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## **R<sup>3</sup> – Management in Demil Operations: Today and Tomorrow**

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### **Abstract**

#### **Increasing environmental performance in munition demil during 50 years**

After World War II surplus munition in Sweden was dumped in lakes, mines and in the open sea. During the late 60's environmental concerns led to a ban on dumping. OB/OD therefore became the main method for demil of munitions. Growing environmental concern in the 70's resulted in a small scale start of industrialized demil which during the 80's steadily increased. During the 90's demil of munition has been characterized by focus on recovery, reuse and recycling. This is due to a more rigorous environmental legislation coupled with an awakening environmental awareness in the Armed Forces and the discovery that an environmentally adapted demil process can be economically beneficial compared to OB/OD. A high degree of resource recovery and reuse (R<sup>3</sup>) is now obtained in the demil process, but some problems remain e.g. smoke and illuminating ammunition. Some approaches to handle these challenges are discussed.

The problem with the old dumpsites are also discussed: a survey has been performed in order to locate the numerous sites and measures are taken to investigate the risk for ecological effects. The dumped ammunition also constitutes a potential safety problem at some of the locations, both with regard to unintentional handling by the public and by potential detonation of unstable munition. (Some results from examination of dumped ammunition are presented).

#### **Environmental efforts on a national level**

The high focus on R<sup>3</sup> in demil operations in Sweden is in line with the political ambition for Sweden to be among the leading nations in the efforts to obtain a sustainable development of society. The Armed Forces and the Defence Materiel Administration are among the governmental authorities actively working to contribute to this strive. The work to implement an environmental management system according to ISO 14001 in the defence sector has started. The government has issued a command to the two authorities to jointly adapt guidelines for environmentally sound provision of defence materiel.

#### **Vision**

The main environmental objective concerning demil in Sweden at present is to totally eliminate the need for OB/OD to dispose of surplus munitions. This method must in the near future be replaced by even more optimized industrial processes focusing on recovering materials, explosives as well as metals, even in those ammunition components where we today still have some problems. State-of-the-art technology is a prerequisite to achieve fully environmentally adapted demil operations, as well as an innovative and life-cycle-oriented way of managing environmental aspects in all processes. International co-operation is of course a valuable tool for sharing knowledge and experience, which is necessary for achieving the best possible demil methods.

## History of demilitarization in Sweden

### ***Dumping ammunition***

During the 1940s Sweden built up large ammunition stockpiles in order to keep a high military preparedness.<sup>1</sup> In the fifties and the early sixties, Sweden needed to get rid of the old munition in order to make room for new, modern munition in the storage facilities as new weapon systems were introduced. This had to be done quickly, as nobody knew how much time was left before the munition may have to be used in a conflict. Another problem was degradation of the smokeless gunpowder in the munition and copper azide corrosion in fuzes. There was no planning in advance of how to get rid of the old munition and nobody had given the problem much thought before, so in many cases it became an acute matter that had to be solved instantly.

Dumping the munition in lakes, mines and in the open sea was considered a fast, cheap, simple and safe way to get rid of the surplus and potentially dangerous munition. There were no industrial demilitarization facilities yet and open burning/open detonation (OB/OD) was considered rather impractical in those days. The OB/OD technique wasn't very developed, so large pieces of ammunition was spread in the surroundings and there were fires which were difficult to fight, especially as there could also be some undetonated explosives left. Therefore dumping was often chosen as the preferred method and Nature was supposed to destroy the ammunition in only a few years time, just as it took care of all garbage from human activities.

How the dumping should be performed was regulated in detail by the Armed Forces, though the instructions were a little different between the Army, the Navy and the Air Force. The Army prescribed the dumping to be done mainly in small forest lakes close to the depots in order to avoid transports. Old mines was also recommended, as they were often used as public dump sites for all kinds of waste. The Navy and the Air Force dumped most of their munition in the open sea. Today we have located about 100 sites where ammunition has been dumped.<sup>2</sup> It has been very difficult to find the deponies, as all the involved authorities of those days had different ways to register where the ammunition was dumped. The authorities have also changed names, ceased to exist and been merged several times during these fifty years, but we are still trying to locate more sites through studying old documents and talking to people who were around when the dumping took place.

### ***Laws and public opinion start to influence dumping***

The laws and regulations concerning dumping of ammunition were very scarce in the beginning. There was a law from 1918 forbidding dumping objects in water that could lead to formation of shoals that the boats could run aground. In the sixties there was a Government investigation about how fishermen could suffer economically from military activities, including dumping. It was decided that fishermen could claim for compensation if they were affected. This investigation also emphasized that dumping must come to an end and that industrial methods must be developed in order to take care of surplus ammunition.

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<sup>1</sup> Hanna Hörnström, *Från dumpning till återvinning: Strategier för ammunitionsavveckling i Sverige 1940-1995*, Swedish Defence Materiel Administration (Stockholm 1997).

<sup>2</sup> Lennart Wiman, *Ammunitionsdumpning: förteckning över platser, mängder och vissa rester*, Swedish Armed Forces (Stockholm 1995).

The newspapers wrote a lot about dumping of ammunition in the sixties. Scientists discussed how fast Nature would destroy the ammunition in the water and the conclusion was that it wouldn't take any longer than at most ten years, even in fresh water. Today when we take up ammunition that has spent fifty years at the bottom of freshwater lakes in sediments without much oxygen, we find that some of it is still as good as new and that it could actually still be used!

In 1964 dumping was forbidden in all freshwater lakes in Sweden except the biggest one; Vänern where it could go on for another four years. In 1972 dumping was forbidden in the open sea as well, as a consequence of an international agreement on the subject.

### ***The need for industrial demilitarization facilities***

During the forties and fifties, the manufacture of ammunition as well as assembling and storing it took place at the same place deep inside the mountains, and it was a very secret business in Sweden. In 1947, there was an accident i Mitholz in Switzerland where a large ammunition depot inside a mountain exploded and rocks and pieces of ammunition were thrown over a village nearby. This was a catastrophe for Switzerland and it happened only about a year after another accident of the same kind, when the ammunition depot i St Moritz exploded. The reasons for the Mitholz accident were never clearly understood, but it made the Swedish military attaché in Bern to write home and suggest to the Swedish authorities that perhaps it wasn't such a good idea to store ammunition in the same place as it was manufactured and assembled. The Supreme Commander was commissioned by the Ministry of Defence to investigate how this should be done in the future.

In 1955, the Supreme Commander concluded that a new engineering industry must be built where ammunition could be manufactured and assembled safely, while the depots was located separately and far from villages. He also mentioned that the industry could be used for demilitarization as well, as the necessary equipment for taking the ammunition apart was the same as for assembling it. It took ten years until a plant was built in Vingåker about 200 km southwest of Stockholm and another five years until the demilitarization started. Today it's Nammo LIAB AB that runs the facility.

LIAB AB was founded in 1953 and dealt with military pyrotechnics. In the sixties they expanded and started to manufacture all kinds of civilian products like washing machines and can-openers. Bofors bought the company in 1970 and the business changed again. Today LIAB AB is part of the Nordic ammunition company Nammo and specializes in environmentally adapted demilitarization of ammunition.

### ***Open burning and open detonation***

As mentioned above, dumping wasn't allowed any longer in the beginning of the seventies and industrial demilitarization at the Vingåker plant had just about begun, so the capacity was still fairly low. In 1971 there was another acute problem, as we had to make room in the ammunition storage facilities for a lot of new torpedos and the old ones had to be taken care of. The Vingåker plant couldn't demilitarize them and a lot of places were investigated where they could be destroyed by open detonation. An artillery range in Älvdalen in the north of Sweden was considered suitable and the torpedos were used to evaluate the range, to find out if the place could perhaps be used for more OB/OD in the future. The tests were considered successful and today we use Älvdalen for most of the OB/OD that is still done. As we don't consider it an environmentally sound method, especially as the emissions can't

be measured satisfactorily, we try to find other ways even for ammunition that is very difficult to demilitarize industrially today.

## **Environmental efforts on a national level**

Today there is a vision of a sustainable development of society. It involves a global view of society where the consideration of ecological prerequisites is combined with a good economic, social and cultural development. The overall objective is to protect the environment and people's health, to use the earth's resources effectively and to reach a long-term sustainable development.

In Sweden a number of national environmental objectives have been formulated and these state the level of ambition for environmental work in all sectors of society. In addition the various sectors have a general responsibility for the environment over and above the requirements of environmental legislation. The government wants authorities to act as forerunners in environmental work as they influence society by, inter alia, extensive purchasing. As a step in the work on integrating environmental consideration in the whole public administration, the Swedish Armed Forces (FM) and the Swedish Defence Materiel Administration (FMV) along with several other national authorities, are assigned by the government to implement environmental management systems based on ISO 14001.

In the environmental review performed by the Swedish Defence Materiel Administration (FMV), procurement of defence materiel was considered one of the most important environmental aspects. Through its procurement, FMV has a significant possibility to influence the market and control the development of more environmentally adapted products. To the defence industry a pronounced environmental profile is also an international means of competition. By taking the environmental aspects into consideration through studies and development work, it's possible to influence the design of the systems so that they are more environmentally adapted. This can also reduce costs for a system in a life-cycle perspective as, for example, toxic components may require special handling, authorisation and expensive winding-down measures.

## **Today's challenges**

### ***Sites with dumped ammunition***

An extensive investigation in order to find all places in Sweden where ammunition was dumped in forties, fifties and sixties has been performed.<sup>3</sup> Hundreds of sites were located and most of them contain a lot of different ammunition and ammunition components all mixed together. A couple of them has been chosen in order to make a closer study of how the old ammunition behaves at the bottom of lakes, in old mines and out at sea when left unattended for sometimes more than fifty years.

At Dalkarlsberg 250 km west of Stockholm, about 900 tons of ammunition and explosives have been dumped in two water-filled mine shafts.<sup>4</sup> The future environmental status of the repository has been evaluated based on field investigations, chemical analyses, toxicity tests and hydrogeological computer modeling. No explosives or its degradation products were found in the wells, shafts or in the sediment from a nearby lake. It has been concluded that

<sup>3</sup> Lennart Wiman, *Försvarets miljöfarliga lämningar*, Swedish Armed Forces (Stockholm 1995).

<sup>4</sup> Birgitta Liljedahl, *Dumpad ammunition i gruvschakt Dalkarlsberg: En miljöriskbedömning*, Swedish Defence Research Institute (Umeå 1997).

the explosives (TNT and lead acid) as well as the metals in the mine shafts will be completely released after about 2000 to 20 000 years, due to the diffusion from the dumped material. With regard to the relatively high dilution in the shafts, the concentration of released components into the water will be very low but not negligible. The decision to be made is to let the ammunition stay where it is and install a system for monitoring the water chemistry in the shafts and evaluate methods for future water treatment.

Trials with taking up dumped ammunition have been done in a couple of places in Sweden. This ammunition has to be destroyed immediately for safety reasons, but it should still be done in a controlled environment where the exhaust gases can be cleaned. The method of taking up and destroying dumped ammunition at the dumpsite demands mobile units if it is to be done at several places in short time intervals. How to proceed with this kind of work is still under evaluation in Sweden.

### ***R<sup>3</sup> challenges and international co-operation***

There is some ammunition that for different reasons is difficult to demilitarize in an environmentally adapted way today. The most common reason is safety, as in the example with the dumped ammunition that has to be destroyed on the site very fast. There are also problems with certain materials in the ammunition, for example fully chlorinated smoke compositions (e.g. hexachloroethane) that may form dioxines during combustion. Rocket motors and primers are also considered problematic in Sweden today, as well as all kinds of pyrotechnic ammunition.

The Swedish Defence Materiel Administration has made experiments with disposal of hexachloroethane smoke generating hand grenades and illuminating shells at a civilian facility for hazardous waste treatment. The ammunition was incinerated in a rotary kiln together with other kinds of waste, the gases were cleaned and the ashes were put in a depony. These experiments were successful, even though the regulations around disposal of explosives are very detailed. The remaining issue is mainly an economical question, as heavily chlorinated compounds are tremendously expensive to dispose of.

Sweden and the U.S.A. have an agreement since 1996 for cooperation on environmental protection in defence matters, which has resulted in several different projects. One project focuses on environmentally adapted demilitarization of ammunition and alternatives to OB/OD as well as recourse recovery and reuse (R<sup>3</sup>) management. The project also includes monitoring, characterization and treatment of process waste and conversion products during combustion.

So far the project group has made a broad survey of demilitarization methods used today and identified common environmental issues associated with demilitarization. Alternative strategies and actions have been compared and some of the current questions are the molten salt destruction technology, the Munitions Items Disposition Action System (MIDAS) and continuous monitoring of metals in combustor exhaust gases. At the moment data is exchanged on the molten salt technology for destroying explosives safely and environmentally friendly.

The Nordic countries also have an agreement to cooperate on defence environmental issues. Within this agreement there has been an information exchange meeting between the different national defence research institutes, where demilitarization of ammunition was a topic among others. All countries share the same problems, though the amounts of

ammunition may change. In this cooperation further exchange of ideas and know-how concerning demilitarization will take place.

## Demil tomorrow - the vision

Resource recovery and reuse (R3) management is an important tool for the industry within the demilitarization market today. The ammunition to be demilitarized often contains potentially valuable metals, explosives and other components that can be recovered. Disassembly of ammunition in order to recover these components also facilitates for handling environmentally hazardous substances. It's very important to have a clear picture of the contents of the ammunition, which can sometimes be very difficult to obtain due to insufficient information.

The next step is to avoid future demilitarization problems with today's ammunition. The Swedish Defence Materiel Administration (FMV) is putting much effort into formulating environmental requirements for the new ammunition that is being developed and produced today. This has been identified as an important question of environmental awareness and training within the defence sector. FMV has an extensive environmental training program for all employees and also more specific training for key personnel and top management.

The training for all employees consists of basic environmental knowledge and basic knowledge of the environmental management system ISO 14001. The environmental impact from the defence sector is of course a major issue in all training. The top management that controls the environmental management system undertakes more thorough training in ISO 14001 and how it affects the whole organization. The objective with all the training is to put the best possible environmental requirements considering technical performance and economical objectives in the whole acquisition process into use. This naturally affects demilitarization of ammunition as well as procuring new ammunition.

A life-cycle perspective in all defence procurement is also considered a major area of interest in Sweden. As the defence sector influences the defence specific materiel from development to recovery/disposal, the most important decisions concerning future handling are made already during the development phase. Therefore the Swedish government has decided that the Swedish Armed Forces and the Swedish Defence Materiel Administration have a *joint* responsibility for adapting the defence materiel to the environmental demands.

An ecologically sustainable society is a society in which human activity does not damage health, climate or ecosystems.<sup>5</sup> It is a society geared to renewable resources and conserving the resources available so that there will be enough of them for everybody, today and in the future. To achieve this, it's important that all sectors in society takes their responsibility. R<sup>3</sup>-management in demilitarization operations is one small step forward in this direction.

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<sup>5</sup> Ministry of the Environment, Towards an ecologically sustainable society, (Stockholm 1997).

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# R3-management in demil operations: today and tomorrow

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1



# Environmentally sound defence procurement

The Swedish Defence Materiel Administration and the Swedish Armed Forces have a joint responsibility for achieving a long-term and sustainable ecological development.

2



## Remaining challenges

- Smoke compositions  
(e.g. hexachloroethane)
- Illuminating ammunition
- Rocket motors
- Primers



3



## Demil R<sup>3</sup>-vision:



- totally eliminating OB/OD
- using industrial methods focusing on resource recovery and reuse
- life-cycle perspective on ammunition: from development to demilitarization
- managing environmental aspects concerning demil within ISO 14001
- increasing international co-operation

4