International Atomic Energy Agency

Protecting against all possible sources of ionizing radiation through the development and application of state-of-the-art safety standards.

Depleted Uranium

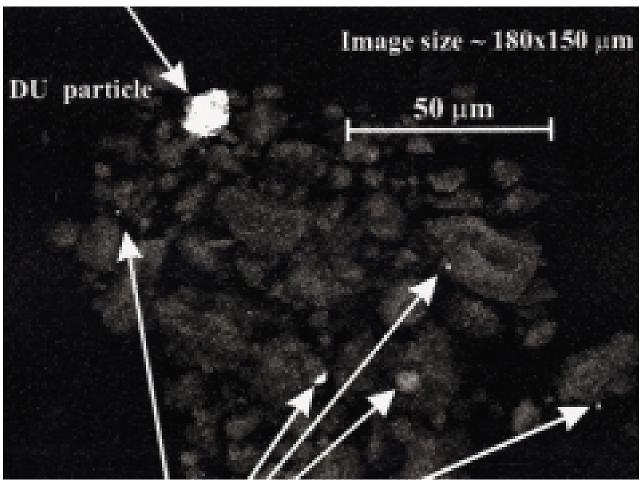
Depleted uranium (DU) is a by-product of the process to make fuel for certain types of nuclear reactors and nuclear weapons. To make such fuel, natural uranium (U) is enriched to increase the amount of the isotope U-235, which is responsible for nuclear fission. The mixture that remains after the enriched uranium has been removed is called depleted uranium because it contains reduced amounts of the isotopes U-235 and U-234. DU is 60% less radioactive than naturally occurring uranium. Chemically, it behaves the same as natural uranium. DU is also a very dense metal, making it suitable for several commercial uses, such as ballast in ships and aircrafts.

DU is also used to make armour-piercing ammunitions. DU ammunitions were first used during the 1991 Gulf War and, more recently, in the conflict involving NATO troops in Kosovo. Concerns have been raised that DU from such ammunitions present in these conflict areas today may pose a risk to the health of those living and working in these areas or to the environment. Such risks could be a result of the chemical or radiological properties of depleted uranium.

Under its Statute, the International Atomic Energy Agency (IAEA) has the specific mandate to establish, in consultation and collaboration with other United Nations and specialized agencies concerned, standards for the protection against ionizing radiation and for the safety of radiation sources and to provide for the application of these standards. With respect to potential radiation hazards, the Agency has jointly developed the International Basic Safety Standards with the World Health Organization (WHO), the International Labour Organization, and the Food and Agriculture Organization. These standards, known as the BSS, cover a wide range of situations that give rise or could give rise to exposure to radiation, such as the radiation hazard posed by depleted uranium.

DU ammunitions used during the Kosovo conflict.
Credit: A. Bleise/IAEA.

Images of DU particles (light areas) obtained by Scanning Electron Microscope equipped with an Energy Dispersive X Ray Fluorescence detector.
Credit: P. Danesi/IAEA.



The BSS sets limits for exposure to any combination of uranium isotopes, including those found in depleted uranium. These limits are based on the recommendations of two expert advisory bodies: the *International Commission on Radiological Protection (ICRP)*, which provides guidance on radiation protection and the *United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)*, which estimates the health effects of radiation. The limits set out in the BSS vary according to whether exposure is to workers or to the general public, but apply to any use of or practice involving ionizing radiation.

The BSS sets the annual dose radiation exposure limits for members of the public and workers at 1 mSv and 20 mSv respectively. In the case of DU, determining whether or not these limits were actually exceeded, for example in post-conflict areas, would require studying a representative group of individuals and calculating their possible doses from exposure to DU particles under the specific conditions present in the area.

Laboratory analysis is an important part of determining potential doses from environmental sources of radiation. Samples likely to be contaminated with radioactivity, which in the case of DU could include soil, trees, or any structures hit by DU ammunitions, must be collected in the field. The Agency's Seibersdorf Laboratory, supported by a global network of expert laboratories, has the capacity to collect and test samples for the presence of a wide variety of radioisotopes. Proper handling and collection of the samples in the field are vital to obtaining quality results. Once the samples reach the laboratory, the next step is to screen them for signs of radioactivity. A gamma spectrometer is one device used at Seibersdorf for this purpose. Should this initial screening detect radioactivity, the next step will be to process the samples for further testing using radiochemical techniques to identify and quantify the source of radiation detected more precisely. In the case of DU, it is also important to determine its physical characteristics (particle size), since the most likely route of exposure is from inhalation of small particles.

The IAEA's Analytical Laboratories Monitoring Environmental Radioactivity (ALMERA) network was established in 1999.

Some 80 laboratories in 65 countries capable of providing radioanalytical support to the Agency in the radiological assessment of areas affected by accidental or intentional release of radioactivity participate in ALMERA.

Radiochemistry, used to identify and quantify the specific radionuclides in the sample, requires destructive analysis of the sample. The equipment and techniques used will depend on what elements are involved — their molecular size and weight and the type of radiation (alpha, beta, or gamma) that they emit. For a heavy isotope like uranium, once the sample has been processed and dissolved, an inductively coupled plasma mass spectrometer (ICP-MS) can be used to analyze for DU. The ICP-MS is able to detect minute quantities of isotopes of uranium and can distinguish between natural and depleted uranium at the parts per trillion level (in samples in solution).

The IAEA, in collaboration with other UN organizations, has assessed other cases of environmental radioactive contamination to determine whether or not they comply with the radiation limits set by the BSS, for example in French Polynesia, the Marshall Islands, Kazakhstan, and Kara Sea. The Seibersdorf Laboratory has also been involved in a number of efforts to monitor a wide range of radioactive elements in the environment, for example in Chernobyl, the Mururoa/Fangataufa Atolls, and Semipalatinsk.

In order for the Agency to undertake a radiological assessment, a formal request must be first made by a Member State, the radiological situation of concern must be well defined (usually through a prior fact finding mission), and financial arrangements must be agreed upon.

If these conditions are met, the IAEA has the expertise to set up and co-ordinate an international study in order to evaluate the radiological situation. This study is generally conducted in four stages:

— determining the source term through an environmental monitoring programme;
— modelling potential transfer pathways from the environment to humans;
— assessing the radiation doses to representative groups of individuals; and
— checking for compliance of doses against the International Basic Safety Standards

Should such a study demonstrate non-compliance with the BSS, the IAEA would recommend possible remedial measures. Should such non-compliance be so extreme as to possibly cause health effects, the WHO would be responsible to deal with these health effects.

With respect to the need to clean up areas where DU weapons were used, the BSS does not include specific criteria to assist in deciding what measures should be taken. However, the ICRP[1] has established dose criteria, which, in principle, could be applied to such decisions. Many radiological protection decisions are based on comparison with an annual dose limit for members of the public of 1 mSv. However, the ICRP has provided guidance using a scale of dose

In November 2000, the IAEA participated in a United Nations Environment Programme (UNEP)-led study of 11 sites where DU ammunitions had been used during the Kosovo conflict. This study concluded that detectable ground surface contamination by DU is limited to areas within a few metres of penetrators and localized points of concentrated contamination caused by penetrator impacts. The mission identified a number of contamination points, but most were only slightly contaminated. The study further concluded that, because of the low levels of radioactivity detected, there is no significant risk related to these contamination points in terms of possible contamination of air, water, or plants. The only risk of any significance was noted to be if someone were to touch a contaminated point, thereby contaminating the hands and risking subsequent transfer to the mouth or if someone directly ingested the contaminated soil. Despite the low risk, UNEP recommends a precautionary approach to identify any sites where DU may remain and assess the need for cleanup. Further study into possible longer term environmental contamination and DU contamination of other areas in the region is recommended.

levels to help practical decision-making in a variety of situations.

[1] *ICRP Publication 82, Pergamon Press 1999.*

Any intervention to clean up will need to be justified from a radiological standpoint on a case-by-case basis. Pre-selected individual dose guidelines can only provide an input to decisions, and no single factor should be overriding. With these provisos, the ICRP has recommended a differentiated approach to intervention on the basis of individual effective dose. In cases where an individual effective dose of 100 mSv is exceeded, intervention should be *"…almost always justifiable"*, while if the individual dose is above 10 mSv, intervention *"…may be necessary"*. In contrast, for doses below 1 mSv intervention is *"…unlikely to be justifiable"*.

In order to decide whether remedial measures (including a cleanup operation) would be justified, it first is necessary to carry out an assessment of the dose received by individuals from DU exposure and to compare these with the ICRP guidelines. Potential doses to the population living in areas affected by DU are shown for a range of different exposure situations in the table below. The doses presented are theoretical doses, based on conservative assumptions.

[i] *S. Fetter and F. N. von Hippel, Science and Global Security, 8:2 125–161, 1999. The UNEP report "Depleted Uranium in Kosovo, Post-Conflict Environmental Analysis" gives similar estimates.*

[ii] *Using maximizing assumptions S. Fetter and F. N. von Hippel have calculated doses of 30 µSv in a year (*S. Fetter and F. N. von Hippel, ibid.*). Maximum doses of between 30 to 100 µSv in a year, depending on the age group considered, were calculated by A. Nusser et al., in a document prepared for the Article 31 Working Group on Depleted Uranium of the European Commission (*Nusser, A., Kugeler, E., and Thierfeldt, S. Estimation of Effective Doses due to Depleted Uranium, Brenk Systemplanung, Aachen, 2001*). Comparable doses were estimated in the UNEP report "Depleted Uranium in Kosovo, Post-Conflict Environmental Analysis".*

Pathway	**Estimated effective dose**	**Remarks**	**Intervention justified?**
Handling of DU projectiles	A few tens of mSv	Based on a contact dose rate of 2 to 2.5 mSv per hours to the skin[i], assuming that a person is in contact with the object for 10% of the time. Comparable to dose received by a person in tanks fully laden with DU munitions.	Intervention may be necessary.
Inhalation of DU aerosol	A few mSv	Likely doses to people inhaling dust when entering military vehicles hit by DU ammunitions.	Doses are in a range where intervention should be considered.
Exposure to DU in the environment	Less than 1 mSv	Doses include those from inhalation and ingestion of dispersed DU aerosol. Probably in the region of a few µSv for most people, even in the vicinity of battlefields[ii].	Doses are below the public dose limit of 1 mSv and probably close to the IAEA *"exemption"* levels.

These theoretical doses indicate that the only remedial measures necessary in post-conflict areas may be to remove DU ammunitions still lying on the ground and, possibly, any armoured vehicles hit by DU projectiles in order to prevent people from coming into direct contact with a potentially contaminated source. The extent of this operation would depend on several factors, such as the number and location of affected areas, the number of DU ammunitions and targets still present. Precautionary measures could also include an information campaign aimed at informing the local population (including military personnel) on the possible risks of DU ammunitions and discouraging them from collecting any found in the area. It is unlikely that an extensive cleanup of the affected areas, where DU ammunitions have been used, such as removal of soil or filtration of drinking water, will be justified on radiological protection grounds.

Based on the information currently available, DU ammunitions do not appear to present a significant risk to health from a radiological point of view. Since only limited studies have been undertaken in post-conflict areas where DU ammunitions were used however, further assessment and studies of DU in such areas would increase the confidence in this observation.

In addition to radiological assessment, the IAEA is also developing a training course to assist Member States in analytical methods and techniques that could be used to detect and measure DU in post-conflict areas. Using practical exercises, case studies, and laboratory work, this course will train participants in techniques to identify, characterize, and monitor sources of depleted uranium. Participants will also be able to learn how to obtain representative samples and reliable data, how to establish the basis for assessing the health significance of any contamination, how to perform radioecological modelling, and how to evaluate the exposure situation. The initiative is part of the ongoing IAEA work to strengthen radiological protection in Agency Member States.

Radiological survey of areas in Kosovo where DU weapons were used. Credit: A. Bleise/IAEA.

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Seibersdorf — Analysis of soil samples from sites in Kosovo where depleted uranium was detected. Credit: P. Pavlicek/IAEA.
Left: Raw soil sample; Center: Processing samples; Right: Analysis on the ICP-MS.