Despite increased efforts by the international community to minimise the risks of unintended explosions of ammunition, undesired explosions have continued to occur in ammunition storage areas, with appalling loss of life. Over the past eight years, available records show that thousands have been killed and injured by such explosions. In 2008 alone, explosions in Albania, Bulgaria, Iran, Iraq, Ukraine and Uzbekistan are reported to have caused hundreds of casualties and scattered munitions over many kilometres of previously safe land. Accordingly, the first section in this chapter identifies good practice in the safe storage of ammunition.

The remainder of the chapter addresses the issue of stockpile destruction, which is one of the five pillars of mine action. Each State Party to the Anti-Personnel Mine Ban Convention is required to destroy all its stockpiled anti-personnel mines within four years of becoming a party to it, and those States Parties in a position to do so must assist others to fulfil this obligation. The Convention on Cluster Munitions, once it enters into force, will require States Parties to destroy stockpiles of cluster munitions under their jurisdiction and control within eight years of joining the convention.

Physical destruction techniques available range from the relatively simple open burning and open detonation techniques, to highly sophisticated industrial processes. The decision to opt for any particular technique is likely to be based on cost, safety and environmental considerations, as well as the type of munitions being destroyed.

This chapter addresses first the safe storage of ammunition. It then describes different techniques for carrying out stockpile destruction, and discusses the advantages and disadvantages of open detonation and industrial demobilisation, based on the International Mine Action Standards (IMAS). The chapter then reviews environmental concerns in stockpile destruction. Finally, it considers briefly the role of stockpile destruction within mine action.

There are two main risks arising from the unsafe storage of ammunition. First, the population and environment close to ammunition storage areas (ASAs) are at risk from the unintended explosion of ammunition. Second, unless sufficiently protected, such ASAs are vulnerable to theft, especially by terrorists and other criminal groups. In developing countries ASAs may also be targeted for theft by civilians seeking to earn income from the sale of scrap metal or explosives.
Risks during storage of ammunition and explosives are significantly reduced by correct storage, handling and transportation methods. Ammunition is designed to be as lethal as possible when used and as safe as possible in storage, but by its very nature it contains highly reactive compounds. The level of risk is primarily dependent on:

- physical and chemical condition of the ammunition and explosives
- training and education of the personnel responsible for the storage and surveillance of the stockpiles
- handling, repair, maintenance and disposal systems in place, and
- storage infrastructure and environment.

In order to ensure the safety of ammunition up to the point of its final use it should meet the following criteria, so it is:

- manufactured under controlled conditions and subject to quality control standards
- subjected to handling and storage tests
- assigned a shelf life
- the subject of periodic inspection, and
- stored with other ammunition that will not add additional effects should an undesired explosion occur.
Environmental factors affecting ammunition

Ammunition is susceptible to the following environmental factors:

- extremes of temperature
- rapid changes of temperature
- physical impact
- high levels of electro-magnetic radiation
- ingress of moisture
- (some components are) susceptible to attack by vermin, and
- tampering by inquisitive unqualified personnel.

In general, therefore, explosives should be:

- kept dry and well ventilated
- kept as cool as possible and free from excessive or frequent changes of temperature
- protected from direct sunlight, and
- kept free from excessive and constant vibration.

Some substances used in ammunition and explosives attract and hold moisture, which may result in the degradation of explosive performance. It may also cause them to become dangerous to handle, due to the potential for the formation of sensitive explosive crystals between the fuze and main body of the munition. Rain, dampness and humidity can cause enormous damage to ammunition and explosives in a very short time. Every effort must be made to ensure dry conditions prevail in storage and transportation. Good ventilation of explosives will keep them cool and prevent condensation.
CHAPTER 10

AMMUNITION STORAGE AND STOCKPILE DESTRUCTION

THE DEFINITION OF STOCKPILE DESTRUCTION

The IMAS provide that, in the context of mine action, the term ‘stockpile’ refers to a large accumulated stock of explosive ordnance.¹ Stockpile destruction is defined as “the physical destructive procedure towards a continual reduction of the national stockpile.”² A State or other entity holding stocks of weapons may wish to destroy explosive ordnance as part of a disarmament process, to implement a legal obligation, upon expiry of shelf life, or for reasons of safety.³

As the IMAS notes, the transparency of the destruction programme is an important security and confidence-building measure. International organisations, national ambassadors, media and NGOs should be invited to witness the destruction process. They should also be given access to the ammunition account for anti-personnel mines in order that they can verify those destroyed against the declared stockpile levels.

TECHNIQUES FOR STOCKPILE DESTRUCTION

A wide variety of techniques exist for the destruction of explosive ordnance stockpiles. The IMAS focus on the destruction of anti-personnel mines, based on the requirements of the Anti-Personnel Mine Ban Convention and, indirectly, of Amended Protocol II to the Convention on Certain Conventional Weapons.⁴ Some examples of techniques for anti-personnel mine stockpile destruction are set out in Box 1.⁵

There were traditionally five options for the logistic disposal of ammunition and explosives; however, in the case of anti-personnel mines four of these options are banned by international treaties. The Anti-Personnel Mine Ban Convention does not permit the sale, gift or increased use in training of anti-personnel mines, and the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (the Oslo Convention) has outlawed deep sea dumping.⁶ Therefore, the international community is now left with destruction as the only available option for the disposal of anti-personnel mines.

The Anti-Personnel Mine Ban Convention does not define what constitutes ‘destruction’. The term has been interpreted by States Parties broadly to include a number of different approaches, among others, dismantling, crushing and recycling, as well as physical detonation. States Parties are permitted to retain a small number of anti-personnel mines for the development of, and training in, mine detection, mine clearance, or mine destruction techniques, and to transfer an unlimited number for the purposes of destruction.
Physical destruction techniques range from the relatively simple open burning and open detonation (OBOD) techniques, contained detonation, crushing, through to highly sophisticated industrial processes. According to various estimates, the costs of demilitarisation of anti-personnel landmines range from US$2 to US$4 each, depending on the type of mine, although certain States have quoted higher figures. Generally, open detonation is likely to be the cheapest means to destroy stockpiles of up to one million anti-personnel landmines. It does, however, require significant knowledge of explosives engineering and close supervision of personnel as the shock wave caused by detonation may not destroy all the mines but throw some out, requiring additional EOD work in a potentially more dangerous situation.

Industrial scale demilitarisation has many advantages: mechanical disassembly, incineration in environmentally-controlled systems and the ability to operate 24 hours a day, 365 days a year. Its major disadvantage is the high capital set-up costs of design, project management, construction and commissioning. The operating costs are generally lower than OBOD (typically 50 US cents to US$1) although high labour costs in developed countries account for a large percentage of the OBOD costs. This technique was applied successfully in Albania where all antipersonnel landmines stocks were demilitarised, in the same factory where some of the stocks (Albanian) were originally produced.

Notwithstanding this, OBOD can be a cheaper option dependent on the economy of scale. In the United States (US), for example, average OBOD costs are US$850 per tonne, whereas industrial demilitarisation is US$1,180 per tonne; but it must be recognised that these costs are for all ammunition types, not just anti-personnel mines. The IMAS also notes that salvage of metallic scrap or explosive waste can result in a potential income stream. Some explosive fillings of anti-personnel mines may be useful to the commercial explosive industry, while scrap steel is always in demand.

In many cases, the development of such purpose-built demilitarisation facilities to enable State Parties to fulfil their obligation for stockpile destruction will be well beyond available resources and therefore may not be a practical option. Factors such as cost, location and safety may mean that OBOD is the only pragmatic and feasible option.
CHAPTER 10

AMMUNITION STORAGE AND STOCKPILE DESTRUCTION

**Box 1 | Technology: pre-process**

It may be necessary to disassemble or break down anti-personnel mines prior to the destruction process. This is necessary because of limitations on the amount of contained explosive that can be incinerated, the anti-personnel mine design or the requirement for different components to have separate destruction methods. All of these methods require the movement of exposed bare explosive to the final destruction facility. Available technologies include: manual disassembly, mechanical disassembly (pulling apart, defuzing and depriming), robotic disassembly, mechanical breakdown (bandsaw, guillotine, cracker mill, rock crusher, punch), cryofracture, hydro-abrasive cutting, laser cutting, and microwave explosive melt-out. The following are brief descriptions of these techniques:

**Manual disassembly**
This technique implies the use of human resources to physically dismantle anti-personnel mines by manual labour using simple hand tools. It has the advantage of requiring limited capital investment, but is a labour-intensive process which results in relatively slow production rates. This method requires semi-skilled, yet well-trained staff.

**Mechanical disassembly**
This is the use of mechanically-operated systems to dismantle anti-personnel mines. The different technologies available, as noted above are: pull apart, defuzing and depriming. In contrast to manual disassembly, mechanical disassembly has the advantages of high production rates, it is an efficient system of work and has low staff requirements. It is environmentally friendly for this stage of the demilitarisation cycle and the technology is readily available. A major disadvantage, however, is the requirement for high capital investment. This is further complicated by the need for a wide range of equipment necessary to cope with all pre-processing and safety requirements.

**Robotic disassembly**
This is a fully-automated disassembly system. Similar advantages and disadvantages to mechanical disassembly, however the initial capital costs are much greater. This system would only be economically efficient for very large production runs due to the high start-up costs.

**Mechanical breakdown**
This process is mainly concerned with techniques required to expose the explosive fillings of anti-personnel mines prior to the destruction phase. There are low staff requirements for mechanical breakdown, and it is an environmentally friendly operation during this stage of the demilitarisation cycle. The technology is now readily available and there is no secondary waste stream, which reduces scrap salvage and disposal costs. A major disadvantage is the requirement for high capital investment. This is further complicated by the need for a wide range of equipment necessary to cope with all pre-processing and safety requirements. Production rates per machine can be slow and there is always the danger of explosion of the anti-personnel mines during processing.
CHAPTER 10

AMMUNITION STORAGE AND STOCKPILE DESTRUCTION

Box 1 | Technology: pre-process

**Cryofracture**
This process is used to break down an anti-personnel mine into small enough pieces to be processed through an incineration destruction method. It involves the use of liquid nitrogen to change the mechanical properties of the munition casing to a more brittle phase by cooling it to minus 130°C. The munition can then be easily shattered using simple mechanical shear or press techniques. A cryogenic wash out system is in the early stages of development. The principle is similar to cryogenic fracture; except that the filling is attacked with liquid nitrogen in order to make its removal easier.

Cryofracture is an environmentally friendly technique during this stage of the demilitarisation cycle with low staff requirements. The technique can also be used for any other type of munition, explosive or propellant with limited pre-preparation of the munition required. There is no secondary waste stream, hence cutting final disposal costs. In financial terms low capital investment only is required for set up costs. Sensitivity tests have shown that even at minus 196°C there is little change to the insensitiveness of the munition.

**Hydro-abrasive cutting**
Hydro-abrasive cutting (HAC) is the use of water and abrasives at pressures from 240 to 1,000 bar to cut open anti-personnel mines bodies by an erosive process. There are two distinct technologies; 1) “entrainment” or 2) “direct injection”. Research has now proven that the direct injection technology should be the preferred option for safety reasons. There are low staff requirements for HAC systems and a wide range of target munitions can be attacked. The explosive safety of systems is well proven and it is a cost-effective technique in comparison to other pre-processing methods. The major disadvantage is the requirement for initial high capital investment for infrastructure. The systems also produce contaminated waste-water, which requires a complex filtration system to clean it up. In terms of post-process operations, the explosive content is “grit sensitised” and requires careful handling during any further processing or destruction to avoid inadvertent detonation.

**Laser cutting**
This technology is still in the research phase in the US.

**Microwave melt-out**
This technology is under development in the US. It uses microwaves to heat up TNT-based explosive fillings. It is a rapid, clean technique but has one major disadvantage: the lack of control over heating can lead to the formation of “hot spots” with a resultant initiation of the filling. Work continues on its development, but it is not yet a feasible production technique. It is more energy efficient than steam and improves the value of any recovered explosives.
ENVIRONMENTAL CONSIDERATIONS IN STOCKPILE DESTRUCTION

Concerns have been expressed as to the environmental consequences of destroying certain mines by open detonation, both by the State holding the stockpiles and also potential donors, which may fall foul of national or international environmental legislation and guidelines. For instance, the PFM-1 remotely-deliverable anti-personnel mine contains hydrogen chloride, the open detonation of which may lead to unacceptable environmental pollution. One solution may be contained detonation in a pollution control chamber as the mine cannot be disassembled.

Traditionally, military organisations are usually responsible for the destruction of anti-personnel mines using OBOD techniques, while civilian companies use industrial demilitarisation. The availability, or not, of qualified manpower may have a significant influence on the destruction technique to be used. Certain destruction techniques result in the production of ‘special’ or ‘hazardous’ waste, which itself requires destruction or disposal in an environmentally benign manner. This is usually done by a specialist environmental disposal company.

In Europe, many nations have banned OBOD of all munitions unless there is no alternative and it can only be justified on safety grounds. This has necessitated the construction of expensive demilitarisation facilities, hence the requirement for the disposal of ammunition types other than anti-personnel mines and the necessity for economies of scale if pursuing this option. The argument as to the environmental effect of OBOD is still ongoing. Sound scientific evidence has been developed to support a case that OBOD of certain anti-personnel mine types may not be a threat to the environment. This means that OBOD still remains a viable destruction option for anti-personnel mines and may well be the most suitable option for regions with little or no industrialised demilitarisation capacities.

There are also internationally-accepted standards for the determination and measurement of air pollution from industrial processes. These standards apply to any pollution control systems used during industrial demilitarisation operations, but only in terms of the measurement of emissions as the standards do not provide any guidance on what the overall emission limits
should be: this remains the responsibility of the national authority. The only supra-national legislation that covers emissions into the atmosphere from the incineration of hazardous waste is the European Union Council Directive 91/689/EEC of 12 December 1991 on hazardous waste.\textsuperscript{12} This provides a comprehensive standard and is in use by all European Union countries and those countries with associate status. It does not prohibit open detonation.

DETERMINING THE APPROPRIATE TECHNOLOGY FOR STOCKPILE DESTRUCTION

According to the IMAS, there are so many inter-relational factors involved in anti-personnel mine stockpile destruction that it is not possible to provide ‘template solutions’.\textsuperscript{13} The selection of the most suitable technique or technology by a national authority will depend primarily on the resources available, the physical condition and quantity of the stockpile, the national capacity and the applicable environmental and explosives legislation.\textsuperscript{14} For instance, the stability in storage and degradation or deterioration rates of the explosive content will influence the degree of urgency for disposal, type of transport that can safely be used and destruction methodology.

The IMAS note that, although current anti-personnel mine stockpiles tend to be relatively small in terms of weight and net explosive content, they are typically large in quantity and the destruction of the stockpiles can be a complex logistic operation.\textsuperscript{15} It must be remembered that the physical destruction process of anti-personnel mines is only one process of the complete demilitarisation cycle. The processes in this cycle must be considered in parallel with the technical factors before a final disposal solution is produced.
As Figure 1 illustrates, the demilitarisation cycle is complex, comprehensive, wide-ranging and includes activities such as transportation and storage, processing operations, equipment maintenance, staff training and accounting. Stockpile security is obviously an important issue. Every effort must be taken to ensure the physical security of anti-personnel mines during storage, transportation and processing.

In terms of stockpile destruction, anti-personnel mines are no different to other types of munitions. They all contain fuzing systems and high explosives so the inherent dangers present during transport, storage, processing and destruction are generally the same. For this reason, the IMAS recommend that the stockpile destruction of anti-personnel mines should not be looked at in isolation.

There is, however, one notable difference. In many mines, the detonator, which is the first stage in the explosive chain, is kept separate from the body of the mine and is not inserted until laying. This is not the case for many other types of ammunition, e.g. rockets or mortar ammunition, where generally the ammunition main charge is transported and stored complete with the fusing
An influential factor in determining the method of anti-personnel mine stockpile destruction is likely to be economies of scale. The greater the number of anti-personnel mines requiring destruction, the larger the economies of scale and therefore the wider range of available technology. National authorities may wish to consider anti-personnel mine destruction on a regional basis, and/or to include other ammunition in the destruction plans, in order to achieve economies of scale. For example, the destruction of anti-personnel mines could be done in conjunction with the disposal of large-calibre artillery shells. These can then act as booster charges for the anti-personnel mines, thereby reducing the costs of explosives during open detonation disposal operations.

It is generally suggested that a national stockpile destruction programme be overseen by staff with the necessary technical skills and experience to manage large-scale ammunition destruction. There may be significant numbers of staff who have good demining skills, but quite limited EOD skills, including for stockpile destruction. Most national armies do, however, have highly skilled ammunition managers who are very capable in this area.

**TECHNIQUES FOR DESTRUCTION OF STOCKPILES OF CLUSTER MUNITIONS**

A range of techniques are recommended for the practical destruction of cluster munition stockpiles, ranging from open detonation to closed detonation or incineration, disassembly, cryofracture and “harvesting” of explosives.

**Open detonation**

Open detonation techniques may be the only practical solution to destroy stockpiles of cluster munitions for certain countries. This is especially the case where the numbers to be destroyed are limited and where there is no suitable industrial base to develop alternative techniques. It is not, however, suitable for large-scale destruction of cluster munition stocks. Very careful positioning and calculation of donor charges is necessary to ensure the destruction of all submunitions and supplementary charges. Incomplete detonation of submunitions may result in ‘throw-outs’, requiring additional EOD work in a potentially more dangerous situation.

**Closed detonation**

Two techniques for closed detonation have been used successfully for cluster munitions destruction: detonation deep underground in worked-out in mines in Norway; and destruction in closed detonation chambers.
CHAPTER 10

AMMUNITION STORAGE AND STOCKPILE DESTRUCTION

Closed incineration
Complete cluster munitions cannot be incinerated but explosive components can be incinerated after the munitions have been broken down. Pre-treatment may include the removal of fuzes from submunitions (after which the fuzes can be incinerated), the removal or deformation of the cones of shaped charges and, in the case of rocket-fired cluster munitions, breaking down the rocket motors into segments suitable for incineration. Closed incineration requires highly specialised explosive waste incinerators with pollution control systems to prevent the emission of noxious gases.

Disassembly
According to an expert, cluster munitions of Soviet manufacture may be particularly suitable for destruction by disassembly. This technique has the advantage of requiring limited capital investment, but is a labour-intensive process which results in relatively slow production rates. This method requires semi-skilled, yet well-trained staff. A problem during manual disassembly is that certain munition types are designed to arm on separation from the canister, which increases risk during the demilitarisation process.

Disassembly is not a complete solution to cluster munition destruction, because the explosive components require further treatment after disassembly. This may involve closed incineration or cryofracture.

Cryofracture
This technique is widely used for the neutralisation of small submunitions such as the M42, M46 and M77 grenades disbursed by artillery cluster munitions. The grenade fuzes are cut off mechanically before the grenades are passed through a bath of liquid nitrogen to embrittle their structures. They are then crushed to expose the explosive filling and passed under a flame in an enclosed environment to ignite the explosives, which burn to extinction. The metal scrap is then separated into ferrous and non-ferrous elements.
“Harvesting” of components of cluster munitions

In Cambodia, the Explosive Harvesting Project of the Golden West Humanitarian Foundation takes place in a town about one hour’s drive from the capital, Phnom Penh. A cutting machine, located behind protective walls and embankments, is used for demilitarisation. The machine can cut ammunition safely, which allows the explosives to be recycled and the metal casing to be turned into scrap, for example, for use in the construction industry. Shaped-charge artillery submunitions harvested by the process have been used for EOD operations, which may also have the advantage of providing donor charges for mine clearance. In some countries, lack of explosives has been cited as an obstacle to fulfilling clearance obligations under the Anti-Personnel Mine Ban Convention.

THE ROLE OF STOCKPILE DESTRUCTION WITHIN MINE ACTION

On 17 August 2000, the UN Inter-Agency Co-ordination Group on Mine Action agreed that stockpile destruction be formally incorporated as the fifth core component of mine action. Accordingly, the IMAS developed under UN auspices, also deal with stockpile destruction. In addition, the stockpile destruction section of the UN’s Electronic Mine Information Network (E-MINE) provides a consolidated reference point containing technical papers, policy guidelines, lessons learned and other relevant information on the destruction of stockpiles.

The UN has a general responsibility to encourage and support the effective management of stockpile destruction programmes. Thus, for example, according to the UN Development Programme (UNDP), stockpile destruction should form part of each integrated mine action programme that UNDP supports. The GICHD also provides technical assistance for the destruction of stockpiles to States requesting it.
CHAPTER 10

AMMUNITION STORAGE AND STOCKPILE DESTRUCTION

ENDNOTES

1 IMAS 04.10, Second Edition, 1 January 2003 (incorporating amendment numbers 1, 2 & 3) Definition 3.244.

2 ibid., Definition 3.245.

3 IMAS 11.10, Second Edition, 1 January 2003 (incorporating amendment numbers 1, 2 & 3), Section 6.11, p. 6.


5 These are taken from the Electronic Mine Information Network (E-MINE) website maintained by UNMAS, available at www.mineaction.org.


8 ibid., p. 7.


10 The NATO Maintenance and Supply Agency (NAMSA), for instance, will not award contracts for stockpile destruction by open detonation.

11 See www.iso.ch.

12 Further information on the background and contents of the directive may be found on the EU website europa.eu.int/scadplus/leg/en/lvb/l21199.htm.


14 ibid., p. 6.

15 ibid., p. vi.


17 See www.mineaction.org.


19 See www.gichd.org.