessment of Environmental Consciousness

At this point it would be useful to focus on the issue of Consciousness, describing, at first, its components.

One could suggest that there is an evolution in the development of consciousness. So, the first stage of a consciousness development is knowledge. One has to be informed at first. Then he (or she) can shape his own attitude versus a certain object. And after that, he (or she) will formulate his **behaviour**, which is the heart of the issue of implementing sustainability in defence.

It is noted that the issue of consciousness has long been identified as crucial for the implementation of environmental policies.

To this end, the evaluation of the formed environmental consciousness and ethics of the Armed Forces has been conducted. It has been done through an online questionnaire and covered all officers and civilians of the Hellenic Armed Forces.

Soldiers will participate in the assessment of environmental consciousness as a second step.

The questionnaire was launched in May 2014, and was online for one (1) month, while the statistical process was concluded in December 2014.

The questionnaire itself was elaborated by a Working Group within the Hellenic MoD, based on international literature (Markowitz et al., 2012, Steg et al., 2009, Unsworth et al., 2013), and was validated scientifically by Professor Tsaltas, Rector of Panteion University of Social and Political Sciences of Athens.

Of course, launching of the questionnaire was approved by the Minister of the Hellenic MoD.

In more detail, 100% of the permanent personnel, military and civilian were requested to respond to the questionnaire. This is pioneer by the military and perhaps among all consciousness studies conducted by organisations.

Access to the questionnaire was enabled by a web platform, which was developed in-house, by the ICT Dept. of the Ministry. A unique password was assigned to everyone so that no duplicated answers would be received. Anonymity was of course an option to everyone. And finally, the Commanders were instructed to encourage the personnel to participate to the project.

The questionnaire consisted of two parts.

In the first part of the questionnaire, the personnel was asked to provide demographic details, family and service status, along with social, educational and work background details. The time required to fill the first part was approximately five (5) minutes.

The second part consisted of sixteen (16) questions specifically targeted to assess the Knowledge, the Attitude and the Behaviour of the personnel. The time required to fill this part was again about five (5) minutes.

There were multiple choice questions and some final questions concerning the factors believed by the personnel to affect Environmental Consciousness. This would be useful also to be shared with authorities that are responsible for education.

The personnel was also asked to provide proposals in a free text to improve the environmental management within the Military Camps. This would enhance the tendency of the personnel to participate actively in everyday environmental procedures.

Some questions were also set to serve as control questions, so that any misleading responses could be identified and evaluated accordingly.

So, the objective of the whole questionnaire was:

a. To assess the environmental consciousness of the personnel.
b. To correlate various aspects of knowledge, attitude and behaviour with personality components.

Results of the study

The response to the questionnaire was eight (8) percent approximately, as an average between the Branches of the Armed Forces, which is Army, Navy and Air Force.

Two representatives of the academic field, Associate Professor Mr. Kehagias, from the Hellenic Open University and Assistant Professor Ms. Rigopoulou, from the Athens University of Economics and Business worked on the statistical process and produced a Report of the Study. The Ministry is grateful to them for their contribution.

The SPSS program was employed in the statistical process.

As approved by our Minister, the analytical results will be releasable to all after their publication, in an international, peer-reviewed journal, which is planned to be concluded by the end of 2015.

Major findings of the research, were that the personnel is actually environmentally alert, although more is still to be done to achieve a uniform and harmonised adoption of sustainability principles across the army, the navy and the air force, and also at all levels of hierarchy.

Of course, these findings cannot de directly generalised to other armies, since the self-identity of each nation is expected to play significant role.

The following contribution (as **Part II**) by Professor Kehagias, is including main findings of the study.

Way Ahead

In order to enhance the environmental consciousness of the personnel, the Hellenic MoD is opting to valorise the "Golden Triangle", that is the co-operation of Government, Industry and Academia.

Indicatively, we are in the middle of putting together the pieces of about twenty (20) research projects in the Infrastructure area, and of about eight (8) in the Manpower domain.

We are also planning to develop an environmental campaign, both internal, addressed to our personnel, and external, aiming at the society's view on the Armed Forces as a socially responsible organisation. That might lead to a collective awakening towards sustainability.

In this context, we will implement the Outcome of the delivered report, and a re-assessment we come after two (2) years, to check the results of the actions taken to enhance the Environmental Consciousness of the personnel.

We will consider the project to be completed after one "Assessment Cycle", after two (2) years by using the same questionnaire tool to examine the effect of our actions to the environmental consciousness of the personnel. It is to be noted that upgrading the environmental consciousness is a continuous process.

To that end, further actions dedicated to Manpower as well as Infrastructure and Financing will be implemented.

Also, we are determined to promote diffusion of the results within the military and the academia, since such work is rare until now.

Our MoD official motto, issued & delivered last year to every single military unit WITHIN Greece, is "**Hellenic Armed Forces… towards "green" transformation**". The motto has been also included in our MoD GREEN PAPER.

We hope that we have already made an important step forward towards the formation of an army which, without declining from its operational mission, will contribute to the sustainable development of the country. In this context, our MoD will be contributing to the development of Sustainability Standards within the military and the society as a whole.

Summary

To summarise, the factors of Manpower, Infrastructure and Financing, as affecting the implementation of sustainability in defence, were discussed. Among them, the issue of consciousness underlying the manpower factor was further investigated within the Hellenic Armed Forces by an online questionnaire, addressed to 100% of the personnel, military and civil. It was found that the staff is environmentally alert, while adoption of the sustainability principles may be enhanced. Actions to this end are already being scheduled.

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Investigating Environmental Consciousness within Hellenic Armed Forces - Part II: Statistical Findings and Conclusions

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INTRODUCTION

The purpose of the field research was "the investigation of the degree of awareness, the existing attitudes and the everyday behaviour of the Hellenic Armed Forces personnel regarding Sustainable Development.

METHODOLOGY

The Survey sample

The questionnaire consisted of a respondent profiling section and a number of questions that were aiming at highlighting issues relevant to Sustainable Development as seen by the respondents. The survey was electronically conducted across all Branches and Ranks of the Armed Forces. The survey was conducted during the period 5-31 of May 2014 and 7,384 completed questionnaires were collected.

A first picture of the response rates is derived from the distribution of the responses among the Services/ Branches of the Armed Forces. More specifically: 13,7% came from the staff of the Ministry itself, 4,1% from the Hellenic National Defense General Staff (HNDGS), 6,3% from the Hellenic Army General Staff (HAGS), 5,6% from the Hellenic Navy General Staff (HNGS) and 14% from the Hellenic Air Force General Staff (HAFGS).

Respondent Profiling

The following Table shows a picture of the respondents in terms of the main demographic characteristics:

SEX: *Male 85.7%* *Female 14.3%*

Army	***85.7%***	*14.3%*
Navy	***81.6%***	*18.3%*
Air Force	***87.6%***	*12.2%*

AGE: *18-30 28%* *31-45 62.4%* *46+ 9.6%*

Army	*31.6%*	***61.2%***	*7.2%*
Navy	*26.1%*	***60.7%***	*13.2%*
Air Force	*25.1%*	***64.6%***	*10.4%*

Area of growing up:

	Athens – Thessaloniki 23.1%	***Provincial Town 41.8%***	***Village 33.7%***	***Foreign country 1.4%***
Army	*18.1%*	***41.6%***	*38.7%*	*1.6%*
Navy	*4.7%*	***30.4%***	*21.4%*	*1.2%*
Air Force	*20.5%*	***45.7%***	*32.6%*	*1.2%*

Schooling: *Private 2.9%* *Public 97.1%*

Army	*3.1%*	***96.9%***
Navy	*3.1%*	***96.9%***
Air Force	*2.7%*	***97.3%***

Family status: *Married: 58.4%* *Single: 41.6%*

Army	*55.7%*	*44.3%*
Navy	*56.8%*	*43.2%*
Air Force	*61.6%*	*38.4%*

The above tables show that the sample is quite representative of all three Branches of the Armed Forces and consequently the results can be safely generalized.

A further and thorough analysis of the background and status of the respondents is necessary in order to reach for any differences that could affect the findings, is depicted in the following tables.

***Type of Personnel**:* *Military: 95.2%* *Civilian: 4.8%*

Army	***95.5%***	*4.5%*
Navy	***89.1%***	*10.9%*
Air Force	***96.1%***	*1.9%*

Recruitment source** (only for military personnel)**:

Military Academy 47% *Award/Contest/Hiring 53%*

Army	*36.7%*	***63.7%***
Navy	***56%***	*44*
Air Force	***55.9%***	*44.1%*

***Additional studies** (excluding Higher Military Academies) **Postgraduate studies** (MSc etc):*

YES: 14.7% *NO: 85.3%*

Army	*12.7%*	***87.3%***
Navy	*15.6%*	***84.4%***
Air Force	*16.1%*	***83.9%***

***Postgraduate studies relevant to environment/energy** 2.7%*

Army	*2.6%*
Navy	*2.9%*
Air Force	*2.7%*

***Postgraduate studies not relevant to environment/energy** 11.9%*

Army	***9.9%***
Navy	***11.6%***
Air Force	***13.2%***

Have attended seminars on environmental protection or saving energy

Yes 15.2% *No 84.8%*

Army	*14.1%*	***85.9o%***
Navy	*16%*	***84.00%***
Air Force	*16.2%*	***83.80%***

Work duties relevant to environment or energy:

Directly 3.9% *Indirectly 32.3%* *Not at all 63.8%*

Army	*3.6%*	*34.2%*	*62.2%*
Navy	*3.2%*	*35.9%*	*60.9%*
Air Force	*4.[illegible]*	*29.[illegible]*	*66.[illegible]*

The analysis of the responses to the questions of:

1. Work duties dictate frequent contact with the public
2. Having exercised supervisory / managerial duties in the last 3 years, again do not point at any significant discrepancies among the three Branches.

Having examined the profiling part we preceded with the analysis of the responses to the main body of the questionnaire that contain questions revolving around:

1. Behavioural questions
2. Statements on the perceptions of the term "sustainable development"
3. Statements regarding beliefs about sustainability
4. Statements that suggest perceptions of issues relating to sustainable development
5. Factors that negatively affect environmental awareness in general
6. Factors that that are generally relevant to environmental awareness/consciousness

It must be noted that recognizing the interactions of Awareness, Beliefs, Perceptions and Behaviours, the above "six-parametric" conceptual framework circumvents the notion of culture within the armed forces. In this framework the answers to the relative questions give the following picture.

STATEMENT OF THE TERM "SUSTAINABLE DEVELOPMENT"

To me the term "sustainable development" means:

	A fashion or one more trend of the times 4.3%	*Energy saving 10.1%*	*Protection of the environment 27.2%*	***A better future 58.4%***
Army	*6.3%*	*10.2%*	*26.8%*	***56.7%***
Navy	*3.8%*	*12.1%*	*28.9%*	***55.1%***
Air Force	*2.4%*	*9.4%*	*27.3%*	***61%***

STATEMENTS THAT IMPLY BELIEFS

Every generation should function in such a way that the next to have more "rights":

	True 97.4%	*False 2.5%*
Army	***96.4%***	*3.6%*
Navy	***96.3%***	*3.7%*
Air Force	***98.9%***	*1.1%*

In the context of sustainable development the most important thing is:

	The Economy 3.2%	*The Society 4.6%*	*The Environment 12.6%*	***All the above 79.6%***
Army	*4.5%*	*5.9%*	*13.3%*	***76.1%***
Navy	*3.2%*	*4.9%*	*13.4%*	***78.5%***
Air Force	*1.6%*	*3.1%*	*11.5%*	***83.9%***

Each one of us alone cannot do much for the sustainable development of the armed forces:

	TRUE 28.5%	***FALSE 71.4%***
Army	*33%*	***66.9%***
Navy	*28.8%*	***71.2%***
Air Force	*23%*	***76.5%***

The achievement of environmental protection is mostly a matter of severe legislation rather than people's attitudes:

	Agree 1	*2*	*3*	*4 Disagree*
	51%	*25.5%*	*14.7%*	*8.7%*
Army	***47.6%***	*24.6%*	*16.8%*	*11%*
Navy	***48.7%***	*27.7%*	*13.5%*	*10%*
Air Force	***55.4%***	*25.6%*	*13%*	*6.1%*

STATEMENTS THAT IMPLY PERCEPTIONS

Working for an organization that promotes the protection of the environment is important to me:

	To a small extent 1	*2*	*3*	*To a great extent 4*
	2.8%	*8.7%*	***53.8%***	*34.5%*
Army	*4.2%*	*10.6%*	***53.4%***	*31.8%*
Navy	*3%*	*9.3%*	***54.6%***	*33.1%*
Air Force	*1.3%*	*6.7%*	***54.4%***	*37.6%*

The handling of the impact of the operations of the Armed Forces as a parameter in planning of every day activities, is considered meaningful:

	TRUE 90.9%	*FALSE 9.1%*
Army	***89.4%***	*10.6%*
Navy	***96.1%***	*13.9%*
Air Force	***94.1%***	*5.9%*

During recent years there is an important and noticeable improvement in the field of protection of the environment in my work

	I Agree 1 10.3%	2 19.8%	3 **38.5%**	I disagree 4 31.4%
Army	*12.7%*	*21.2%*	***36.7%***	*29.4%*
Navy	*12.8%*	*26.9%*	***37.5%***	*22.8%*
Air Force	*6.8%*	*15.7%*	***40.8%***	*36.7%*

STATEMENTS THAT REFER TO BEHAVIOURS

I take care so that I my residential waste is recycled:

	Nowhere *9.5%*	*At home* *28.8%*	*At work* *3.8%*	***Both*** ***57.9%***
Army	*12.2%*	*31.3%*	*3.9%*	***52.6%***
Navy	*10.5%*	*36.8%*	*3.2%*	***49.4%***
Air Force	*6.4%*	*23.4%*	*3.8%*	***66,4%***

After finishing work I check and deactivate lights, air condition units electric appliances etc:

	Never *1.2%*	*Seldom* *2.8%*	*Often* *13.1%*	***Always*** ***82.9%***
Army	*1.3%*	*2.4%*	*13.8%*	***82.4%***
Navy	*3.1%*	*9.4%*	*19.6%*	***67.8%***
Air Force	*0.4%*	*1.2%*	*10.5%*	***88%***

I participate voluntarily in initiatives for cleaning beaches, reforestation etc:

	Never ***41.2%***	***Seldom*** ***42.2%***	*Often* *13.3%*	*Always* *3.3%*
Army	***41.5%***	***40.5%***	*13.1%*	*4.8%*
Navy	***47.2%***	***40.3%***	*11%*	*1.4%*
Air Force	***38.6%***	***44.8%***	*14.4%*	*2.2%*

For my everyday transport I prefer:

	Car or motorbike 54.2%	*Car-pooling 14.9%*	*Public Transport 14.2%*	*Bicycle or walking 16.6%*
Army	***51.4%***	*14.9%*	*14.9%*	*19%*
Navy	***64%***	*8.2%*	*19.6%*	*8.2%*
Air Force	***54%***	*17.3%*	*11.9%*	*16.8%*

I urge my colleagues or my friends for the responsible use of energy % dangerous waste:

	Never 7.1%	*When a problem is reported 16.4%*	***When I spot a problem 59.4%***	*On a daily basis 17%*
Army	*8.9%*	*17.2%*	***57.1%***	*16.8%*
Navy	*9.9%*	*19.1%*	***57.9%***	*13%*
Air Force	*4.3%*	*14.8%*	***62.3%***	*18.6%*

STATEMENTS OF ADVERSE FACTORS

In our times, the level of environmental consciousness is more negatively affected by:

	YES Total	***Army***	***Navy***	***Air Force***
The incorrect information from State or other Institutions	***49.7%***	***50.4%***	***48.4%***	***49.1%***
The lack of effecting penalties for not conforming to legislation	*47.3%*	*46.7%*	*48.4%*	*47.3%*
The insufficient parental guidance	*47.9%*	*45.5%*	***51%***	***49.4%***
The crisis in values and ideals	*47.4%*	*43.1%*	***54.1%***	***49.7%***
The 1st and 2nd degree insufficient education	*40.6%*	*40.9%*	*42.1%*	*40%*
The economic crisis	*39.3%*	*38.8%*	*45.2%*	*38%*
Other	*4.2%*	*5.4%*	*4.9%*	*2.8%*

FACTORS THAT ARE RELEVANT TO ENVIRONMENTAL CONSCIOUSNESS

I think that the following factors are generally relevant to the notion of "environmental consciousness"

	YES Total	***Army***	***Navy***	***Air Force***
Environmental Consciousness	**74.7%**	**71.5%**	**75.5%**	**77.9%**
Environmental indoctrination	68.3%	63.9%	67.4%	73.5%
Environmental morality	60.3%	58.9%	60.8%	61.9%
Social responsibility	*60.7%*	*55.7%*	***63.2%***	***64.9%***
Environmental security	39.3%	39.5%	45.3%	38.7%
Awareness of sustainability principles	22.8%	23.4%	25.5%	21.3%
Democratic ethics	14.9%	14.5%	13.5%	15.8%
Religious perceptions	9.6%	10.3%	9.1%	9%

STATISTICAL TESTS

To check for the distribution of the data the normality test was applied through the SPSS. The results showed that the Skewness and Kurtosis values fall outside the +/- 2, whereas the significance level, Sig is lower than p=0.05. As a result of this, the normality tests proved that the data are normally distributed and any further testing should apply non parametric tests.

Factor analysis

In the context of the statistical analysis it was examined whether al l eight factors that can be considered "generally relevant to the notion of environmental consciousness" can be grouped to a smaller number of "major factors" as a result of their conceptual similarity and/or relationships. The testing was safely effected since the number of respondents was well above the threshold of five times the number of the factors treated.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.753
Bartlett's Test of Sphericity	Approx. Chi-Square	6591.793
	Df	28
	Sig.	.000

Total Variance Explained Extraction Method: Principal Component Analysis

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.353	29.406	29.406	2.353	29.406	29.406	2.004	25.051	25.051
2	1.359	16.992	46.399	1.359	16.992	46.399	1.708	21.347	46.399
3	850	10.623	57.021						
4	797	9.963	66.984						
5	710	8.874	75.858						
6	679	8.487	84.345						
7	635	7.934	92.279						
8	618	7.721	100.000						

As the above tables indicate, two factors account for 46.4% of the total variance, thus suggesting that other factors that have not been included in the research instrument are contributing in the “explanation” of the variance.

Rotated Component Matrix[a]

	Component	
	1	2
Environmental indoctrination	**703**	-024
Environmental morality	**665**	141
Environmental security	**657**	265
Environmental consciousness	**645**	-077
Social responsibility	*408*	*317*
Democratic ethics	092	**756**
Religious perceptions	-075	**723**
Awareness of sustainability principles	197	**645**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

According to the factor loadings, the first four factors can be consolidated into a “major factor” that can be described as “environmental factor” whereas the last three factors form a second major factor “Regulatory framework: State-Religion-Principles”. The Social responsibility variable cannot be included in any “major factor” since its loading is lower than the 0.6 (o.317) level.

Statistical testing of differences and correlations

By utilizing the non parametric equivalent of t-test the existence of differences among sub-groups of respondents was tested and no statistically significant differences were detected apart from very few cases (as in the case of special job characteristics of personnel of the three Branches) that cannot adequately challenge the conclusion of the uniformity and applicability of the findings across respondent personal and job related characteristics.

In the context of further analysis of the responses (to the extent that this was possible due to the variety of the scales used i.e. nominal, categorical, ordinal, dichotomous), cross tabulations were used to check for correlations among behavioral statements and other statement relating to beliefs and attitudes across the three Branches.

CONCLUSION

As an important finding of the statistical analysis it should be noted that through the application of all the possibly applicable non parametric tests, it can be safely concluded that the sporadic differences detected, allow us to argue that there is no “pattern” of differentiation among the Branches that could support the notion of existence of different subcultures within the Hellenic Armed Forces in relation to the environmental and sustainability issues.

As a general conclusion of this research, is that the diffusion of the principles of Sustainability, at all levels of hierarchy, can be enhanced within the Hellenic Armed Forces through certain initiatives. These may include reinforcement of the participation of the personnel in relevant initiatives, targeted education, dedicated campaigns and others. Of course the development of a research based monitoring system is necessary in order to assess the effectiveness of the action plan that will be deployed.

Managing Environmental Information -
Advanced Environmental Data Management System in Finnish Defence Administration

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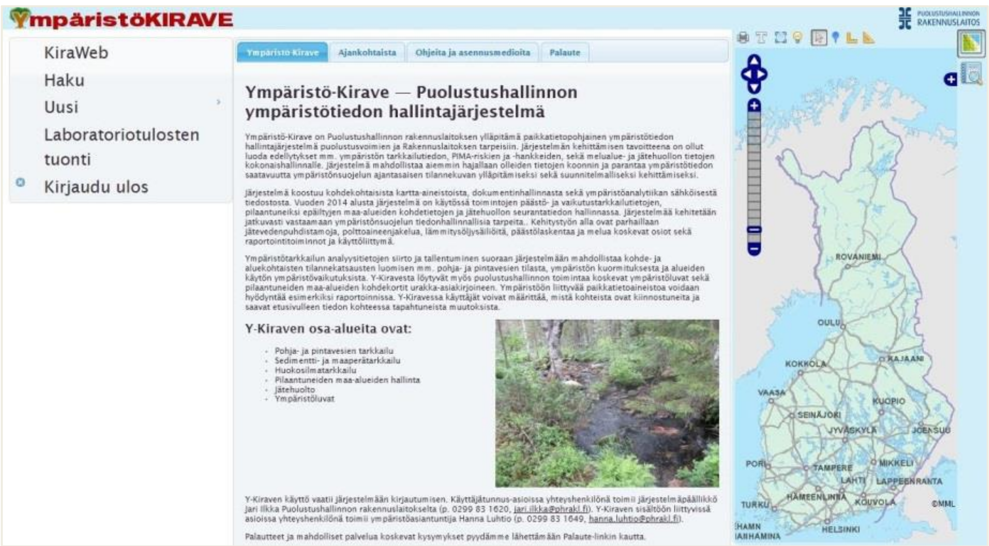
The increased level of environmental protection and the improvement of risk assessment methods and monitoring have substantially increased the amount of gathered environmental information. Furthermore, organizations gather data for example from energy usage, waste management and hazardous chemicals, to optimize processes, to lower costs and to improve corporate and environmental responsibility. To manage, analyze and conclude all this data, right information technology solutions are required.

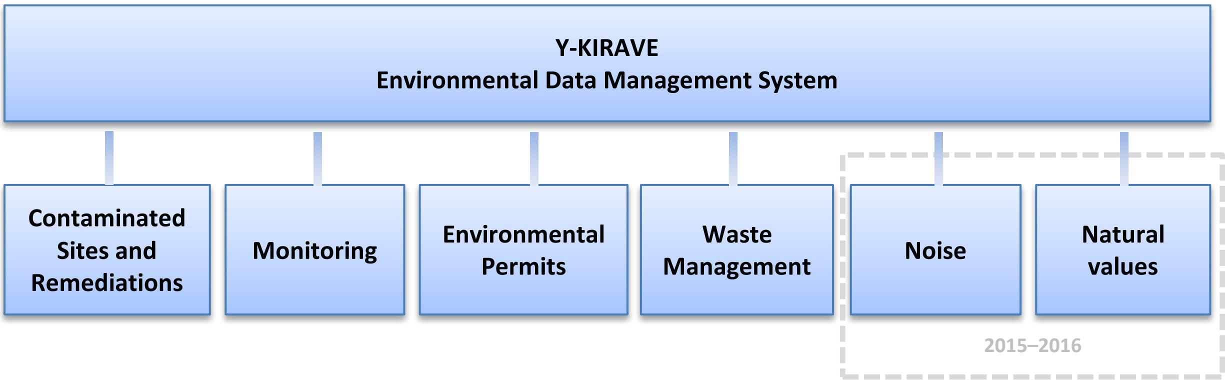
Environmental Data Management System in Finnish Defence Administration

The Construction Establishment of Finnish Defence Administration (CEDA) has developed and introduced an advanced environmental data management system called Environment-Kirave. The system is a tool for the defence administration to manage and process environmental data via a web browser. It is GIS-based and developed as part of a wider geographic information system used in the CEDA. Developing a GIS-based data management system alongside with an existing one, a high level of cost-efficiency has been reached. The layout of the front-page is shown in picture 1. The environmental data management system is a tool for systematical improvement of environmental protection. The aim is to support cost-efficiency of limited resources and to achieve a wider overview and a deeper knowledge of environmental aspects. The system provides an up-to-date review of environmental subjects and produces reports, maps, trends and graphics to improve annual reporting and to assist the coordination of environmental protection measures. With systematic follow-up, the efficiency of locally-made measures can be quantified.



Picture 1. Front-page of the GIS-based system via browser

The system consists of several sections such as monitoring, contaminated sites and remediation, environmental permits and waste management. The structure of the system is illustrated in picture 2. All sections have documentary archives and the data can be linked to each other, like sampling points to monitoring programs and the programs further to environmental permits. Data management takes place through sheets that are generated for different functions, for example groundwater wells or specific types of contaminated sites. Along with the basic information, the data sheet can include laboratory results, risk-assessment status, documents, photos and graphs. Laboratory results from water, soil and soil gas samples can be transferred to the system electronically and automatically from the laboratories' own databases without delay. Different geographical background materials, such as aerial maps, nature reserves and groundwater areas, are also available, as well as link to existing buildings and structures.



Picture 2. The Structure of the Environmental Data Management System of Finnish Defence Administration

Electronic data transfer

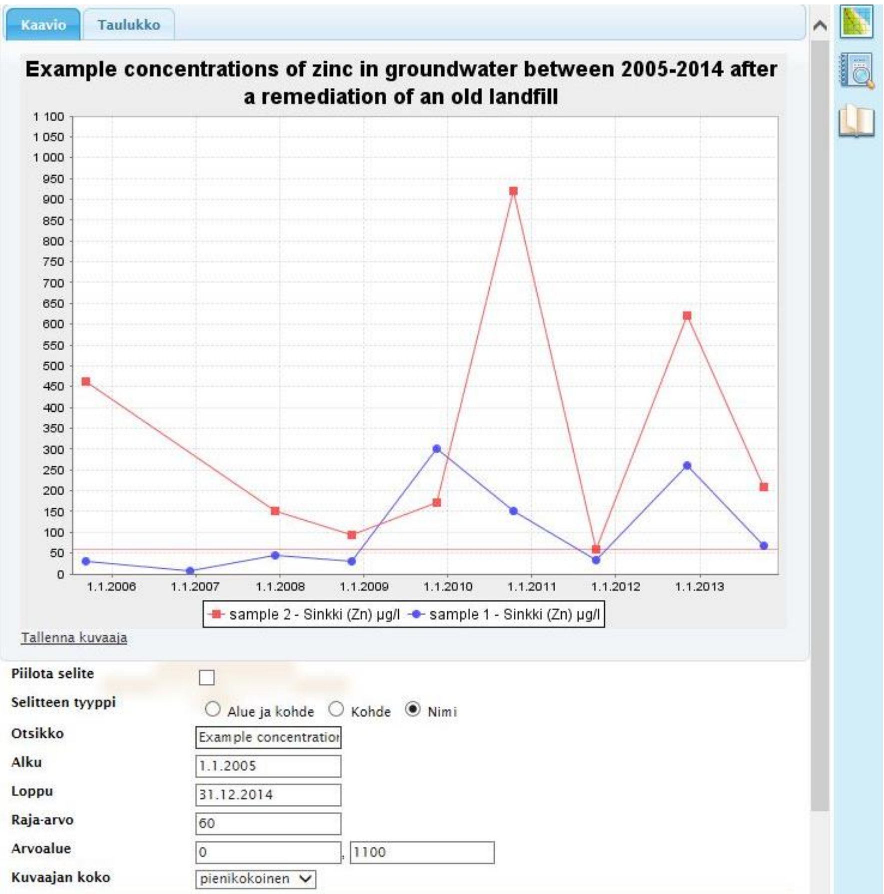
The majority of water, soil and soil gas samples are analyzed in commercial laboratories. Several laboratories in concert with consultant agencies have developed their data management systems to provide electronic data transfer to clients, for example municipalities and local authorities. By using electronic data transfer and automation, specialists' resources can be released from filling in excel sheets to concluding, analyzing and searching for causal relations and proportionalities.

The electronic data transfer is under major development also in the waste management sector. Due to increased environmental awareness, material and cost-efficiency and responsibility of awareness, organizations require numbers and statistics of waste management more frequently and more specifically. Managing all the data manually demands a great deal of human resources. CEDA has initiated a pilot project with communal waste management companies and The Finnish Solid Waste Association that tests electronic data transfer between waste management companies and large enterprises. The aim is to find a technical solution for waste management companies to provide and transfer information electronically and automatically between suppliers and customers' information systems.

Reporting tools

The archive of environmental data forms the foundation for a good information system. To derive conclusions from a massive database of information, and to arrange the imported environmental data to serve user-specific requirements, basic reporting tools are required. In the Environment-Kirave, the reporting is carried out through particular searching tools by which the user can determine specifically what information is relevant in each case. For example, the user can choose all ground water samples analyzed from shooting ranges last year that have concentrations of certain substances over guideline values. Another example of reporting tools in waste management sector is the search for amounts of bio-waste collected and composted in a five year time period.

The results of the searches are presented in graphs and tables such as one shown in picture 3, and can be transformed into excel-sheets or pictures.



Picture 3. Example of a graphic tool that visualizes the similarities in zinc concentrations between two sampling points.

Graphs can be manually adjusted to include several different substances and commonly used guideline values are coded into the system in advance. Alternatively, comparison values can be set manually, for example in cases where guidance values that differ from the norm are set through an environmental permit.

The electronic archive enables comparison for example between concentrations of metals in surface water collected from different shooting areas. The advantage of electronic archiving is, that it does not require a huge amount of manual labor to collect the data from reports time and time again, and to restore the results to yet another excel-form. Instead, it provides a searching tool by which the user can find the right information in only few seconds and display the results in graphs or excel-sheets automatically.

Ongoing development

Environmental data management in Finnish defence administration is under continuous improvement, and in 2015 the development concentrates on natural values and noise management. The aim is to gather the existing information of rich birdlife, rare vegetation and endangered insect and animal species in military areas into the data management system, so that the information is geographically stored and serves processing and usability better. The maps will be complemented with the markings of noise areas, and the noise survey documentation will be linked to the noise maps.

Key elements to consider when adopting an environmental data management system

Based on experience gained by introducing an environmental data management system in the Finnish defence administration, there are a few key elements to consider. First of all, does the organization require a customized system to match organization-specific requirements or are there suitable commercial applications available? Building a whole new data management system often requires significant economic resources. Calculating the cost benefits of the system is relatively challenging due to the enormous amount of improvements which have not existed before and are difficult to price. However, with Environment-Kirave, the cost-efficiency was found by building the environmental data management system inside an existing GIS-based system. This solution also supported the regard of the data security policy and regulations.

When adopting an environmental data management system, it is important to find a balance between the level of automation and the need for administrative functions, to not only lower costs during the development phase, but to keep also the operating costs reasonable in the future. Electronic data transfer has proven to be a critical feature that minimizes manual labor and operational costs. However, IT-based environmental data management systems are rather new tools in organizations and therefore all suppliers do not yet provide the possibility to utilize electronic data transfer.

The level of automation also implies to the amount of manual work needed to produce reports and reviews. The third key element to consider when adopting an environmental data management system is the reporting tools. What information is relevant concerning reporting and analyzing the data? How must the information be sorted to best serve reporting and analyzing, and in which form should it be presented? Many decisions have to be made from the users' point of view since the data management system is primarily a tool. The ground work must be done carefully. Although changing the basics of the system can be technically rather easy, it can cause an enormous amount of repairs elsewhere.

Conclusion

Before introducing an electronic archive for environmental information, composing and sustaining a nationwide overview of environmental protection was relatively challenging. A GIS-based information system with documentary archive enables managing and analyzing the environmental information and producing reports and reviews quickly and cost-efficiently. The cost-efficiency of operating costs yet improves by increasing the use of electronic data transfer in future.

Strategic Environmental Assessments (SEA) in in defense planning and decision making

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Introduction

This paper deals with a proposed model for Strategic Environmental Assessments (SEA) in the Swedish Armed Forces (SwAF) planning and decision making processes. The work has included establishment of project organisation, method development and testing of the model in two 'pilot processes' within SwAF. The SEA model was assessed as being able to capture most of the strategic issues that emerged in the interviews and reported experience. Nevertheless it should be continuously developed and improved. In addition, it was proposed that SwAF also should evaluate how detailed SEA surveys can be performed, when justified. The paper furthermore discusses the adoption of SEA as a mean to reduce the environmental footprint of military and civilian actors operating in conflict and crises situations. We suggest that any new crises or conflict area should benefit from coordinated SEAs, including the needs, vulnerability and resilience of the affected people, society and geographic region, as well as the cumulative (aggregated) impact (positive and negative) from the various actors involved.

The importance of strategic environmental assessments

Whereas Environmental Impact Assessments (EIA) today is mandatory for many actors operating in conflict and crises areas, strategic environmental assessments (SEA) are less common. The SEA concept has mainly evolved from the recognition that many sustainability concerns can only be solved by addressing them at the strategic level, long before any project is commenced and a traditional EIA has been initiated.[1] Indeed, regular EIAs have received much criticism for addressing environmental issues far too late in the decision making processes, jamming the possibilities to mitigate or prevent negative environmental impact in advance, or for that matter, leverage on the environment to better be able to deliver on the

[1] Wood & Dejeddour, 1992

mission goals. This holds especially true for international actors involved in conflict and crises situations, where there also may be the notion that the mission, weather civilian or military, would be hampered by environmental considerations.

In short, while EIA addresses potential impacts at the project level, SEA is a systematic process that aims to ensure that sustainability considerations are integrated in policies, plans or programme initiatives. As stated in one SEA definition; *SEA is a systematic process for evaluating the environmental consequences of proposed policy, plan, programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision making on par with economic and social considerations*.[2]

The enabling SEA policy environment and development towards cooperation

Today the EU (through the European Union Directive 2001/ 42/ EC ´on the assessment of the effects of certain plans and programmes on the environment) as well as the UN (United Nations Economic Commission for Europe (UNCECE) Protocol on SEA) and OECD/DAC (Guidelines and Reference Series Applying Strategic Environmental Assessment) have developed procedures for SEA in policy and planning. It should be emphasized that the approaches these documents explain are applicable to SEAs worldwide as well that there is notable difference of the legislative power of *policy* and *directive*.[3]

The use of SEA is also emerging in **military organisations** and is for instance established within the British Ministry of Defence and as discussed below, in the Swedish Armed Forces.

In **humanitarian response**, the environment is an issue that is supposed to be mainstreamed in all the sectors (clusters) activities which so far unfortunately mostly has led to confusion and not a whole lot of coordinated activities. However, some improvements have been made recently with the updated SPHERE-standards[4], some environmental champion clusters such as the shelter cluster, deployment of strategically deployed Environmental Field Advisors, and environmental assessments undertaken by i.e. UNHCR.[5]

For **corporate businesses** there have been different approaches to engage with environmental impact assessment and improve social corporate responsibility with a focus at the same time

[2] Sadler & Verheem, 1996
[3] Therivel, 2006
[4] SPHERE 2011
[5] Ebziabher et al 2012

to reduce costs *(leaning*). Lockheed Martin Corporation is one company that has applied Lean thinking to its chemical and waste management activities. The benefits are, among others, stated to be; improved environmental quality, improved employee morale and commitment and lowered risk of non- compliance (of e.g; customer expectations). In the best of worlds, the above entities would collaborate and learn from each other's environmental performance including the respective comparative advantages. In reality however, to get an overview of the accumulated environmental footprint in a conflict or crises area is indeed a challenge.

Challenges and opportunities with SEA in a conflict and crises contexts

Considering the fragility of the natural environment and the affected people in many crises and conflict situations, such as Mali, Haiti, Afghanistan and South Sudan, a more coherent approach including environmental considerations is required. In this respect, special SEA resourcing and capacity, as well as a common understanding of the challenges and possibilities, will be particularly needed. SEAs are challenged to cope with a huge range of decision- making situations, from the broadest international policy down to organizations goals and visions. Activities subject for SEAs although intended (or rather hoped to be) not permanent, tend to be just with the associated uncertainties of events that can unfold unexpectedly, such as droughts or floods, rapidly increasing oil prices or disease outbreaks that turn epidemic. Although a SEA in conflict or crises situations, cannot be as detailed and ´scientific´ as a peacetime SEA/EIA, the methodology might indeed set the framework for resource allocation (e.g. budgeting, human resources/ tasking) and priorities, for successful and environmentally mindful operations. Environmental and human security issues are fundamentally interconnected. Recognizing their multiple interdependencies offers a number of benefits, including fully realizing the potential of long-term trends analysis, avoiding unintended consequences, saving money and time, and producing better results due to greater community buy-in.

The enabling SEA policy environment and development towards increased cooperation in operations

In line with the increasing complexity of modern societies, international crises, aid and conflict assistance has grown to involve more actors. At the same time, corporate organizations seek to establish, or re-build, business relations in the very early stages after disasters and conflicts. In reality, this means that the needs to include not only EIA's for projects, but also SEA's in planning and coordination, has increased in crises and conflicts.[6]

Time constrains and coordination: Natural disasters and/or escalation of violent conflicts may occur with little previous notion. Disaster response and crises support as well as peace support operations generally requires rapid decision making and quick deployment capabilities. The idea often is to stay only for a while, so considering the environment may not always be a priority on the onset of an operation. This also means that the time that would normally be allocated for a SEA or an EIA, which could be months or even years, now has to be reduced to weeks, days or hours, if they take place at all. From a host nation perspective, however, the cumulative (aggregated) presence of several deployed organizations may continue over months or even years, and the need for a joint holistic approach regarding potential impacts is even more crucial, than if a single operator is present over time.

Experiences have shown, that the environmental work, even with good intentions, seldom reach an acceptable level, until after the first months, or even years, of an operation. With continuously new short-term actors, management of environmental impact is likely to show shortcomings repeatedly, rather than progress over time to an efficient management program. The importance of communication and coordination mechanisms to be established in advance, as well as pre-crises joint multi stakeholder environmental awareness trainings to facilitate expedient EIA and SEA based decision making is crucial, in order not to stall environmental consideration. Also, robust tools specially designed for time constraints and multi-organization coordination is in dire need. However, most of all, addressing environmental considerations under time constrains requires cross-organizational trust since complex decision making involving several actors under time pressure only will work if the parties know that they can rely on each other. This is especially important considering the fact that organizations in crises and conflict situations often compete over the same funding and donor attention. If corruption is a concern in the region, which is often the case, this will need special attention, also in the environmental work. Moreover, where civil and military coordination must take place, trust is an even bigger issue, than "just" military-military and civilian to civilian cooperation.

The aggregated footprint; The significant amount of deployed personnel, from different nations and organisations, as well as investor and business presence that work side by side in conflict and crises areas can create a substantial environmental impact on the ecological

[6] Liljedahl et al 2014

system and its inhabitants. This environmental pressure often stresses an already vulnerable population and its ecosystem services and can in the worst case also lead to security and health implications. In Haiti for instance, the unexpected outbreak of cholera in the aftermath of the 2010 earthquake can serve as a striking example of the need for advance environmental planning.[7] The earthquake that caused more than 200.000 deaths and displaced 2.3 million Haitians also caused extensive damage to the already limited infrastructure, including water and sanitation infrastructure. Few predicted the outbreak and rapid spread of cholera in Haiti as cholera was not present in Haiti prior to the earthquake. The conclusion was made that it must have been introduced, likely by the international presence, such as the many rapidly mobilized relief organisations. As it turned out however, the blame in the court of public opinion fell on the UN peacekeeping mission in Haiti (MINUSTAH). The takeaway from this example is that omitting to include environmental aspects in conflict analysis and pre-mission assessments such as military reconnaissance and the humanitarian MIRA (Multi-Cluster/Sector Initial Rapid Assessment) can severely aggravate the situation and counter the very mission itself.

Understanding the complexity of coordinating international operations gives realisation to the importance of the *strategic* component to environmental assessments and its implementation, firstly, within organisations and institutions, secondly between them. To get an overview of how to understand environmental impact interactions in order to be able address the accumulated environmental impact in a conflict or disaster area, Figure 1 provides some explanation.

[7] Liljedahl et al 2012

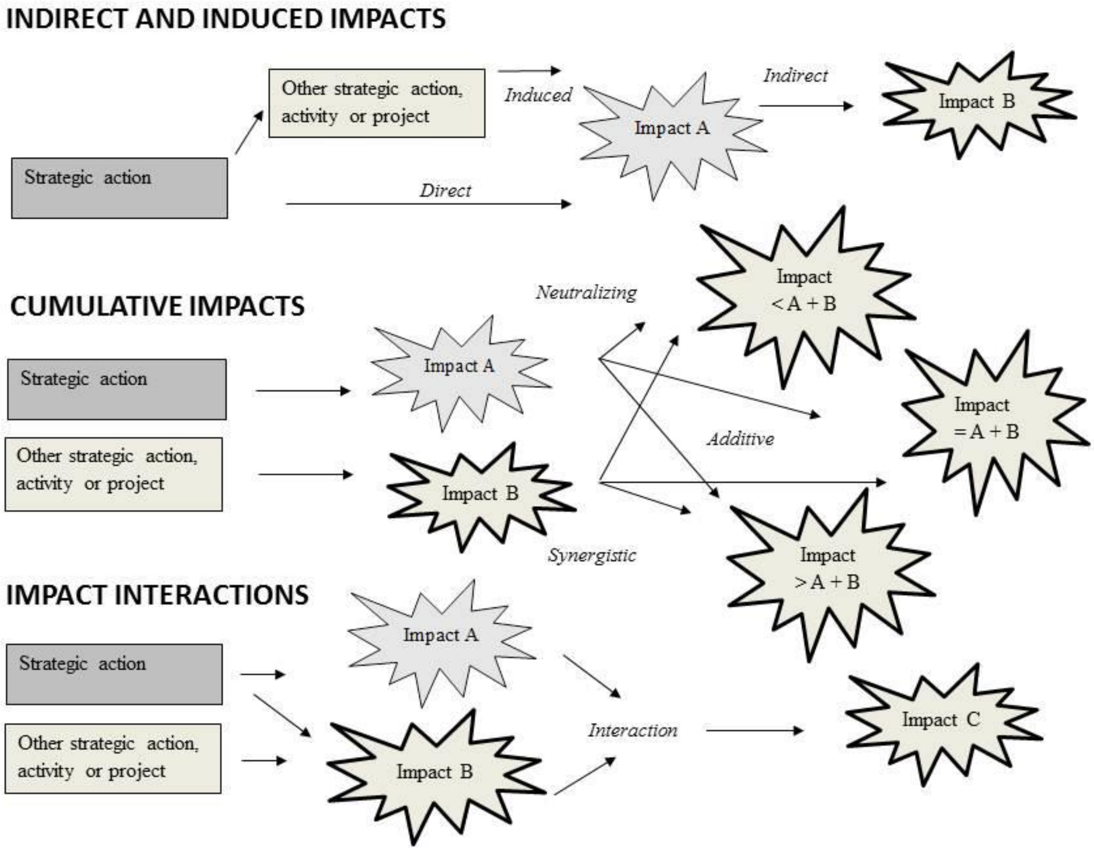

Figure 1. Environmental impacts and interactions, indirect, direct as well as cumulative.[8]

It is further argued, that coordination and cooperation in the development of environment impact assessments in general, and SEA in particular in conflict and crises situations, are vital components to secure that any action will be in line with, and supporting the progress towards desired strategic end states of the mission as well as high level international political strategies and goals, where ‘sustainability’, ‘poverty reduction´, ‘policy reform’ and ‘implementation’ and “accountability to the affected people” are key parameters. The often fragile states subjected to humanitarian interventions or peace support operations are states that are often characterized by widespread poverty, lack of state capacity and high levels of corruption that hampers development. Having a plan, methods and tools for planning a successful operation, facilitates the possibilities of foreseeing the unforeseen and build back better and safer. The SEA process, which is highly specific for each organisation at its operating level, has been argued to gain effectiveness if developed within its own

[8] Therivel 2004

organisational structure before wider attempts are approached that facilitate trans-boundary co-operation. In a conflict or crises context, trans-boundary approach will be crucial.

The benefits are, among others, improved environmental quality, improved employee morale and commitment and lowered risk of non- compliance (of e.g. customer expectations). In order to secure sustainable operations it is crucial for the above entities to collaborate and learn from each other's environmental performance including the respective comparative advantages. In reality, however, getting an overview of the cumulative environmental footprint in a conflict or crisis area is indeed a challenge. Good first steps are EIAs undertaken by UN Peacekeeping in South Sudan, Somalia and Kenya.[9][10]

SEA in the Swedish Armed Forces

According to directions from the Swedish Ministry of Defence, the Swedish Armed Forces (SwAF) shall report progress with regards to its work with implementing SEAs in planning and decision making processes. SwAF commissioned the Swedish Defence Research Agency (FOI) to conduct a study with the aim to develop a proposal for a customized SEA approach with complementing tools. The work has included establishment of project organisation, method development and testing of the model in two 'pilot processes' within SwAF. The project has also conducted a number of interviews with relevant stakeholders within SwAF.

The proposed SEA model developed for SwAF focuses on six main areas which are considered to capture some of the core issues of a strategic nature for SwAF:

a. Impact on SwAF environmental policy, priority areas in the defence sector, thematic priorities, environmental legislation and other applicable regulations,

b. Environmental issues that may affect the security situation

c. Environmental issues affecting health of personnel and the general population

d Environmental effects that may impact the confidence in SwAF and Sweden

e. Resource use from a life cycle and economic perspective, and;

f. Protection against financial/liability claims.

The main SEA checklist is supported by four additional checklists regarding

(1) the 16 Swedish national environmental objectives,

(2) SwAF environmental priority targets,

[9] Liljedahl et al 2013a
[10] Liljedahl et al 2013b

(3) a checklist for strategic environmental assessments modified from the British Ministry of Defence (see Figure 2) and

(4) tentative assessment criteria for 'high' and 'low' environmental impact, developed in the framework of SwAF Medical Intelligence (MedIntel, Figure 3).

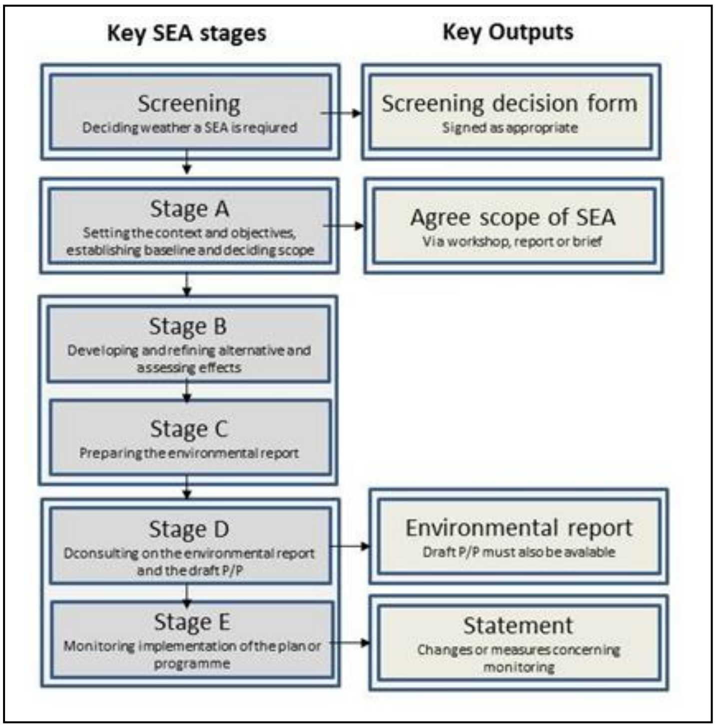

Figure 2. Main steps of an SEA, Modified after UK MoD[11]

Example	
VERY HIGH	**Link to conflict, no resilience/ irreversible, very severe stress**
HIGH	**Link to crime, low resilience, severe stress**
ELEVATED	**Link to corruption, limited resilience, under stress**
LOW	**Limited concerns, good management, resilient/ reversible**

Figure 3. Tentative assessment criteria for 'high' and 'low' environmental impact, developed in the framework of SwAF Medical Intelligence (MedIntel)

The SEA model has been tested against the strategic defence planning process, the redeployment from the Kosovo mission and for the planning for the SwAF deployment to Mali.[12] The last one is displayed below in Table 1.

[11] United Kingdom Ministry of Defence, 2010.

[12] Liljedahl et al 2014

Table 1. SEA for the planning for the SwAF deployment to MINUSMA, Mali.

SEA Screening Mali (UN PKO) **Date:** 18 March 2014, **Sign:** INSS J4 / FOI			**Environmental Assessment**		**Uncertainty in assessment**		**Need for further assessment?**	
SwAF proposed Environmental Core values	**Explanation and examples**	**Reasoning, preconditions, comments**	**Low/ Medium/La rge**	**Short /Medium/ Long term**	**Precise/ Moderate/ Uncertain**	**Joint Env Dept been consulted? YES/NO**	**NO**	**YES**
1. Impact on SwAF environmental policy, doctrine, regulations and procedures and/or the Environmental Act, Nato, EU, UN environmental policy etc or MEAs	SwAF Environmental Policy etc gives direction on prioritised environmental areas, e.g. .energy consumption, procurement, exercises, new materials	E.g. pre-conditions for environmental considerations on operations and exercises. Environmental Governance and Institutional capacity is very low in Mali and waste management infrastructure etc is poor. If The UN build/ run the camp, the likelihood for SwAF to implement sustainable solutions will be constrained. Organic capabilities for e.g. hazardous waste will most likely be needed	Medium	Medium Long	Precise	NO	NO (SwAF)	YES (UN)
2. Environmental issues impacting security	Environmental issues / natural resources are often one part of the conflict panorama. It is paramount not to add fuel to such conflicts	Natural resources (e.g. water, land) play a significant role in fuelling and sustaining conflict and crises at the local level	Medium-large	Medium- Long	Moderate		NO	YES
3. Environmental issues impacting health of the personell or local population	Hazardous substances, particulate matter or air pollutants and noise are examples.	Bamako: locally assumed high levels of particulate matter and organic volatile pollutants Timbuktu: sand storms	Bamako: Low, TimbuktuMe dium	Bamako Long Timbuktu Short	Moderate		NO	YES (air samples
4. Environmental issues impacting the reputation of SwAF and Sweden	Adherence to environmental policies and standards is critical to ensure a good reputation	The UNSC resolution for (MINUSMA) has a dedicated environmental paragraph.[13] The UN is however currently assessed as unable to implement the environmental considerations warranted. Even failures not involving SwAF may reflect badly on SwAF and Sweden.	UN: Large SwAF unknown	UN: Long SwAF unknown	Moderate-Certain-		NO	NO
5. Resource consumption from a life cycle perspective	Initially higher costs can for e.g. energy and waste infrastructure, in a life cycle perspective result in considerable financial savings.	The environmental work in MINUSMA has not reached its full potential. No EBS or EIA yet undertaken. Cost benefit analysis for potential system solutions should be performed.	UN: Medium-High SwAF: Low	UN: Medium-Long SwAF: Short	Moderate		NO	JA
6. Protection against liability and financial claims	E.g. the "Polluter Pay Principle"	NA. UN is formally responsible	UN: Large SwAF: Low	UN: Medium SwAF: Short	Moderate		NO	NO

[13] Security Council resolution 2100, which established United Nations Multidimensional Integrated Stabilization Mission in Mali (MINUSMA); "32. Requests the Secretary-General to consider the environmental impacts of operations of MINUSMA when fulfilling its mandated tasks and, in this context encourages MINUSMA to manage them, as appropriate and in accordance with applicable and relevant General Assembly resolutions and United Nations rules and regulations, and to operate mindfully in the vicinity of cultural and historical sites."

Result

The developed SEA model was assessed as being able to capture most of the strategic issues that emerged during the interviews and reported experiences. The proposed model represents an initial needs assessment (i.e. SEA screening) and is adapted to a time-critical process, where an assessment needs to be carried out within a matter of hours or days. If necessary, the SEA screening can, and should, be followed by a detailed SEA survey.

Areas in need of further development in the model include answering the following questions:
a) How to secure environmental expertise in the assessments?
b) Is there a need for adapted training and/ or particular environmental support in the assessments?
c) How can it be secured that SEA screening will be carried out in practice?
d) Is there a need for priorities for the decisions / processes where SEA screening should be implemented?

Furthermore, a definition of indicators and impact levels need to be defined.

The report[14] presented some recommendations in order to enable effective implementation of SEAs in SwAF planning and decision making processes, namely to:

- Initiate a work to ensure responsibilities, command structure and assessments of the SEA process, where SwAF environmental functions at the HQ level routinely is involved.
- Perform complementary SEA screenings on relevant processes related to equipment and procurement, after which the SEA checklist should be re-evaluated and amended, if necessary.
- Ensure simple and quick access to already existing environmental information in SwAF including point of contacts to facilitate time-critical SEA assessments.
- Promote efforts to enhance strategic environmental approaches through collaboration with EU, NATO and the UN, including that environmental expertise from the Swedish defence sector can be used to fill relevant positions in EU and the UN.
- Determine criteria for ' high' and 'low' environmental impact.

[14] Liljedahl et al 2014

Finally, it was proposed that the Swedish Armed Forces also should evaluate how detailed SEA surveys can be performed, when justified, including how ‘positive opportunities’ could be caught by strategic planning.

Summary

This paper has discussed the approach to strategic environmental assessment (SEA) in the Swedish Armed Forces as well as advocated the adoption of SEA as a mean to reduce the aggregated or accumulated environmental footprint in conflict and crises situations. It stresses the need for SEAs not only to be undertaken by different actors, but moreover, the need to better coordinate those efforts, thereby addressing any potential interacting impact, direct or indirect, including the cumulative impacts. What this means is addressing any synergistic-, neutralizing- and/or additive effects between different stakeholder’s actions, operating in the same geographical area at the same time or over time. In short, we need to create a joint strategic environmental assessment approach for conflict and crises situation to be launched in the very early phase, before any civilian or military actors deploy. Otherwise, good intentions risk not only to fail, but to also contradict each other, causing a series of unintended environmental consequences as experiences has shown.

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Environmental Intelligence support to military operations- the case of Mali and MINUSMA

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Introduction

Environmental and medical intelligence are subsets of intelligence, and an integral part of an overall intelligence assessment. In Sweden, environmental intelligence is performed by the Swedish Defence Research Agency (FOI) in the framework of the Swedish Armed Forces (SwAF) medical intelligence (MedIntel).[1] This intelligence subset has evolved dramatically in recent decades and its benefits are currently highlighted by the Swedish Armed Forces, which utilize it to generate data when planning for overseas operations.

Framing the intelligence domain

Intelligence is a discipline in support of decision making utilized by military, law enforcement agencies but also by businesses. It is a product from a four phase process: direction, collection, processing (analysis) and dissemination (Figure 1). Intelligence activities are conducted at all organizational levels; tactical to operational and strategic, and may include a variety of areas of interest.

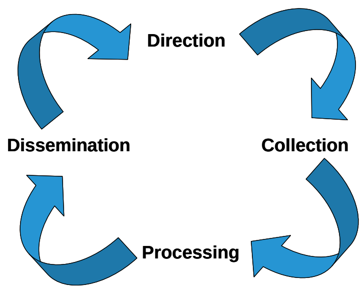

Figure 1. Visual generalization of the intelligence cycle. The sequence is cyclic in nature since intelligence requires constant reappraisal and updating if it is to remain current and relevant to the needs of the customer. However, further processing or collection to further the analysis might be needed so these arrows could in fact go in both directions. Figure credit FOI.

[1] According to NATO (2012) the general definition of medical intelligence is the "product of collection, evaluation, analysis, interpretation and dissemination of foreign medical, epidemiological, bio scientific, environmental or other information related to human and animal health." A similar definition of environmental intelligence has yet to be developed.

Environmental and Medical Intelligence

When Sweden deploys personnel in overseas peace and crisis-management operations they regularly face an environment that has been negatively affected by the consequences of conflict or disaster as well as poverty and poor livelihood opportunities, corruption and/or environmental degradation and climate change impacts. Such operations constitutes numerous challenges related to the environment such as potential health risks to the personnel, the risk of further damaging the environment as a result from the operation but also that environmental drivers of the conflict and/or crisis, situation is poorly understood and may negatively impact the strategic end state of the mission. Whereas medical intelligence addresses health related concerns, environmental intelligence can provide early indications of the types and magnitudes of environmental degradation and natural resources exploitation, crime, or risk for relapse into conflict in a region. It can also be utilised in early warning capabilities i.e. anticipating future events, weak signals detection and trends analysis. The role of SwaF Environmental Intelligence is to, among other things, support mission planning and the operational cycle of an operation, as it is critical to ensure that the implications of environmental concerns such as availability of fresh water, or the potential role of natural resources fuelling the conflict or contributing to the crises itself, is adequately understood.

The experience that environment and health in practice are two sides of the same coin, with strong links and co-dependencies, makes a joint assessment routine highly valuable. Techniques used to facilitate the analysis include satellite imagery, Geographic Information Systems (GIS), dispersion modeling of air, soil and water or forensic fingerprint analysis of chemicals and hazardous materials. The bulk of the work is however performed by environmental intelligence analysts, operating the interrelated areas of environmental change, environmental health, security and socio-economy/ livelihood issues.

There are several applications for environmental intelligence. This paper provides an elaboration of the usefulness and potential of the environmental vulnerability assessment (EVA) for the purpose of planning and executing peace support and crises management operations.[2] EVAs have been performed for all recent considered SwAF deployment areas such as Mali, Libya, Liberia, Democratic Republic of Congo, the Horn of Africa, South Sudan, Central African Republic, Iraq and Afghanistan. Presently the assessments constitute a table format assessment, GIS imageries and an elaborated report. Topics covered include

[2] Liljedahl et al 2012

environmental and conflict-, crime- and corruption relations, environmental legislation and governance, natural resources, cultural and historical values, biodiversity, climate change impacts and food security. Focus is on how these topics relate to the security situation- at the strategic, operational and tactic level. The EVA is furthermore aimed at helping minimize unintended negative consequences from the military presence as well as ‘catch opportunities’ (i.e. “do no harm- build back better).

The case of Mali

The case of Mali is interesting in many ways, not least as MINUSMA (the UN Multidimensional Integrated Stabilization Mission in Mali) is the first UN peacekeeping mission ever containing an environmental provision in its mandate from the UNSC (UN Security Council).[3] UNDFS (United Nations Department of Field Services) is also working towards deploying best practice solutions for e.g. water, waste and energy.[4]

The SwAF environmental vulnerability assessment for Mali indicates areas where deployment may constitute a threat to the local environment, and highlights the need for precaution and specific planning. The assessments constitute a table format assessment (Figure 2a-b, an executive summary, GIS imageries (Figure 3-5) and an elaborated report. Below the topic of “Environment conflict, crime and corruption relations”, “Biodiversity and wildlife” and “Cultural and historical resources” are descried in some detail to illustrate how the topics may be elaborated in the EVA reports.

Threat estimate	Reliability of the source		Credibility of the data	
VERY HIGH	A	Fully reliable	1	Confirmed by another source
HIGH	B	Normally reliable	2	Probably true
ELEVATED	C	Quite reliable	3	Possibly true
LOW	D	Normally not reliable	4	Doubtful
No observable	E	Not reliable	5	Improbable
NA – Not assessed	F	Cannot be assessed	6	Truth cannot be judged

Figure 2a. The legend for the assessments illustrating quality control of the data. Figure credit:SwAF

[3] *S/RES/2100(2013) on the establishment of the UN Multidimensional Integrated Stabilization Mission in Mali (MINUSMA) adopted 25 April 2013* requests in OP32 the Secretary-General to consider the environmental impacts of the operations of MINUSMA when fulfilling its mandated tasks and, in this context, encourages MINUSMA to manage them, as appropriate and in accordance with applicable and relevant General Assembly resolutions and United Nations rules and regulations, and to operate mindfully in the vicinity of cultural and historical sites

[4] Greening the blue (2013)

ENVIRONMENTAL VULNERABILITY Mali Assessment *Latest update: 2014-09-15*	**Vulnerability assessment**	**Source reliability**	**Data credibility**	**Comments**
Environment conflict, crime and corruption relations	High	B	2	Natural resources play a significant role in fuelling and sustaining conflict and crises
Institutional capacity and legal framework	High	B	2	Environmental Governance and Institutional capacity is very low and combined with a fragile natural environment and unsustainable coping mechanisms of the population
Natural resources	High	B	2	Natural resources are scarce and under stress. Natural resource dependence is high
Biodiversity and wildlife	Elevated	B	2	Wildlife is threatened by drought, poaching, and environmental degradation.
Cultural and historical resources	Very High	B	2	Trafficking in cultural objects from historical sites, including world heritage listed sites
Livelihood and Socio-economic processes/issues	High	B	2	Mali is one of the world's poorest countries. Livelihoods are closely tied to environmental conditions. Stresses are multiple and the environmental risks that people face vary from year to year and place to place
Food security	High	B	2	Local variations

Figure 2b. Preliminary Environmental Vulnerability Assessment (EVA) for Mali.

Important to bear in mind however is that the assessments are very rough and that each category illustrates that specific topic in general, not in detail. It does not, at present, take into account any cumulative impacts, that is, impacts which are caused from one or several separate events, but together magnify each other. Inter-linkages are therefore also something that needs to be considered in order to make a more comprehensive approach about environmental governance, conflict resolution and anti-corruption measures. Also, the often fast changing situations in conflict and cries affected regions create a short 'sell by date, regarding the information and analysis. In addition, the quality of the information may vary, and is therefore assessed for each topic (Figure 2a).

Environmental key concerns in Mali

The environmental key concerns in Mali are the increasing desertification, soil erosion, deforestation, loss of soil fertility and loss of pastureland pose additional problems. Deforestation is an especially serious and growing problem. Climate variability and climate change impacts further exacerbate these problems. According to the Ministry of Environment, Mali's population consumes 6 million tons of wood per year for timber and fuel. To meet this demand, 4,000 square kilometres of tree cover are lost annually, virtually ensuring destruction of the country's savannah woodlands, contributing to Mali's continuing deforestation. In addition, traditional fuels, particularly fuel wood and charcoal, provide the bulk of all energy used in Mali, with a severe impact on deforestation and soil erosion, as well as outdoor and indoor air quality. Food scarcity and natural disasters are also aggravating factors for conflicts and crisis in Mali. Emerging environmental issues include so called land and water "grabbing" and conflicts between pastoralists and farmers over these resources have been occurring for a rather long time. The costs of environmental degradation and unsustainable use of natural resources were estimated by the Ministry of Economy and Finance to be 21 % of Mali's GDP in 2012.[5]

Although a legal framework has been established apparently covering several important aspects of environmental protection indications support that it is poorly implemented. A lack of sufficient awareness making and a lack of sufficient resources and institutional capacity to allow for proper enforcement of laws and regulations have resulted in current environmental legislation being recognized as largely ineffective. This lack of enforcement of environmental legislation is stated to represent one of the most challenging current obstacles preventing effective environmental protection in Mali.

[5] Mali Ministry of Economy and Finance (2012)

Environment conflict, crime and corruption relations

Although environmental issues are not the direct cause of the current conflict, natural resources play a significant role in fuelling and sustaining conflict and crises in Mali at the local level.[6] It is estimated that some 600 natural resource related conflicts such as land disputes occur each year involving the death of pastoralists, farmers or governmental workers, the destruction of farms or houses and the injury or death of animals. Resource scarcity is increasing, caused by a combination of climate variability and climate change, deforestation, soil erosion, desertification and population growth. The pastoralist Tuareg living in the northern part of Mali are particularly affected by the situation.

The conflict involving the Tuaregs[7] has strong roots in the access to and control over natural resources, especially land. The pastoral land tenure reform and resource management ('terroir' approach) applied in Mali in 1990/91 involves extensive demarcation of rigid boundaries for pastoralists, legal titling of individual and collective lands and the reallocation of land to different uses. This approach contributed to the loss of mobility of Tuareg and their livestock and disturbed their ability to adapt to the conditions of the dry-land Sahel. Coupled with the erosion of access to land, Tuareg experienced increased material hardship and had to compete for diminishing resources. Conflict erupted not only between Tuareg and the Malian government but also within the different Tuareg groups and pastoralist society. Furthermore, the droughts in the 1970-s and 1980's that made farming and livestock-keeping very difficult in the north, forced many of the Tuaregs to migrate to neighbouring countries were some were exposed to revolutionary ideas contributing to the uprisings that have followed. However complex historical and political factors and regional instability were significant determinants of the insurgency. Even today any climate and livelihood challenges experienced in underdeveloped and underpopulated areas of the country are rarely addressed by national government institutions which are among the deeper root causes of today's conflict.

Disputes over land take several forms, including: within communities (tenancy); between generations; and between different groups of natural resource users. Conflicts occur, when a

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[6] Benjaminsen T. A (2008)

[7] The Tuareg (also spelled Twareg or Touareg) are Berber people with a traditionally nomadic pastoralist lifestyle. They are the principal inhabitants of the Saharan interior of North Africa. The Tuareg Rebellion of 2012 was an early stage of the Northern Mali conflict; from January to April 2012, a war was waged against the Malian government by rebels with the goal of attaining independence for the northern region of Mali, known as Azawad.[For decades prior to the 2012 rebellion, Tuareg political leaders had asserted that the nomadic Tuareg people were marginalized and consequently impoverished in both Mali and Niger, and that mining projects had damaged important pastoral areas. Issues such as climate change and a rooted background of forced modernization onto the northern Nomadic areas of Mali have caused much tension between the Tuareg peoples and the Malian government. Tuareg separatist groups had staged previous unsuccessful rebellions in 1990 and in 2007.

family that lent land to another attempts to retrieve it, or when the borrowers start to invest on the land, which is land holder considers an attempt to appropriate the land. Fighting for access to land between young or landless members within family groups can also generate conflict.[8] Land scarcity has also been accentuated by land-grabbing by agro-businesses following new land laws that encourage private land ownership; and by the growth of artisanal gold miners who both squeeze herders off transhumance routes but also poison water points with chemicals. Most conflicts arise out of a misunderstanding, on both sides, of land regulations and rules that protect both agricultural land and transhumance paths.

In addition, violent disputes over water access and use are frequently occuring. For instance, in 2013 Islamic militants cut water supply to Timbuktu. Reports were also that Malian forces dumped bodies in water wells in conflict areas around Sevare, Mopti, and Niono.[9] In 2012, an agreement between Dogon villagers from Mali and nomadic Fulani herders from Burkina Faso to share water and pasture land, was revoked causing clashes along the border. At least 30 persons were killed.[10] In 2008, one person was killed and five injured when security forces opened fire on protests over an attempt to privatize water services in Lere, northwestern Mali.[11] In 2007 a conflict over a well between the Nigerien Fulani/Peulh herders and Malian nomadic Touaregs took place in 1997 resulting in 22 people losing their lives.[12]

Any significant flow of money into a poorly developed region needs to address the potential for corruption to play a role. Corruption is a very serious problem in all parts of West Africa. In 2014 Transparency International's Corruption Perceptions Index ranked Mali at number 115, score 32 (compared to Sweden rank 4 score 88). A country or territory's score indicates the perceived level of public sector corruption on a scale of 0 - 100, where 0 means that a country is perceived as highly corrupt and 100 means it is perceived as very clean. A country's rank indicates its position relative to the other countries and territories included in the index. Furthermore, Mali scored 35 on the open budget index which translates to (minimal transparency and availability for the public of key budget documents.[13] Given that corruption exist to a higher than average level in Mali, that corruption in the water sector generally is

[8] Beeler 2006
[9] CNN World 2013
[10] Xinhua News 2012
[11] AFP 2008
[12] Uppsala University Conflict database, 2015
[13] Transparency International 2014

widespread and there is presently higher than average scarcity of water and land it is likely that Mali experiences problem in this area.Information gaps however exist.

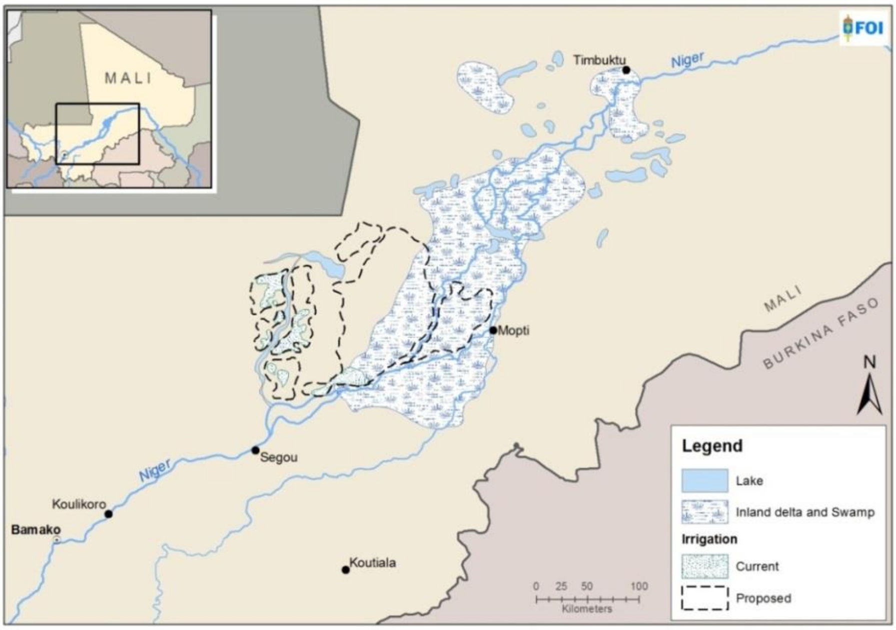

Figure 3. Water projects in the Niger delta involving foreign investors.
Figure credit FOI, adopted from National Geographic's.[14]

Figure 3 illustrates another area with potential links to corruption and potentially illicit activities, namely the geographical extent regarding potential "water grab" in Mali, i.e. water projects in the Niger delta involving foreign investors.[15] An overall assessment regarding corruption, governance as well as the potential negative impact on livelihoods would address how large scale water investments might or might not be in a grey zone of countering development goals for the geographical region.

Biodiversity and wildlife

Mali has a national park and four animal reserves that cover a total of 808,600 ha, as well as six forest reserves covering 229,400 ha (Figure 4). In addition, the Sahel has an elephant reserve of 1,200,000 ha and a giraffe reserve of 1,750,000 ha. However, the authorities lack the means to prevent poaching of protected animals or cutting down of trees for firewood. The nation's wildlife is threatened by drought, poaching, and the destruction of the environment. In 2001, 13 of Mali's mammal species and six bird species were endangered. There were also five species of plants threatened with extinction. Threatened species include the addax, cheetah, and barbary sheep. The Sahara oryx has become extinct in the wild.

[14] National Geographic's 2012
[15] Ibid

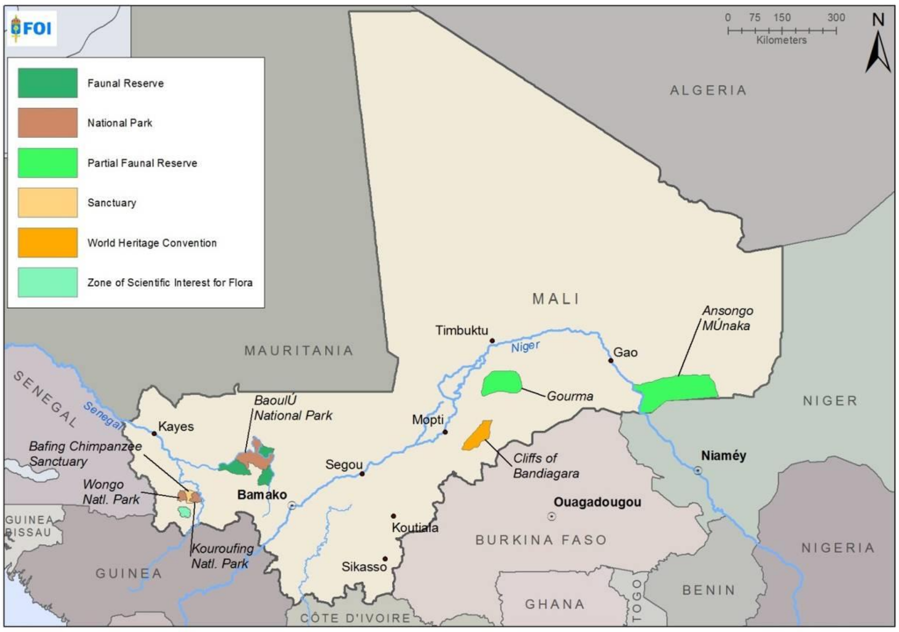

Figure 4. The map shows the protected areas in Mali.

Cultural and historical resources

Trafficking in cultural objects from historical sites, including world heritage listed sites is increasing in Mali due to poverty and the increased presence of international staff. In addition extensive damage to Timbuktu's cultural heritage due to fighting between Government forces and Tuareg’s are reported. Culture property protection is a growing area in military operations, both in terms of safeguarding cultural and historical sites and avoiding personal unintentionally purchasing items trafficked from such sites.[16]

Mali’s culture is rich with music, art and literature. Mali also has a number of sites on the World heritage list (Figure 5). Mali has ratified the following conventions on cultural property protection

- The 1954 Hauge Convention for the Protection of Cultural Property.[17]
- The UNESCO Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property[18]
- The 2003 Convention for the Safeguarding of Intangible Cultural Heritage[19]

[16] For instance, an Advance Research Workshop on Best Practices for Cultural Property Protection in NATO-led Military Operations is taking place in June, 2015.
[17] *la Convention pour la protection des biens culturels en cas de conflits armés (1954), ratifiée par le Mali le 18 Mai 1961,et son Deuxième Protocole de 1999, auquel il a adhéré le 15 novembre 2012*
[18] *la Convention pour la lutte contre le trafic illicite des biens culturels (1970), ratifiée par le Mali le 06 avril 1987*
[19] *la Convention pour la sauvegarde du patrimoine culturel immatériel (2003), ratifiée par le Mali le 03 juin 2005*

Timbuktu was an appreciated tourist goal, and home for local festivals before the conflict. Timbuktu was an intellectual and spiritual capital and a centre for the propagation of Islam throughout Africa in the 15th and 16th centuries. Its three great mosques, Djingareyber, Sankore and Sidi Yahia, recall Timbuktu's golden age. Although continuously restored, these monuments are today under threat from desertification.

In addition, destruction of e.g. the Timbuktu mausoleums following armed attacks in 2012 is believed to have caused unrepeatable destruction to the site which has been strongly condemned by the World Heritage Committee as well as by the UN SRSG. Trafficking in cultural objects from the sites, has urged the African Union and the international community to do everything possible to help protect Timbuktu. However, 28 May to 3 June, an UNESCO led team with support from MINUSMA discovered that 14 of Timbuktu's mausoleums, including those that are part of the UNESCO World Heritage sites, were totally destroyed. UNESCO has commitment to help Mali reconstruct and safeguard its cultural heritage.[20,21]

Inhabited since 250 B.C., the **Old Towns of Djenné** became a market centre and an important link in the trans-Saharan gold trade. In the 15th and 16th centuries, it was one of the centres for the propagation of Islam. Its traditional houses, of which nearly 2,000 have survived, are built on hillocks (toguere) as protection from the seasonal floods.

The **Cliff of Bandiagara (Land of the Dogons)** is an outstanding landscape of cliffs and sandy plateaux with some beautiful architecture (houses, granaries, altars, sanctuaries and *Togu Na*, or communal meeting-places). Several age-old social traditions live on in the region (masks, feasts, rituals, and ceremonies involving ancestor worship). The geological, archaeological and ethnological interest, together with the landscape, makes the Bandiagara plateau one of West Africa's most impressive sites.

The 17-m pyramidal structure of the **Tomb of Askia** was built by Askia Mohamed, the Emperor of Songhai, in 1495 in his capital Gao. It bears testimony to the power and riches of the empire that flourished in the 15th and 16th centuries through its control of the trans-Saharan trade, notably in salt and gold. It is also a fine example of the monumental mud-building traditions of the West African Sahel. The complex, including the pyramidal tomb,

[20] UNESCOPRESS 2013
[21] BBC 2013

two flat-roofed mosque buildings, the mosque cemetery and the open-air assembly ground, was built when Gao became the capital of the Songhai Empire and after Askia Mohamed had returned from Mecca and made Islam the official religion of the empire.

Figure 5. The map shows the World Heritages in Mali.

Swedish troop contribution till MINUSMA

The Swedish troop contribution to MINUSMA has deployed to Timbuktu. Hence this area is of particular interest in the EVA. On topic of interest are seasonality, climate variability and extreme weather events. The flooding season in Timbuktu is vital for the livelihood, including agricultural, livestock and transportation, and grass is collected from the flooded areas, for livestock. But the flooding also causes several concerns, not least from a health perspective, when stagnant water becomes breeding ground for mosquitos, causing i.e. malaria outbreaks. The effect from previous rains upstream creates flooding in the Timbuktu region around September – February, normally with a peak in December. During this period, the canal between Timbuktu and Kabara is used for transportation. A rough estimate over potential flooded areas in Timbuktu is seen in Figure 6.

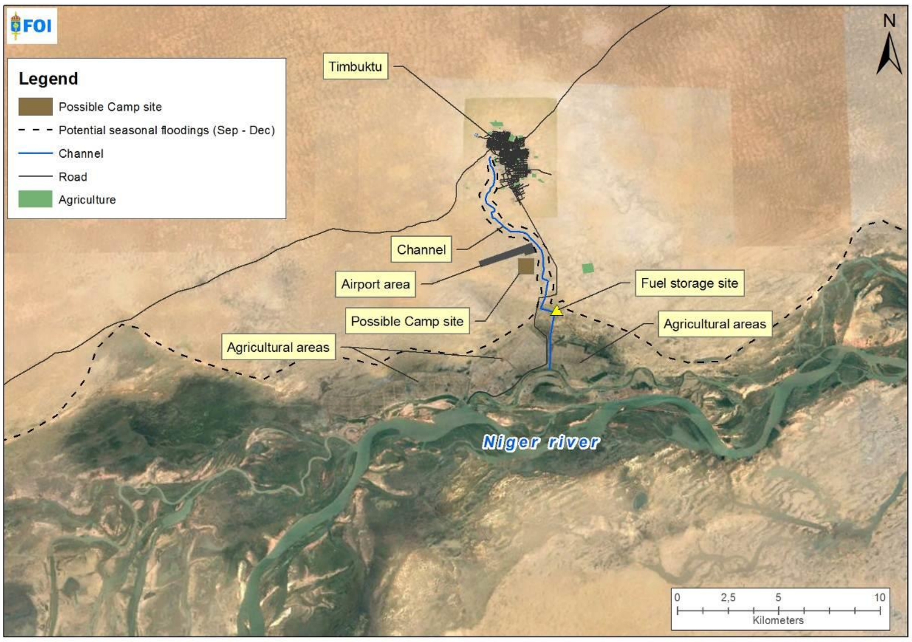

Figure 6. The map shows a close up image of Timbuktu and its vicinity to Niger River including the multinational UN camp site and indications of areas that potentially are affected by seasonal flooding (Nov-Feb).

Early warning

Apart from assessing the current situation in a region, it is crucial to also look into potential future situations (early warning). It is furthermore important to not look only at the most likely or median possibilities but also at the extremes. For instance, access to land, quality of the land available for various purposes, precipitation and recharge of aquifers as well as the lengths of growing periods, may change drastically due to e.g. projected climate change. Thus, a geographical area of relatively little value today might become an important and possibly contested resource twenty years ahead. This will be of high importance when assessing potential links between the environment, conflict, governance and corruption in conflict or post conflict areas, in West Africa as well as e.g. East Africa, the Middle East or Asia.

Summary

The global trend is that there is a general increase in the demand for both the military and civilian components and capabilities in peace-support and security-promoting operations. This trend appears to be continuing. There is also a great demand for contributions to the civilian operations and although these contributions have traditionally applied principally to police resources, a further increase in demand for personnel from other parts of the legal system, i.e. prosecutors, judges, prison personnel and customs personnel, is also anticipated.

The need is increasing for understanding the nexus between security, on the one hand, and environmental issues and natural resources, on the other. Robust and transparent tools can aid in the recognition of environmental drivers of conflict and potential environmental risks to human health, and they can improve the ability to predict and mitigate negative environmental impacts from operations. Moreover, an early understanding of the environmental drivers of conflict enhances the opportunity to identify and secure monetary and human resources for environmental actions within a mission.

The Swedish perspective is that participation in peace support and security-building operations ultimately is intended to contribute to maintaining international peace and security, and consequently to facilitate fair and sustainable global development.[22] This holds equally true for all three pillars of sustainable development (i.e. the economic, social, and the environmental).

Although the primary purpose of the environmental vulnerability assessments is to provide military planners with timely environmental information and intelligence, the products are already utilized by other actors also for e.g. environmental awareness training before deployments. The product already consist information useful for multiple actors and could easily be modified even further to facilitate accurate assessment regarding a variety of topics.

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