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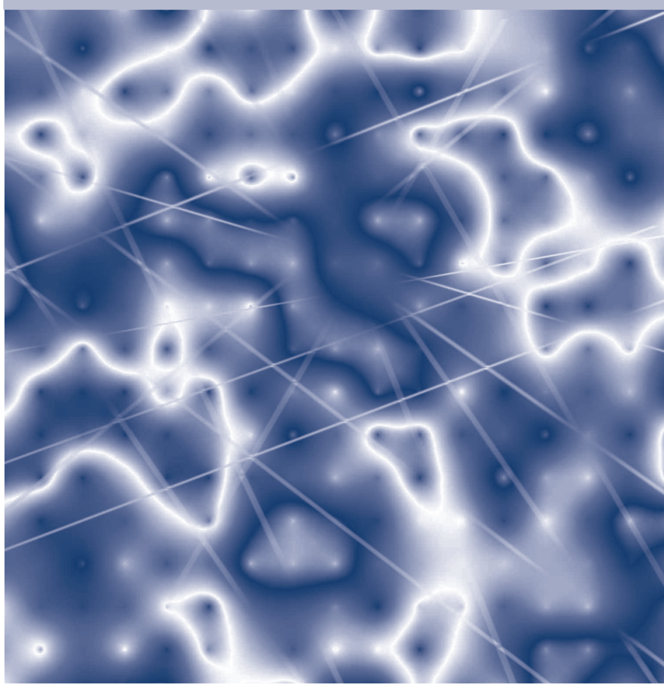

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URANIUM WEAPONS

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EDITOR'S NOTE

This issue of *Disarmament Forum* explores the "hot topic" of uranium weapons. Between calls for a moratorium on uranium weapon use and assurances from national and international sources that these weapons are safe and have valuable military utility, there is both uncertainty and confusion amongst decision makers and the wider public on the scientific and legal debates at hand. What exactly are these weapons and what is their perceived utility? What legal regimes are applicable to their use? What are the known and suspected health and environmental effects? What sort of research needs to be undertaken to have a more complete view of the issues?

The next issue of *Disarmament Forum* will consider small arms issues in West Africa. It will examine small arms transfers and proliferation and analyse some of the activities being undertaken in the region to combat the problem, from government-led initiatives to civil society projects, from technical and legal fixes to peace education. What are the impacts of these programmes? What lessons can be learned for the future? And what are the chances of achieving a real, durable improvement in security for West Africa through small arms control?

On 16 June UNIDIR's conference on Community Security and Operational Effectiveness brought together academics, senior policy-level experts and field practitioners from operational agencies as well as representatives of over thirty-five governments. Participants used experiences from Nepal and Ghana, and elsewhere in Sub-Saharan Africa to demonstrate how a deeper understanding of local cultural realities and security needs of communities can improve project design and increase the effectiveness of field-level operations. The conference was part of UNIDIR's Security Needs Assessment Protocol (SNAP) project. SNAP is working to improve the effectiveness of humanitarian, development and security operations by improving the design of field-level activities that pertain to community security. The objective of the project is to devise a means to assess local security problems as they are understood by community members themselves to assist with programming solutions.

In celebration of the 40th anniversary of the conclusion of the Treaty on the Non-Proliferation of Nuclear Weapons, UNIDIR organized a seminar on 1 July 2008 in Geneva. The anniversary seminar celebrated the *raison d'être* of the Treaty as well as its achievements from 1968 through to 2008. It also examined the NPT's purpose and achievements as the cornerstone of worldwide nuclear disarmament and non-proliferation. After opening remarks from the Director-General of the United Nations Office at Geneva and Secretary-General of the Conference on Disarmament, Sergei Ordzhonikidze, and from the High Representative for Disarmament Affairs, Sergio Duarte (by video), Ambassador Dáithí O'Ceallaigh of Ireland, Ambassador Valery Loshchinin of the Russian Federation, Ambassador John Duncan of the United Kingdom and Garold Larson of the United States of America spoke on the NPT yesterday and today. The seminar concluded with presentations from Ambassador Mohamed Shaker, Vice-Chairman, Egyptian Council for Foreign Affairs and Jozef Goldblat, Resident Senior Fellow at UNIDIR, on the relevance of the NPT.

Audio files for the presentations made at both of these meetings are available for download from UNIDIR's web site, <www.unidir.org>. You can also listen to presentations from the meetings on Disarmament and Non-proliferation Education, Information and Communication Technologies and International Security, and Conventional Arms Control and Disarmament. Where possible, audio proceedings of UNIDIR events will be added regularly from now on, so if you are unable to attend our meetings, be sure to check our web site, where you will to be able to listen at your leisure.

UNIDIR actively participated in the Biennial Meeting of States (BMS) on implementation of the UN Programme of Action on Small Arms and Light Weapons (14–18 July 2008) at UN headquarters in New York. At the opening session of the BMS, UNIDIR and its project partners (UNDP, UN Office for Disarmament Affairs and the Small Arms Survey) distributed their Draft Report analysing the national reports submitted by states between 2002 and 2008; a more detailed overview of the findings was presented on 17 July at a side event seminar. UNIDIR researcher Kerry Maze spoke at the opening session, examining the issue of how to match needs and resources to ensure improved targeting and coordination of international assistance on SALW issues. The following day, at the side event entitled "Making the PoA Work: Three Practical Tools for States", Ms Maze presented UNIDIR's web-based prototype for matching needs and resources. UNIDIR Deputy Director Dr Christiane Agboton Johnson spoke at the panel "Conflict of Interests: Children and Guns in Zones of Instability" organized by the Office fo DA, the Office of the Special Representative of the Secretary-General for Children and Armed Conflict and the International Action Network on Small Arms and featuring Emmanuel Jal, musician and former child soldier.

Kerstin Vignard

The health hazards of depleted uranium

Ian Fairlie

For over two decades, there has been considerable public debate about the health effects of depleted uranium (DU). Military services in many countries use depleted uranium in munitions and to strengthen armour in vehicles. This is because uranium is a very dense metal (approximately 70% more dense than lead), which is useful in a military context—and the chemical and physical properties of natural uranium metal and DU metal are very similar. DU alloys are very hard and pyrophoric, properties which make them superior to tungsten armour-piercing munitions. DU armour-plating is also more resistant to penetration by conventional anti-tank munitions. DU munitions were first used extensively in the First Gulf War (1991), in Bosnia (1995) and Kosovo (1999), and continue to be used in Iraq since 2003 and perhaps in Afghanistan since 2002. Table 1 indicates the amounts of DU used in recent wars by the United States (US) armed forces—the most frequent user of DU munitions.

Table 1. Depleted uranium used by the United States in recent wars (metric tons)

First Gulf War	*Balkan wars*	*Second Gulf War*
286	11	75

Source: National Research Council, 2008, *Review of Toxicologic and Radiologic Risks to Military Personnel from Exposure to Depleted Uranium during and after Combat*, Washington, DC, National Academies Press, Tables 1–4.

On impact, DU may be dispersed as aerosols, which can be inhaled or ingested, or imbedded in tissue as shrapnel. Frequent, continuing reports of illnesses suffered by combatants[1] and civilians[2] in these wars have resulted in speculation that these may be due to DU exposures. (See Box 1 for a discussion of Gulf War Syndrome.)

DU is obtained as a waste product of nuclear power and of the manufacture of nuclear weapons. It is a radioactive heavy metal that can be hazardous to humans in four ways:

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- as a toxic heavy metal;
- as a genotoxic (i.e. carcinogenic and mutagenic) agent from its chemical properties;
- as a genotoxic agent from its radiation; and
- as an endocrine disruptor.

Box 1. Gulf War Syndrome

Many soldiers and civilians from Gulf War areas have self-reported a variety of symptoms, often collectively termed Gulf War Syndrome. The syndrome appears to be a complex, progressive, incapacitating multi-organ system disorder whose symptoms can include fatigue, musculoskeletal and joint pains, headaches, neuropsychiatric disorders, confusion, visual problems, changes of gait, loss of memory, swollen or enlarged lymph nodes, respiratory impairment, impotence and urinary tract morphological and functional alterations.

Whatever the causes, it is clear that the suffering is widespread, measurable and real to those affected. Nearly 20% of all US personnel deployed to the 1991 Gulf War were receiving some form of disability compensation due to these effects by 2001.[a] A number of studies, summarized by Komaroff, have found that armed forces from several countries deployed to the Persian Gulf region were statistically significantly more likely to report chronic, debilitating symptoms than military personnel deployed to other areas.[b] Eisen et al. measured the prevalence of self-reported chronic illness among Gulf War combatants compared to a control group of non-deployed veterans. They found that deployed veterans reported dyspepsia, a group of common skin conditions (fibromyalgia), and chronic fatigue syndrome much more often than the control group. The most striking association was chronic fatigue syndrome.[c]

Some authors[d] have alleged these symptoms may be due, at least in part, to DU exposures. However, many soldiers and civilians reporting these symptoms were clearly unexposed to DU, or were exposed to very small amounts, so the single explanation of DU exposure is highly unlikely.

In addition, many Gulf War personnel were exposed to many substances that in theory could have produced chronic tissue damage: solvents, insecticides, smoke and other combustion products, agents of chemical warfare (irreversible anticholinesterase inhibitors, such as sarin), and pyridostigmine bromide (a reversible anticholinesterase inhibitor taken to prevent the effects of sarin). Also, they received an intensive battery of simultaneously administered immunizations, which some believe[a] could have produced chronic debility.

In conclusion, although our understanding of the aetiologies of these symptoms remains poor to say the least, it is difficult to ascribe anything more than a minor role to DU exposures.

[a] M. Davis, 2003, "Overview of Illnesses in Gulf War Veterans", in J.M. Colwill (ed.), *Gulf War and Health. Volume 2: Insecticides and Solvents,* Washington, DC, National Academies Press, pp. 533–561.
[b] A.L. Komaroff, 2005, "Unexplained Suffering in the Aftermath of War", *Annals of Internal Medicine,* vol. 142, no. 11, pp. 938–939.
[c] S.A. Eisen et al., 2005, "Gulf War Veterans' Health: Medical Evaluation of a US Cohort", *Annals of Internal Medicine,* vol. 142, no. 11, pp. 881–890.
[d] A. Durakovic, 2003, "Undiagnosed Illnesses and Radioactive Warfare", *Croatian Medical Journal,* vol. 44, no. 5, pp. 520–532; R. Bertell, 2006, "Depleted Uranium: All the Questions about DU and Gulf War Syndrome Are Not Yet Answered", *International Journal of Health Services,* vol. 36, no. 3, pp. 503–520.

DU has about 75% of the radioactivity of natural uranium (see below), and the same chemical toxicity, endocrine disruptive property and mutagenicity as natural uranium.

Because of the controversy over DU, uranium is now one of the most studied radionuclides. Over the past decade, there have been at least nine official reports on the toxicity and health effects of uranium and DU.[3] There have also been a number of informative reviews.[4] Until the recent United States' National Research Council (NRC) report, perhaps the most authoritative were the two reports of the United Kingdom's Royal Society on chemically toxic risks and radiation risks, respectively. These stated that there were legitimate concerns about the possible health consequences of using a radioactive and chemically toxic material for munitions, but they concluded that the risks of DU munitions to soldiers were very low.[5] However, since the Royal Society's reports, much new evidence from radiation biology studies has emerged.

There are two main sources of information on DU health risks. The first is epidemiology studies—i.e. studies of DU exposures and possible added risks to human populations. The second is radiation biology studies in cells and animals. As we shall see, much more information on DU's health effects is available from the latter than the former source.

What is depleted uranium?

Natural uranium (U) is a constituent of the Earth's crust at a concentration of about 3 parts per million on average. Some uranium ore regions of the world contain much higher concentrations of uranium—typically about 1,000 parts per million.

In the nuclear power fuel cycle, uranium ore is mined, and uranium is leached from ore and refined to almost pure uranium dioxide (UO_2) for use in nuclear fuel.[6] This natural uranium consists of three main isotopes, U-238, U-235 and U-234 (see Table 2). U-238 and U-235 are primordial—that is, they were created at the same time as the Earth about 4.5 billion years ago. U-234, on the other hand, is a decay product of U-238.

The vital consideration is that U-235 is *fissile,* which means that it can maintain fission in nuclear power stations and can be used in nuclear weapons. Most reactors are designed for uranium fuel that has been slightly enriched in U-235. Typically, the U-235 concentration is required to be increased from 0.7% to between 2% and 4%. This is known as low-enriched uranium (LEU). This concentration is effected by the process of enrichment, whereby UO_2 is converted to a gas (uranium hexafluoride, UF_6) and passed through gaseous diffusion or centrifuge facilities. U-235 is also a vital ingredient of many nuclear weapons but here the enrichment required is to about 90% U-235. This is termed highly enriched uranium (HEU).

The enrichment processes for nuclear weapons and nuclear fuel create about 7 metric tons of depleted uranium for each metric ton of enriched uranium produced. The result is that very large quantities of depleted uranium are produced as waste streams. In 1996, worldwide production of DU was estimated by the European Parliament's Science and Technology Options Assessment (STOA) panel at about 35,000 metric tons.[7] As a result, it is estimated that over 1.2 million metric tons of DU are currently stockpiled worldwide, mostly in the United States.[8]

DU is used in radiation screens and, in the past, has been issued in counterweights in aeroplane wings; however these uses are small in comparison with the amounts generated each year. The largest users of DU are military services, although the STOA report estimated that the total quantity of DU in ammunition used in Iraq and Kosovo corresponded to only four days of DU production worldwide. Therefore DU stockpiles worldwide are increasing at the rate of about 35,000 metric tons per year and they pose serious disposal problems to governments involved with uranium enrichment.

How radioactive is DU compared to natural uranium?

This is an easy question to ask, but difficult to answer. Many reports state that DU has 60% of the radioactivity of natural uranium. However, the correct figure is closer to 75% for two reasons: enrichment facilities sometimes use reprocessed uranium (as opposed to 100% mined uranium), and all forms of DU contain decay products.

Table 2. Main isotopes in natural and depleted uranium at the factory

Isotope	*Half-life (years)*	*Specific alpha activity (Bq per gram)*	*Concentration in natural uranium (weight %)*	*Concentration in depleted uranium (weight %)*
U-234	2.46×10^5	2.31×10^6	0.0055	0.001
U-235	7.04×10^8	7.99×10^4	0.72	0.2
U-236	2.34×10^7	2.40×10^6	nil	0.0003 from reprocessed uranium
U-238	4.47×10^9	1.24×10^4	99.3	99.8
Natural U	-	2.53×10^4	-	-
Depleted U	-	1.42×10^4	-	-

Source: Royal Society, 2001, *The Health Hazards of Depleted Uranium Munitions: Part I,* London.

The use of reprocessed uranium in DU

Depleted uranium as used by the US military contains the isotope U-236 (see Table 2), which is not present in natural uranium. This isotope arises only in nuclear reactors and its presence indicates that the DU batch contains some uranium from the waste streams of reprocessing spent nuclear fuel—carried out mainly by France, the Russian Federation, the United Kingdom and the United States. Thus there are two types of depleted uranium—both come from the enrichment process, but one includes small amounts of reprocessed uranium from spent nuclear fuel.

This is a problematic matter because reprocessed uranium is contaminated with the fission and activation products of spent fuel. In particular, the fission product Tc-99 and the activation products Np-237, Pu-238, Pu-239, Pu-240 and Am-241 are sometimes found in DU munitions.[9] Depleted uranium made with some reprocessed uranium is therefore more radioactive than the DU derived solely from mining uranium ores.[10] Most reports state that the amounts of contaminants in DU munitions from spent nuclear fuel are low. According to the US Office of the Special Assistant for Gulf War Illnesses, the dose from these contaminants amounts to less than 1% of the equivalent dose from DU exposures, and the authors concluded that their risk impact was low.[11] The Royal Society also stated that these concentrations had been found to be low in the DU batches it had examined, but it recommended continued vigilance on the matter.[12]

Uranium decay products

Once DU has been made into munitions and placed in a warehouse, its U-238 and U-235 isotopes decay and create various daughter products as shown in Tables 3 and 4, respectively. Within about six months, these daughters are in secular equilibrium with their parents, i.e. the amounts of the daughters being created by the parent are equal to the amounts of the daughters disintegrating. Therefore the radiation from these decay products should be added when assessing the dangers of DU. The key matter is that the decay products are beta emitters, especially Pa-234m, which emits very energetic beta particles. As explained in the Royal Society report of 2001, these beta radiations may constitute as much as 40% of the absorbed dose[13] to tissues near embedded DU. It is important to realize that this additional risk from the beta particles of decay products is currently not taken into account by the International Commission on Radiological Protection (ICRP) in its dose coefficients (which estimate the radiation doses from incorporated radioactive substances) for uranium isotopes.

Bishop[14] has estimated the total alpha, beta and gamma emissions per year from 1g samples of natural uranium and DU. He concluded that DU together with its decay products in equilibrium are 75% as radioactive as natural uranium plus its decay products. The report to the European Parliament's STOA panel, using a cruder method, estimated that DU is 80% as radioactive as natural uranium. This means that the adjective "depleted" may give a misleading impression: a more accurate description would be the phrase "slightly less radioactive".

Table 3. U-238 decay series[a]

Nuclide	*Half-life*	*Decay*	*Energy (MeV)*
U-238	4.5 x 10^9 years	alpha	4.198
Th-234	24 days	beta	0.199
Pa-234m	1.2 minutes	beta	2.271
Pa-234	6.7 hours	beta	0.471
U-234	2.5 x 10^5 years	alpha	4.775

[a] truncated after U-234 because its very long half-life ends the decay chain for practical purposes.

Table 4. Truncated U-235 decay series

Nuclide	*Half-life*	*Decay*	*Energy (MeV)*
U-235	7.0 x 10^8 years	alpha	4.596
Th-231	26 hours	beta	0.390
Pa-231	3.3 x 10^4 years	alpha	5.059

Pathways for DU exposures

DU in the environment

DU exposures can occur via several pathways. One is external radiation, whereby beta radiation (and, to a much lesser degree, gamma radiation) from the decay products of DU irradiate the body, but in most cases such exposures are very small. More important are the internal exposures resulting from inhalation of DU aerosols and dusts, from ingestion of DU-contaminated water and food, and from wounds, i.e. inoculation by DU shrapnel.

When DU projectiles penetrate armoured vehicles, their occupants are often injured by DU shrapnel, which can remain in the body for lengthy periods. When tanks are struck by DU projectiles, depending on the material and thickness of their armour, about 10%[15] is volatilized into an aerosol that immediately burns to form poorly soluble uranium oxides that may remain in high concentrations in enclosed spaces, i.e. tanks and bunkers. These aerosols can contain very small particles of uranium oxide of between 0.1 and 10 microns[16] in diameter, which can be inhaled and deposit in the lungs. White blood cells scavenge these particles and transport them to tracheobronchial lymph nodes for lengthy periods. These particles are usually insoluble, and are unlikely to be detected in urine samples. Therefore the practice of routine urine sampling of returning soldiers may be ineffectual at detecting uranium oxide exposure.

DU in humans

Initial distribution of uranium compounds strongly depends on their solubility and absorption route. Large fractions of administered soluble uranium compounds are absorbed. For example, 20% to 30% was found in the bones of male rats within 2.5 hours of uranium administration, and 90% of the uranium remaining after 40 days was in the bone.[17]

Uranium compounds are distributed to all tissues, preferentially bone, kidneys, liver and testes.[18] Rats implanted with DU pellets also show uranium concentrations in the heart, lung tissue, ovaries and lymph nodes.[19] Like many heavy metals, uranium reacts with DNA and ions and blood proteins to form compounds (called complexes). Uranium can cross the placenta and the blood–brain barrier and accumulate in the brain. Soluble uranium compounds are cleared more rapidly than insoluble compounds: two-thirds of uranium in blood is excreted in urine over the first 24 hours. Elimination of soluble uranium is primarily by the kidneys and urine. The release of DU from embedded particles in shrapnel is slow: it takes 1.5 years for 80–90% of uranium in bone to be excreted.[20]

Health effects of DU

Since the Second World War, it has been known that uranium, a radioactive heavy metal, is hazardous to humans in at least two ways. Like other heavy metals, such as chromium, lead, nickel and mercury, uranium is chemically toxic to kidneys, the cardiovascular system, liver, muscle and the nervous system. Also, since all uranium isotopes are radioactive, they emit radiation—a known carcinogenic agent. This was thought to be of concern mainly when uranium was inhaled as aerosols or dusts because their long residence times in the lung could result in lung cancers.

This means that, in the United States, which perhaps has the most detailed regulations covering uranium, uranium exposures are regulated by radiation protection and chemical regulation authorities in two different ways: by maximum doses from uranium radiation exposures to the lung via insoluble uranium particles; and by maximum concentrations of soluble uranium chemicals, particularly in the kidney.[21] Uranium's chemical toxicity effects generally occur at lower uranium concentrations than its radiation effects.[22]

Chemical carcinogenicity of DU

Scientists are increasingly aware that uranium and DU are hazardous to humans in a third way: they are chemically (as well as radiologically) carcinogenic. This considerably increases our perception of the hazards of DU and natural uranium because low concentrations of soluble uranium throughout the body—previously considered to be harmless (and therefore neglected)—may be carcinogenic without threshold. In other words, no matter how low the DU or uranium concentration, a small risk of chemical carcinogenesis remains. However, Taylor and Taylor estimated that these risks were very low.[23]

Low concentrations of soluble uranium throughout the body—previously considered to be harmless—may be carcinogenic.

The Royal Society's report of 2001 discussed the emerging evidence of DU's chemical carcinogenicity, and suggested that uranium's chemical and radiation effects may act synergistically, that is, their effects may need to be multiplied together rather than added together. More recently, the NRC report examined uranium's chemical carcinogenicity and expressed variable views. For example, chapter 7 called for research on "whether" a chemical mechanism of uranium carcinogenesis existed. However, chapter 8 recommended that studies be conducted to determine the relative contributions of the chemical and radiological mechanisms of uranium carcinogenesis.[24]

Uranium as an endocrine disruptor

Recent evidence from the United States suggests that DU may be hazardous to humans in a fourth way: it may act as an endocrine disruptor, that is, a substance that interferes with hormones. A number of studies have indicated that heavy metals may act as endocrine disruptors.[25] For example, cadmium stimulates the proliferation of human breast cancer cells,[26] interacts with estrogen receptors[27] and stimulates estrogenic responses *in vivo*.[28]

Raymond-Whish et al. tested whether depleted uranium added to drinking water caused responses in the female mouse reproductive tract like those caused by the estrogen diethylstilbestrol.

They concluded that uranium is an endocrine-disrupting chemical and that populations exposed to environmental uranium (including indigenous populations in the United States living near uranium mine tailings) should be examined for increased risk of fertility problems and reproductive cancers. [29]

Cell, animal, human and epidemiological studies

Human cell evidence (*in vitro* studies)

A comprehensive body of research indicates that the exposure of human cells *in vitro* to DU results in genotoxic effects and induces cell phenomena closely associated with carcinogenesis. These cell phenomena include the following:

- genomic instability—a process involved in carcinogenesis;[30]
- transformation to a tumorigenic state, whereby affected cells grow as cancers when injected into mice;[31]
- induction of mutations whose presence characterizes most cancers;[32]
- DNA oxidative damage;[33]
- activation of gene expression pathways;[34]
- formation of DNA-U adducts;[35]
- induction of dicentrics in chromosomes—a radiation-specific change in human cells;[36] and
- chromosomal damage.[37]

Animal evidence (*in vivo* studies)

Long-term studies in monkeys of uranium oxide (i.e. insoluble) inhalation indicate the carcinogenicity to the lung of this kind of exposure and possibly its involvement in non-Hodgkins lymphoma.[38] Monleau et al. measured the induction of DNA double strand breaks by inhaled DU in rats.[39] Hahn et al. found an elevated risk of cancer in rats implanted with small DU foils. They concluded that DU fragments embedded in muscle tissue were carcinogenic if large enough; however, they stated the mechanism was unclear.[40]

After mice were exposed to embedded DU for 3 months then injected with progenitor cells, Miller et al. found that 75% of mice developed leukaemia (compared with 10% in control mice). In addition, mice showed changes in the musculoskeletal system, i.e. bone formation and remodelling, after oral, intraperitoneal, intravenous and implantation uranium exposure.[41]

In vivo studies with embedded DU pellets in animals showed aberrant expression of oncogenes and tumour suppressor genes associated with carcinogenesis.[42] Although these effects may be caused by DU radiation, there are many reasons suggesting that its chemical effects predominate. In the *in vitro* transformation and sister chromatid exchange studies, induced effects were very much more frequent than expected from the very small number of cells hit by an alpha particle (1 in 100,000 cells from a 10μm-sized particle of DU). In addition, similar transformation frequencies were observed with the non-radioactive heavy-metal carcinogens nickel and lead; it was speculated that DU's genotoxicity may be due to uranyl ions acting to produce free radicals, especially if the ions are effectively chelated to DNA like other metal ions.[43]

Human evidence

Uranium is a well-established nephrotoxin (i.e. it is toxic to kidneys) in humans, the primary target being the proximal tubule. Damage occurs when uranium forms complexes with the phosphate ligands and proteins in tubular walls, which impair kidney function. Biomarkers of these tubular effects include enzymuria and increased excretion of small proteins, amino acids and glucose. Uranium is also a bone seeker and is incorporated into the bone matrix by displacing calcium to form complexes with phosphate groups.[44]

McDiarmid et al. observed a statistically significant increase in mutations in peripheral lymphocytes in three US Gulf War veterans with embedded DU fragments reflected in measurements of uranium in urine. However, their continuing surveillance (for 14 years) has yielded no evidence of reproductive system dysfunction in males, abnormalities in sperm or alterations in neuroendocrine function.[45] Nevertheless, it should be recalled that soldiers are a healthy subset of the wider population, and the numbers of exposed soldiers in these studies are relatively small. Monleau et al. found that repeated uranium inhalations tended to potentiate, that is, increase the effect of or act synergistically with uranium's genotoxic effects.[46] Zaire et al. observed the induction of chromosome aberrations in uranium mineworkers in Namibia.[47] Such rearrangements of genetic material in chromosomes are involved in the carcinogenic process.

Epidemiological studies

Few human epidemiology studies have showed convincing effects from DU exposures. The Royal Society examined 14 epidemiological studies of occupational uranium exposures to workers engaged in the extraction, milling and machining of uranium.[48] These showed no sign of excess deaths due to cancer or kidney disease related to inhaling or ingesting uranium. However, the report stressed that these studies should be interpreted with care. First, there were few reliable data on uranium exposure levels to workers, especially in the early years of uranium processing, when exposures due to inhalation of uranium-containing dust were thought to be high. In addition, smoking was a powerful confounder, causing approximately 90% of lung cancers, and information on smoking habits was not available for any of the studies. Another problem was the healthy worker effect, which meant that risk comparisons should be made with other workers and not the general population. The report stressed that these types of epidemiological studies are not able to detect small increases in risk, although a twofold increase might have been detectable.

In addition, a cardinal rule in epidemiology is that absence of evidence in a study should not be used to allege evidence of absence.[49] It many cases, it may mean that the study was not powerful enough to detect an increased risk.

A number of studies have examined health effects in military personnel,[50] but their brief exposures to uranium dusts and aerosols have been much lower than those experienced by uranium mining and milling activities. Unfortunately, very few studies have been made of the many civilians exposed to DU in various conflicts.[51] Those carried out raise as many questions as answers, especially on the unusually low incidence rates of congenital malformations in Iraq pre-1990.[52] Hindin et al. carried out an extensive literature review of congenital malformations following DU exposures in US military personnel and concluded that the human epidemiological evidence was consistent with increased risk of birth defects in offspring of persons exposed to DU.

Possible synergism between radiation effects and chemical effects

Many studies clearly indicate that DU has both chemically induced and radiation induced effects. An important question is whether synergism exists between these two effects, i.e. whether they potentiate one another. There is suggestive evidence for this:

- synergistic responses when nickel exposures are combined with gamma radiation;[53]
- bystander cells (i.e. unirradiated) are vulnerable to both radiation-induced and chemical-induced effects.[54]

A number of authors have theorized that synergism may occur. For example, Miller et al. specifically proposed that DU's radiological and chemical effects might play tumour-initiating and tumour-promoting roles.[55] If this were the case, it would be a clear example of synergism.

In addition, the Royal Society stated:

> One could speculate … that the potential for synergistic effects between the radiation and chemical actions of DU would be greatest in the vicinity of particles or fragments of DU, from which essentially all the surrounding cells are chemically exposed and may thereby be sensitized to the occasional radioactive decay particle.[56]

It concluded that further studies were required to examine the possibility of synergy between the chemical effects and radiation effects of DU. The NRC report also recommended that studies be conducted to determine the relative contribution of chemical and radiological mechanisms of uranium carcinogenesis. It added that if the chemical contribution were found to be substantial, studies should then be undertaken to calculate cancer risks resulting from DU's combined chemical and radiological effects.

Conclusions

Despite the existence of many reports on DU, it remains difficult to assess whether (and if so to what degree) DU exposures have caused increased incidences of ill health among exposed soldiers and others. This is because of the inconclusive findings of some of the reports; the large uncertainties in the assessed doses and risks from DU exposures; the possible presence of confounders; and the paucity of data from battlefield and other exposures. In other words, the available epidemiological data are sparse and inconclusive.

However, as shown above, we have two main sources of data to derive uranium's risks—animal and cell studies as well as epidemiological studies. In fact, uranium's chemical risks are derived from the former for safety regulation purposes. In general terms, the risks of almost all chemicals are based on the concentrations found not to be harmful in animals. These concentrations are divided by safety factors of 10 to 1,000 then applied to humans, i.e. acceptable concentrations for humans are 10 to 1,000 times safer than those in animals. This rather simple system works well and is clearly precautionary.

With radionuclides, this precautionary approach is not used. Instead, radiation scientists insist that human data (i.e. from epidemiology studies) must be used to derive risks. Many may think that these are a better source because humans are different from animals and cells, and in theory this is correct. But in practice it is less clear cut: there are a large number of practical difficulties with epidemiology studies. In essence, they are a blunt tool for investigating risks, and insisting on using such studies alone rather than relying on cell and animal studies as well means that we might be underestimating DU risks.

The problem is that sole reliance on epidemiological data tends to downplay the substantial body of radiobiological evidence that overwhelmingly points to DU as a very hazardous substance.[57] This evidence points to DU being:

- a chemical carcinogen mutagen and teratogen;
- a radiological carcinogen mutagen and teratogen;
- a chemical toxin with pronounced effects on kidneys and other organs; and
- an endocrine disruptor.

Indeed, continued reluctance to act on the many research findings from radiobiology could be considered a breach of the precautionary principle in law.[58]

Sole reliance on epidemiological data tends to downplay the substantial body of radiobiological evidence that overwhelmingly points to DU as a very hazardous substance.

Given the preponderance of cell and animal studies indicating that DU is a very hazardous substance, the safest approach would be to seek a moratorium on its use. It is notable that, in December 2007, the UN General Assembly carried a motion by 136 votes to 5, recognizing the health concerns over the use of uranium weapons and requesting that states report to the Secretary-General on the matter.[59] Also in May 2008, the European Parliament carried a motion that strongly reiterated its call on all European Union member states and North Atlantic Treaty Organization countries to impose a moratorium on the use of depleted uranium weapons and to redouble efforts toward a global ban. The resolution was adopted with 491 votes in favour, 18 against and 12 abstentions.[60]

Recommendations

It is recommended that, for practical purposes, DU should be treated as being equally as radioactive as natural uranium. As regards the dose coefficients for DU and uranium, a precautionary approach would be to assume that their uranium isotopes coexist in equilibrium with their main decay products (the ICRP assumes the opposite). This means that the dose coefficients for U-238 should be increased by about 40%. This would result in uranium and DU doses (and risks) being increased by about 40%.

It is also recommended that isotope surveillance should be maintained on new batches of DU to ensure that reprocessed DU is not being added to DU obtained from uranium ore.

Further research

There have been many attempts in the literature to assess likely exposures and risks to military personnel from Gulf War operations and correspondingly few among civilians. Most military studies have concluded that the estimated exposures and resulting risks are minor and too small to be detected in epidemiology studies among the relatively few DU-exposed soldiers. In light of this, further studies of military personnel do not seem to be merited. Instead, research should be carried out on the health impacts among the tens of thousands of Iraqi civilians estimated to have been exposed to DU and their offspring. Populations exposed to DU and natural uranium should be examined for increased risk of fertility problems and reproductive cancers.

It is also recommended that further radiobiological research be carried out into possible synergistic effects of DU exposures. Finally, further research should investigate the properties of DU as a possible endocrine disruptor.

Notes

1. See, for example, Naomi Harley et al., 1999, *A Review of the Scientific Literature as It Pertains to Gulf War Illnesses, Volume 7: Depleted Uranium,* Santa Monica, CA, RAND Corporation.
2. See, for example, M. Aitken, 1999, "Gulf War Leaves Legacy of Cancer", *British Medical Journal,* August, vol. 319, p. 401.
3. National Research Council, 2008, *Review of Toxicologic and Radiologic Risks to Military Personnel from Exposure to Depleted Uranium during and after Combat*, Washington, DC, National Academies Press; M.A. Parkhurst et al., 2004, *Depleted Uranium Aerosol Doses and Risks: Summary of U.S. Assessments,* Battelle Press; Royal Society, 2001, *The Health Hazards of Depleted Uranium Munitions: Part I,* London; Royal Society, 2002, *The Health Hazards of Depleted Uranium Munitions: Part II,* London; World Health Organization, 2001, *Depleted Uranium: Sources Exposures and Health Effects,* WHO document WHO/SDE/PHE/01.1, Geneva; Carolyn E. Fulco et al. (eds), 2000, *Gulf War and Health, Volume 1: Depleted Uranium, Sarin, Pyridostigmine Bromide, Vaccines,* Washington, DC, National Academies Press, chapter 4; Office of the Special Assistant for Gulf War Illnesses (OSAGWI), 2000, *Environmental Exposure Report: Depleted Uranium*; Harley et al., op. cit.; Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services, 1999, *Toxicological Profile for Uranium,* Atlanta, GA.
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6. Uranium mining is highly destructive of local environments and uranium refining creates large quantities of radioactive tailings, which continue to release large quantities of the radioactive gases radon and thoron for millennia.
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8. Wise Uranium Project, *Depleted Uranium Inventories,* at <www.wise-uranium.org/eddat.html>, last updated 21 April 2008.
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Depleted uranium weapons: the next target for disarmament?

Avril McDonald

Disarmament efforts have reaped a number of notable successes over the past years. These endeavours have not been completely random, but have generally aimed at putting beyond use and out of circulation weapons that may breach the law of armed conflict (LOAC).[1] States moved from banning chemical weapons in 1993 to outlawing blinding lasers in 1995, and then anti-personnel mines in 1997.[2] The latest disarmament campaign has succeeded in prohibiting cluster munitions (for those states that join the 2008 Convention on Cluster Munitions).[3] Which problematic weapons should be next in line for a treaty ban or restriction? Many believe that prime candidates are weapons containing depleted uranium.[4]

Depleted uranium's military applications and utility

A by-product of the uranium enrichment process, depleted uranium (DU) is an extremely dense material, which is alloyed with other metals principally to make armour-piercing ammunition and to harden armour used to shield military vehicles.[5] Armour-piercing incendiary projectiles that contain DU are designed to penetrate hard targets, such as tanks, armoured personnel carriers and concrete bunkers. The DU penetrator contains no explosive charge but relies on kinetic energy; its density and velocity allow it to bore through targets without buckling or losing much speed.[6] The energy and heat released when the DU comes into contact with air inside the target cause it to ignite. The crew risks death or disablement from the spalling and fire inside the target, which may explode if a vehicle's fuel tanks ignite.

Although approximately 18 states[7] possess or are developing DU ammunition, most DU has been shot by the United Kingdom and the United States.[8] Both states claim that the use of DU ammunition is militarily necessary on account of its superior ability to penetrate hard armour compared with tungsten (the main alternative).[9] Depleted uranium is also cheaper to purchase than tungsten and more widely available. Moreover, its density and velocity mean that pilots who air-deliver DU can shoot at a greater distance from their targets, increasing their safety.[10]

The controversy surrounding the use of depleted uranium

DU's military applications have provoked controversy since the weapon's first battlefield testing during the 1991 Gulf War.[11] After that conflict, some persons who either did or might have come into contact

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with DU metal or dust, either directly or indirectly, began to exhibit a host of pathologies, which have collectively come to be known as Gulf War Syndrome.[12] After subsequent military uses of DU in the Balkans, a range of illnesses, collectively dubbed "Balkan War Syndrome", was reported among some military personnel.[13] None of these conditions have ever been conclusively linked with DU,[14] and those states that consider its use militarily necessary have dismissed any suggestion that exposure to DU might be a causal factor.[15] But, as Fahey notes, "[a]bsence of evidence should not be interpreted as evidence of absence, however, as there have been few long-term health studies of soldiers or civilians with confirmed DU exposure."[16] Nor have there been comprehensive epidemiological studies where DU has been used, i.e. Afghanistan, Bosnia, Iraq, Kosovo, Kuwait and Serbia.

Despite the current knowledge gaps regarding the effects of exposure to DU, given what is already known about the substance it would be negligent to discount it as a possible causal factor. It is beyond dispute that DU is toxic and radioactive,[17] and is known to be hazardous for human health in certain exposure scenarios.[18] Those persons at greatest risk are personnel inside targets struck by a DU penetrator or those that enter such targets immediately afterwards.[19] Civilians living close by hit sites may also be at risk. A growing body of evidence links DU exposure with pathologies in laboratory animals and human cells, and the limited testing that has been carried out indicates that contact with high levels of DU may cause pathologies such as kidney damage and cancer.[20]

Depleted uranium's current status under disarmament law

It has been posited that DU weapons are already prohibited by international law, despite the absence of a discrete disarmament treaty.[21] DU weapons do share some properties of weapons (both conventional and weapons of mass destruction) already addressed by arms control law. However, even if DU weapons can be toxic and radioactive, or can have incendiary or poisonous effects, that does not mean that they meet the legal definitions of nuclear, radiological, toxin, chemical, poison or incendiary weapons. Generally speaking, under international law, the defining feature of all of these types of weapons is that they are specifically designed (and/or used) to kill or injure by means of their particular characteristic property, and this is not the case for DU weapons.

DU weapons are not nuclear weapons

As there is no international convention prohibiting nuclear weapons, there is no universally agreed definition. However, it seems from existing controls on the manufacture and use of nuclear weapons that depleted uranium armaments cannot be considered as nuclear weapons.

Protocol III to the Modified Brussels Treaty of 1954 on the Control of Armaments defines an atomic weapon as "any weapon which contains, or is designed to contain or utilise nuclear fuel or radioactive isotopes and which, by explosion or other uncontrolled nuclear transformation of the nuclear fuel, or by radioactivity of the nuclear fuel or radioactive isotopes, is capable of mass destruction, mass injury or mass poisoning".[22] Article 1(c) of the Treaty on the Southeast Asia Nuclear Weapon-Free Zone defines a nuclear weapon as "any explosive device capable of releasing nuclear energy in an uncontrolled manner but does not include the means of transport or delivery of such device if separable from and not an indivisible part thereof".[23]

DU weapons are not explosive devices. Nor are they used with the purpose of killing by radiation. It is unsettled whether they are capable of mass destruction, mass injury or mass poisoning. In any event, the International Court of Justice (ICJ) in its Advisory Opinion on the *Legality of the Threat or Use of Nuclear Weapons* found that "[t]here is in neither customary nor conventional international law any comprehensive and universal prohibition of the threat or use of nuclear weapons as such".[24]

DU weapons are generally not radiological weapons

Radiological or radiation weapons are designed to kill or injure as a direct consequence of dispersing radiation—usually by means of an explosion—and inducing radiation sickness. An example of such a weapon is a so-called dirty bomb. While armour-piercing projectiles containing DU may spread radiation as a secondary effect of penetrating targets, it is not the primary purpose and effect of their use. However, one cannot exclude the possibility of DU being used in a dirty bomb with the express intention of indiscriminately killing civilians. Thus, a DU weapon could conceivably be considered as a radiological weapon in some (limited) cases.

DU weapons are not chemical weapons

DU weapons do not appear to meet the definition of chemical weapons set out in Article II of the 1993 Chemical Weapons Convention (CWC). DU is not among the toxic chemicals or their precursors listed in the Annex on Chemicals to the CWC. Nor are DU weapons specifically designed to cause death or other harm through the toxic properties of toxic chemicals and their precursors. While the 1925 Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare (1925 Gas Protocol) does not specifically require these effects to be primary and not secondary or unintended results of the use of a weapon, the majority of jurists consider this requirement to be implied.[25] In the case of DU, its chemically toxic effects are a side-effect of its combat use.

DU weapons are not biological or toxin weapons

DU weapons do not fit the definition of biological weapons as laid down in the 1972 Biological and Toxin Weapons Convention (BTWC), as it is concerned with "[m]icrobial or other biological agents or toxins" and "[w]eapons, equipment or means of delivery designed to use such agents or toxins for hostile purposes or in armed conflict." (Article I.) Although the BTWC does not define bacteriological (biological) weapons, it is accepted that they refer to weapons that spread living organisms, which can kill or injure when used for hostile purposes.[26]

DU weapons as conventional weapons

Few conventional weapons are addressed by arms control law. And depleted uranium weapons cannot be considered among the ones that are, including those that they ostensibly most closely resemble, namely incendiary and poison weapons.

DU weapons are not incendiary weapons

Protocol III of the Convention on Certain Conventional Weapons states that incendiary weapons do *not* include munitions designed to combine penetration, blast or fragmentation effects with an additional incendiary effect, such as armour-piercing projectiles, fragmentation shells, explosive bombs and similar combined-effects munitions in which the incendiary effect is not specifically designed to cause burn injury to persons, but to be used against military objectives, such as armoured vehicles, aircraft and installations or facilities (Article 1(1)(b)(ii)). This clearly excludes DU munitions.

DU weapons are not poison weapons

Poison or poisonous weapons are those that are specifically designed or intended to have this effect. According to the ICJ, such weapons "…have been understood, in the practice of States, in their ordinary sense as covering weapons whose prime, or even exclusive, effect is to poison or asphyxiate."[27] Any toxicological effects of DU are secondary and incidental. As the ICJ was unwilling to find nuclear weapons to be poison weapons,[28] perforce the definition would exclude DU weapons, whose toxicological effects are relatively less pronounced.

Depleted uranium use as a violation of the law of armed conflict?

As DU is not the subject of any existing disarmament agreement, currently the only possible restrictions on its use arise under LOAC. With the exception of poison weapons[29] and expanding bullets,[30] LOAC does not impose any absolute prohibition on the use of any weapon. This means that the legality of the use of any weapon under LOAC is case specific.

In battle, the use of weapons is largely guided by the principle prohibiting superfluous injury and unnecessary suffering to combatants and the principles of distinction and proportionality. It is these principles of LOAC that are in any case of most practical relevance to DU use.

The principle prohibiting superfluous injury and unnecessary suffering to combatants

This "cardinal principle" of LOAC[31] prohibits the use of weapons of a nature or designed to cause (that have the effect of causing)[32] superfluous injury or unnecessary suffering to enemy combatants.[33] There is a minimum threshold of injury or suffering that could potentially be considered as superfluous and unnecessary, i.e. "a harm greater than that unavoidable to achieve legitimate military objectives".[34] For example, if a weapon needlessly aggravates the suffering of personnel who will be killed anyway, or if it renders their death inevitable where it is not necessary to kill them, it would have crossed this threshold.[35] But even then, whether this is considered as superfluous injury or unnecessary suffering will depend on the military necessity of the weapon's use. If the weapon provides a military advantage not otherwise available, the suffering and injury will be justified because it is necessary and not superfluous.

A bone of contention is whether this principle applies only to anti-personnel weapons or also anti-materiel weapons.[36] If it were to be considered to apply only to the former, it would mean that LOAC would offer few restrictions on the use of DU weapons vis-à-vis combatants, given that it is mainly designated and used as an anti-materiel weapon. But, arguably, the principle can be and is applied to both types of weapons, both at the point of legal review of a weapon and during military operations.[37]

If the principle were to be applied to DU weapons used against both materiel and personnel, the test would be: does the suffering and injury caused to combatants go beyond the required threshold? In that case, is it necessary (and therefore not superfluous) because no other weapon can match or outperform a DU weapon? It is difficult to answer either of these questions categorically in the affirmative when DU is used against materiel. The gaps in knowledge regarding DU's effects mean that it cannot yet be asserted with certainty that DU will permanently disable combatants in all cases of its use, or render their death inevitable, and the user states claim that no alternative munition exists with comparable military utility. Still, in the majority of cases of its use, tungsten would in fact suffice. As there seems to be no military necessity for using DU against personnel, provided that the suffering and injury caused to combatants exceeds the minimum threshold, DU use could be considered as breaching the principle as there are many more effective ways of disabling combatants.

The principle of distinction, including the proportionality principle

Although DU use per se cannot be said to violate the principle of distinction between combatants and civilians (codified in Article 51 of 1977 Additional Protocol I to the Geneva Conventions), arguably, in certain cases, its use might constitute an indiscriminate attack. "Since the use of DU weapons in combat results in an uncontrolled release of DU",[38] it is "a method or means of combat the effects of which cannot be limited", a definition of discriminate attack according to Article 51(4)(c) of Additional Protocol I. When used against military objectives in urban areas, it is impossible to spatially restrict DU's spread. Considering that most DU falls within 50m of its release, but that it can travel up to 400m from the hit site immediately following an impact,[39] any civilian within this radius runs the risk of being exposed to its radioactive and toxic effects.

Although DU use per se cannot be said to violate the principle of distinction between combatants and civilians, arguably, in certain cases, its use might constitute an indiscriminate attack.

Regarding another relevant definition of indiscriminate attack, it is difficult to be categorical about whether the use of DU weapons against military objects could cause disproportionate civilian casualties in any case of their use,[40] due to the lack of complete certainty regarding the effects of DU weapons and the difficulty in concluding whether these are then excessive compared to the military necessity of their use.

The principle of precaution

Parties to armed conflicts are required to ensure that precautions are taken in planning and conducting military operations to minimize their effects on civilians (Article 57 of 1977 Additional Protocol I). Of particular relevance are Article 57(2)(a)(ii), requiring military commanders to "take all feasible precautions in the choice of means and methods of attack with a view to avoiding, and in any event to minimizing, incidental loss of civilian life, injury to civilians and damage to civilian objects" and Article 57(2)(a)(iii), requiring parties to "refrain from deciding to launch any attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated". Along with Article 51(4)(c), this could provide a legal basis for restricting the use of DU.

Parties to an armed conflict are also obliged, to the extent feasible, to take the necessary precautions to protect the civilian population, individual civilians and civilian objects under their control against the dangers resulting from military operations (Article 58(c) of 1977 Additional Protocol I). This could provide some legal basis for requiring states to take certain remediation measures in the aftermath of the use of DU weapons to reduce the dangers to civilians.

Time for a ban on depleted uranium weapons?

DU-containing projectiles are not banned or restricted under conventional or customary disarmament law. The legality of using DU weapons during the conduct of hostilities is case specific. In relation to combatants, there is room to argue that their use might in some cases violate the principle prohibiting causing superfluous injury and unnecessary suffering, particularly when used in an anti-personnel capacity, and even potentially in some cases of anti-materiel use where an alternative weapon would suffice. DU use could in some cases potentially violate the principle of distinction, such as when used in heavily populated areas where civilians risk being exposed, given the weapon's indiscriminate nature.

The only way to ensure maximum safety for enemy and friendly troops and the civilian population is for user states to observe a moratorium on the use of DU weapons.

Given what is already known about DU's toxicity and radioactivity, an approach that is predicated on hoping for the best but planning for the worst would mean the cessation of all use of DU weapons until a more complete picture of their effects is revealed. After all, if the worst-case scenario proves true, we will find it very difficult to remove all traces of DU that have already been released.[41] The only way to ensure maximum safety for enemy and friendly troops and the civilian population is for user states to observe a moratorium on the use of DU weapons pending further research, or to ban their use and dissemination.

As user states seem unlikely to adhere voluntarily to a moratorium, the best way forward is for other states and civil society to make depleted uranium weapons the next target for a disarmament treaty and to vigorously campaign to that end. Although it is true that user states might seem as unlikely to join a treaty banning the possession and use of DU weapons as they would be to observe a moratorium, a disarmament campaign culminating in a ban would increase the opprobrium attached to the use of such weapons—even for non-states parties—and limit their proliferation. Could this be the moment when the campaign to prohibit the possession and use of DU weapons gets legs? Perhaps, if recent developments are any indication. In December 2007, the UN General Assembly passed its first resolution concerning DU weapons, which called on the "Secretary-General to seek the views of Member States and relevant international organizations on the effects of the use of armaments and ammunitions containing depleted uranium".[42] On 22 May 2008, the European Parliament issued its strongest resolution yet dealing with depleted uranium, in which it reiterated "its call on all EU Member States and NATO countries to impose a moratorium on the use of depleted uranium weapons and to redouble efforts towards a global ban".[43]

Notes

1. "When adopting the Convention on Certain Conventional Weapons and the Ottawa Convention banning anti-personnel landmines, States were basing themselves on the prohibition of 'weapons, projectiles and material and *methods* of warfare of a nature to cause superfluous injury or unnecessary suffering' (emphasis added)." J.-M. Henckaerts and L. Doswald-Beck, 2005, *Customary International Humanitarian Law, Volume 1: Rules,* Cambridge, Cambridge University Press and International Committee of the Red Cross (ICRC), p. 242.
2. Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction (Chemical Weapons Convention), adopted 13 January 1993, entry into force 29 April 1997; Protocol on Blinding Laser Weapons, Protocol IV of the Convention on Certain Conventional Weapons, adopted 13 October 1995, entry into force 30 July 1998; Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on Their Destruction (Mine Ban Treaty), adopted 18 September 1997, entry into force 1 March 1999.
3. Adopted on 30 May 2008, at <www.clusterconvention.org/convention/text/english/#toc-convention-on-cluster-munitions>.
4. This paper uses the term "weapon" in its most generic sense, to refer to all armaments containing depleted uranium, that is, both munitions and armour.
5. For a discussion of the military uses of DU, see Dan Fahey, 2008, "Depleted Uranium and Its Use in Weapons", in Avril McDonald, Jann K. Kleffner and Brigit Toebes (eds), *Depleted Uranium and International Law: A Precautionary Approach,* The Hague, TMC Asser Press, p. 3.
6. APFSDS Ammunition - Armoured Piercing Fin-Stabilised Discarding Sabot, *army-technology.com,* no date, at <www.army-technology.com/contractors/ammunition/apfsds.htm>.
7. Bahrain, China, Egypt, France, India, Israel, Kuwait, Oman, Pakistan, Russian Federation, Saudi Arabia, Taiwan, Thailand, Turkey, Ukraine, United Arab Emirates, United Kingdom and United States. Fahey, op. cit., pp. 8–9.
8. Fahey, op. cit., pp. 8–19, 12–14.

9. Ministry of Defence, 2001, *Memorandum: Gulf War Illnesses,* presented to the House of Commons Defence Select Committee on 26 April 2001, London, HMSO, p. 37. Department of the Air Force, Headquarters United States Air Force, *JA letter to AF/RDF, Subject: Legal Review of 30 mm Ammunition,* 14 March 1975, with attached legal memorandum; Department of the Army, Office of the Judge Advocate-General, *DAJA-IO Memorandum for US Army Armament Research, Development and Engineering Center, Subject: M829A2 Cartridge, 120 mm APFSDS (Depleted Uranium Tank Round); Law of War Review.* For a discussion see B. Carnahan, 2008, "A Military View on Depleted Uranium", in McDonald et al., op. cit., pp. 99, 104–110.
10. For a discussion of the military utility of DU see Carnahan, 2008, op. cit.
11. Fahey, 2008, op. cit., pp. 12–13.
12. "Iraq: The DU Dust Settles", *Jane's Defence News,* 2 April 2004; "A 'Silver Bullet's' Toxic Legacy", *The Christian Science Monitor,* 20 December 2002; "Iraqi Cancers, Birth Defects Blamed on U.S. Depleted Uranium", *The Seattle Post-Intelligencer,* 20 November 2002.
13. "Depleted Uranium: EU Concern Grows", *BBC News,* 6 January 2001.
14. The Royal Society, 2002, *The Health Hazards of Depleted Uranium Munitions: Part II,* London, p. vii; A. Marusic and S. Ramsay, 2001, "NATO Doctors Question 'Balkan War Syndrome'", *The Lancet,* vol. 357, no. 9251, p. 201.
15. "Pentagon Officials Say Depleted Uranium Powerful, Safe", *Armed Forces Press Service,* 14 March 2003, at <www.defenselink.mil/news/newsarticle.aspx?id=29292>.
16. Dan Fahey, 2008, "Environmental and Health Consequences of the Use of Depleted Uranium Weapons", in McDonald et al., op. cit., pp. 29, 64–71.
17. Royal Society, op. cit., p. vii; DU has been described as a "low level alpha radiation emitter which is linked to cancer when exposures are internal, chemical toxicity causing kidney damage. … Aerosol DU exposure to soldiers on the battlefield could be significant with potential radiological and toxicological effects." Report prepared by the US Army Production Base Modernisation Activity, Picatinny Arsenal, New Jersey, July 1990; "When soldiers inhale or ingest DU dust, they incur a potential increase in cancer risk. … Expected physiological effects from exposure to DU dust include possible increased risk of cancer (lung or bone) and kidney damage", Col. Robert G. Claypool, director of Professional Services, *Memo from US Army Chemical Medical School on Depleted Uranium Safety Training,* 18 August 1993; "Strong evidence exists to support [a] detailed study of potential DU carcinogenicity", Dr David McClain, US military depleted uranium researcher, speaking to a presidential committee investigating Gulf War illnesses, quoted in D. Fahey, 2001, "The Final Word on Depleted Uranium", *Fletcher Forum of World Affairs,* vol. 25, no. 2, p. 197.
18. Such as when it enters the body through inhalation of DU dust or injection of DU fragments. See Fahey, 2008, op. cit., pp. 41–48.
19. The Royal Society, 2001, *The Health Hazards of Depleted Uranium Munitions: Part I,* London, p. 5.
20. For details, see Fahey, 2008, op. cit..
21. According to the author of a working paper on depleted uranium and other weapons that was prepared for the UN Sub-Commission on the Promotion and Protection of Human Rights, depleted uranium and the other weapons that formed the subject of his paper "should be considered banned, whether or not there is a specific treaty banning them". *Human Rights and Weapons of Mass Destruction, or with Indiscriminate Effect, or of a Nature to Cause Superfluous Injury or Unnecessary Suffering,* Working Paper submitted by Y.K.J. Yeung Sik Yuen, UN document E/CN.4/Sub.2/2003/35, 2 June 2003, paragraph 55.
22. Protocol III of the Modified Brussels Treaty, signed 23 October 1954, Annex II, paragraph I(a).
23. Treaty on the Southeast Asia Nuclear Weapon-Free Zone, signed at Bangkok, 15 December 1995, at <www.aseansec.org/2082.htm>.
24. International Court of Justice, *Legality of the Threat or Use of Nuclear Weapons,* Advisory Opinion of 8 July 1996, paragraph 105.
25. See Guido den Dekker, 2008, "The Law of Arms Control and Depleted Uranium Weapons", in McDonald et al., op. cit., pp. 75, 86–87; Stefan Oeter, 1995 "Methods and Means of Combat", in Dieter Fleck (ed.), *The Handbook of Humanitarian Law in Armed Conflicts,* Oxford, Oxford University Press, paragraph 434.
26. Den Dekker, op. cit., p. 86; Oeter, op. cit., paragraph 439.
27. International Court of Justice, op. cit., paragraph 55.
28. Ibid., paragraphs 54–56.
29. Instructions for the Government of Armies of the United States in the Field of 1863 (Lieber Code), Article 70; Brussels Project of an International Declaration concerning the Laws and Customs of War of 1874, Article 13(a); Laws of War on Land of 1880 (Oxford Manual), Article 8(a); The Hague Convention (II) with Respect to the Laws and Customs of War on Land and Its Annex: Regulations Concerning the Laws and Customs of War on Land of 1899, Article 23(a); The Hague Declaration (IV, 2) Concerning Asphyxiating Gases of 1899; The Hague Convention (IV) Respecting the Laws and Customs of War on Land and Its Annex: Regulations Concerning the Laws and Customs of War on Land of 1907, Article 23(a); Treaty Relating to the Use of Submarines and Noxious Gases in Warfare of 1922, Article 5.
30. The Hague Declaration (IV, 3) of 1899 declared it illegal to use bullets that expand or flatten easily in the body.
31. International Court of Justice, op. cit., paragraph 78.

32. Henckaerts and Doswald-Beck, op. cit., pp. 240, 242.
33. The term is used here in its broadest sense, to mean anyone who participates in hostilities, regardless of whether or not they are entitled to the privileges of combatancy. See Henckaerts and Doswald-Beck, op. cit., p. 3.
34. International Court of Justice, op. cit., paragraph 78.
35. St Petersburg Declaration; the ICRC says that "A relevant factor in establishing whether a weapon would cause superfluous injury or unnecessary suffering is the inevitability of serious permanent disability." Henckaerts and Doswald-Beck, op. cit., p. 241.
36. Marten Zwanenburg opines that "There are good arguments for applying the principle to anti-materiel as well as to anti-personnel weapons." However, he concludes that, "these considerations do not represent current international law on the issue…". "The Use of Depleted Uranium and the Prohibition of Weapons of a Nature to Cause Superfluous Injury or Unnecessary Suffering", in McDonald et al., op. cit., pp. 111, 117.
37. For a discussion see Avril McDonald, 2008, "Averting Foreseeable and Unexpected Damage: The Case for a Precautionary Approach vis-à-vis Depleted Uranium Weapons", in McDonald et al., op. cit., pp. 281, 285–286.
38. Fahey, 2008, op. cit., p. 7.
39. Fahey notes that "About 90 percent of the DU dust created by the impact of a tank round against a hard target falls to the ground within 50 metres of the target, although airborne DU has been found up to 400 metres from the impact site immediately following an impact." Fahey, 2008, op. cit., p. 31.
40. Contrary to Article 51(5)(b) of 1977 Additional Protocol I to the Geneva Conventions.
41. Given that DU, once released, contaminates the air, soil and water. See Fahey, op. cit., pp. 33–41. It should also be remembered that since DU has a half-life of 4.5 billion years it decays extremely slowly (Federation of American Scientists Military Analysis Network, *Depleted Uranium,* 29 April 1999, at <www.fas.org/man/dod-101/sys/land/du.htm>).
42. UN General Assembly resolution 62/30 of 5 December 2007, UN document A/RES/62/30, 10 January 2008, paragraph 1.
43. Approved by 491 votes in favour, 18 against and 12 abstentions. European Parliament resolution of 22 May 2008 on (depleted) uranium weapons and their effect on human health and the environment – towards a global ban on the use of such weapons, document P6_TA(2008)0233.

Uranium weapons: why all the fuss?

Chris Busby

"When you have eliminated the impossible, whatever remains, however improbable, must be the truth", Sir Arthur Conan Doyle, 1890, *The Sign of Four.*

The radiation risk model, currently employed by all governments of the world, predicts that the exposures of civilians and soldiers to particulate fallout from depleted uranium (DU) weapons are too low to cause any measurable health effects. At the same time, there are persuasive reports of increases in leukaemia, cancer and birth defects and a bewildering array of ill-health conditions in people exposed to this material. In addition, and increasingly, there are new studies published of animal and cell culture experiments that show alarming levels of genetic damage following exposure to uranium, depleted or not. How can there be such contradictory opinions on something that one assumes is a matter of scientific fact? Who is correct? And how can we find a way forward?

Depleted uranium

DU contains about 12,400,000Bq of U-238 per kilogram. The average level of U-238 in soil, unless you are in one of the rare areas of the world where there are uranium deposits, is between 10 and 20Bq/kg. By way of example, in Kosovo, some soil samples analysed by the United Nations Environment Programme (UNEP) contained 250,000Bq/kg, thus indicating contamination. The approximately 350 metric tons of DU[1] used in the First Gulf War represents 4.3 TBq (4.3×10^{12}Bq) of uranium alpha activity (13.0×10^{12} Bq if the radioactive beta-emitting daughter isotopes are included). If this were dropped into 100 square kilometres, the resultant deposition would be 130GBq/km^2. This is extremely high, considering that land surrounding the Chernobyl site after the 1986 accident was considered as contaminated from a level of 37GBq/km^2.[2] This amount of DU, assessed as pure radioactivity, is equivalent to about 2kg of plutonium; no one would argue that dropping this amount of plutonium dust on a population was anything but a disaster. However, the military, and the governments and the risk agencies that the military depend upon, argue that in these cases of uranium exposure the radioactivity of uranium was too low and the doses were too small to be of concern. These were exactly the same arguments that I addressed in my 1995 and 2006 books, which examined the health effects of low-level radioactive pollution from the nuclear industry and the atmospheric weapons tests

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of the 1960s.[3] The analysis of the books, based upon several years of research and an examination of radiobiology and epidemiology, concluded that the internationally accepted risk model for radiation exposure was in error when applied to internal exposure.

The radiation risk model

The current radiation risk model is that of the International Commission on Radiological Protection (ICRP). This calculates *cancer risk* on the basis of *radiation dose*. It does so by relating doses mathematically to those received by the atomic bomb survivors of Hiroshima and Nagasaki from external gamma radiation, the largest dataset in existence on radiation exposure and health. Gamma radiation is electromagnetic radiation, like visible light only with a much shorter wavelength and therefore much more energetic: sufficiently energetic to break chemical bonds in molecules. The exposure to gamma rays at the bombed cities was like standing outside when a giant flashbulb went off. All the cells in the body receive the same amount of energy, so it can be averaged. But there is a different kind of radiation. Some radioactive elements (uranium is one) emit energetic particles instead of (sometimes as well as) gamma rays. These alpha and beta particles have the same effect on molecules, but their effects are much more local.

DU exposure is therefore a totally different sort of exposure to that of the atomic bomb survivors—it is chronic, internal, low-dose exposure. Because of the *internal* exposure from uranium, it is the quantity, radiation dose, which is the problem.[4] Radiation dose is an average energy absorbed over large volumes of tissue and does not distinguish between external and internal radiation. But radiation exercises its harmful effects by causing ionization on or near the DNA in the nucleus of cells, therefore it is *ionization density* near the DNA that is the key quantity in any risk model, and not radiation dose. The range of an alpha particle from uranium is only the diameter of a few cells and all the alpha energy is deposited in this range. Therefore if the uranium atom is outside the body, the dose is almost zero. But if it gets into the body, by inhalation or by drinking water or eating food, then it becomes very dangerous. For certain internal exposures like DU particles, or where the uranium is bound chemically to the DNA itself, the ionization near the DNA or near the DU particle is hundreds of thousands of times greater than the *absorbed dose* would suggest.

Moreover, there is a second and entirely new scientific development. Uranium binds strongly to DNA but it also, by virtue of its high atomic number, absorbs natural background radiation about 500,000 times more efficiently than water, the main component of the body, and scatters this into local tissue as photoelectrons. It therefore exhibits *phantom radioactivity* and focuses external natural background gamma radiation into the DNA.[5] The failure of the current radiation risk model to allow for these facts is the key which unlocks the conundrum and answers the implied question in Sherlock Holmes's remark. Uranium is dangerous because it gets into the body and causes high levels of ionization and genetic damage to the DNA.

Uranium is dangerous because it gets into the body and causes high levels of ionization and genetic damage to the DNA.

The health consequences of uranium weapon use

I have been actively involved with the issue of DU weapons since the mid-1990s, when initial reports emerged of "Gulf War illness" in US veterans. It seemed to me then, and seems to me now even more, that this condition—and also the reported increases in child leukaemia, cancer and birth defects seen in the Iraqi population—pointed to an effect which was probably radiological. Since uranium, a radioactive substance, was used in that war in large quantities it was clearly the most likely cause.

In 2000, I undertook a field study and visited Iraqi hospitals, talked with doctors and examined the cancer registry figures. I took radiation measuring equipment and travelled to the southern battlefield to measure the uranium that was still there 10 years after its use. In 2001, I carried out a similar survey in Kosovo, where uranium weapons had been used during the 1999 conflict; also talking to doctors, measuring radiation and bringing back samples to the United Kingdom for analysis.

It is extraordinary that hardly any independent epidemiology has been carried out on populations who have been living in areas where DU was used, such as in the Balkans and Iraq. It is no secret that there have been reports of increases in cancer, leukaemia, lymphoma and various birth defects in these places. In addition, there have been reports of increases in cancer in foreign peacekeeping personnel, whose exposure was of relatively limited duration.

The Iraqi data I received in 2000 persuaded me that there was an increase in childhood leukaemia in the areas where most of the bombing had occurred, with the 5–9 year-old child cohort born after the First Gulf War exhibiting the highest rates. Data from the Sarajevo cancer registry shows an enormous increase in cancer and leukaemia between 1995 and 2000.[6] I also examined the Italian government-funded study[7] of their Balkan peacekeepers, which showed a rapid increase in lymphoma and other cancers. Independent investigations by the media and others showed support for the widespread belief that there were serious health problems following DU exposure. Independent documentaries have also found increases in cancer and leukaemia in Italian, Portuguese and Spanish veterans of Kosovo.[8]

By 2001 I was convinced that:

- radiation exposure from DU under battlefield conditions had a radiological impact on health;
- the increases in illness in areas where DU had been used were related to uranium exposure;
- there were provable increases in cancer or birth defects in Iraq related to uranium exposure;
- Exposure to uranium caused, or significantly contributed to Gulf War Syndrome;
- DU particles generated by burning on impact were long lived and moved in the air from the site of impact over significant distances (miles)—they remained in the atmosphere and were resuspended from the ground; and
- the current risk models for radiation exposures and health were unsafe when applied to internal radiations, like those from uranium particles.

Nevertheless, the accumulating evidence that there were significant health effects from DU exposure that were unexplained by the radiation risk model did not prompt responsible officials to look further into the matter or to question whether the model was appropriate for such exposures. In discussions between the United Kingdom's Medical Research Council and the Depleted Uranium Oversight Board with regard to the veterans of the First Gulf War, the Research Council took the stance that since the risk model predicted that there could be no increase in cancer risk, there was no point in looking for it.[9]

Uranium dust circulates in the atmosphere and is transported around the planet; therefore it is of concern far beyond the conflict zone. Uranium weapons produce an aerosol of uranium oxide particles that are very long lived in the environment. I measured these particles in precipitation puddles in Kosovo 12 months after the use of the weapons and in Iraq some 9 years after uranium weapons' use. The particles are mostly smaller than a tenth of a micron in diameter, and behave like a gas, so it is no surprise that they are highly mobile. It is a matter of public record that levels of uranium in the municipal water supplies of Los Angeles (where it is measured routinely) suddenly increased following the Second Gulf War.[10] In 2006 Saoirse Morgan and I were able to show that there were statistically significant increased levels of uranium in the high-volume air samplers deployed around the Atomic Weapons Establishment at Aldermaston in the United Kingdom for the six weeks of the Second Gulf

War starting in March 2003.[11] At the time, the winds were blowing from Iraq across Europe to the United Kingdom, and the United States' powerful National Oceanic and Atmospheric Administration's computer model showed that air masses in the United Kingdom originated from Iraq.

New findings, tests and observations

By the early 2000s public concerns were building and becoming reflected in the media largely through the work of three types of non-governmental organization (NGO): those concerned about radiation and health; those concerned about increases in leukaemia and birth defects in Iraq; and the military veteran support groups. The public suspicion of science, fuelled by the BSE (mad cow disease) crisis and other science policy failures, contributed to scepticism regarding the official arguments about DU. This had the effect of creating a number of government-backed forums for apparently reinvestigating the issue. At the minimum, the result was that new evidence and old arguments were formally presented to various committees.[12] I was involved in many of these initiatives: in 2001–2002 I gave evidence to the United Kingdom's Royal Society Working Group on depleted uranium weapons and to the US House Committee on Veterans' Affairs; I discussed the issue with the Committee Examining Radiation Risks of Internal Emitters (CERRIE); and I gave lectures to various national bodies, NGOs and the European Parliament.

The Royal Society finally concluded that the uranium exposures were not harmful unless the levels of dust were so high that people would choke to death before suffering radioactivity harm. It also held that DU on the battlefield stayed where the impact occurred; it was not possible to determine DU as the cause of Gulf War Syndrome; and there was no evidence of any increase in cancer or birth defects in Iraq.[13]

One might therefore find it puzzling at the least that, following its final report downplaying the health effects of DU weapons, the Royal Society Working Group suggested that the issue should be followed up by measuring DU in the urine of veterans from the First Gulf War. The UK Ministry of Defence funded this research, setting up the Depleted Uranium Oversight Board (DUOB).[14]

The DUOB had two tasks: the first was to devise a test to measure depleted uranium in veterans and to oversee the measurements; the second was to recommend other tests that might be employed and to examine the scientific basis for the health effects. The DUOB continued from 2002 to 2006, and a test was devised and applied. Most of the relevant scientific uranium research was discussed.

Over time, increasing evidence appeared suggesting that uranium was far more deadly than had been believed: there was some anomalous quality that caused very large amounts of genetic damage in cells at very low doses. The Gulf War illnesses, and the increasingly believable reports of large increases in cancer and other mutation-related conditions in the Iraqi populations and in others exposed to battlefield uranium, had encouraged a number of researchers to examine the genetic effects of uranium in cell cultures and animals.

By 2008 at least 20 serious scientific papers have been published in the peer-reviewed literature showing that uranium is a more dangerous mutagen than had been previously thought. This was shown in cell culture analyses, in animal studies and in theoretical arguments based upon its known physical properties. Uranium's powerful affinity for DNA, first shown in the 1960s when it began to be employed as an electron microscope stain, has been rediscovered. The ability of such heavy metals to absorb gamma rays and retransmit them into the DNA has even been the origin of patent applications: in 2005 US researchers had successfully patented gold nanoparticles to be used for cancer radiotherapy in conjunction with X-rays; the gold particles released photoelectrons and destroyed mammary tumours in mice.[15] Uranium, which binds to DNA and has a higher atomic number, is far more effective at amplifying radiation. The evidence of the health effects of DU in the peer-reviewed and grey literature had become impossible to ignore—yet it appears that in many parts of the world national governments, their militaries and the relevant risk agencies continue to do just that.

Uranium weapons: what do we need to know and how can we find it?

Many questions concerning uranium weapons remain unanswered, but they are certainly not unanswerable.

Many questions concerning uranium weapons remain unanswered, but they are certainly not unanswerable from a scientific point of view. We need to know how much uranium is being used, what kind of uranium it is, where and when it has been used, and by whom. We need to know if *natural* uranium is being used in weapons, now that DU can be routinely tracked by mass spectrometry. We need to know the origin of the *enriched* uranium that is now being found on various battlefields: is there a new fusion weapon which either employs enriched uranium or produces it from U-238 or is there some other explanation? We need to know the truth about the health consequences of the use of uranium weapons. This means believable and independent epidemiology of exposed populations. We need to know more about which weapons have uranium in them, the quantities per weapon and how they are used. We need especially to know how widely uranium is dispersed from the site of its use and how long it remains in the environment in a form that enables it to become resuspended, ingested or inhaled. We need to know what the biological or biophysical origins of the anomalous genetic effects of uranium are: are they caused by the phantom radiation effects caused by photoelectron amplification of background gamma rays? Although we know that the current radiation risk model is inappropriate and thus unsafe in its application to internal exposures, we need to know how much it is in error for different isotopes.

What can be done to address these questions in a way that all will be reasonably sure that the right measurements have been made, and that will permit accurate conclusions to be drawn? In the remainder of this article, I propose to briefly address the questions I have listed and refer to what is currently already known or suggested from research and what might usefully be investigated by an independent entity.

Looking for DU

There are many misconceptions about the radioactivity of DU, and many mistakes have been made by those looking for evidence of its use, often concluding erroneously that it had not been used. DU, a by-product of the nuclear fuel cycle, contains less of the fissile isotope U-235 than natural uranium. The atomic ratio in nature is 137.88 atoms of U-238 to one atom of U-235. So any ratio higher than this flags up depleted uranium. If a sample has an isotopic ratio which is more than 1 or 2 units away from the 137.88 that defines natural uranium, then it has a man-made source. Thus a urine sample with a ratio of 140 or above indicates DU; one of 136 or below indicates enriched uranium (and enriched uranium is indeed increasingly turning up in the environment, for reasons which are not yet wholly clear). Testing of the bullets (penetrators) I saw lying around in Iraq on the Kuwait border had a ratio of *more than 400*. The dust I found with a scintillation counter detector in Kosovo contained DU as indicated by an isotopic ratio of between 300 and 500. It is this ratio that defines DU.

To detect DU or uranium used in weapons, one must be aware of the nature of the material. Surveys must *employ the right equipment*. Because uranium is only a very weak gamma emitter, conventional Geiger counters are not an appropriate tool. Early surveys of Kosovo concluded that there was no uranium contamination because the wrong survey instruments were used.[16] The ideal instrument is a sensitive, large-area scintillation counter that detects the beta emissions from two daughters of uranium-238 decay, thorium-234 and protoactinium-234m. The detector is trailed slowly about 20cm above the ground, which must be dry, as water significantly absorbs the beta emissions so that they do not reach the detector. The airborne DU dust, precipitated by rain, is found in dried out puddles or under melted snow that has dried. Once high readings are obtained (counts of above 2–3 times the natural background radiation level) the samples must be carefully removed for laboratory analysis.

Since uranium weapons produce particles of uranium oxide, filtering water samples will remove the uranium. This was demonstrated in the UNEP Kosovo survey of 2001, where samples were sent to two laboratories, one of which filtered (Sweden) and one did not (Bristol). More recently, enriched uranium was found in one half of a split water sample from a bomb crater in Lebanon by the Harwell laboratories in the United Kingdom whilst the Swiss Spiez Laboratory found no enriched uranium. As previously mentioned, uranium particles remain in the atmosphere and travel large distances, but their presence in air is easily established by analysing vehicle air filters from the area where the uranium is suspected to have been employed. This method has been used to show the presence of enriched uranium in the air in Beirut (described below).

Choice of laboratory method is important. A number of laboratories have attempted to show the presence or absence of DU using gamma spectroscopy of the daughter isotopes of U-238. This is not a method that gives the correct result for environmental samples since there are solubility differences between uranium and the thorium isotope used as a flag for U-238. Neither can the ratio of U-234 to U-238 be employed, for similar technical reasons. The ratio of U-238 to U-235 must be measured directly. The only methods that give the true values are either chemical separation and alpha spectrometry or high resolution mass spectrometry. For urine tests, only mass spectrometry has sufficient sensitivity to distinguish the isotopic ratios at the low levels of contamination found.

In all cases, samples should be split and coded separately and sent to separate laboratories in such a way that the measurements are truly blind. This was the protocol established very early in the DUOB urine testing of Gulf War veterans and most samples measured in that project were blinded and measured by two separate laboratories. These generally came back with the same results; if they did not there was a reanalysis.

Natural uranium and enriched uranium

The issue of DU has been publicized quite widely and measurements are increasingly made of samples from areas where uranium weapons have been used. The results support increasing reason to believe that the discussions about depleted uranium might camouflage a second sort of weapon—that using natural uranium.

As a result of high levels of natural uranium found in urine of sick civilians in recently bombed locations in Afghanistan (measurements organized by Tedd Weyman, working with Dr Asaf Durakovic in the United States),[17] the question was raised in the DUOB and elsewhere about the possibility that the bunker-busting bombs and cruise missiles used during that conflict may have employed uranium penetrators. The United Kingdom and United States military have consistently denied using DU in cruise missiles, but this wording leaves open the possibility of the use of a natural uranium penetrator. I personally saw the remains of a nine-storey building in Kosovo, where a large missile or bomb had neatly stitched through all nine floors of reinforced concrete and left quite a small hole in each floor before exploding in the ground. Weapons patents have been found that refer to such penetrators.[18] Given the military need to destroy deep reinforced bunkers, the existence of such an impact reinforcement is almost a requirement. Tungsten is the only other reinforcement possibility, but Harwell's elemental analysis of an ambulance air filter from Beirut, where a massive bunker-busting missile had penetrated and destroyed a Hezbollah bunker, showed no tungsten but a significant amount of uranium. Of course, given the density of uranium we are talking about a very large amount in a single bomb, perhaps 1000kg. It would be difficult to explain such a huge amount of DU, but natural uranium is another matter. If there were a future epidemiological or other study, any excess could be dismissed as "natural uranium". Additionally, the UK troops who served in the Second Gulf War in 2003 had high levels of uranium in their urine, but it was not uniformly depleted uranium: in fact the isotopic signature was quite broad, suggesting both depleted and natural uranium.[19]

How can the fallout or residues of such uranium weapons be distinguished from DU? Obviously not by the isotopic signature, but perhaps the characteristic is the dust itself. If anomalous levels of uranium are found in soil samples or filters, the material should be physically separated from the matrix (on the basis of its extremely high mass/density) and examined using a scanning electron microscope and X-ray fluorescence to characterize the material as uranium.

Recently, a bomb crater in Southern Lebanon was found to be radioactive.[20] Samples from this crater were measured using mass spectrometry at the Harwell laboratories and by alpha spectrometry at the University of Wales, Bangor. Water samples from this and other craters were examined, and an ambulance air filter from Beirut was analysed. The results showed anomalously high uranium levels. The presence of enriched uranium was confirmed in the bomb crater, water samples and the air filter. Later analysis of separate samples by Dr M.A. Kobeissi of the Lebanese National Council for Scientific Research confirmed the existence of enriched uranium in some samples and depleted uranium in others.[21] A few months later (November 2006), UNEP carried out a series of analyses in the area, but did not find depleted nor enriched uranium, although the levels of natural uranium they did report were anomalously high.[22]

The existence of enriched uranium in these samples is very puzzling. One explanation is that it might be used to camouflage the use of depleted uranium since the final mix would then be approaching the natural signature. There is another possibility: speculation has been advanced by a physicist to Rai News of the existence of a new type of weapon that either employs enriched uranium or creates it through a fusion reaction involving hydrogen dissolved in U-238.[23]

I don't know much about science, but I know what I like

This was the writer Martin Amis's joke, but it is a good description of what happens at the science–policy interface, where research results are turned into policy. There is considerable bias in scientific research, and also bias in this political arena.[24] By way of example, in a series of peer-reviewed papers, the philosopher Christina Rudén examined the translation of scientific evidence about the cancer-producing effects of the widely used industrial solvent trichloroethylene into European Union policy. She showed that the recognition of the carcinogenic qualities of the substance was delayed many years by scientific advice argued by industry scientists.[25] From the health consequences of asbestos to those of BSE, governmental committees have often been slow to acknowledge independent scientific findings that run counter to their political or economic interests.

In the case of DU we are dealing with an issue where the military as well as industry are involved, and where employment of uranium weapons (note I do not say *depleted* uranium weapons) is believed to have military utility. All of the risk agencies involved in these debates are predominantly funded by the same governments that have the greatest political, economic and military investment in uranium weapons.

Politicians are not scientific experts—they cannot be—but increasingly they have to make decisions based upon expert advice. And ultimately politicians answer to the people they represent. But which experts should we listen to? The problem of which expert to trust with regard to environmental health was discussed recently by the Policy Information Network for Child Health

Politicians are not scientific experts—they cannot be—but increasingly they have to make decisions based upon expert advice. Which experts should we listen to?

and Environment (PINCHE). PINCHE took the view that *no science is value free*, and that to obtain the truth in any area where there is argument about some environmental agent there must be an oppositional committee funded to produce a report that contains all sides of the argument.[26] Such a report should be the basis for the political decision, and the report would be transparent and available to the public if later there were questions.

Conclusions: whatever remains, however improbable

If further research were to show that uranium weapons do have significant, wide-ranging and devastating effects on health, there would be considerable consequences for governments. If it were seen to be a weapon of indiscriminate effect that poisons large civilian populations, governments would be forced to stop using it, thus removing a useful weapon from their arsenals. If it were proven that scientific evidence had been wilfully ignored, whole governments could be disgraced and might even face legal action from individuals, groups or other governments.

But there is perhaps an even greater issue, with repercussions that go far beyond the military uses of uranium. If uranium exposure causes genetic damage at low doses, decisions of national importance—ranging from the continued operation of nuclear energy, in civil reactors and in ships and submarines, to public health issues relating to cancer clusters near nuclear sites—are being taken based on a risk model that does not represent the real risks or consequences and will require immediate reconsideration.

The health effects of uranium exposure are therefore part of a bigger story. But don't take my word for it. It seems so improbable. Let us investigate together.

Notes

1. Final Report of the Depleted Uranium Oversight Board, February 2007, at <www.duob.org> or <www.mod.uk/defenceinternet/aboutdefence/corporatepublications/healthandsafetypublications/uranium/finalreportofthedepleteduraniumoversightboard.htm>.
2. *Information on the Economic and Social Consequences of the Accident at the Chernobyl Nuclear Power Plant, Submitted by the Delegations of the Union of Soviet Socialist Republics, the Byelorussian Soviet Socialist Republics and the Ukrainian Soviet Socialist Republics* [*sic*], in UN document A/45/342 – E/1990/102, 9 July 1990, p. 4.
3. Chris Busby, 1995, *Wings of Death: Nuclear Pollution and Human Health,* Aberystwyth, Green Audit; Chris Busby, 2006, *Wolves of Water. A Study Constructed from Atomic Radiation, Morality, Epidemiology, Science, Bias, Philosophy and Death,* Aberystwyth, Green Audit.
4. This is an issue that has been dealt with quite well by the 2003 report of the European Committee on Radiation Risk: C. Busby et al., 2003, *2003 Recommendations of the European Committee on Radiation Risk—The Health Effects of Ionising Radiation Exposure at Low Doses and Low Dose Rates for Radiation Protection Purposes: Regulators' edition,* Brussels, ECRR.
5. C. Busby, 2005, "Depleted Uranium Weapons, Metal Particles and Radiation Dose", *European Biology and Bioelectromagnetics,* vol. 1, no. 1, pp. 82–93; C. Busby and E. Schnug, 2007, "Advanced Biochemical and Biophysical Aspects of Uranium Contamination", in L.J. De Kok and E. Schnug (eds), *Loads and Fate of Fertilizer Derived Uranium,* Leiden, Backhuys Publishers.
6. C. Busby, 2001, "Health Risks Following Exposure to Aerosols Produced by the Use of Depleted Uranium Weapons", presentation to *Res Publica* conference on DU, Prague, 24–25 November 2001, see <www.greenaudit.org>.
7. *Seconda Relazione Della Commissione Istituita dal Ministro della Difesa sull' Incidenza di Neoplasie Maligne tra i Militari Impiegati in Bosnia e Kossovo* [in Italian]*,* 28 May 2001, Rome, Ministry of Defence.
8. See, for example, E. Goncalves, 2001, "The Secret Nuclear War", *The Ecologist*.
9. This appears in the minutes of the meetings of the Depleted Uranium Oversight Board, which are available from the author.
10. The annual water quality reports of the Los Angeles Department of Water and Power are available on their web site, at <www.ladwp.com/ladwp/cms/ladwp001965.jsp>.

11. Chris Busby and Saoirse Morgan, 2006, "Did the Use of Uranium Weapons in Gulf War 2 Result in Contamination of Europe?", *European Biology and Bioelectromagnetics,* vol. 1, no. 5, pp. 650–668.
12. Even if these committees dismissed the evidence, its presentation was important from a legal point of view, since it withdrew any future defence of ignorance on the part of government decision makers.
13. Royal Society, 2001, *The Health Hazards of Depleted Uranium Munitions: Part I,* London; Royal Society, 2002, *The Health Hazards of Depleted Uranium Munitions: Part II,* London.
14. The author represented the veterans and the Low Level Radiation Campaign on the Depleted Uranium Oversight Board, see <www.llrc.org>. Final Report of the Depleted Uranium Oversight Board, op. cit.
15. J.F. Hainfeld et al., 2004, "The Use of Gold Nanoparticles to Enhance Radiotherapy in Mice", *Physics in Medicine and Biology,* vol. 49, no. 18, pp. N309–N315.
16. United States Department of Defense, *Information Paper: Depleted Uranium Environmental and Medical Surveillance in the Balkans,* last updated 25 October 2001; see also the information on depleted uranium available from NATO, at <www.nato.int/du/home.htm>.
17. See A. Durakovic, 2005, "The Quantitative Analysis of Uranium Isotopes in the Urine of the Civilian Population of Eastern Afghanistan after Operation Enduring Freedom", *Military Medicine,* vol. 170, no. 4, pp. 277–284.
18. See the article by Dai Williams in this issue of *Disarmament Forum*.
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20. C. Busby and D. Williams, 2006, *Evidence of Enriched Uranium in Guided Weapons Employed by the Israeli Military in Lebanon in July 2006: Preliminary Note,* Green Audit Research Note 6/2006, Aberystwyth, Green Audit.
21. M.A. Kobeissi, "A Study on the Presence of Depleted and Enriched Uranium Used by Israeli Bombardments on Lebanon during the July\August Conflict 2006", presentation to the Fondazione Internazionale Lelio e Lisli Basso Issoco, 28 March 2008, at <www.internazionaleleliobasso.it/public/contributi/Kobeissi_Italy_Lecture2008.pdf>.
22. UNEP, 2007, *Lebanon: Post-conflict Environmental Assessment,* Nairobi, at <www.unep.org/pdf/Lebanon_PCOB_Report.pdf>, pp. 151 and 159.
23. See "Khiam Southern Lebanon: A Bomb's Anatomy", documentary by Flaviano Masella, Angelo Saso and Maurizio Torrealta, *Rainews24,* 9 November 2006, at <www.rainews24.rai.it/ran24/inchieste/09112006_bomba_ing.asp>. I am unable to comment on the feasibility of such a fusion weapon, but conversations with physicists indicate that it is possible.
24. M. Scott Cato et al., 2000, *I Don't Know Much about Science: Political Decision-Making Involving Science and Technology,* Aberystwyth, Green Audit.
25. C. Rudén, 2003, "Science and Transscience in Carcinogen Risk Assessment—The European Union Regulatory Process for Trichloroethylene", *Journal of Toxicology and Environmental Health Part B: Critical Reviews,* vol. 6, no. 3, pp. 257–278.
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Under the radar: identifying third-generation uranium weapons

Dai Williams

Uranium is a heavy metal: it has a number of properties that make it a strategic material for nuclear and other weapons and a genotoxic hazard.

- Radioactive isotopes: natural uranium contains radioactive isotopes of different energy levels: primarily U-238 (99.28%), U-235 (0.71%) and U-234 (0.005%). Radioactive decay, combustion and nuclear reactions create daughter products, thermal radiation and ionizing radiation (alpha, beta and gamma). High-energy, short-range alpha particles are genotoxic, causing potentially carcinogenic and mutagenic chromosome damage.
- High density: uranium has a density of 19g/cm^3. This is similar to tungsten and gold, 1.7 times the density of lead and 2.4 times that of iron. The use of uranium can increase a weapon's kinetic energy, enabling it to penetrate tanks and bunkers.
- High strength: uranium creates very hard alloys with certain metals (e.g. titanium, niobium or cobalt). These alloys can be used for defensive armour, armour-piercing penetrators and high-impact warheads.
- Low melting point: at 1132ºC, less than half that of tungsten, uranium's melting point makes it suitable for shaped charge liners. When fired, these liners melt to form a focused jet of liquid metal that travels at very high speed to burn through metal or rock.
- Pyrophoric: uranium burns in air. Temperatures at explosion can reach up to 5000ºC (compared with phosphorus at 900ºC, napalm 1300ºC and thermite at 2500ºC). [1]
- Ultrafine dispersal: uranium burns to a black dust or aerosol of mainly insoluble oxides. Due to the minute size of particles, contamination disperses widely, resuspended by the sun, vehicles and wind.
- Toxicity: uranium dust is toxic, and can cause severe skin and lung irritation and damage the kidneys. High doses can cause renal failure within days.[2]

Strategic context and known uranium weapons

The first generation of uranium weapons exploited the fission potential of the U-235 isotope in enriched uranium to create nuclear weapons. Global contamination from nuclear fallout started in 1945 and continued from over 500 atmospheric nuclear tests up to 1996.[3] Highly enriched and depleted uranium and plutonium are the main materials in many nuclear warheads. Testing has added

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several hundred tons of uranium and other oxides to global background alpha radiation sources in soil and oceans as well as gamma-emitting fission products.

The horrors of the use of nuclear weapons in the Second World War made them an arms control priority. Nuclear weapons were classified as weapons of mass destruction (WMD); in 1968 the Treaty on the Non-proliferation of Nuclear Weapons was signed and the non-proliferation regime took root. Concerns over the health effects of nuclear fallout had led to the Partial Test-Ban Treaty in 1963 but testing continued, with global health consequences. The Comprehensive Nuclear-Test-Ban Treaty was signed in 1996, although it has not yet entered into force.

Since the 1970s a second generation of uranium weapons has been developed, which exploits the non-fission properties of uranium. Depleted uranium (DU, a by-product of the nuclear enrichment process) is used to create strong and dense alloys for tank armour and anti-tank ammunition. These solid DU penetrators burn through armour and may fragment inside the target into smaller particles that ignite to cause a high-temperature incendiary explosion. In 1991, 286 metric tons of DU ammunition were used in the First Gulf War; 3 tons were used in Bosnia in 1994–1995; 11 in Kosovo and Serbia in 1999; and over 75 in Iraq in 2003—in total over 375 tons reported since 1990.[4]

Penetrators that hit their targets and burn cause airborne uranium oxide dust contamination. Unburned penetrators contaminate soil and groundwater. Official reports from the North Atlantic Treaty Organization (NATO)[5], and for governments and military in the United Kingdom[6], United States[7] and Europe[8] have consistently minimized radiological health risks from DU weapons. But complex health problems for civilians in recent conflict zones (Bosnia, Iraq) and illnesses known as Gulf War Syndrome for veterans of the First Gulf War have caused widespread concern.[9] This has led to investigations such as environmental testing by the United Nations Environment Programme and urine testing of veterans by the United Kingdom's Depleted Uranium Oversight Board, but no official testing of civilians in conflict zones. Almost all the investigations have focused on analysis and testing for depleted uranium.

Growing concern about the hazards of DU weapons are slowly seeing some response from the international community: the European Parliament has voted for a moratorium on DU ammunition in 2001, 2003 and 2008.[10] In October 2007 a United Nations General Assembly resolution requested the Secretary-General to submit a report on the "effects of the use of armaments and ammunitions containing depleted uranium" for its Sixty-third session.[11] However, the latest European Union and United Nations resolutions have been carefully restricted to the use of DU, excluding other non-nuclear uranium weapons. By restricting debate and scientific testing to depleted uranium weapons the arms control agenda has been diverted from a third generation of undisclosed uranium weapons developed to meet more recent strategic concerns—guided weapons enhanced with undepleted uranium.

Enhanced weapons and warheads

In the 1980s and 1990s the threats of large-scale tank warfare, and of chemical and biological weapons, led to the desire to modify or enhance a wide range of conventional weapons. These included retrofitting AGM-86 nuclear cruise missiles with non-nuclear warheads[12] and developing new bomb and missile warheads designed for hard or deeply buried targets, some with agent defeat (to burn up chemical or biological warfare agents) and anti-personnel effects. The United States Air Force (USAF) Mission Plan of 1997 included nine upgrades of bombs and missiles using "dense metal" warheads.[13] The possibility that these dense metal warheads might exploit uranium (or depleted uranium) for its high-density and incendiary properties was put forward in 2001 to explain radiation anomalies in the Balkans.[14] Jane's web site states that "some guided weapons used depleted uranium to increase the penetration effect".[15]

Data on these warheads are publicly available on military research and manufacturers' web sites,[16] but the high-density metals used are classified. Three different conventional warhead technologies can be enhanced using uranium components: shaped charge warheads and submunitions can use uranium in their liners; hard-target bomb and missile warheads can exploit uranium in their casings or as ballast; and high-density, reactive metal or thermobaric explosives can use the pyrophoric property of uranium. While tungsten alloys are also strong and dense, uranium has added advantages regarding its incendiary properties, and penetrates better.

Uranium-enhanced shaped charge warheads

The 1980s saw the development of increasingly complex and powerful anti-tank missiles, including small guided weapons with tandem warheads (which detonate twice or more), some of which used shaped charges. Short-range guided weapons were developed with a range of shaped charge warheads that could be used on many tactical targets, e.g. tanks, vehicles and bunkers. Shaped charge technology is now widely used in modern weapons from landmines, demolition charges and submunitions up to advanced multistage warheads used for hard-target penetration.

There is evidence to suggest that uranium is being used in shaped charge warheads. Civilian research into shaped charges for oil well perforation in the 1980s showed penetration increased fivefold when copper shaped charge liners were replaced with uranium.[17] The United Kingdom's Ministry of Defence web site reported tests for an "Anglo-French tandem warhead with DU rear liner" in 1999.[18] Upgraded shaped charge weapons (judging from the extra letters used in their names, e.g. AGM-65G) were deployed in the First Gulf War in TOW, Hellfire and over 5,000 Maverick missiles.[19] These systems were used again in the Balkans in 1995 and 1999, and in Afghanistan, Iraq and Lebanon.[20] It is not known how many used, or use, uranium-enhanced warheads, or the levels of contamination they have caused, because uranium liners would have burned or vaporized into fine oxide dust. Weapons manufacture and target inspections and casualty testing are needed to verify the extent to which uranium liners or casings are used in shaped charge weapons.

Uranium ballast in hard-target warheads

The threat that WMD may be hidden in hardened concrete bunkers or deeply buried in tunnels or caves resulted in the development of hard-target or "Bunker Buster" warheads. The 2 metric ton GBU-28 Bunker Buster was first tested in combat in Iraq in 1991.[21] These weapons tend to be much heavier than those using shaped charges, and are used for deep impact on larger targets.

The 1997 USAF Mission Plan and Hard and Deeply Buried Target Defeat System Program defined a new generation of guided weapons with short- and long-range warheads capable of penetrating up to 5m of reinforced concrete or over 20m of soil.[22] These warheads range in size from 250lbs to 20,000lbs. All are intended to achieve at least twice the penetration effect of previous weapons by using smaller diameter warheads and replacing steel with high-density metal casings or ballast. Some are also intended to function as agent defeat warheads.

These warheads are of standard sizes and compatible with existing weapons and delivery platforms. Combined with smart laser or satellite guidance units, e.g. JDAM and Paveway, they become guided bomb units (GBU). Some warheads can be delivered in air-to-ground missiles or sea-launched missiles. Enhancement projects include converting existing Air Launched (ALCM) and Tomahawk cruise missiles (TLAM) to be able to carry new hard-target, Advanced Unitary Penetrator warheads instead of tactical nuclear warheads.[23] Most of the warheads defined in the 1997 USAF Mission Plan became operational between 1999 and 2003 except the 20,000lb Direct Strike Hard Target Weapon (DSHTW).[24]

US patents published in 1999 and 2002, including one for upgrading the 2000lb BLU-109 warhead, confirm that hard-target warhead upgrades could use tungsten or uranium as the "heavy metal" mentioned in the USAF Mission Plan.[25] In November 2001 the UK Government claimed that DU could not be used in guided bombs because it was too soft, although it acknowledged that titanium may be used.[26] But as the new technologies are more clearly understood, the potential advantages of using uranium in hard-target warheads—its high density, its high-strength alloys, and the very high temperatures at which it burns—become clear.

In 1999, an analysis was published of the likely impact of weapon systems deemed to have been used in the Balkans if, as some suspected, they carried depleted uranium warheads (Tomahawk, BLU-109/B, GBU-28 Bunker Buster, BLU-107 Durandal, AGM-114 Hellfire and armour piercing incendiary ammunition).[27] The worst-case scenario estimated that with 400kg of DU in a Tomahawk warhead and 651kg in a BLU-109/B, attacks using 1000 of each could involve 1000 tons of DU. Of this at least 200 tons may be respirable. The study only considered the use of depleted uranium, since at the time there was no suspicion that weapons could be using any other form of uranium, but it is possible these weapons were in fact using undepleted uranium. Such use could explain the increased uranium dust levels observed by neighbouring states at the time (see below).

Uranium-enhanced explosives and thermobaric weapons

Thermobaric explosives produce intense heat and a blast wave that suffocates humans in the blast area (if they are not incinerated).[28] Uranium alloys can be engineered to produce hard but brittle bomb casings or ballast that can fragment and burn at very high temperatures, enhancing conventional weapons to create a blast with a fireball and fragments of burning uranium shrapnel. Video reports from Iraq and Lebanon show explosions with these effects.[29]

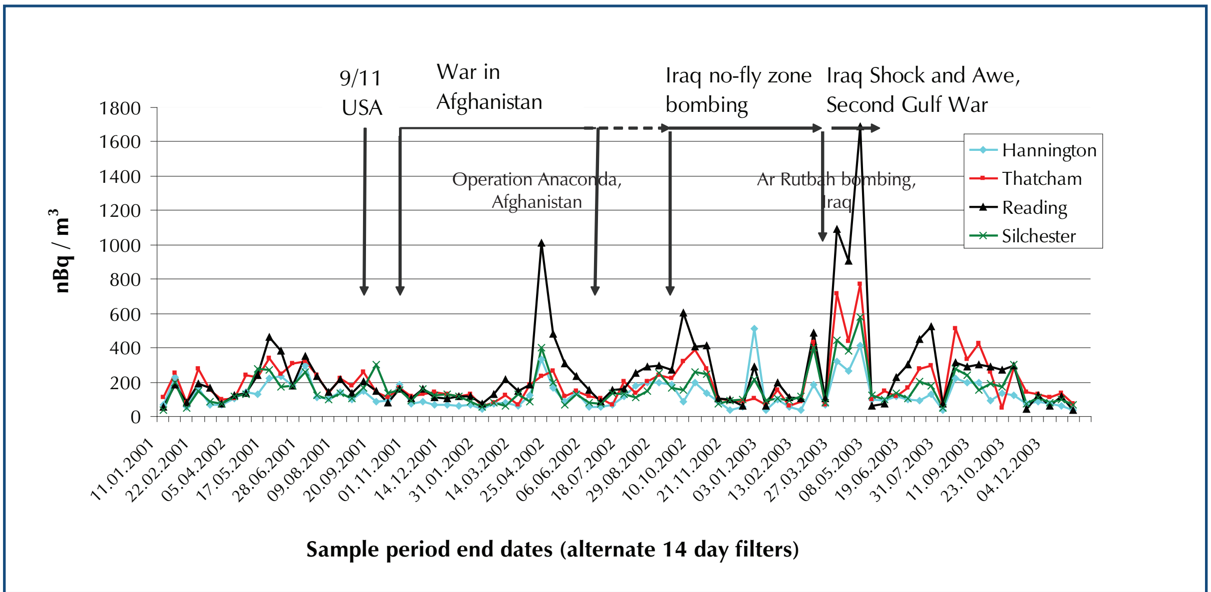
In March 2002 a thermobaric warhead was used on underground targets in Afghanistan. Designated the BLU-118/B, it used the new high-density warhead casings of the BLU-116.[30] The GBU-28 has been upgraded with the BLU-122—another dense metal warhead with a new explosive warhead—to become an enhanced Bunker Buster, EGBU-28 or EGBU-37. Thermobaric and high-density explosives have also been adapted to much smaller guided weapons, such as the AGM-114N Metal Augmented Charge Thermobaric Hellfire and the SMAW-Novel Explosive shoulder-mounted weapon used in Fallujah.[31]

Dense Inert Metal Explosive (DIME), officially using tungsten powder, is another development of concern, anticipated from an examination of US patents.[32] Operationally, tungsten and uranium alloys could be interchangeable. If suspected DIME casualties suffer severe burns, or burning shrapnel injuries, then this raises questions over whether uranium is being added or substituted to make a more reactive high-density explosive.

Evidence of uranium use in recent conflicts

Since the 1986 Chernobyl accident many countries have airborne radiation monitoring facilities. In May 1999 scientists in The former Yugoslav Republic of Macedonia detected an 8-fold increase in airborne uranium levels soon after US bombing attacks began in the Balkans.[33] In southern Hungary Kerekes et al. detected a 14-fold increase in airborne uranium dust (particles less than 2µm in size, with almost normal, not depleted, U-235/U-238 ratios) during the bombing of Belgrade.[34] Kerekes et al.

Figure 1. Uranium in high-volume air sampler filters of the Atomic Weapons Establishment, United Kingdom



Source: Adapted from C. Busby and S. Morgan, 2006, *Did the Use of Uranium Weapons in Gulf War 2 Result in Contamination of Europe? Evidence from the Measurements of the Atomic Weapons Establishment, Aldermaston*, Aberystwyth, Green Audit.

were testing for DU and concluded that what they had detected was natural uranium from soil disturbed by the bombing, an explanation reported by the UK Royal Society in 2002.[35]

In 2000, UNEP conducted an environmental assessment of DU contamination in the Balkans, when it received the necessary data from NATO regarding how much DU had been used and where (this had been initially requested by the UN Secretary-General in October 1999). NATO reported that their forces used 30,000 rounds (10 metric tons) of DU ammunition in about 100 locations in the Balkans in 1999.[36] UNEP did not test bomb or missile targets: it was looking into known DU use. UNEP published its report in January 2001, indicating no detectable contamination more than 10–20m from known DU targets.[37] This represented a major anomaly considering the uranium detected in Hungary and The former Yugoslav Republic of Macedonia. DU contamination from A10 bullets that only travelled 20m does not explain the detection of airborne uranium dust in two different places over 150km away.

Many of the 12,000 guided weapons used in Afghanistan between October 2001 and June 2002 were targeted at suspected caves and bunkers, thus it follows that many employed hard-target warheads. Suspicions of the use of uranium in these warheads were hard to verify: the United Kingdom and the United States have denied that the weapons used contained DU, therefore UNEP's post-conflict assessment of Afghanistan excluded any uranium testing.

But suspicions remained, and from 2002 several independent technical investigations into suspected new uranium weapons began. The Uranium Medical Research Center (UMRC) in Canada arranged two field missions to Afghanistan in 2002 and another to Iraq in 2003. The UMRC collected urine samples from civilians in bombed areas near Jalalabad. These showed no DU, but very high levels of undepleted uranium (80–400ng/l: the normal level among the United Kingdom population is 5ng/l).[38]

In 2004, Chris Busby used air sampling data from the Atomic Weapons Establishment (AWE) in Aldermaston, United Kingdom, from 1998 to 2003 to identify a major increase in airborne uranium dust less than two weeks after bombing in Baghdad (see Figure 1). This correlated with wind tracks from Iraq to the United Kingdom derived from the United States' National Oceanic and Atmospheric Administration (NOAA) modelling system. I ran further NOAA tests and correlated other AWE peaks in uranium levels with Operation Anaconda in Afghanistan (March 2002) and air strikes in Ar Rutbah, Iraq (5–10 March 2003).

Multiple testing verifies uranium contamination in Lebanon

During the 2006 conflict between Hezbollah and Israel in Southern Lebanon, unusual explosions and extreme injuries during the conflict caused Lebanese communities, media and non-governmental organizations to question whether Israel was using DU weapons or other new weapons. The United Nations Human Rights Council voted for an inquiry into the suspected use of DU and other illegal weapons in the conflict, which reported in November.[39]

I visited Lebanon in September and November 2006 and met Lebanese physicist Dr M.A. Kobeissi. I witnessed his radiation reading of 726nSv in Crater A, Khiam. I collected samples of soil and water from Khiam as well as water, dust and urine samples and an ambulance's air filter from south Beirut. These were tested by Chris Busby at Green Audit, by the Harwell laboratory in the United Kingdom and by the School of Oceanographic Sciences' laboratory at the University of Wales. Two samples contained high levels of undepleted uranium and four samples contained low-enriched uranium.[40] Dr Kobeissi continued his studies in 2007: 15 urine samples from Beirut were tested; two were found to contain low-enriched uranium and one a high level of undepleted uranium.[41]

UNEP's first post-conflict survey of Lebanon, undertaken in October 2006, tested 32 locations for DU only, and all were negative, so we met UNEP personnel in Geneva and returned to Lebanon to retest craters in Khiam on 21 November. UNEP did not test Crater B, where my soil and water samples were found to contain low-enriched uranium. But the results of their soil tests in Crater A matched Kobeissi's, with medium and high (26–52mg/kg, where normal is 2–3mg/kg) levels of undepleted uranium. UNEP's statements and final report reflect the results of their first survey, smear tests for DU only. [42] Their more precise soil test results are available on their web site.[43]

Levels and isotopic ratios of uranium contamination distinguish between man-made and natural sources. Bringing together the test results available for Lebanon—those from UNEP, Kobeissi and Busby/Williams—suggests the use of two different types of weapon, one containing undepleted uranium (Khiam Crater A) and one low-enriched uranium (Khiam Crater B); both types of contamination were found in Beirut.

Since 2002 several independent uranium weapons researchers have been collecting combat reports and uranium contamination reports and test results; combining these would create a valuable metadata resource. It has been suggested that the International Atomic Energy Agency (IAEA) should have an international databank of nuclear explosives to allow the identification of the source of nuclear materials following an explosion.[44] A similar facility is necessary for non-fissile uranium sources, weapons and contamination incidents, to build a clearer and more reliable picture of the possible development and use of new weapons and their effects.

Casualty reports

Conflicts are used to combat-test new and prototype weapons. The first warning of the use of new weapons often comes from combat reports of unusual deaths, injuries or destruction. These may not constitute legal or scientific evidence but they serve as early warnings to the possible use of either new and unknown or outlawed weapons, and to the need for operational vigilance and technical investigation.

The first warning of the use of new weapons often comes from combat reports of unusual deaths, injuries or destruction.

Deaths and injuries involving extreme burns indicate the use of high-temperature weapons. In 1945 the heat from nuclear weapons used in Japan carbonized casualties. In Iraq in 1991 casualties in tanks and vehicles hit by second-generation DU ammunition were carbonized; civilians in the Al Amiriya shelter in Baghdad were carbonized by a high-temperature explosion from a bomb or missile. In 2001 US troops bombed by accident in Afghanistan suffered extreme burns. In 2003 Iraqi troop casualties at Baghdad airport were extremely burned on one side but unburned on the other. In one case near Baghdad a child, partly protected by a wall, survived extreme burns that charred his exposed limbs and torso indicating brief, very high-temperature flash burns. In Fallujah, Iraq in 2004[45] and Lebanon in 2006 there were further reports of casualties with extreme burns.[46]

Since 2001 occasional reports from Afghanistan and Lebanon describe victims who died immediately, or within 24 hours, without external injuries, sometimes covered with black dust, sometimes with severe vomiting or internal bleeding;[47] civilian medical personnel would be unaware that these casualty reports match the effects of new thermobaric weapons.

Eyewitness and media reports of explosions

Photographs and television reports of combat situations give direct images of blast, explosions and the size, colour and dispersal of explosion plumes. They also indicate effects such as crater size, penetration and blast damage. Military personnel will recognize most types of explosion, plumes and craters, and which weapons cause them. Some journalists and media teams are also skilled observers of the effects of weapons and the casualties in combat zones, collating eyewitness reports and scientific or photographic data for public information.[48]

Pictures from Baghdad in 2003 and Beirut in 2006 (see above) all show explosions with a brilliant white flash (brighter than lightning) followed by a large fireball (up to 50m diameter). Fragments of burning shrapnel are blown 100–200m or more from the target, indicating high-density pyrophoric metal. Photos of explosions in Lebanon in 2006 often showed two explosions on targets—one from a high explosive and one fireball. Eyewitnesses several hundred metres from targets reported "silent" explosions and brief asphyxia "as if all the oxygen has gone". It appears that very large incendiary bombs are being used frequently, and their difference from high explosives is clear when looking at a mixed strike.[49]

Unusual illnesses and deaths

International and regional organizations involved in emergency response and post-conflict recovery must be alert for unusual health problems after an attack, not to forget the peacekeepers or coalitions that might also be exposed, and national emergency response, health and arms control agencies. Health reports from combat zones are quickly forgotten among the many other urgent concerns, but they may be early indications of communities contaminated by the use of new weapons and deserve investigation.

However, acute exposure to toxic, biological or radioactive sources can be fatal within hours or days. In chaotic conflict situations medical personnel able to assess the cause of death are likely to be scarce and victims are often buried quickly for health, cultural or religious reasons. Medical assessments for the most acute casualties are rare in remote locations so eyewitness reports of unusual deaths are important in trying to establish the cause of death.

Even for well-resourced populations like the United Kingdom and the United States, health anomalies among troops may be undiagnosed, misdiagnosed or not reported. In 1991 US troops in Iraq reported early onset symptoms of nausea, numb hands and feet, joint pains, weakness etc. These symptoms were widespread and also affected non-combatants e.g. technicians. In 2000 several NATO personnel from Italy and Portugal died after post-conflict deployment to heavily bombed areas in the Balkans.[50] Most died of rapid onset leukaemias or lymphomas, and classified investigations are ongoing.

In July 2003 a US soldier was evacuated from Baghdad with a mysterious, non-bacterial pneumonia after hauling contaminated soil from targets in Baghdad to the desert. He died three days later of renal failure. Nineteen other troops were reported with similar conditions.[51] Severe lung irritation and toxic effects could be symptoms of exposure to large amounts of uranium oxide dust. This possibility was recognized in the United Kingdom's Royal Society report on DU in 2002, but as the investigation was on known uses of uranium in combat, there was no expectation of possible lethal toxic exposure from uranium or depleted uranium in large warheads.[52]

In Afghanistan there were several reports of unusual illnesses and fatalities in combat regions: doctors reported several undiagnosed deaths within 2–3 days of bombing incidents that they suspected were due to non-conventional weapons.[53] In November 2001 the World Health Organization's Epidemic and Pandemic Alert and Response web site reported a major epidemic of leishmaniasis in the Kabul region. In February 2002 it reported 30 deaths from Crimean-Congo haemorrhagic fever out of season.[54] In April 2003 visceral leishmaniasis was reported in northern Iraq soon after bombing and an influenza epidemic in western Iran, downwind of bombing in Iraq. Perhaps understandably, symptoms and injuries are being explained by "known" possible causes, as medical experts are not looking for the possible effects of the use of new weapons. However, these explanations can seem far-fetched.

Health problems that may be delayed onset effects of weapons use (three to five years or more after attacks) were reported in Iraq in the mid-1990s, Bosnia in the late 1990s, and more recently in Afghanistan and Fallujah, Iraq. Reported problems include severe birth defects, leukaemias, lymphomas and a range of other chronic or fatal health conditions.[55]

Comprehensive public reports about overall post-conflict health and mortality for military personnel in Europe and North America are rare. Rigorous uranium testing for veterans only started with the United Kingdom's Depleted Uranium Oversight Board project after 2002.[56] Most veterans who have served in locations presumed or known to have been contaminated by uranium have not been fully tested for uranium contamination. There has been no systematic national uranium testing of civilians from recent conflict zones since 1991. The search of veterans and civilians involved in the First Gulf War for answers to their long-term health problems remains far from over in 2008.

Conclusion

Undepleted uranium dust is effectively invisible to conventional field and laboratory tests. It gives no gamma radiation indication in the field and shows an almost normal isotopic ratio in laboratory tests. This is perfect camouflage for large quantities of radiological contamination—it appears to be natural background uranium.

Recent public and scientific discourse has been restricted to depleted uranium, mainly because this is the only form of uranium that has been admitted as used in weapons. However, as long as it is suspected that new weapons are being developed and used that contain other forms of uranium, scientific assessments of veterans' and civilians' health, and of the post-conflict environment, must consider the use of any combination of uranium isotopes.

The borderline between conventional, radiological and nuclear weapons is increasingly blurred.

This paper describes warhead enhancements planned over 10 years ago. If these weapons are using uranium, the levels of contamination could be massive. Moreover, what developments have there been in the meantime? The borderline between conventional, radiological and nuclear weapons is increasingly blurred, both technically and legally. In 2004 the United Nations Advisory Board on Disarmament Matters noted that:

> The nuclear non-proliferation and disarmament regime does not address the issue of radiological weapons and warfare, as it is strictly devoted to nuclear weapons and the respective fissile materials. No international instrument is available in the realm of radiological weapons.[57]

The board recommended that the Conference on Disarmament begin negotiations on a convention for the prohibition of radiological weapons. International debate and far wider health studies and scientific review are needed to uncover the full scope of radiological weapons technology, their use, and hazards for civilians, troops and global contamination.

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The risks of depleted uranium contamination post-conflict: UNEP assessments

Mario Burger

Perhaps the most endangered natural resource in times of war is truth. So concluded, in the year 2000, the United Nations Environment Programme's (UNEP) first post-conflict environmental assessment. For the safety of local populations and international workers in post-conflict situations, it is essential that reliable and accurate information be available to evaluate the risks to life and human health from the environmental consequences of war, and to take appropriate measures for their mitigation.

Depleted uranium (DU), the main by-product of uranium enrichment, is a chemically and radiologically toxic heavy metal. It is mildly radioactive, with about 60% of the activity of natural uranium. This dense metal is used in munitions for its penetrating ability and as a protective material for armoured vehicles. The health effects resulting from DU exposure depend on the route and magnitude of exposure, as well as characteristics such as particle size, chemical form and solubility. Where DU munitions have been used, the penetrators, penetrator fragments, and jackets or casings can be found lying on the surface or buried at varying depths, leading to the potential contamination of air, soil, water and vegetation from DU residue.

To evaluate and address the potential contamination of the environment by depleted uranium, UNEP has conducted environmental assessments and measurements on DU-targeted sites in the Balkans and in Iraq. In addition to these surveys, UNEP has carried out a range of capacity-building activities in environmental assessment techniques for Iraqi Ministry of Environment staff to identify, assess and address potential, immediate and long-term DU-related risks to human health and the environment.

UNEP has from the beginning maintained close cooperation with the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) in this field of work. According to respective mandates, all radiological calculations necessary to conclude on radiological conditions in areas contaminated with DU residue have been performed by the IAEA—and then discussed with partner organizations—while WHO is responsible for calculations regarding the toxicology of DU, and has developed scenarios and published health-related materials on the basis of UNEP's findings.

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UNEP in the Balkans

As part of the post-conflict assessments conducted by UNEP in the Balkans, three environmental assessments of sites targeted with depleted uranium were carried out. The first, which made environmental contamination data from zones attacked with this type of ammunition publicly available for the first time, was conducted in Kosovo in 2000–2001. It was followed by surveys in Serbia and Montenegro in 2001–2002 and in Bosnia and Herzegovina in 2002–2003.

Kosovo 2000–2001

UNEP's work on depleted uranium started midway through 1999, with a desk study of the potential effects of the possible use of DU during the conflict, which was conducted as part of the general assessment of the impact of the Kosovo conflict on the environment and human settlements.[1]

The following year, the North Atlantic Treaty Organization (NATO) provided UNEP with new information concerning the use of DU during the Kosovo conflict, including maps, number of rounds used, and coordinates of the targeted areas. With accurate details regarding where DU penetrators are likely to have struck, inspectors are able to conduct far more precise assessments. UNEP was able to carry out the first ever international environmental assessment of DU when used in a real conflict situation.

Because one and a half years had elapsed since the conflict, the overall aim of the UNEP mission was to examine the possible risks from any remaining DU contamination of ground, water and biota, and from solid pieces of DU (i.e. intact or fragmented penetrators) still in the environment. The key questions facing the mission were: what are the present levels of DU contamination in Kosovo? What are the corresponding radiological and chemical risks, both now and in the future? Is there any need for remedial measures or restrictions? If so, which measures are reasonable and realistic?

The final report, *Depleted Uranium in Kosovo: Post-conflict Environmental Assessment,*[2] published in March 2001, concluded that analyses of the samples collected showed only low levels of radioactivity. Furthermore, the results suggested that there was no immediate cause for concern regarding toxicity. However, major scientific uncertainties persisted over the long-term environmental impacts of DU, especially regarding groundwater.

Due to these scientific uncertainties, UNEP called for precaution and recommended action to be taken for the clean-up and decontamination of the polluted sites, for awareness-raising among the local population, and for future monitoring.

Serbia and Montenegro 2001–2002

During the Kosovo conflict, a few sites outside Kosovo, in Serbia and Montenegro, had also been targeted with ordnance containing depleted uranium. It was therefore evident that a second phase of scientific work would be needed following the Kosovo assessment. This started in September 2001 and was concluded in March 2002 with the publication of the report *Depleted Uranium in Serbia and Montenegro: Post-conflict Environmental Assessment in the Federal Republic of Yugoslavia.*[3]

The report provided additional information and revealed important new discoveries on the environmental behaviour of DU. Experts found that more than two years after the end of the conflict, particles of DU dust could be detected from soil samples and from sensitive bio-indicators like lichen. However, as the levels were extremely low, it was only through state-of-the-art laboratory analyses that these could be detected. Based on the findings, UNEP could confirm that contamination at the targeted sites was widespread, though no significant level of radioactivity could be measured.

Furthermore, during this assessment the UNEP team used modern air sampling techniques and detected airborne DU particles at two sites. While all levels detected were below international safety limits, these results added valuable new information to the scientific body of knowledge concerning the behaviour of DU and had important implications for site decontamination and construction works.

As in the Kosovo case, UNEP called for precaution, monitoring and awareness-raising for the local population. Clean-up and decontamination had started in both Serbia and Montenegro when the assessment was ongoing, and detailed recommendations on these issues were given in the report.

Bosnia and Herzegovina 2002–2003

Finally, DU was used in Bosnia and Herzegovina during bombings in the mid-1990s, and UNEP undertook an assessment of the impacts in September 2002. Fifteen sites were selected for analysis, of which five were areas where NATO had reported using DU munitions. The remaining ten were areas where the local population or authorities had concerns that DU may have been used. The final report, *Depleted Uranium in Bosnia and Herzegovina: Post-conflict Environmental Assessment,* was released in March 2003.[4]

This report contained four significant findings. First, detailed laboratory analyses of surface soil samples revealed low levels of localized ground contamination. While local ground contamination could be detected up to 200m from the impact zone, it was typically detected within a 100m radius.

Second, penetrators buried near the ground surface and recovered by UNEP had decreased in mass by approximately 25% over seven years. Based on this finding, and correlated with penetrators examined in UNEP's earlier studies, it was possible to determine that a DU penetrator could be fully oxidized to corrosion products, including uranium oxides and carbonates, within 25 to 35 years of impact. Following that time period, no more metallic DU from penetrators would be found buried in the soil of the Balkans.

Third, DU contamination of drinking water was found for the first time at one of the surveyed sites. The concentrations were very low and the corresponding radiation doses insignificant for any health risk. Nevertheless, because the mechanism that governs the contamination of water in a given environment is not known in detail, it was recommended that water sampling and measurements should continue for several years, and that an alternative water source should be used when DU was found in drinking water.

Finally, DU contamination of air was found at two sites, including air and surface contamination inside two buildings at two different sites. Resuspension of DU particles due to wind or human activities was the most likely cause. The concentrations were very low and resulting radiation doses insignificant. However, precautionary decontamination and clean-up steps were recommended for the buildings on site, as they were being used by the military and the civil population.

The levels of DU contamination were not a cause for alarm, but some uncertainty remained.

Overall, the findings of this study were consistent with the findings of UNEP's earlier assessment work in the region: the levels of DU contamination were not a cause for alarm, but some uncertainty remained with respect to future potential groundwater contamination from penetrator corrosion products.

UNEP in the Persian Gulf

The 1991 Gulf War was the first conflict in which depleted uranium munitions were used extensively. In total, some 300 metric tons of DU-containing munitions were fired by the United Kingdom and the United States in the course of the war, with DU remaining in the environment as dust or small fragments. While no independent scientific assessment of the impacts of the 1991 conflict has been conducted in Iraq to date, UNEP participated in an assessment led by IAEA in January 2002 of the possible long-term radiological impacts of DU residue at 11 locations in Kuwait. Although the findings of the report, which was published in 2003, were not alarming, further policy action and additional research were recommended to resolve uncertainties relating to the use and effects of DU munitions in the country.

The Second Gulf War[5] broke out on Iraqi territory on 19 March 2003. Approximately 120,000 troops from the United States, 45,000 from the United Kingdom, and smaller forces from three other nations, collectively called the Coalition Forces, were deployed for the operation.

The war itself was preceded by air attacks on selected Iraqi targets, which continued during the land invasion. Several air attacks were conducted by A-10 Thunderbolt II aircraft, which utilized DU munitions. DU munitions were also used by UK and US tanks in several land battles, mainly against Iraqi tanks. The UK Ministry of Defence has reported that its troops fired approximately 1.9 metric tons of DU munitions during this conflict, and in June 2003 it provided UNEP with the coordinates of DU firing points of the UK Challenger 2 tanks. Information concerning the overall quantity of DU munitions used and the corresponding coordinates of the firing points from the United States has, as yet, not been made available.

Assessing the environmental impacts of the conflict

UNEP continuously monitored the potential environmental impacts of the conflict throughout its duration and organized a series of round-table meetings to share findings on key environmental issues and coordinate activities with relevant stakeholders, such as the Iraqi government ministries.

Following the conflict, in April 2003, UNEP published a *Desk Study on the Environment in Iraq*.[6] The report outlined the environmental vulnerabilities in Iraq resulting from years of conflict, the low priority attached to the environment by the previous regime, and the unintended effects of sanctions in the 1990s. In July 2003, the United Nations Development Group and the World Bank jointly carried out a needs assessment for Iraq, covering 14 priority sectors and three cross-cutting themes. As the lead agency on the environment, UNEP provided substantive input to this report.[7] Field missions to Iraq were undertaken in mid-2003, and in October 2003 the findings were published in UNEP's progress report on the *Environment in Iraq*.[8]

Both the desk study and the progress report identified the need for an environmental assessment of selected contaminated sites in order to identify risks to human health and livelihoods and to initiate urgent risk reduction measures.

In early 2004, UNEP actively participated in drafting the United Nations' action plan for Iraq, *A Strategy for Assistance to Iraq*. The strategy brought together a range of prioritized programmes addressing humanitarian, reconstruction and development needs to be undertaken by the UN family, its partners and others working closely with the Iraqi authorities. Presented at a donor conference in Abu Dhabi in February 2004, the strategy was used as a basis for follow-up and to secure financial pledges.[9]

To identify priorities for 2004 and 2005, UNEP held a number of major consultation sessions with Iraq's Ministry of Environment. In July 2004, UNEP was awarded a project for "strengthening environmental governance in Iraq through environmental assessment and capacity-building", which was supported by the United Nations' Iraq Trust Fund through funds made available by the Government of Japan. It was under this programme that UNEP undertook to build the capacity of Iraqi environmental authorities to assess and address the potential damage caused by the use of depleted uranium munitions during the 2003 war.

Capacity-building for the assessment of depleted uranium in Iraq

The possible health effects on the Iraqi population of DU residues on the battlefield raised concern both among the Iraqi population and in other parts of the world. In April 2005, UNEP convened a meeting in Geneva with the IAEA and WHO to discuss, coordinate, agree and plan collaborative work on the environmental and health effects of DU residues in Iraq. The three organizations also agreed to work with the Iraqi Radiation Protection Center (RPC) of the Iraqi Ministry of Environment on DU-related matters.

Given that the prevailing security constraints prevented international experts from travelling to Iraq, the project focused on delivering capacity-building and training to national staff outside Iraq to enable them to conduct fieldwork in country.

UNEP's depleted uranium capacity-building project in Iraq, detailed in a report published in August 2007,[10] had five main objectives: to train officials from Iraq to undertake a field-based assessment of depleted uranium using internationally accepted methodologies and modern equipment; to provide the trained officials with precise information on sites to assess and type of samples to collect; to supervise remotely the assessment and retrieve samples; to analyse the field observations, monitoring results and samples to draw conclusions on the effectiveness of the capacity-building activities; and to review the results and provide recommendations to the Ministry of Environment on follow-up action.

UNEP provided training to Iraqi experts from the RPC through three workshops designed to cover all the aspects of DU assessment in the affected areas. The first, which was held at the Spiez Laboratory in Switzerland in May 2004, focused broadly on environmental inspections and laboratory analyses, rather than specifically on depleted uranium. UNEP and Spiez Laboratory experts trained participants in the basics of environmental inspections, as well as soil, air and water pollution, hazardous chemicals and waste management.

The second workshop—on DU site investigation techniques—took place in June 2005 in Amman, Jordan. The objective of the workshop was to provide training, equipment and technical assistance to selected Iraqi professionals. Eleven experts from the Ministry of Environment's RPC and four from the Ministry of Health received basic technical training. Participants were trained in the use of instruments that were then handed over to the Head of Delegation, as well as in equipment to be provided in the near future. Selection criteria for the equipment included durability, portability and suitability to the operating environment of Iraq.

A third workshop held in Geneva in August 2005 concentrated on site investigation techniques in urban areas. The practical session of the workshop had a comprehensive agenda covering nearly all the measurement techniques that are useful in urban areas. It also comprised detailed training on sampling methods, clean-up and small-scale decontamination measures. The practical work focused on realistically simulating the prevailing conditions on a site targeted by DU weapons. Measurement and clean-up techniques were demonstrated by the UNEP expert team and experimented in detail by each participant. Sampling strategies and techniques were also developed.

Map 1. Sites tested for depleted uranium contamination, 2006–2007

Source: Based on United Nations Cartographic Section map no. 3835 Rev. 4, January 2004.

Local expert DU site assessments

Having completed the training, national staff then collected environmental samples at selected sites in southern Iraq during sampling campaigns conducted in 2006–2007. The sampling campaigns were part of the final module of the capacity-building process. Trained Iraqi RCP staff utilized specialized documentation prepared by UNEP, known as *Local Expert DU Site Assessment Packages I and II*. A total of 520 samples of soil, water and vegetation were collected as well as smear samples at four areas in southern Iraq, As Samawah, An Nasiriyah, Al Basrah, and Az Zubayr, as indicated on Map 1.

Due to the limited analytical infrastructures available to the Iraqi RPC and in order to ensure a better scientific reliability, the collected samples were sent to UNEP Geneva for analysis by Spiez Laboratory for their content of various uranium isotopes (U-238, U-236, U-235 and U-234) using high-resolution inductively coupled plasma mass spectrometry.

The following exposure pathways were considered in the radiation dose assessments: inhalation of DU-contaminated soil resuspended by the action of wind or human activity; inhalation of resuspended DU dust inside military vehicles hit by DU munitions; ingestion of DU-contaminated soil; ingestion of DU-contaminated vegetables and drinking water; direct contact with DU penetrators or DU fragments; and ingestion of DU-contaminated dust from flat surfaces (metal, concrete, walls). In addition, consideration was given to the risk of inhalation of DU dust during the scrapping of military vehicles hit by DU munitions and the re-melting of the scrap metal.

The radioanalytical results were shared between UNEP and the IAEA for an estimation of the radiation doses and corresponding risks to which the Iraqi population living at the four investigated locations could become exposed. The radiation doses were calculated as committed equivalent doses corresponding to one year's intake of DU. The estimation was done in a very conservative way, generally utilizing, of all the data provided by Spiez Laboratory, only that which showed the highest DU contamination (the so-called "worst cases") and assuming habit data for the local population that in most cases corresponded to (usually unrealistically) high DU intakes.

On the basis of the measurements carried out and the committed doses calculated it was concluded that DU residues in the environment did not pose a radiological hazard to the population at the four studied locations, as long as minimum precautionary measures were implemented, such as not entering vehicles hit by DU munitions, not undertaking long-lasting activities around objects hit by DU, not collecting penetrators or shrapnel that could contain residues of DU, and not recycling or processing objects hit by DU. Taking these precautionary steps, the estimated annual radiation doses that could arise from exposure to DU would be low (less than 90μSv)—below the annual doses received by the population of Iraq from natural sources of radiation in the environment and therefore of little radiological concern. The doses were also far below the action level of 10mSv suggested by the International Commission on Radiological Protection as a criterion to establish whether remedial action is necessary.

It must be emphasized that from the strictly scientific point of view these conclusions cannot be extrapolated to other locations in Iraq where DU ammunition was used as they strongly depend on many factors, including the amount of DU munitions fired, the specific geographical and meteorological conditions, the land characteristics and uses, the population habits and, last but not least, the intrinsic limitations of any assessment of the presence of DU residues from ammunition in the environment, which rarely extends more than a few metres away from the DU source. However, it is unlikely that these findings would be significantly different at other locations in Iraq where DU has been used.

Concerning the handling of DU penetrators and penetrator fragments, it was concluded that the dose received could become significant only if a person were in contact with them for a considerable period of time. A higher potential radiological risk was found to exist where vehicles hit by DU ammunition were present and people were entering them. Of particular concern were the scrapyards where destroyed military equipment was stored and scrap operations were apparently being conducted. An estimation of the potential doses received by workers involved in the re-melting of DU contaminated scrap metal was difficult to perform, however, in the absence of relevant experimental data.

Final recommendations

On the basis of the findings of the assessment work detailed above, a number of detailed recommendations were developed to ensure that risks emanating from the use of depleted uranium munitions during the conflict in Iraq are addressed and mitigated. These are valid for any location potentially contaminated with DU. In zones where DU munitions have been used, UNEP recommends that:

- a campaign is conducted to educate people, in particular children, about the importance of avoiding being in close contact with war-related equipment;
- steps are taken to prevent anyone from entering military vehicles hit by DU munitions;
- metal scrapping of DU-contaminated military equipment and its re-melting are avoided;
- secure areas for storing DU-contaminated equipment are identified;
- all war-related equipment is assessed for the possible presence of DU and, when positively identified, is moved to secure locations;
- access to these secure locations is restricted, as well as to all scrapyards where war-related equipment contaminated by DU is stored;
- DU-contaminated equipment is not decontaminated, as this may imply radiation hazards and the management problems associated with the radioactive waste generated would represent an additional problem;
- contaminated equipment is diposed of without further treatment by appropriate burial (this represents the most cost-effective option);
- DU residue (DU penetrators, penetrator fragments and their corrosion products) is safely removed from surfaces at targeted zones by authorized personnel and following appropriate storage practices; and
- the local residents and workers are informed of the possible hazards associated with the remnants of DU weapons, and advised, in case of clear necessity (e.g. when authorized personnel are not available), to minimize handling and use protective gloves.

UNEP hopes that the body of knowledge gathered through its assessment and capacity-building activities since 1999 will help countries to address the potential risks related to the contamination of air, soil, water and vegetation from the use of depleted uranium in times of conflict, and stands ready to provide further assistance upon request.

Notes

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UNIDIR FOCUS

PROJECT UPDATE

Implementing the UN Programme of Action on Small Arms and Light Weapons: Analysis of the National Reports Submitted by States from 2002 to 2008

As part of the ongoing project Capacity Development for Reporting to the UN Programme of Action on Small Arms, with the United Nations Development Programme, the United Nations Office for Disarmament Affairs and the Small Arms Survey, UNIDIR presented a draft report to the 2008 Biennial Meeting of States on Small Arms and Light Weapons, which analysed all national reports submitted since the adoption of the Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects (PoA), covering the period from 2002 to 2008.

Unlike the previous biennial meetings of states (BMS) to consider the national, regional and global implementation of the PoA, the third BMS focused on a select number of issues identified through consultation with states and civil society: illicit brokering in small arms and light weapons, stockpile management and surplus destruction, and the International Instrument to Enable States to Identify and Trace, in a Timely and Reliable Manner, Illicit Small Arms and Light Weapons (the International Tracing Instrument). As a cross-cutting issue, the meeting also discussed international cooperation and assistance and national capacity-building.

UNIDIR's PoA study analyses national implementation of PoA commitments relating to these focus themes as reflected in the reports that states submitted to the UN Office for Disarmament Affairs. A review of national reports indicates that significant efforts are being made by states to fulfil their commitments under the PoA and to curb the illicit trade in small arms.

This report is the third in a series of national report analyses (2004 and 2006). The draft report is available on the UNIDIR web site, at <www.unidir.org>, and the final analysis report will be published before the end of 2008, taking into consideration feedback on the draft report and updated reporting from the BMS. Its aim is to enhance reporting by states to the end of providing a more comprehensive picture of the progress that is being made to implement the PoA, thus increasing international cooperation and assistance to help states implement their PoA commitments, and ensure that global efforts to implement the PoA are coordinated and sustained.

In each issue of *Disarmament Forum*, UNIDIR Focus highlights one activity of the Institute, outlining the project's methodology, recent research developments or its outcomes. UNIDIR Focus also describes a new UNIDIR publication. You can find summaries and contact information for all of the Institute's present and past activities, and download or order our publications, online at <www.unidir.org>.

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NEW PUBLICATION

Implementing Resolution 1540: The Role of Regional Organizations

Over the past several years, there has been progressive recognition of the relevance and value of regional and subregional organizations in the area of peace and security, with particular reference to United Nations Security Council Resolution 1540. Resolution 1540 is one in a series of measures taken to address threats deriving from access to, or use of, weapons of mass destruction, related materials and means of delivery. It is distinct from existing treaty-based non-proliferation and arms control regimes—the Treaty on the Non-Proliferation of Nuclear Weapons, for example—in several respects: it covers all weapons of mass destruction and it reaches beyond the state and focuses explicitly on the risk posed by non-state actors. It also goes beyond existing anti-terrorism conventions that collectively impose similar though less comprehensive obligations on parties in that, being adopted under Chapter VII of the UN Charter, the resolution is binding on all Member States of the United Nations.

The Security Council recognizes the important role that regional and subregional organizations play in peacekeeping, peacebuilding and the fight against terrorism and illicit weapons: while implementation of national controls is a national responsibility, priorities should be set by national governments and regional organizations. It can be easier to set priorities and deal with national controls in regional rather than in bilateral or universal forums.

This book examines the experiences of regional organizations in Africa, Latin America and South-East Asia and the Pacific Islands, to the end of identifying what these organizations can do to motivate and assist their members, and invest them with ownership of the problems posed by weapons of mass destruction and non-state actors.

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