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.

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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. Which experts should we listen to?

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 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*.
19. These data were requested from the Ministry of Defence on my behalf by the DUOB, and my analysis was included in the DUOB's final report.
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.
26. P. Van den Hazel et al., 2006, "Policy and Science in Children's Health and Environment: Recommendations from the PINCHE Project", *Acta Paediatrica,* vol. 95, no. 453(supp.), pp. 114–119.