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Depleted uranium: a new environmental radiotoxological pollutant*

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Abstract

The paper discusses the possible applications of depleted uranium (DU), a by-product of the nuclear industry. Large quantities of DU, mostly in the form of UF_6, have been accumulated in the last 25 years, especially in the United States. There has been some efforts devoted to extend the rather limited civilian applications of DU. But the major efforts have been in military areas such as kinetic weapons. Civilan and military use of DU leads to environmental pollution and its effects of human health is possibly associated with the so called "Gulf War Syndrome".

Key words: depleted uranium, DU, environment protection, gulf war syndrome, heavy metal, radioactivity, soil pollution, uranium

Zusammenfassung

Abgereichertes Uran - ein neues radiotoxikologisches Umweltgift

Der Beitrag beschreibt Anwendungsmöglichkeiten für abgereichertes Uran (DU), das als Nebenprodukt bei der Herstellung von Kernbrennstoffen anfällt. In den vergangenen 25 Jahren sind die auf Halde liegenden Mengen an DU, meist in der Form von UF_6 , erheblich angewachsen, insbesondere in den Vereinigten Staaten. Anwendungen von DU im zivilen Bereich sind nur sehr begrenzt möglich. Die weitaus größten Mengen an DU werden dagegen im militärischen Bereich zur Herstellung kinetischer Waffen eingesetzt. Zivile und militärische Nutzung von DU bedingen zwangsläufig Umweltbelastungen, deren Auswirkungen auf die menschliche Gesundheit mit dem sogenannten „Golfkrieg Syndrom" in Zusammenhang gebracht werden.

Schlüsselwörter: abgereichertes Uran, Bodenbelastung, DU, Golfkrieg Syndrom, Radioaktivität, Schwermetall, Umweltschutz, Uran

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1 Introduction

This paper discusses the problems posed by environmental pollution due to depleted uranium (DU). Depleted uranium is a radioactive waste product of uranium enrichment for nuclear fuel and especially for nuclear weapons production. Today there are huge stockpiles mostly managed by nuclear weapons states. DU is currently being used in a few civilian applications. But the main controversy concerns its use in military applications which has already resulted in the release of several hundred to thousands of tones of DU into the natural environment since its first widely-reported use in the Gulf war in 1991. It has been suspected as a partial cause of the Gulf War Syndrome (GWS) afflicting a large percent of the mostly American and British soldiers as well as a sudden increase in birth defects, genetic diseases and cancers in Iraq itself. Much of the DU involved in such armed conflicts end up as ultra fine oxide particles circulating in the atmosphere, or as corroding shells on the battlefield. Eventually most of the DU will end up in the soil and water system somewhere. It can affect the civilian population by being inhaled or being ingested from the water or food supply and so will add to the radiation dose of the population due to natural or other manmade sources (remnants from atom bomb testing, nuclear accidents such as Chernobyl, etc.).

In order to make the discussion intelligible to the non-specialist, it is necessary to introduce some parts of radiological physics including the concepts of health physics. This includes discussing the controversial problem of judging the danger of low level radiation dose on the health of the population in a scientific manner.

For this it is important to consider the total activity of the DU released to the environment and the fact that DU is an α-emitter and thus especially dangerous when incorporated into the lungs or ingested. The total activity depends on the total mass of DU involved in the many military attacks since 1991, and actual data has only been very grudgingly divulged by the military in cases when plausible denial would no longer work. No *independent* verification of this data has been possible, and in fact, evidence of political interference in scientific decisions (All the President's yes-men? 2003; Michaels et al. 2002).

2 Basics of radiological physics

Earnest Rutherford made the fascinating discovery that the mass of an atom is not homogenously spread-out over its volume, but concentrated in an astoundingly small nucleus. This nucleus carries an electric charge (conventionally labeled positive), which is compensated by an equal negative charge filling most of the volume of the atom, but representing little of its mass. This nucleus is built up of two units: positive charged protons and neutral (uncharged) neutrons, both with almost equal weight. Thus the number of protons is called the atomic number A and characterizes the type of atom (iron, nickel...). The number of protons plus neutrons is called the atomic mass Z. Atoms with the same A but different Z are denoted isotopes. It was soon learned that some isotopes are spontaneously unstable: they transform into other atoms with different A (and perhaps Z) sending out charged particles. An example which will be confronted in this paper is uranium: its many isotopes are all unstable. Two types of spontaneous transformations are observed. In α-decay, a doubly charged particle composed of two neutrons and two protons is ejected at high energy. The resulting reaction is:

$$ {}^{Z}_{A}\mathrm{X} \rightarrow {}^{Z-4}_{A-2}\mathrm{Y} + {}^{4}_{2}\alpha \ . $$

X and Y are the parent and daughter isotopes, respectively. The α particle is really only a nucleus of the most common helium isotope. The second is β-decay, where the ejected β particle can carry either a positive or negative charge, but otherwise essentially is an energetic electron. This reaction would be written:

$$ {}^{Z}_{A}\mathrm{X} \rightarrow {}^{Z}_{A\pm1}\mathrm{Y} + {}^{0}_{\mp1}\beta $$

This latter decay is usually accompanied by the further emission of excess energy of the daughter nucleus in the form of one or more γ rays. (In the β decay the emission of another particle called a neutrino is neglected since this has no consequences in health physics. Variations on β+ decay, as well as other nuclear reactions are also neglected). The daughter isotopes formed from these reactions are not necessarily stable, and may decay further in their turn, forming a well-defined decay chain. Many radioisotopes found in nature can be grouped into one of three known decay chains. The activity is defined as the number of disintegrations per unit time in Bq. Averaged over many parent nuclei, the activity is proportional to the number present, leading to a description in terms of a decay constant λ:

$$ N(t) = N_0 e^{-\lambda t} \ , $$

where the constant λ can be expressed as the half-life $t_{1/2}$:

$$ t_{1/2} = \ln 2 / \lambda \ , $$

which is the time necessary to reduce the activity N to one half the starting value N_0 . Half-lives of several α emitters can reach more than the necessary 10^8 a (years) in order to be present the earths crust without being constantly created by some decay chain. Thus ^{235}U is present (7.04 x 10^8a), while ^{205}Pb is not (3.0 x 10^7a).

Health physics is a discipline born of the observation that energetic radiation emitted from sources of spontaneous radioactivity damage tissue when absorbed. The following topics are confined to the anthropomorphic question of human tissue. α and β particles loose their kinetic energy in tissue by ionizing atoms which they encounter. γ radiation is absorbed by a complex cascade of effects which also leads to direct ionization as well as high energy electrons which are also slowed by ionization processes. For completeness the health effects of neutrons emitted by some nuclear reactions has to be considered. Neutrons are not charged but are absorbed by nuclei, which can lead to activated (radioactive) daughter nuclei.

The effects of radiation can be grouped into immediate ones, and long term effects. The immediate (up to days) is known as radiation sickness, and is only a problem by doses much larger than the radiological contamination which is the subject of this paper. The severity of the radiation sickness is a monotonically increasing function of the dose, and below a certain threshold, no effects are seen. The long term effects include incidence of cancers and genetic mutations. Their probability (not severity) is a monotonically increasing function of dose. Changes are seen long afterwards, making risk assessment difficult. Populations have been misused, even by their own governments, for radiation experiments, but health science must rely on the data collected on the health effects of the survivors of the nuclear bombing of Hiroshima and Nagasaki, as well as the different inadvertent industrial accidents (most notably Chernobyl) as well as data collected for example around atomic power plants.

The absorbed dose from ionizing radiation is measured as the energy per unit mass absorber, in Gray (Gy = 1 Joule per kilogram). However, even the earliest research on radiation damage showed the sensitivity to the type of radiation: x-rays, β or α particles or neutrons. It was found necessary to distinguish radiation with a low linear energy transfer (LET), such as γ rays or x-rays and electrons, as opposed to radiations with a high LET, such as neutrons or α particles. Thus it was necessary to introduce weighting factors for each (unity for the first, up to 20 for the second), with the sum equal to the effective dose in Sievert (Sv, also in energy per unit mass). These factors are 20 for α-particles, 10 for thermal neutrons, 1 for β-particles and 1 also for γ-rays. In order to adjust for the different sensitivities of different parts of the body, an organ/body part weighted whole-body effective dose (also in Sv) was introduced. The early goal was to introduce one measure for all forms and rates of radiation dose both for radiation sickness and long-term risk assessments. Since the interaction of ionizing radiation with living tissue is so complex, there is no *a priori* guarantee that such an all-purpose measure is scientifically reasonable. Second there is the problem of physical incorporation. While for electromagnetic radiation, this does not complicate matters, for particles which can only weakly penetrate tissue, such as the high LET (Linear Energy Transfer = loss of energy divided by flight distance) α particle this is the major danger. Incorporation also adds the complication of internal heavy metal poisoning, as well as possible reinforcement between radio toxicity and chemo toxicity.

The definition of normative limits for exposition to ionizing radiation has a long and controversial history. The following describes the basic principles involved. In order to judge risk assessment for cancer and genetic mutations, it is necessary to establish a reliable scale for predicting mutagen risk based on exposure to ionizing radiation. The "mainstream" view is espoused for example by the World Health Organization (WHO). According to the WHO, occupational exposure should not exceed 5 mSv/a and for the general public 1mSv/a. (cited in M. Betti 2003). In the area of low dose exposition with low LET radiation (mainly γ rays and β particles), the work of Gofman (1990, 1996), the person who built the first radiation safety institute at Laurence Livermore Laboratories, has been seminal in demonstrating the absence of any safe dose or dose rate. This work focused on the range of zero to five cGy (1 cGy = 0.01Gy = 1 rad), the important region for environmental, occupational and medical diagnostic radiation (as long as x-rays, Gy and Sv scales are considered to be identical). In addition, this study shows, using the data from the A-bomb survivors, that the risk from low doses is higher than a linear extrapolation from the high dose region would predict. This has serious consequences on the prediction of risk for populations exposed to preventable radiation dose. An example, as discussed by Gofman and O'Conner in 1997 (Gofman, O `Connor 1998), a (US) government-sponsored report estimated that an approximate doubling of the natural background rate (ca. 1 mSv/a) would lead to an additional one in 400 cancer fatality per lifetime. This corresponds to some 6500,000 extra fatalities for a population of the US (ca. 260 million). The results of Gofman would estimate just under 5 million extra cancer fatalities in the same population. This is to illustrate that a "negligible" additional personal risk (compared to the natural radiation dose) translates into a large additional national rate.

The case of risk assessment from incorporated radioactive α emitters has received much less treatment in the past because the problems affecting the whole of the population concerned mainly low LET radiation. But it must be mentioned that the Department of Energy (DOE) uranium enrichment facility at Paducah, Kentucky, (now approved site of the new DU conversion facility) is the object of a court case involving 100,000 former employees claiming compensation. They were "contaminated because of flagrant non-compliance with basic safety standards." (Parsons 2002). According to many sources, the site in Kentucky may never be decontaminated and be declared instead a "National Sacrifice Zone" as will be

many other sites of nuclear arms fabrication and testing. For an extensive study of the decontamination projects necessitated from radiological pollution at American nuclear weapons labs, see (RWMA 2004).

The Depleted UF6 Management Information Network was set up by the Department of Energy (DOE) to develop an infrastructure for civilian and other uses for DU. This site contains several links to documents concerning potential civilian uses of DU (EAD 2005). These documents include those from a series of meetings organized by the DOE and the American Nuclear Society on potential uses of DU as well as easing licensing requirements for DU use.

Now with the advent of large-scale testing and use of DU-containing munitions and so-called hard-site "Bunker Busters" and cruse-missiles, the question of adding to the natural "background" α-emitting isotopes in an irrevocable way has become a crucial question of public health. Clearly, there are some circles interested in making radiological pollution politically correct, especially if it solves a nasty and costly problem of disposing of low level refuse created mainly by the production of nuclear weapons.

It is instructive to look at the experiences of John Gofman in more detail. (See Curriculum Vitae of Dr. John W. Gofman, in (1990, 1996). Already by 1969, Gofman together with Dr. Arthur R. Tamplin had concluded that human exposure to radiation was much more serious than had previously been recognized. Both spoke out publicly against two Atomic Energy Commission (AEC) programs which they had previously accepted. One was Project Plowshare, a program to explode hundreds or thousands of underground nuclear bombs in the Rocky Mountains in order to liberate (radioactive) natural gas, and to use nuclear explosives also to excavate harbors and canals. The second was the plan to license about 1,000 commercial nuclear power plants (USA) as quickly as possible. In 1970, they proposed a 5-year moratorium on that activity. The AEC was not pleased. By 1973, Livermore de-funded Gofman's laboratory research on chromosomes and cancer. He returned to teaching full-time at U.C. Berkeley. After an early retirement he has concentrated on pro-bono research into human health-effects from radiation.

Gofman published a series of books starting in 1981 which present his findings. His 1990 book (Gofman 1990) includes his proof, "by any reasonable standard of biomedical proof," that there is no threshold level (no harmless dose) of ionizing radiation with respect to radiation mutagenesis and carcinogenesis --- a conclusion supported in 1995 by a government-funded radiation committee. His 1995/96 book (Gofman 1996) provides evidence that medical radiation is a necessary co-actor in about 75 % of the recent breast cancer incidence (USA), a conclusion doubted but not at all refuted by several peer-reviewers. Gofmans position on adding to the radiation background was clearly expressed in an open letter he published in 1999, available at http://www.mothersalert.org/gofman.html. In this letter Gofman highlights the following text passages: ... *"there is no safe dose, ...just one decaying radioactive atom can produce permanent mutation in a cell's genetic molecule. ... citizens worldwide have a strong biological basis for opposing activities which produce an appreciable risk of exposing humans and others to plutonium and other radioactive pollution at any level. ... Mutation is the basis not only for inherited afflictions, but also for cancer."*

Since there is no lower safe level of exposure to ionising radiation, there is really no hope in setting such a level. The accepted procedure for limits on other toxic substances with no known safe level is to set a permissible level, based on value judgments. Thus a benefit must accrue both for the individuals exposed (livelihood, medical diagnosis, etc.) as well as to the general society. Even in the linear model, merely diluting contamination among a a larger population does not lead to fewer deaths. This was admitted even in the explicitly "mainstream" work of (for example) Fetter and von Hippel discussed below.

An extensive review of the health studies on uranium and DU exposure has been given by Dr. Dan Bishop (2005), available for example at www.idust.net. Cited is the important work of Alexandria Miller (2003), who after showing the biologic activity of DU exposure to produce genotoxic effects in cells, as well as gnomic instabilities lasting through 30 cell generations. After these new and crucial works, she seems to have stopped publishing (or has been stopped, as she works at the Air Forces Radiobiology Research Institute, Bethesda MD USA).

3 Proposed and probable civilian and non-conflict military applications of DU

Despite the fact that almost no one would think of any present or past civilian products containing uranium outside of the nuclear power industry, there have been actually a series of such applications (table 1). The reader might be surprised to learn that DU has been used in making the porcelain for dental prostheses. In fact there are only very few *current* applications for DU in the civilian sector. The most well known case is the use as counterweights in aircraft, especially the Boeing 747. However, it seems that the aircraft companies have discontinued this use at least in the civilian sector (Betti 2003). Such aircrafts were involved in at least two air crashes. The first was in Amsterdam in 1992, and the second in Stanstead in 2000. The only other large scale current use seems to be in shielding for radioactive materials with much higher activity.

There is some uranium used in the manufacture of jewelry (Betti 2003), but the amounts are small. The use in dental porcelains seems to have been discontinued in the

Table 1:
Proposed and probable civilian and non-conflict military applications of Depleted Uranium (DU) (according to Ranek et al. [11], shortened).

Exemption	Examples of exempt products containing DU	Date final exemption was published
Chemical mixture, compound, solution, or alloy containing <0.05 percent by weight of source material Dental porcelain	Dental prostheses	January 14, 1961
Glazed ceramic tableware containing <20 percent by weight of source material	Plates, dishes, bowls, cups, and saucers (in six-piece sets)	January 14, 1961
Piezoelectric ceramic containing not more than 2 percent by weight of source material	Gyroscopes for military applications, accelerometers, and other sensors for aerospace applications; high-frequency delay lines used in the broadcasting industry to convert TV signals	April 18, 1970
Glassware containing not more than 10 percent by weight source material but not including commercially manufactured glass brick, pane glass, ceramic tile, or other glass or ceramic used in construction	Drinking glasses, wine glasses, tumblers, candy dishes, vases, pitchers, goblets, ash trays, candlestick holders, and other ornamental and decorative objects	January 14, 1961
Photographic film, negatives, and prints containing uranium or thorium	Old black and white photographic prints	March 20, 1947
Uranium contained in counterweights installed in aircraft, rockets, projectiles, and missiles	Counterweights and ballasts used to balance hinge points and control surfaces (rudders, stabilizers, ailerons, and elevators) of aircraft	September 9, 1969
Natural or depleted uranium metal used as shielding constituting part of any shipping container	Containers designed for the transport of g-ray sources, such as radiography sources	November 22, 1961
Detector heads for use in fire detection units, provided that each detector head contains not more than 0.005 μCi of uranium	Prototype fire detectors (only two or three were built, none were manufactured for sale)	December 27, 1963

early 1980s. There are also some current applications in the oil and gas industries in the Ni-U catalyst, but little literature information is available (Betti 2003).

The DOE has initiated a large scale DU management program with the aim of finding new "beneficial" civilian uses of DU. A report by Brown et al. (1997) at the "Beneficial Re-Use '97 Conference" is quite instructive. The figure 1 is taken from this report.

Clear from this figure is that probably the only real large scale civilian application is in radiological shielding, with some possibility in oil well drilling. Much of the proposed shielding applications actually concern military or partially military applications, or in disposing of high level radioactive waste materials. The applications for shielding include composite materials. The two discussed are mixtures of DU mixed with basalt (denoted DUAGG™), or with polyethylene (called DUPoly™). DUAG has been used mixed with concrete (denoted DUCrete™) as shielding for long-term storage of radioactive waste. There is also some discussion at the "The Depleted UF6 Management Information Network" (EAD 2005) on other civilian uses of DU, mainly as semiconductors or in catalysis. However it is not clear to what extent these are real possibilities.

It should be noted that there are also large scale military applications other than directly in weapons (considered later), mainly in radiological shielding (try http://web.ead.anl.gov/uranium/uses/index.cfm), naturally from the DOE perspective.) There is also some interest in using DUO_2 to catalyze chemical reactions, and as a semiconductor material. The environmental problems in large scale civilian applications outside the narrow limits of radiological

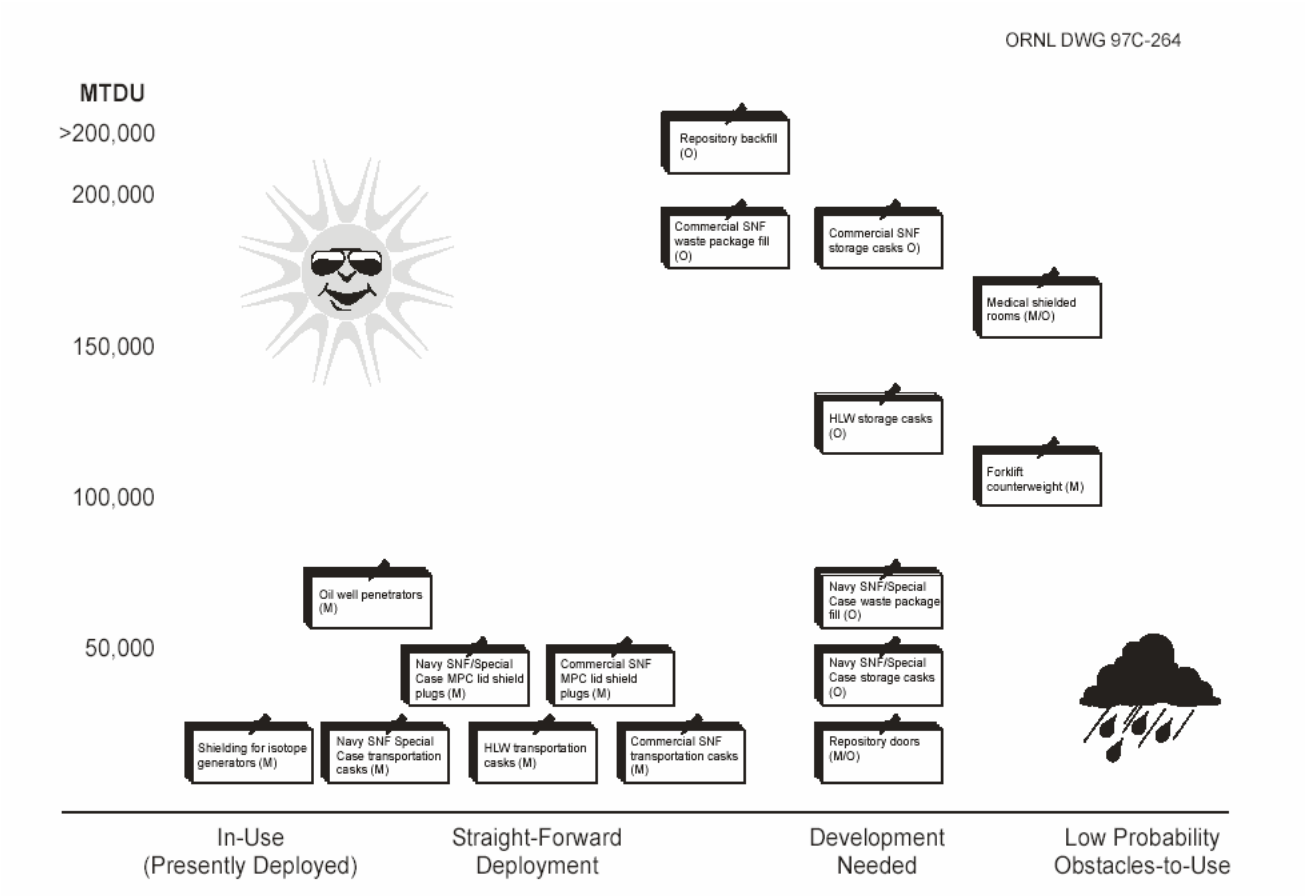

Figure 1:
Beneficial uses of Depleted Uranium (Brown et al. 1997)

shielding seem insurmountable, since such material is by nature completely outside any system of accountability and control. There are already many radioactive sensors used in industry for example in monitoring plate thickness in rolling mills, or level controllers in storage containers. Many of these sensors disappear at some point even though they are nominally under governmental license. In the limited application of disposal of high level radioactive waste, there is at least a case to be made for using DU-containing shielding, especially considering that we can no longer avoid this problem. (A review of this problem, admittedly from a well-connected standpoint, has been given in Alvarez et al. 2003).

4 Contamination of soils in Europe and the Near East by DU in kinetic munitions

They are called “hellfire”, “smart bombs”, “advanced penetrators” or “bunker-busters”. They all have the component of depleted Uranium (DU) in common. DU remains after the fissile isotope ^{235}U has been extracted from natural Uranium for the production of nuclear fuel or nuclear weapons. However ^{235}U only comes to 5 % of the total Uranium content, so that DU consists of the isotope ^{238}U almost entirely. Between DU and natural Uranium there are no chemical and toxicological differences, merely the radioactivity is approximately 40 % less. DU is a waste product of the nuclear industry, for which there is no further use. Worldwide over 1.1 million tons of DU lie on dumpsites, a minimum of 46 thousand tons are added to this every year. The frontrunners of the DU production are the US and Russia, Great Britain and China are ranking after them by a wide margin.

The military has become a grateful purchaser of DU because DU has special advantages for the production of missiles compared with conventional materials like tungsten. With a specific weight of 19 kg/L DU is 70 % more heavy than lead, almost as heavy as gold or tungsten, but simply incomparably cheaper than those. Because of its metallurgical properties, depleted uranium is more penetrating than tungsten, which is equally dense. The heavy missiles go through armor plating of vehicles and buildings better than any other material. Furthermore DU is pyrophoric i.e. it burns when mechanically stressed and therefore increases the destructive effect of the munitions. When a DU projectile strikes a hard target it mainly forms large quantities of depleted uranium are available as a waste product from decades of uranium enrichment, main-

ly forms extremely small particles that burn in air. Natural uranium would work just as well, but for nuclear weapons production (much higher enrichment necessary).

Such weapons do not pose a new radiological contamination hazard. However, as mentioned above, the difference in activity between uranium and DU is only small. The first known military application for DU was in kinetic munitions against tank armor. These have been tested, mainly in the US (and presumably in the then Soviet Union) for several decades, and this has led to serious problems in site clean up at the test sites. Besides the US, France, Great Britain, Israel, Pakistan, Russia, Saudi Arabia, Thailand and Turkey possess or develop DU munitions. In wars of the past 14 years (Iraq, Kuwait, Bosnia, Kosovo, Serbia, Montenegro, Afghanistan) approximately 1.4 million DU missiles were used up, amounting to a mass of 400,000 kg DU.

In order to compare the figures for the weight of DU they have to be converted into activity first. DU has the specific activity of 40MBq/kilo (both including daughter nuclides). Estimating the admitted $3*10^5$ kilo of DU in the 1991 war, this leads to an activity of 12TBq or 324Ci. It is useful to compare this with the activity limits allowed below which no governmental control is required. The 1989 allowed limit in Germany (Strahlenschutzverordnung 1989) was 5MBq for natural U, now superseded by the 2001 limits of 10kBq for U^{238} +, and only 1kBq for U-sec (U^{238} + denotes ^{238}U and its immediate daughter isotopes, U-sec denotes the long-term daughter isotopes). The specific activity of natural U is ca. 50MBq/kg, while that of DU ca. 40MBq/kg. This means that previously about 100g was the limit, and now no more than 0.2 g of natural U.

The effects of this contamination contributing to the infamous complex of disorders known collectively as Gulf War Syndrome (GWS) has been hotly debated. It was the object of a hearing in London conducted by Lord Lloyd of Berwick. The final report is available at www.hodge-jones-allen.co.uk/news/LloydReport.pdf. Hodge-Jones & Allen were the solicitors who represented more than 600 British Gulf War veterans. While the cause of GWS was not determined (actually a medical, and not a legal, question), but among the most likely contributing factors stated was the exposure to DU dust. This is the first time that DU has been admitted as contributing to GWS by anyone connected with established power, although it was quickly rejected by the British government (The Times 2004). On the other hand, the usual "mainstream" analysis of the effects of DU contamination do not rely on empirical evidence on GWS but only on calculations assuming a linear model, and one which assumes that ionizing radiation both from external and internal sources can be treated on the basis of deposited energy. A good example is the work of Fetter and von Hippel (1999). Von Hippel is a former assistant director for national security in the White House Office of Science and Technology. In the case of "mainstream" sources, this type of conflict of interest is not usually discussed.

The principal DU munitions used in the Gulf War were tank-fired shells containing 4- or 5-kilogram DU penetrator rods and 30-millimeter rounds (each with a 0.3-kilogram DU penetrator) fired by the A-10 "Warthog," a "tank killing" aircraft later used over Kosovo.

About 4,000 large-calibre rounds and about 800,000 small-calibre rounds were fired. An additional 10,000 large rounds were used in practice in Saudi Arabia or destroyed in accidents - including a fire at Dohoa, Saudi Arabia. In all, about 300 tons of depleted uranium were scattered in southern Iraq, Kuwait, and Saudi Arabia.

But the recent concentration on kinetic weapons obscures the fact that the real future of DU in weaponry is in reality much larger. This concerns so-called "hard-target" weapons such as the recently much touted "Bunker Busters", which can contain around a metric ton of DU each. The independent researcher Dai Williams (2002 a, b) has studied recent developments in military hardware. Shaped charge munitions, explosive charges, thermobaric bombs, and a new generation of hard target "Bunker Buster" guided weapons that use a "dense metal" to double their penetration effect are all suspected of containing uranium. The possible DU load would go from the few kilogram range used in the Gulf War, up to tons. The testing or use of such weapons (such as possibly presently in Iraq or in Afghanistan) leads to much more severe problems that those already confronting us now due to the legacy of DU from past conflicts.

The most serious one may be the permanent contamination of soils diminishing their potential to grow unpolluted plants as first step in a healthy food chain. The UNEP (United Nations Environmental Program (2001) depicts the typical attack of an A10 bomber on an aim on the ground as "a burst of fire of approximately 2 seconds, during which approximately 200 projectiles in straight line in a distance of 1-3 metres cover an area of approximately 500 m^2". However, hardly more than 10 of these 200 missiles hit their aims the rest disappears in the soil. UNEP assumes 30.000 DU-projectiles used up in Kosovo. However, the search expedition of the "Balkan Task Force" sent by UNEP in November 2000 only found seven and a half projectiles. Herein lies a problem: Up to now one has been concerned toxicologically and ecologically only with DU of the few hit-missiles, burning to Uranium oxide dust during the impact, which pollutes the air or contaminates objects. The DU's destiny from the far larger number of missiles, which get into the soil without hitting any aim, is unknown to a great extent. Lamas (2005) and Rivas (2005) have extensively investigated factors responsible for the dissolution of Uranium and its oxides in the soil. The Uranium concentrations they put in the soil corresponded to the pollution of a "standard attack" with DU

munitions as described by UNEP (2001). The results showed that Uranium, applied to the soil as Uranium oxide, is dissolved and can be absorbed by plants by physicochemical and biological processes. After three years up to 40 % of the supplied Uranium was converted into mobile species. Such mobile Uranium species can either be absorbed by plants or leached from the soil to water bodies. The Uranium contents supplied by the plants directly depended on the Uranium concentrations in the soils. In respect to the total Uranium content of the soil 0.4 - 0.6 %, or in respect to the available Uranium share, extractable with ammonium-acetate solution, 5 - 6 % went over to above ground of plants from the soil. The Uranium concentrations of the plants were thousand times higher up even in the lowest levels of contamination. The investigations showed also that the mobilisation of Uranium increases with a decreasing fertility of the soil (low pH values, less content of available plant nutrients, especially phosphorus) (Schroetter et al. 2006). But soils with low levels of fertility are typical for crisis areas and the population has to rely on self-sufficiency of their own soil. Both aspects severely increase the tragic consequences of the DU-munitions, DU is really just a “metal of dishonor” (The Depleted Uranium Education Project 1997).

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