3rd Int. Disposal Conf.,
Karlskoga, Sweden, 2003.

ENVIRONMENTAL RESEARCH ON MUNITION AT FOI

Joakim Hägvall
Swedish Defence Research Agency, Weapons and Protection, Tumba, Sweden

ABSTRACT

The environmental constraint on all activity in society increases. Conventional munition is not an exception and there is a rising need for new methods to evaluate and to limit the effect that munition has on the environment. This is the subject of a number of research projects at FOI in Sweden. The range of these projects is wide and varies from theoretical studies to the actual measurements at site. This presentation will cover two of these projects.

Life Cycle Assessment (LCA) is a tool to examine the environmental impact of a service or a product over its whole life cycle. In LCA, data is collected from the cradle to the grave for a specific service or product. Using databases and evaluation codes, a picture of the environmental impact is drawn. Hereby, the life cycle part responsible for the most severe environmental impact can be identified, and comparison can be made between different impact sources and other systems. The study also includes the use of a simplified LCA called the MECO method. The MECO is a much faster method but it does not include all the data that a qualitative LCA does. The goals of the project are to get an idea of the impact of the munitions' life cycle, to see which part/parts have the most severe environmental impact and to see if the qualitative and the simplified LCA differ in result.

The need for new demilitarization methods is accentuated these days, especially the reuse of higher value explosives. Here, the driving force is not only environmental, but also economical. The project aims at the reuse of HMX and RDX. Especially, already available methods are evaluated for different RDX or HMX containing explosives. The examined methods originate from TPL Inc and from Nexplo AB. The project aims to look at how well the selected methods fulfil current and future Swedish needs.

INTRODUCTION

In Sweden, environmental issues take a prominent place even when talking about military materials. Thus the armed forces use FOI to do research for them in the environmental field. This paper describes two projects in the Swedish armed forces environmental research programme.

LCA

LCA is used to evaluate a product's or service's impact during its whole life cycle. It is becoming a frequently used method in several industrial areas. The use of LCA when evaluating military materials especially munition is not commonly practise but has been done before (Demex 2000).

This project looks at several aspects of LCA and a possible outcome is for the Swedish Defence Material Administration to use LCA or the simplified MECO method in their acquisition process. At the present time there are no available results from the complete LCA or MECO.

LCA principles

Life cycle assessment (LCA) is the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle. The life cycle includes mining of raw material, production, use and disposal of a product (*i.e.* from cradle to grave) (ISO, 1997). The term 'product' includes physical products as well as services. LCAs are often used as comparative studies. It is not the products that are compared, but the function of the products.

The assessment is standardised in the ISO 14040- series (ISO, 1998; ISO, 2000a; ISO, 2000b; ISO, 1997). A guide to the standards is made by Guinée *et al*. (2001).

The analysis is performed in four phases, as described (according to Guinèe *et al.* 2001) and illustrated below. During the process it can be necessary to return to earlier phases to improve them.

- ***Definition of goal and scope:*** The goal of the study ought to be explained and the intended use of the results, the initiator of the study, the practitioner, the stakeholders and the intended users of the results ought to be specified. A scope definition establishes the main characteristics of an intended LCA study, for example a technical or a geographical study. The function, functional unit alternatives and reference flows ought to be defined in this phase.
- ***Inventory analysis:*** The product system is defined in the inventory analysis. The definition includes setting the system boundaries, designing the flow diagrams with unit processes, collecting data for each of these processes, performing allocation phases for multifunctional processes and completing the final calculations. The main result is an inventory table listing the quantified inputs and outputs to the environment associated with the functional unit, for example x kg carbon dioxide.
- ***Impact assessment:*** The results from the inventory analysis is further processed and interpreted in the Life Cycle Impact Assessment (LCIA). This phase includes classification, characterisation as well as the optional phases: normalisation, grouping and weighting. A list of impact categories is defined and it is used to classify the results from the inventory analysis, on a purely qualitative basis. The actual modelling results are calculated in the characterisation phase. The optional normalisation serves to indicate the share of modelled results to a reference, *e.g.* a worldwide or regional total. The results can be grouped and weighted to include societal preferences of the various impact categories.
- ***Interpretation:*** The results from the analysis, the choices and assumptions made in the analysis are evaluated, in terms of soundness and robustness. Conclusions are drawn and recommendations are made.

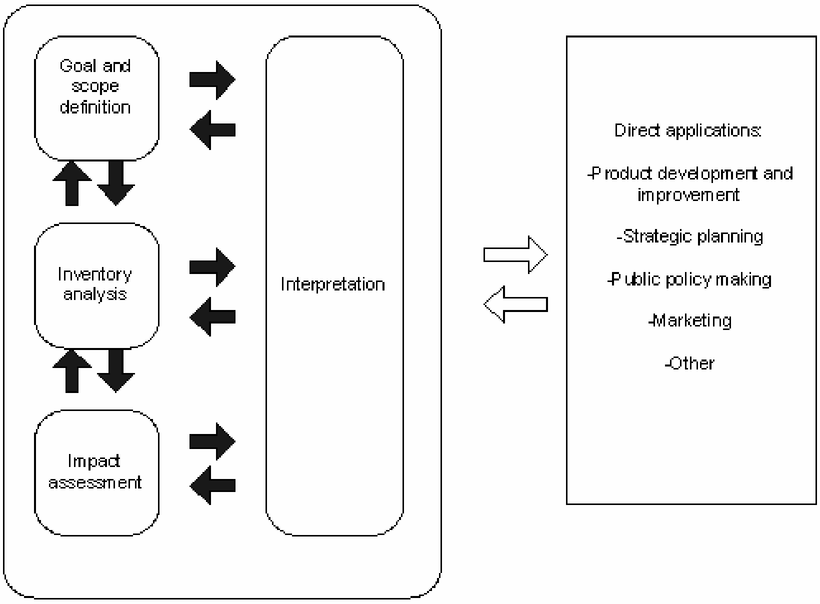

Figure 1. The framework for life cycle assessment, based on ISO 1997.

Since LCAs focus on products they are useful for product development, improvement and for comparison when purchasing a product.

It is not possible to quantify everything, so qualitative data and estimations are therefore necessary to create a comprehensive picture even in a quantitative LCA. It is then possible to consider quantitative information in a qualitative LCA, especially when such is easily accessible (Johansson *et al*., 2001)

The MECO principle

The Danish Institute for Product Development and dk-TEKNIK have developed the MECO principle in co-operation with a larger Danish project. The use of the principle is described in "Handbook for Environmental Assessment of Products" (Pommer *et al*., 2001), which is intended for small and medium-sized companies. The principle divides the assessment into four areas in accordance with the underlying causes of the product's environmental impacts. These areas, which have given the principle its name, are Materials, Energy, Chemicals and Others (Wenzel *et al.*, 1997).

The information on the studied product/system is first structured in the MECO chart, see Figure 2. The analysis with the chart can be followed by a more detailed LCA, making a gradual evaluation of the product.

	Material	Manufacture	Use	Disposal	Transport
1.Materials a) quantity					
b) resource					
2. Energy a) primary					
b) resource					
3. Chemicals					
4. Others					

Figure 2 MECO chart (Pommer et al. 2001).

All inflows and outflows must be considered for one category at a time with bases on the functional unit and the chosen life cycle phase.

The category ‘Material’ includes all the materials needed to produce, use and maintain the product. Materials that are being reused in the disposal phase are entered in the Disposal box, marked with a minus sign. The use of materials is partly presented as quantity (1a) and partly as resources (1b).

The category ‘Energy’ includes all energy used during the product’s life cycle, including the use of energy during the supply of materials. The use of energy should be indicated as primary energy (2a) and as use of oil resources (2b).

To be able to compare products, the use of material and energy should be calculated as consumption of resources in millipersonreserve (mPR). One personreserve is the resource consumption in proportion to the global reserves of a resource, available for one person, for all future posterity. The use of energy is calculated as use of oil resources.

The category ‘Chemicals’ includes all chemicals in the product’s life cycle. The chemicals are classified as type 1, 2 or 3 according to their environmental hazard level. Type 1 refers to very problematic substances, type 2 to problematic substances and type 3 to less problematic substances. The classification was made by combining EU directives on the marking of chemicals (EU directive 67/548/EEG, European Commission, 1967) and Danish lists, according to:

- Type 1: very problematic substances, substances on “Effekliste” and/or “Listen over uønskede stoffer”, ozon-depleting substances.
- Type 2: problematic substances: Substances on “Listen over farlige stoffer”, with other R-phrases than fire-and explosion risks. Substances with unknown information
- Type 3: less problematic substances: Substances on “Listen over farlige stoffer”, with only fire-and explosion risks. Substances with very little environmental impact.

Environmental impacts that do not fit into the categories described above should be included in the category ‘Other’.

For a detailed description of how to use the method, see Pommer *et al*. (2001, in Danish) or Hochschorner *et al*. (2002, in Swedish)

Application of LCA principles to munition

For the application of the LCA principles, the 40 mm L/70 PFHE II grenade was chosen. It is a fairly old munition that has been produced in very large quantities. The basis of this choice was that it was old and quite simple in construction, which implied that the amount of available information would be higher than for newer munitions.

There are several goals for this study:

- To identify which aspect of the Life cycle has the largest impact on the environment
- To identify which of the aspects with a large impact that it is possible for the buyer or producer to modify
- To make a comparison between different waste managements and technologies to see the difference in the environmental impact.
- To compare the information you get from a qualitative LCA with the information from a simplified LCA. When would it be wise to use the different methods?
- To make a demonstration case about LCA on military material.

Most of the data were collected in the early stages of the project. The main source of information was the manufacturer Bofors Defence AB. A lot of information on chemical processes was provided by North Carolina State University.

The first simulation showed that there are some specific materials that have a big impact on the environment. One of those was copper and it is important to notice that the impact was significant only if the copper is not recycled. Otherwise chemicals had a big impact, however the validity of that is not certain since there were data gaps in the first simulation.

The final version of the LCA is not finished at the time of writing of this paper so no results can be enclosed here.

REUSE OF HIGHER VALUE ENERGETIC MATERIALS

The project “reuse of higher value energetic materials” was initiated by the Swedish armed forces and started in 2002. It is a study of different methods for reclaiming higher value explosives and evaluating them for Swedish needs.

The purpose of reclaiming energetic materials (EM) is foremost an environmental issue. The production of EM has an impact on the environment, though it is important to notice that the reuse of these materials will most likely not have the same large impact as the production of new ones. The method mostly in use in the world today is open burning (OB) and open detonation (OD). These methods are criticized since knowledge of the environmental impact when using these methods is unclear. The use of new methods could clarify the impact on the environment and therefore give a possibility to reduce it.

When reclaiming higher value EM there is also an economical issue involved. When you destroy the EM you destroy an asset. If it were possible to reuse these EM the profit could be substantial, especially if they could be reused for military purposes.

The third and last issue for reusing explosives is that there are fewer and fewer producers of EM in the world. Some production, for example TNT, is located in areas of the world where a safe supply is uncertain. A way of securing a country’s need for EM could be to reuse the EM already in the stockpile. This is doubtful for newer EM but works for bulk EM as TNT.

The part of the Swedish stockpile that is up for destruction today is mostly munitions containing TNT. In the future this will change and a higher amount of munition containing higher value EM will be up for destruction. That will create a need for new “destruction” methods that comply with Swedish legislation and goals for the armed forces.

The major enticement in Sweden for the reuse of EM is environmental impact reduction. Naturally the economical issue is a positive side effect.

This project started with an inventory of accessible methods for reuse of higher value EM and it focused mainly on RDX/HMX-based explosives since these are the EM most common in the Swedish stockpile.

At the beginning of 2003, three methods were identified as having good potential and an evaluation process started.

Each process was tested on three explosives. The explosives were chosen based on the binder materials. Those binders were plastic, TNT and wax, which are the most common binder materials in the Swedish stockpile.

The methods derive from Nexplo AB, TPL inc. and are based on three different ways of reclaiming the EM:

- Nexplo AB has a patent for a process that uses organic solvents to dissolve the energetic material. They filter the solution so that only an energetic solution is left and the energetic is then crystallised. The method is mostly used when the binder material is TNT.
- TPL has patented two methods. The first one uses inorganic acids. The acids destroy the binder materials and leaves the EM untouched. The EM only has to be washed to be ready to be used again. This method is mostly used on explosives with plastic binders.
- The second method from TPL uses inorganic salts to dissolve the binder. The binder is then removed from the solution and the EM are collected. This method is mostly used when the binder material is wax.

Currently an evaluation of the methods is underway and the results are not ready to be included in this paper.

The project will continue during 2004 and the next step is to test the methods from this year on newer energetic materials synthesized at FOI.

REFERENCES

Bofors defence AB (2002), Manufacturing standards for L/70 PFHE II.

Demex Consulting Engineers A/S (2000). A study into the Demilitarisation of Advanced Conventional Munitions, Part 2. Royal Ordnance PLC.

Edesgård and Eriksson (1999). Miljöanpassad Produktutveckling, Livscykelanalys på 40/48 kulsgr 95LK(3P). Examensarbete. Karlstad universitet.

Finnveden, G., Johansson, J., Lind, P., and Moberg, Å. (2000). Life Cycle Assessment of Energy from Solid Waste .fms report.

Guinée, J B, Gorrée M, Heijungs R, Huppes G, Klejn R, Koning A de, Oers L van, Wegener Sleeswijk A, Suh S, Udo de Haes H A, Brujin H de, Duin R van and Huijbrects M A J (2001): Life cycle assessment, An operational guide to the ISO standards, Dordrecht, Kluwer Academic Publishers.

Hochschorner, E., Finnveden, G., and Johansson, J. (2002). Utvärdering av två förenklade metoder för livscykelanalyser: FOI).

ISO. (1997). Environmental Management - Life Cycle Assessment - Principles and Framework.

ISO. (1998). Environmental Management - Life Cycle Assessment - Goal and scope definition and inventory analysis: International Organisation for Standardisation).

ISO. (2000a). Environmental Management - Life Cycle Assessment - Life Cycle Impact Assessment: International organisation for Standardisation).

ISO. (2000b). Environmental Management - Life Cycle Assessment - Life Cycle Interpretation: International organisation for Standardisation).

Miljøstyrelsen. (2000a). Listen over farlige stoffer (Denmark: Miljø- og Energiministeriet).

Miljøstyrelsen. (2000b). Effektlisten 2000 (Denmark: Miljø- og Energiministeriet).

Miljøstyrelsen. (2000c). Listen over uønskede stoffer, En signalliste over kemikalier, hvor brugen på laengere sigt bør reduceres eller stoppes (Denmark: Miljø- og Energiministeriet).

Pommer K., Bech P., Wenzel H., Caspersen N., and Olsen S. I. (2001). Håndbog i miljøvurdering af produkter -en enkel metode. In Miljønyt Nr. 58 2001: Miljøstyrelsen, Miljø- og Energiministeriet, pp. 187.

PRé. (2001). SimaPro 5 User Manual: PRé Consultants B.V, Amersfoort, The Netherlands.

Wenzel, H. (1998). Application Dependency of LCA Methodology: Key Variables and Their Mode of Influencing the Method. International Journal of LCA *3*, 281-288.

Phillips R.S, Cain A.W, Schilling T.J, Miks M.W (1998), Recovering nitroamines and reformulation of by-products, US patent no 6,063,960.

Tompa A.S, French D.M, White B.R, Breakdown of solid propellant and explosives, recovery of nitramines (1983), US patent no 4,389,265.

Nyqvist J (2000), Method for working up mixed explosives, US patent no 6,013,794, SE patent nr 9500280.

Hägvall J (2002), Methods for Reuse of Higher Value Explosives, (SV), FOI-R--0638—SE.