Depleted Uranium Causes Cancer.
The coroner's inquest of Stuart Raymond Dyson; Sept 10th 2009, Smethwick Council Chambers, Smethwick West Midlands UK

Collected papers

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Sept 11th 2009
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Background

Stuart Raymond Dyson was a young, fit and healthy man when he joined the army in 1985. According to his wife, Elaine he was interested in sports and kept fit in the gym and by boxing. In 1991 he was a member of the Royal Army Pioneer Corps and in May 1991 was sent to Iraq where he served for four months. Photographs of him in the desert show a slim, healthy young man in uniform, smiling at the camera. His duties included general work in the areas of the battlefield and involved cleaning vehicles in areas where Depleted Uranium weapons had been used. Within three years of returning to the UK he was a wreck, suffering a whole range of peculiar symptoms, those which have been described as Gulf War syndrome. He was awarded a pension by the MoD on the basis of the "ill defined symptoms and conditions " formula applied to Gulf War illnesses.

In 2007, at the age of 38, he was diagnosed with colon cancer and despite an operation to remove the tumour and chemotherapy, died at the age of 39 in 2008 of multi-system organ failure resulting from carcinomatosis. Dyson had tried to get his urine tested for uranium, but apparently there were always problems. He was convinced that his ill health and finally his cancer was caused by exposure to DU. The Smethwick coroner, Mr Robin Balmain, agreed to carry out an inquest on Dyson's death. He wrote to me in early 2009 asking me to look at all the medical reports, Elaine Dyson's statement, his medical records and other papers and to provide an expert opinion. I supplied a report in March 2009. I concluded that on the evidence the cancer was more likely than not caused by the DU exposure. Balmain sent this to the Ministry of Defence in May in order to obtain the opposite view: an expert testimony addressing what I had said. He heard nothing until about 2 weeks before Sept 10th when the inquest was due to be carried out. He then received a 17 page report from the MoD written by Ron Brown. He sent this to me for comment and I responded quickly, as there was not much time.

At this time I was also working on another similar case, a Pensions Appeal Tribunal case for Dawn Pritchard, whose husband Gwylim, an A-Bomb Test veteran had been stationed with the RAF at Christmas Island. My position on the A-Bomb test veterans has been that their main exposures, invisible to the film badges they may have worn, was to uranium. Whilst working as an expert for Rosenblatt on the big class action in the Royal Courts of Justice I had analysed a report by AE Oldbury which measured radiation at Christmas Island as part of a clean up in 1963, five years after the last bomb. The beta gamma ratios were anomalous for fission fallout and pointed unequivocally to massive contamination by uranium, mainly U-238, the main component of the bombs by weight. I have now won several pensions tribunals for various A-Bomb veterans on the basis of this Oldbury study which I have published elsewhere (Busby 2008). Whilst preparing papers for Dawn Pritchard I stumbled upon an interesting report in the Lancet, November 2008 (Ballardie et al 2008). This report is vitally important for the Gulf War cases and also for the A-Bomb veteran cases. It describes the illness of a British soldier who returned from Bosnia with all the usual Gulf syndrome symptoms. He was quite ill. The doctors at the Manchester Royal Infirmary carried out a whole battery of tests. The most important result, one which is critical to these issues, was that the chromosomes in his kidney were opaque to electrons in the electron microscope, which is a quality of heavy metal poisoning. Further work revealed that the heavy metal was uranium. The uranium was enriched.

This result provides the missing link: uranium is tied to Gulf War syndrome. In passing, it also raised questions about the weapons used in Bosnia, where there have been sharp increases in cancer and where the Italian veterans study has shown increases in cancer. I found enriched uranium in an air filter from the Lebanon in 2007 and more recently from Gaza. You will see from the papers in this collection that I have shown elsewhere that uranium has the peculiar property of acting as an antenna for background radiation and focusing it into the DNA. This is called photoelectron amplification.

The inquest on Stuart Dyson took a whole day. It is very unusual (less than 2%) for a coroner to have a jury, but in this case, because the hearing was so important, Mr Balmain organised that it should be a jury inquest. Evidence was given by the pathologist, by Mrs Elaine Dyson and by Prof Busby. The Ministry of Defence did not send an expert and did not attend. The jury retired but returned after an hour to ask some questions of Prof Busby and Mrs Dyson. At 4pm they returned and gave their written verdict:

Stuart Raymond Dyson had died of multi-system organ failure resulting from cancer of the colon. The colon cancer was caused by or contributed to by his exposure to Depleted Uranium in the 1991 Gulf War.

The verdict was unanimous. Each member of the jury signed to say that was their opinion. Following this, the Coroner invoked section 42 of the Coroner's Act which deals with deaths which might involve situations which could lead to others dying of the same cause: under these circumstances the coroner has to formally inform the Home Secretary. The section was aimed at ensuring that there was early reporting of unusual deaths from plague, smallpox, other serious diseases.

This is a landmark case, a British jury has found that depleted uranium causes cancer. And so I have collected together the evidence here so that individuals can consider the arguments and counter arguments.

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Sept 11th 20089

Reference:

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The illness of Stuart Raymond Dyson, Deceased and his previous exposure to Uranium weapons in Gulf War I.

Report on probability of causation
for HM Coroner
Black Country Coroners District
Smethwick, W. Midlands

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Causality and the death of Mr Stuart Raymond Dyson

1. I have been asked by HM Coroner to examine documents relating to the illness and the death from carcinomatosis of Stuart Raymond Dyson who died in 2008 aged 39. Dyson's death was a final outcome of a cancer of the colon diagnosed in 2007 when he was 38. I have carefully examined the documents which include medical records, Pensions Application papers, a statement from his wife Elaine Dyson and a report by Prof Malcolm Hooper. The question I will address is the probability that Mr Dyson's cancer was a late consequence of exposure to Depleted Uranium when, as a young man in 1991, he was stationed in the Persian Gulf. There, among other duties he apparently cleaned tanks and other army equipment contaminated with Depleted Uranium (DU) dust.

The health effects of DU have been and remain the subject of significant scientific controversy. Government and Military continue to assert that the exposures suffered in the various theatres where the material was employed were negligible and had no subsequent health effects. In this they are supported by a number of so-called independent organisations, e.g. The Royal Society, the National Radiological Protection Board and the World Health Organisation. However all these groups base their *desktop predictions* of the health effects of DU upon a *single risk model*, that of the International Commission on Radiological Protection (ICRP) an organisation that has been criticised for being close to the nuclear industry and funded directly and indirectly by governments of nuclear nations. This ICRP risk model has been increasingly questioned by a number of organisations in the last ten years particularly in its seeming inability to predict or explain a wide range of health effects reported following exposures to internal, that is, ingested and inhaled, radioactive material (ECRR2003, CERRIE 2004, IRSN 2005). These include:

- The health effects of the Chernobyl accident
- The many reports of child leukaemia and female breast and other cancer excess near nuclear sites
- Cancer excess including childhood cancer on the Irish Sea coast contaminated by Sellafield
- Health effects in those exposed to DU; Gulf War Syndrome

This area of radiation risk from internal exposures is one of major and polarised scientific controversy. However, more and more evidence is appearing in the peer-review literature and the grey literature also, both from epidemiology and from laboratory experiments or theoretical work, that there are many serious shortcomings with the current risk model that of the ICRP.

2. I have studied the health effects of radiation for almost 20 years.
My affiliations and expertise are outlined in the CV which I attach. I am Visiting Professor at the University of Ulster in the Faculty of Life and Health Sciences and also Guest Researcher at the German Federal Agricultural Laboratories (Julius Kuehn Institute) in Braunschweig. I have been a member of two government committees on

radiation and health, The Committee Examining Radiation Risk from Internal Emitters, CERRIE (www.cerrie.org) and the MoD Depleted Uranium Oversight Board DUOB (www.duob.org). In the area of radiation risk I have conducted epidemiological studies, theoretical cell biology studies and laboratory experiments. I have surveyed radioactively contaminated sites in the field. I have visited Iraq and also Kosovo and measured Uranium in both those theatres of war. As a result of my researches I have concluded that the current radiation risk model is in error for internal exposures, that is radioactivity that is inhaled or ingested and chronically irradiates tissue from within. This is particularly the case of Uranium, for reasons which I will elaborate below. My research on Uranium and health was the top news story in *New Scientist* for 6th September 2008 and I wrote a major article for the *United Nations Disarmament Forum* on the issue of Uranium Weapons in early 2009. I have acted as expert witness on the health effects of radiation exposure in many courts in the UK and the USA. I am currently an expert witness and advisor in the current Royal Courts of Justice case where the A-Bomb Test veterans are suing the government. I am the Scientific Secretary of the European Committee on Radiation Risk ECRR and senior author of the ECRR2003 Report which presented an alternative risk model to that of the ICRP (ECRR2003). I have written two books on the health effects of internal radioactive contamination, the more recent one also dealing with the causes of cancer and the responses of the authorities to evidence presented at the science policy interface (Busby 1995, 2006), a subject I have experience with as former leader of the Science Policy Interface group of the EU Policy Information Network for Child Health and Environment PINCHE.

3. This was not just a person who, like many, developed colon cancer and died. Mr Dyson's cancer was very rare in someone his age and so we should be able to find a biologically plausible cause.

Cancer is a common disease. About 1 in 3 or 4 will die from cancer and this rate is increasing due to the increasing genetic effects of environmental pollution, including radioactivity (Busby 2006). However, it is principally a disease of old age resulting from the lifetime accumulation of genetic lesions on the DNA. In this respect, it is entirely congruent with the processes that underlie aging itself. The question of the origin of cancer is a reasonable one since all effects have a cause and cancer is now universally conceded to be more than 90% environmental in origin (Cairns 1978, Doll and Peto 1981, Busby 2006). The genetic component of some cancers (e.g. Breast) is conceded. Twins studies show up to 15% heritable components for the most genetically linked cancers; but this is not the case for colon cancer which is clearly almost entirely environmental in origin. Its background rate in different countries of the world is linearly dependent on meat intake, the argument being that the longer stasis period of meat in the bowel results in greater genetic damage to the colonic epithelia from the breakdown products of the meat proteins; others argue that meat contains higher concentrations of mutagenic toxins including radioactive fission products and uranium.

Cancer is a genetic disease expressed at the cellular level and is the consequence of a number of acquired specific genetic mutations in the DNA of the cell (or perhaps group of cells) where the cancer process begins. Colon cancer is a result of such a process. On the basis of theoretical analysis of the incidence rate with age it is believed that five or six fixed genetic mutations are necessary to induce colon cancer. Fig 1 is reproduced from Cairns 1978 and shows the exponential nature of the incidence rate with age: the slope of the log graph enables conclusions to be drawn about the number of cell mutations involved.

Mr Dyson died from colon cancer diagnosed in 2007 at age 38 and he died at age 39. The overall death rates from colon cancer shown in Fig 1 are for the USA in 1968. More recent figures from England and Wales (ONS 1997) give the death rate from colon cancer in the age group 35-39 at 6 per million per year. The reduction from the USA 1968 figure is due to advances in diagnosis and treatment. This is an extremely low rate and so the first conclusion we can draw in Mr Dyson's case is that his death from cancer was very rare indeed. There is no report of colon cancer in Mr Dyson's parents. It follows that we are looking for an aggressive carcinogenic or mutagenic substance to which Mr Dyson's colon must have been exposed at some period, maybe 10-20 years before the cancer was clinically evident. Was there such an exposure? Can we examine his history and find any plausible evidence of such an exposure?

Fig 1 Death rates from cancer of the colon in relation to age in the USA in 1968. Note the clear linearity of the log log graph on the right. Note also the extremely low rate (9 per million persons per year) for someone of age 39, the age of death of Mr Dyson. (Cairns 1978)

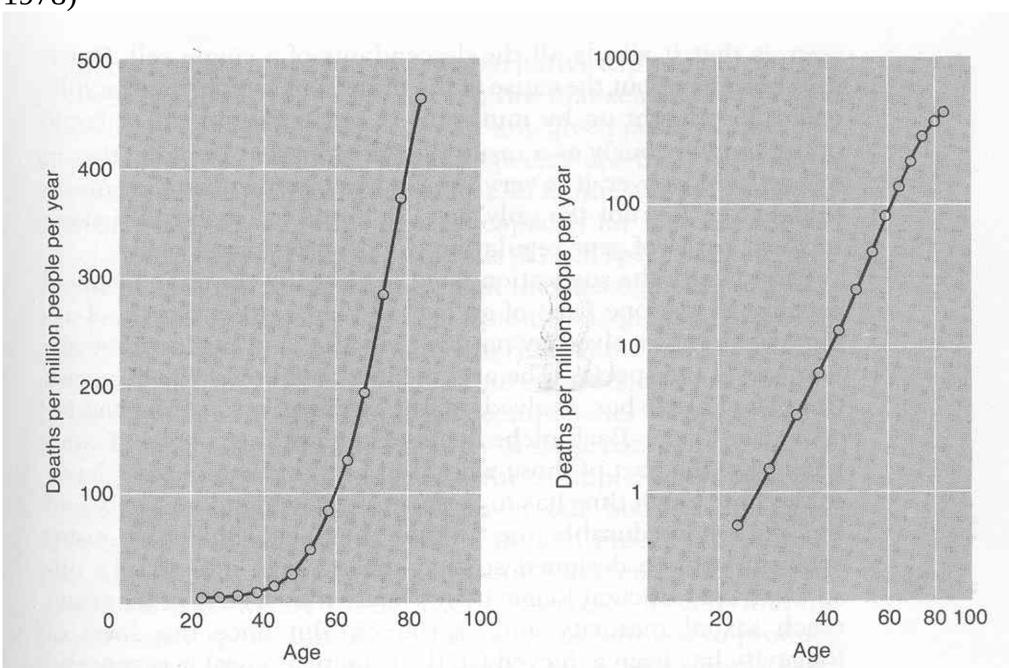


FIGURE 4-1 Annual U.S. death rate from cancer of the large intestine in relation to age, 1968: (a) linear scales; (b) logarithmic scales. [From U.S. Department of Health, Education, and Welfare. *Vital Statistics of the United States*. Volume II. *Mortality*. U.S. Government Printing Office, 1968.]

4. The health effects of Uranium weapons

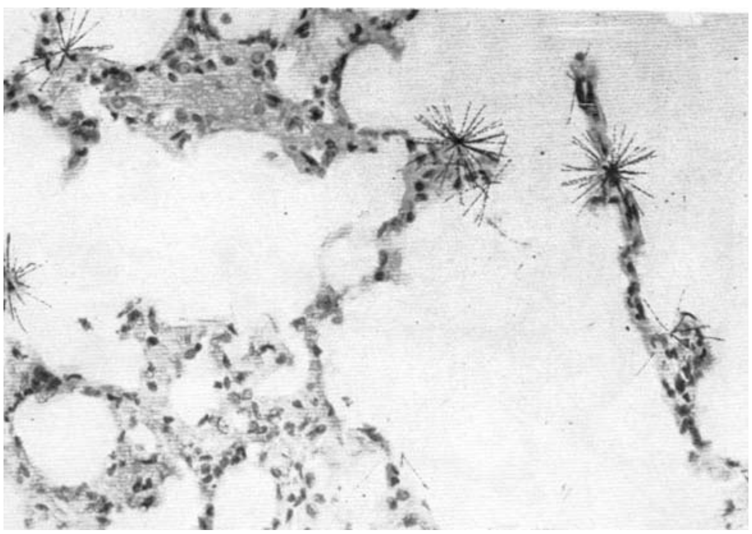
This is a question which has been the subject of more than one hundred reports, books and articles. However, I am interested here in the illness and death from colon cancer of Mr Dyson and will try to focus on that without too much digression. I will attach an article I recently was commissioned to write for the United Nations Disarmament Forum which lays out my position on the issue and the science supporting it. I have studied the health effects of uranium weapons since 1996 and was one of the first to point out that the health effects seen after Gulf War I in the Iraqi populations and also in the veterans was likely to be due to Uranium exposure. Since then I have addressed many bodies concerned with the question, including the Royal Society, the US Congress, the European Parliament, the Swedish Parliament and, of course the MoD, whose DUOB I was a member of. I was also one author of the final report of the DUOB which can be found on the website www.duob.org.

Uranium is an element which occurs naturally on earth and is widespread. So, of course, is Arsenic; and so the *naturalness* of Uranium should not let us imagine that it is somehow safe. It is not. Uranium is radioactive, and is peculiar in that it decays with the emission of alpha particles which are short range, weakly penetrating and highly ionizing (therefore dangerous) radiations. These alpha radiations would not penetrate skin but if the uranium atoms are internal, inside tissue, the alpha particle radiations cause high levels of damage along their short tracks, which involve about four cells. In addition Uranium has two other singular properties. The first is that it has the highest atomic number if any natural element, Z=92. This makes it have a very high stopping power for gamma rays compared with normal living tissue. (Lead, which is used for this purpose by radiographers has Z = 82). Second, it binds very strongly to DNA. These two properties make uranium in the body bind to DNA and focus background gamma radiation into the nuclear DNA of cell where it will have the greatest genetic harm (Busby 2003,Busby 2005, Busby and Schnug 2008).

There are three natural isotopes U-238, U-235 and U-234. The main isotope, U-238 comprises 99.3% of natural uranium as refined from ore; the fissile isotope U-235, used for nuclear power and atomic bombs represents 0.3% by weight. The U-234 is a decay product of the U-238: there are also two other decay products, the beta emitters Protoactinium and Thorium-234 but these latter here need not concern us here although they do add to the radioactivity. DU is uranium that has had much of the U-235 removed; it is a waste product of the nuclear fuel cycle. DU is a very dense (density = 20) metal which is also pyrophoric, that is, it burns in air on impact with a target. The combination of properties has made DU shells (penetrators) capable of transforming armoured warfare. It was the employment of DU weapons that was probably the cause of the US and UK success against Saddam Hussein's tanks in the Gulf War.

On impact, the DU burns to a fine aerosol of ceramic uranium oxide particles of mean diameter from about 1000nm (1μ) down to below 100nm. These particles are long lived in the environment (and in tissue), and can travel significant distances from the point of impact up to thousands of miles (Busby and Morgan 2005). They become resuspended in air, are found in air filters in cars at some distance from the attacks, and of course are respirable. Because their diameters are so small, below 1000nm, they are able to pass through the lung into the lymphatic system and in principle can lodge anywhere in the body. Here they may remain for several years in the same place. The half life of such particulate uranium is unknown but is very long. According to research with animals it can be greater than 13 years (Royal Society 2001). Although uranium itself is weakly radioactive (owing to its long half life or 4.5 million years) because the DU particles are made of solid uranium oxide, they are significantly radioactive and can deliver several high dose alpha tracks to the same local tissue. This is an important point as it goes to the core of the argument about the ICRP risk model, the one that has been employed to argue that DU is not a significant hazard. The ICRP models cancer on a quantity termed ‘absorbed dose’ which is defined as energy per unit mass. This is an average of the ionisation over large amounts of tissue, kilograms, and is a reasonable unit for quantifying the effects of external radiation e.g. from an atom bomb’s gamma rays but is not scientifically justified for internal anisotropic radiations where there are large doses in one place and no dose everywhere else. An analogy would be to compare the same acquired by warming oneself in front of a fire with eating a red hot coal. This ‘hot particle effect’ has been the basis for most of the arguments about cancer and DU (and indeed also plutonium and fuel particles after Chernobyl and the Atomic tests and near nuclear power stations). A photograph (radiograph) of the alpha tracks (called an ‘alpha star’) from such a particle in rat lung is shown in Fig 2.

Fig 2 Radiograph of alpha track stars from sub micron diameter radioactive ‘hot particles’ in rat lung (IRSN France).



But there is another far serious error in the ICRP model for DU. DU oxide particles are made largely of uranium, atomic number Z=92. The absorption of gamma radiation is proportional to the 5th power of the atomic number. This means that if we compare the absorption of natural background gamma rays by a DU particle with the absorption of an equivalent tissue mass (whose highest atomic number element is oxygen in the water Z = 8) we see that the uranium particle absorbs more than 201,000 times the background radiation. For particles smaller than 1000nm diameter we have shown (Busby et al 2005, 2008) that all the energy is transferred to the local tissue as photoelectrons of various ranges. Thus the tissue that contains such a particle receives a continuously high level of radiation damage, as if from a microscopic embedded radioactive speck. This effect is in addition to any alpha emissions from the uranium and is purely a consequence of the atomic number of the element. It is ‘phantom radiation’.

5. Mr Dyson's colon cancer and DU particles

In an environment where Mr Dyson was cleaning vehicles and equipment which had been contaminated with DU dust it is inevitable that he will have been contaminated internally both through inhalation and inadvertent ingestion. Simon (1995) reviewed the evidence for inadvertent ingestion and referring to measurements made on weapons fallout in Australia and the radiological analysis of the faeces of Aboriginals concluded that in dusty conditions as much a 1 gram of material could be ingested in a day. The material is transferred from the hands to the mouth in a number of obvious ways. We do not need so much to account for Mr Dysons colon exposure. I will assume that there was such an inadvertent ingestion and that a quantity of DU particles were ingested. It only requires that some of these were trapped or absorbed by the intestinal epithelium (which is highly convoluted and ideal as a trap for a substance which would quickly destroy local tissue yet remain *in situ* for a long time causing continuous irradiation of that tissue and other local tissue though the mechanisms I have already outlined. Thus the colon tissue would receive a much greater dose of radiation than it would have received from natural background and accordingly the mutation rate in the cells of that tissue would have been proportionately higher. How much higher?

If the photoelectron effect actually increases the dose to local tissue in proportion to the 5^{th} power of the atomic number, the normal UK natural background annual gamma radiation dose to the colon of about 1mSv can be multiplied by 201,000 for the tissue near the DU particle. It is possible to make a simple approximation based on a 1μ Uranium Oxide particle. The results show that in one year this 1mSv results in an enhanced photoelectron dose to a 120μ diameter sphere around this trapped particle of greater than 1Sv. There are about 5000 cells in such a sphere and each will get a mean dose equivalent to 5.7 lifetimes (70 years) of natural background radiation. This is in excess of the alpha dose, which in a particle of this size is a further 0.3Sv (CERRIE 2004). In addition to these mechanical doses from the particle, uranium dissolving from the particle becomes bound to the DNA of the intestinal epithelium and causes direct emission of local photoelectrons into the DNA. The particle embedded in the colon epithelium can be seen as being very like the one in Fig 2 in terms of its effect. Therefore this colon tissue, local to the embedded DU particle will have aged much faster than normal colon tissue. If the particle stays in the same place for one year, several lifetimes of radiation dose will have been compressed into a short time. Accordingly, for Mr Dyson's colon, its age will be much greater than his chronological age and the probability of developing cancer will be greater as the acquisition of necessary lesions I referred to is now more probable. Dyson is pushed to the right on the cancer age graph of Fig 1. This is why he developed this cancer at such an unusually young age.

I began from the diagnosis and worked back to a necessary cause. I have now shown that DU particles are a sufficient necessary cause

Therefore, I conclude, that Mr Dysons colon cancer was most probably caused by his exposure to DU. What other evidence is there that the DU had an effect on his health? After all, a material that is as genotoxic as I have suggested, would be expected to have earlier effects. This brings me to a brief discussion of Gulf War Syndrome and Mr Dyson's other conditions.

6. Gulf War Syndrome and Mr Dyson

Stuart Dyson, who was apparently a fit young man before Gulf War, became a wreck after he came home. He complained of a wide range of symptoms and conditions which he realised at some point were similar to those which had been identified in other personnel from the UK and the USA who had served in the Gulf in 1991. The group of such conditions became known as Gulf War Syndrome and affected a large fraction of veterans. There were, and still are, polarised differences of opinion over two main questions relating to this issue. These are:

- Is there such a thing as Gulf War Syndrome?
- If there is, what is its aetiology, how does the cause produce such a wide array of symptoms?

Naturally (and as with the Atomic Test Veterans and the Porton Down veterans, other similar groups which I have studied) the military and the government say that there is no problem, it’s all in the mind. To back up their position large sums of money are given to ‘safe’ research scientists to conduct research or produce reports that back up this position. The veterans have no money for their own research and few scientific advisors, retired honest scientists living on pensions (like Malcolm Hooper) or maverick greenies funded by Quaker Charities (like me). Any other affiliated scientist soon gets to learn the disadvantage of opposing the military, the government or industry (who largely pay for all research, and hence all the wages and mortgages). The bias that exists in the science policy interface is horrifying. A good example is the BSE scandal. I have written extensively about this (Scott Cato et al 2000, Busby 2006, Van den Hazel et al 2005).

In the UK, the military have funded biased studies of atomic test veterans and biased studies of Gulf War veterans. A good example of the latter is the series of epidemiological questionnaire studies paid for by the MoD and conducted by Prof Simon Wessely and psychiatry colleagues of Kings College London whose published papers reveal a clear attempt (using complex mathematical models) to show that there is no such thing as Gulf War Syndrome, that it is a merely a loose aggregate of psychiatric symptoms that are to be found in all groups of soldiers, but that in the Gulf War these conditions were merely greater in intensity. In passing, note that the sickness intensity found by Wessely was Gulf War>> Bosnia> UK soldiers, the order of DU exposure. On the other hand, Dr Robert Haley in the USA has employed a quite similar method (Factor Analysis) to show that there is in fact a Gulf War Syndrome. I note that the psychiatrists Wessely et al did not include many real physical symptoms in their analysis whereas Haley et al did. But Haley went on to conduct a far more significant study. Haley realised that the apparent disparate nature of the symptoms and conditions in GW syndrome could be explained if the origin of the damage was in the brainstem and lower brain. He approached the millionaire ex-Presidential candidate Ross Perot for funding. Using the large amount of money necessary to carry out magnetic resonance imaging of the brainstem and lower brain he was able to carry out a case control study of veterans, and showed that the veterans suffering from GW syndrome also had significant brain cell damage in the lower brain and brain stem. Thus all the physiological housekeeping mechanisms had been deranged at their point of origin. Haley's research shows unequivocally that it is not, primarily a psychiatric illness, but a neurophysiological illness.

This brings me to the cause of the lesions in the nervous tissue. Here I divert slightly from the conclusions drawn by Haley and others who blamed organophosphate pesticide and nerve gas exposures, perhaps also other multiple chemical exposures, for such damage. It may be that some combination of these chemical exposures could cause long term destruction of such tissue. However, research carried out in France and elsewhere after 2000 has shown, using animal studies, that Uranium targets the brain in and binds to nervous tissue (ENVIRHOM 2005). Therefore Uranium exposure is also a candidate for the cause of the brainstem damage leading to GW syndrome.

There is one other pointer. Many veterans from GW1 suffered skin rashes. This was also common in veterans of the A-Bomb testing in Australia and Christmas Island (also exposed to uranium in large amounts). Uranium binds to DNA, as I have stated. But Uranium has another property: it has a very low energy photoelectric work function and will emit photoelectrons when illuminated with visible light of wavelength 450nm (blue light). People with uranium bound to the DNA in skin cells will suffer rashes and inflammation as soon as they are exposed to sunlight.

7. Can this account of Mr Dysons history be further investigated?

I am assuming that Mr Dyson was exposed to DU and all my arguments are based upon this. If he was, then it is likely that there will still be DU particles in his body, and he should have a higher level of uranium in his bones and teeth. Analysis of the tracheobronchial lymph nodes should show the presence of DU particles. The MoD funded a urine analysis of the GW1 veterans but this was carried out some 13 years after their exposures and owing to the existence of enriched uranium in the environment, the results were hard to interpret. In addition, it is likely that the ceramic uranium particles will not give risk to any uranium in the urine but will remain in situ in the body until death. Despite many suggestions that a deceased GW veteran be analysed by an independent laboratory for DU this has never been done.

8. Conclusions

On the basis of the information I have seen I conclude that Stuart Dysons death from cancer of the colon at the age of 39 in 2008 was more probably than not a late consequence of his exposure to DU whilst deployed in the Persian Gulf in 1991.

Signed

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March 27th 2009

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CURRICULUM VITAE (Feb 2009)

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Member: Ukraine Committee: Physicians of Chernobyl

UK Government Committees

Member: (Department of Health and DEFRA) CERRIE
Committee Examining Radiation Risk from Internal Emitters 2001-2004
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Member: Ministry of Defence DUOB
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Other Committees

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www.pinche.org

1.2 EMPLOYMENT

1969 – 1975	Research physical chemist, Wellcome Foundation, Beckenham
1975 - 1978	Self employed scientific consultant and science writer
1979 - 1981	PhD student University of Kent
1981- 1982	SERC Research Fellow University of Kent
1983- 1992	Self employed scientific consultant and science writer
1992- present	Science Director, Green Audit, commissioned to research the health effects of ionizing radiation and funded by a number of charities and independent bodies.
1995	Funded by the Joseph Rowntree Charitable Trust to write and produce 'Wings of Death- The health effects of low level radiation.'
1997-2000	Directed research at Green Audit Funded by Irish State to research health effects of Sellafield
1997	Appointed UK Representative of European Committee on Radiation Risk (ECRR)
1997	Foundation for children with leukaemia; research on non-ionising radiation
2001	Appointed Scientific Secretary of ECRR and commissioned to prepare the report ECRR 2003- The Health effects of low doses of Ionizing Radiation (Published 2003**)**
2001	Appointed to UK Government Committee Evaluating Radiation Risk from Internal Emitters (CERRIE)
2001	Appointed to the UK Ministry of Defence Oversight Committee on Depleted Uranium (DUOB)
2002	Funded by the Joseph Rowntree Charitable Trust to write a new book on the epidemiological evidence of health consequences of exposure to ionizing radiation: 'Wolves of Water'
2003	Appointed Honorary Fellow, University of Liverpool, Faculty of Medicine, Department of Human Anatomy and Cell Biology
1992-2008	Science Director, Green Audit
2003	Funded by Joseph Rowntree Charitable Trust to write Book *Wolves of Water Cancer and the Environment*
2004	Leader of Science Policy for(EU) Policy Information Network for Child Health and Environment ***PINCHE*** based in Arnhem, The Netherlands
2005	3 year research funding by Joseph Rowntree Charitable Trust; Corporate Responsibility in Science and Policy
2008	3-year research funding from The Joseph Rowntree Charitable Trust; Corporative Responsibility in Science
2008	Appointed Guest Researcher, German Federal Research Laboratories, Julius Kuhn Institute, Braunschweig, Germany
2008	Appointed Visiting Professor, School of Molecular Bioscience, Faculty of Life and Health Sciences, University of Ulster, Coleraine, Northern Ireland

1.3 TEACHING EXPERIENCE

1970	Taught O-level Chemistry part time, Inner London Education Authority
1980-1981	Gave tutorials in quantum mechanics at the Dept. of Chemistry. University of Kent
1995-1997	Invited lecturer at the University of Sussex Dept. of Physics.
1995-1997	Invited lecturer in the University of Wales, `Aberystwyth, Physics Department and Geography Department
2000 – 2005	Invited lecturer in the University of Liverpool Faculty of Medicine SSM5 'Environment and Health' addressing internal radiation risk and cancer epidemiology of small areas.
2005	Invited lecturer University of West of England; Radiation Risk and epidemiology
2006	Invited lecturer: Dept. of Law, University of Wales, Aberystwyth
2006	Invited lecturer: Dept. of Environment, University of West of England
2007	Invited lecturer: Centre for Molecular Bioscience, University of Ulster

1.4 ADMINISTRATIVE EXPERIENCE

Professional Administration:
Senior Scientist
Dept of Physical Chemistry, Wellcome Research Laboratory, Langley Park, Beckenham
Science Director, Green Audit
2004-2006 Leader: Workpackage 6 Science and Policy; PINCHE (EU)

Editorial boards (Current):
European Journal of Biology and Bioelectromagnetics

Invited Reviewer
European Journal of Biology and Bioelectromagnetics
European Journal of Cancer
Journal of Public Health (Royal College of Physicians, School of Public Health)
Science and Public Policy
The Lancet
Occupational and Environmental Medicine (BMJ)

1.5 EXPERT WITNESS

Since 1997 Chris Busby has been engaged as an expert witness in several cases that relate to the effects of radioactive pollution on health, in several refugee appeals (Kosovo) based on Depleted Uranium risks, several trials of activists accused of criminal damage at weapons establishment and one at the House of Commons (evidence on Depleted Uranium and other radioactive substances), one MoD pension appeals tribunal for the widow of a A-Bomb test veteran and once in the Connecticut State Court for an appeal against licensing releases of radioactivity from the Millstone reactor on Long Island Sound. He is currently acting or has recently acted as expert witness on two cases in the UK involving the health effects of internal irradiation from Depleted Uranium. One of these is in the Royal Courts of Justice and also in three cases in the USA. Two of these (against Exxon) have recently been settled. The third, a landmark case involving childhood cancer near a nuclear plant in Florida is currently being appealed in the US Supreme Court. He also advised on the case of Rocketdyne (Boeing) and the Santa Susana Field Laboratory childhood retinoblastoma cluster in Western Los Angeles which was settled in January 2008 and a TENORM radiation case involving Ashland Oil in Martha Kentucky, also two other TENORM cases in Louisiana. He is currently also expert witness and advisor on the UK Atomic Test veteran litigation in the Royal Courts of Justice.

1.6 APPOINTED or INVITED ADVISOR

Various national and supra-national groups have sought advice from or appointed Dr Busby as an advisor on various issues e.g.

Green Group European Parliament; Radiation and Health (Caroline Lucas MEP)

Canadian Government: Uranium and Health (appointed by Alex Atamenenko MCP, British Columbia)

UK Committee on Radioactive Waste Management (invited by Prof Gordon McKerron)

Royal Society Committee on Health Effects of Depleted Uranium Weapons (invited by Prof. Brian Spratt)

US Congressional Committee on Veterans Affairs and Security (Uranium weapons) (invited by Senator Christopher Shays)

UNIDIR Geneva (United Nations Institute for Disarmament Research) (Kirstin Vignard)

1.7 RESEARCH INTERESTS.

Overview of major lines of investigation

Chris Busby spent seven years at the Wellcome Foundation, where he conducted research into the physical chemistry and pharmacology of molecular drug receptor interactions. He subsequently moved to the University of Kent at Canterbury where he studied Laser Raman Spectro-electrochemistry in collaboration with Shell Research and later as SRC Research Fellow, a project which resulted in a PhD in Chemical Physics. He developed and published theoretical and experimental details of silver and gold electrodes with surface array properties which enable acquisition of laser Raman spectra of adsorbed molecules in dilute solution.

In the late 1980s he became interested in the mechanisms of low dose internal irradiation and developed the Second Event Theory, which distinguishes between the hazards of external and internal radiation exposure. In 1995 he was funded by the Joseph Rowntree Charitable Trust to develop his arguments and write 'Wings of Death: Nuclear Pollution and Human Health', an account of the results of his research into radiation and cancer and also into cancer increases in Wales, which he argued were a result of global weapons fallout exposure. In 1997 he became the UK representative of the European Committee on Radiation Risk. His analysis of the increases in childhood leukaemia in Wales and Scotland following Chernobyl was recently published in the journals Energy and Environment and the International Journal of Radiation Medicine.

From 1997-2000 he was funded by the Irish Government to carry out research into cancer incidence and proximity to the coast. In June 2000 he was invited to present evidence to the Royal Society committee on Depleted Uranium and health, and shortly after this was invited to Iraq to measure DU in the country and relate exposure to health effects which followed the Gulf War. In 2001 he was asked to visit Kosovo to investigate the dispersion of DU using field monitoring equipment. He discovered DU in many areas from analytical measurements made on samples he collected (paid for by the BBC) he showed that there was atmospheric resuspension of DU particles. His work and expertise in the field of environmental health and radioactivity was recognised by his appointment to CERRIE a Government committee reporting on the effects of low level radiation on health. Following his evidence to the Royal Society on the effects of Depleted Uranium, he was appointed to the UK Ministry of Defence committee on Depleted Uranium in 2001. He was invited to address the US Congressional Committee on Veterans Affairs of the Health effects of Depleted Uranium in 2002. He is presently also the Scientific Secretary of the European Committee on Radiation Risk and was commissioned to organise the preparation of the new risk model on radiation exposure and to organise the publication of ECRR 2003: The Health Effects of Exposure to low Doses of Ionizing Radiation, published in January 2003 and now translated into and published in French, Russian, Japanese and Spanish. In 2004, he (jointly with two other colleagues) published the *Minority Report of the CERRIE committee* (Sosiumi Press). In 2006 he produced and jointly edited with Prof. Alexey Yablokov of the Russian Academy of Sciences *ECRR2006 Chernobyl 20 Years On.*

Between 2004 and 2006 he was leader of the Science and Policy Interface Group of the EU funded Policy Information Network for Child Health and Environment and organised the discussions and collation of information leading to their final report on the issue which he wrote large parts of. The culmination of this project which involved over 40 scientists and physicians from all major EU countries was the recommendation that as a result of bias in scientific advice to policymakers, all advice committees involving areas of dispute and possible harm to the public should be oppositional committees with reports including all sides of any argument.

From 2006 Dr Busby has been conducting laboratory experiments researching photoelectron emission from Uranium and elements of high atomic number. He is currently co-supervising a researcher at the Centre of Molecular Biosciences in the University of Ulster on this.
He is also currently engaged in experimental and theoretical development of a novel theory of living systems and their origin.

1.8 RESEARCH EXPERIENCE

Dr Busby's early research was in the Physical Chemistry aspects of molecular pharmacology at the Wellcome Research Labs. This involved the use of spectroscopic and thermodynamic methods for examining cell drug interactions at the molecular level. For a year he began a research degree in NMR on molecular conformational changes on protonation but left to return to Wellcome and resume his drug interaction research. From there he moved to developing descriptions of intercellular and intracellular communication mechanisms, a subject which he is still engaged in researching in the laboratory. Later he moved to examining molecular behaviour at charged interfaces and developed a Surface Raman spectroelectrochemical method as a Science Research Council Fellow at the University of Kent.

Between 1992 and 2004 Dr Busby was engaged in research in three areas associated with ionising radiation and health and also was funded for a year (1997) by the *Foundation for Children with Leukemia* to research the interaction between non ionising radiation and ionising radiation. His research in the area of ionising radiation has been split between the development of theoretical descriptions of radiation action on living cells and the epidemiology of cancer and leukaemia in small areas. After 1994 he conducted survey epidemiology of Wales and England and was the first to point out (in a letter to the British Medical Journal) that increases in cancer in Wales might be related to weapons fallout. Later he examined childhood leukaemia mortality near the Harwell and Aldermaston nuclear sites and suggested that the excess risk might be related to inhalation of radioactive particles. These results were also carried in a research letter in the BMJ which attracted considerable criticism. His description of the mode of radiation action from sequential emitters (his Second Event Theory was developed originally in 1987) has attracted a great deal of interest and also criticism. Between 1997 and 2000 he was funded by the Irish State to carry out epidemiological studies of cancer rates and distance from the Irish Sea using data from Wales Cancer Registry and through a collaboration with the Irish National Cancer Registry. Following this he and his team in Green Audit developed novel small area questionnaire epidemiological methods and applied them to a number of areas in different studies which included Carlingford Ireland, Burnham on Sea in Somerset and Plymouth, Devon and Trawsfynydd, Gwynedd, Wales, which resulted in a TV documentary in 2004. In addition he carried out cancer mortality small area studies in Somerset and later in Essex. He extended these to wards in Scotland in 2002. He has supervised a PhD student, who has subsequently graduated, at the University of Liverpool in the Faculty of Medicine in an epidemiological study of cancer mortality in Scotland with regard to proximity to putative sources of cancer risk. In all the small area studies he carried out it was possible to show a significant effect of living near radioactively contaminated intertidal sediment. The papers and reports were all published by Green Audit and most have been presented by invitation at learned conferences in Europe including through invitations by the Nuclear Industry itself.

In addition to this, in 1998 Busby set up a radiation measurement laboratory and equipped it with portable alpha beta and gamma measuring systems including a portable gamma spectrometer made in Dresden which uses a 2" NaI detector. He used these to show the presence of Depleted Uranium in Southern Iraq in 2000 when he was invited by the Al Jazeera TV channel to visit the country as a consultant and examine the link between leukaemia in children and levels of Depleted Uranium. In 2001 he visited Kosovo with Nippon TV and was the first to show that DU was present in dust in towns in Western Kosovo and through isotope measurements funded by the BBC was able to report to the Royal Society in 2001 and the EU Parliament in Strasbourg that DU became resuspended in dry weather and was rained out, and that it remained in the environment for a considerable time. This subsequently led to UNEP deploying atmospheric particle measuring equipment in areas where DU had been used. More recently, from 2006, Dr Busby has been developing laboratory methods for measuring radiation conversion and amplification by high atomic number micron diameter metal and metal oxide particles (Uranium, Gold). It is his recent contention that such particles amplify background radiation effectiveness by photoelectron conversion and he is the author of a provisional patent application for the use of photoelectrons in cancer therapy to destroy tumours.

In 2005 he was invited by various organisations in New Zealand (NZ Royal Society) to give evidence on the health effects of Depleted Uranium. In 2005 and 2006 he worked with Prof Alexey Yablokov on the ECRR2006 report on Chernobyl which was published on the 20th anniversary of the accident. Most recently he has conducted a study of the health of people living in the vicinity of the Trawsfynydd Nuclear plant in Wales for HTV and also a study of the veterans of the Porton Down human experiments in the 50s. The results of the Porton Down veterans study led to a settlement and an apology by the government to the veterans in 2008. In 2007 he began epidemiological studies of the children of A-Bomb Test veterans and also of people living near mobile phone base stations. The A-Bomb veterans epidemiology study highlighted high rates of miscarriage and congenital illness in their children and grandchildren. The results were presented to the House of Commons committee investigating this issue in November 2007 and have led to a recent agreement by the UK government to fund further epidemiological research on this issue, research which Dr Busby will oversee on behalf of the Test Veterans. He is currently an expert advisor on the Test Veterans' litigation and official scientific advisor to the British Nuclear Test Veterans' Association. He was appointed Visiting Professor in the School of Molecular Biosciences in the University of Ulster in 2008 where he is co-supervising research on the health effects of uranium. His research on uranium and genetic damage was the main news story in the New Scientist of 6th September 2008. Also in 2008 he was appointed Guest Researcher at the German Federal Government Julius Kuhn Institute in Braunschweig where he is co-supervising research on Uranium uptake in plants.

1.9 INVITATIONS TO SPEAK.

Year	Place, Subject etc.
1995	House of Commons. Symposium on Low Dose Radiation
1995	Jersey, Channel Islands: International conference on nuclear shipments; Health effects of low dose radiation
1995	Oxford Town Hall: Low dose radiation effects
1995	Drogheda, Ireland: Sellafield effects
1997	Strasbourg EU Parliament: Euratom Directive
1997	Brussels, EU Parliament STOA workshop on criticisms of ICRP risk models
1997	Kingston Ontario: World Conference on Breast Cancer: paper on cohort effects and weapons fallout
1998	Muenster, Germany, International Conference on Radiation: Second Event effects
1998	Manchester Town Hall, Ethics and Euratom
1999	Copenhagen: Danish Parliament: Euratom Directive and low dose effects
1999	Carlingford, Ireland: Sellafield effects
2000	Kos Island: ASPIS (EC) meeting on 'Is cancer an environmental effect'; low dose radiation and cancer
2000	London: Royal Society: low dose effects and Depleted Uranium
2001	Strasbourg: Green Group; Health effects of Depleted Uranium
2001	Bergen: International Sellafield conference, Sellafield effects on health
2001	Oslo: Nobel Institute: Health effects of low dose radiation and DU
2001	London: Royal Society: Health effects of Depleted Uranium (again)
2001	Kiev: WHO conference on Chernobyl: paper on infant leukaemia
2001	Prague: *Res Publica* International Conference on Depleted Uranium
2001	Strasbourg: EU Parliament, with UNEP; Health effects of Depleted Uranium
2002	Bergen: Conference on Sellafield
2002	Helsinki: Health effects of low dose radiation
2002	London: US Congressional Committee on National Security: Gulf war syndrome and Depleted Uranium
2002	London Greenpeace: Small area statistics and radiation effects
2002	Chilton: Health effects of radioactive waste
2002	Oxford, British Nuclear Energy Society: Effects of low doses of radiation
2002	Royal Society of Physicians: Small area health statistics and radiation
2003	Birmingham: Non ionising radiation. Chaired

2003	Liverpool University: Depleted Uranium and Health
2003	Oxford University: Health Effects of Radiation from Internal Emitters
2003	Munich: Whistleblowers
2003	Copenhagen: Radiation and the foetus
2003	Hamburg: Depleted Uranium
2004	Berlin: Low level radiation
2004	London: PINCHE, child health and environment
2004	London, Westminster: Children with leukaemia
2004	Chicago: Radiation studies
2005	New Zealand Royal Society, Wellington
2005	New Zealand, Auckland University
2005	Chicago: Small area epidemiology by citizen groups
2005	Salzburg, Austria. PLAGE; International Nuclear Law and Human Rights
2005	Stockholm, Swedish Parliament; Low Dose Radiation and Depleted Uranium
2006	ECRR, Charite Hospital, Berlin, Health effects of the Chernobyl Accident
2006	Hiroshima Japan, Depleted Uranium
2007	Kuala Lumpur, Depleted Uranium: War Crimes Tribunal
2007	London, House of Commons: Chernobyl and health; anniversary lecture.
2007	London: Safegrounds Nuclear Industry CIRIA conference; low dose effects
2007	Blackpool: A-Bomb Veterans and low dose radiation effects
2007	University of Ulster: Childhood leukaemia in Ireland and Sellafield
2007	Hanover: Federal Agricultural Laboratories; Uranium chemistry and physics
2007	Geneva: United Nations. Health effects of Uranium weapons
2007	Geneva: United Nations. Chernobyl: WHO and the IAEA
2007	London, House of Commons Select Committee: Nuclear Test Veterans Children Epidemiology study
2007	London, Royal Society: Science Policy Advice and Scientific Dishonesty
2008	Ljubljana Slovenia: Parliament; Nuclear Energy and Human Health
2008	Malmo Sweden; Uranium and health- new discoveries
2008	Helsinki; Chernobyl effects
2008	Moscow, Russian Academy of Sciences; A new theory of living systems.
2009	Stockholm; Parliament. Inadequacy of current radiation models and laws
2009	Greece, Lesvos. Criticisms of current radiation risk system

2. PUBLICATIONS AND SUBMITTED PAPERS

PEER REVIEWED PAPERS.

Busby Chris, Lengfelder Edmund, Pflugbeil Sebastian, Schmitz Feuerhake, Inge (2009) The evidence of radiation effects in embryos and fetuses exposed by Chernobyl fallout and the question of dose response. *Medicine, Conflict Survival* 25(1) 18-39

Busby Chris (2008) Is there a sea coast effect on childhood leukaemia in Dumfries and Galloway, Scotland, 1975-2002 ? *Occupational and Environmental Medicine* 65, 4, 286-287

Busby Chris and Schnug Ewald (2008) Advanced biochemical and biophysical aspects of uranium contamination. In: (Eds) De Kok, L.J. and Schnug, E. *Loads and Fate of Fertilizer Derived Uranium.* Backhuys Publishers, Leiden, The Netherlands, ISBN/EAN 978-90-5782-193-6.

Busby C C and Howard CV (2006) **'**Fundamental errors in official epidemiological studies of environmental pollution in Wales' *Journal of Public Health* March 22nd 2006

Busby C and Fucic A (2006) Ionizing Radiation and children's health: PINCHE conclusions *Acta Paediatrica* S 453 81-86

Van den Hazel P, Zuurbier M, Bistrup M L, Busby C, Fucic A, Koppe JG et al (2006) Policy and science in children's health and environment: Recommendations from the PINCHE project. *Acta Paediatrica* S 453 114-119

Koppe JG, Bartonova A, Bolte G, Bistrup ML, Busby C, Butter M et al (2006) Exposure to multiple environmental agents and their effects. *Acta Paediatrica* S 453 106-114

Van den Hazel P, Zuurbier M, Babisch W, Bartonova A, Bistrup M-L, Bolte G, Busby C et al, (2006) 'Today's epidemics in children: possible relations to environmental pollution' *Acta Paediatrica* S 453 18-26

Busby CC (2005) Does uranium contamination amplify natural background radiation dose to the DNA? *European J. Biology and Bioelectromagnetics.* 1 (2) 120-131

Busby CC (2005) Depleted Uranium Weapons, metal particles and radiation dose. *European J. Biology and Bioelectromagnetics.* 1(1) 82-93

Busby CC and Coghill R (2005) Are there enhanced radioactivity levels near high voltage powerlines? *European J. Biology and Bioelectromagnetics.* 1(2) Ch 7.

Busby Chris and Bramhall Richard (2005) Is there an excess of childhood cancer in North Wales on the Menai Strait, Gwynedd? Concerns about the accuracy of analyses carried out by the Wales Cancer Intelligence Unit and those using its data. *European J. Biology and Bioelectromagnetics.* 1(3) 504-526

Busby Chris and Morgan Saoirse (2005) Routine monitoring of air filters at the Atomic Weapons Establishment Aldermaston, UK show increases in Uranium from Gulf War 2 operations. *European J. Biology and Bioelectromagnetics* 1(4) 650-668

Busby C.C (2002). 'High Risks at low doses.' *Proceedings of 4th International Conference on the Health Effects of Low-level Radiation: Oxford Sept 24 2002.* (London: British Nuclear Energy Society).

Busby, C. C. and Cato, M. S. (2000), 'Increases in leukemia in infants in Wales and Scotland following Chernobyl: evidence for errors in risk estimates' *Energy and Environment* 11(2) 127-139

Busby C.,(2000), 'Response to Commentary on the Second Event Theory by Busby' *International Journal of Radiation Biology* 76 (1) 123-125

Busby C.C. and Cato M.S. (2001) 'Increases in leukemia in infants in Wales and Scotland following Chernobyl: Evidence for errors in statutory risk estimates and dose response assumptions'. *International Journal of Radiation Medicine* 3 (1) 23

Busby Chris and Cato, Molly Scott (1998), 'Cancer in the offspring of radiation workers: exposure to internal radioisotopes may be responsible.' *British Medical Journal* 316 1672

Busby C, and M. Scott Cato, (1997)`Death Rates from Leukemia are Higher than Expected in Areas around Nuclear Sites in Berkshire and Oxfordshire', *British Medical Journal*, 315 (1997): 309.

Busby, C. (1994), `Increase in Cancer in Wales Unexplained', *British Medical Journal*, 308: 268.

Busby C and Creighton JA (1982)' Factors influencing the enhancement of Raman spectral intensity from a roughened silver surface'. *J.Electroanal. Chem.* 133 183-193

Busby CC and Creighton JA (1982)' Efficient silver and gold electrodes for surface enhanced Raman spectral studies' *J. Electroanal Chem* 140 379-390

Busby CC (1984*) J.Electroanal Chem* 162 251-262

Busby CC (1984) 'Voltage Induced intensity changes in surface Raman bands from silver electrodes and their variation with excitation frequency'. *Surface Science* 140 294-306

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Busby, C. C. (1992), Low level radiation from the nuclear industry: the biological consequences. (Aberystwyth: Green Audit)

Busby C.C (1992) Peledriad isaf o'er diwydiant niwcliar: yr canleniadau biolegol. (Aberystwyth: Green Audit)

Busby, C. C. (1994), Radiation and Cancer in Wales (Aberystwyth: Green Audit).

Busby, C. C. (1995), *Wings of Death: Nuclear Pollution and Human Health* (Aberystwyth: Green Audit)

Busby C.C (2003) ed with Bertell R, Yablokov A, Schmitz Feuerhake I and Scott Cato M. *ECRR2003: 2003 recommendations of the European Committee on Radiation Risk- The health effects of ionizing radiation at low dose--Regulator's edition.* (Brussels: ECRR-2003)
2004 Translations of the above into French Japanese Russian and Spanish (see www.euradcom.org for details)

Busby CC, with Bramhall R and Scott Cato MS (2000) *I don't know Much about Science: political decision making in scientific and technical areas*. Aberystwyth: Green Audit (this book influenced the structure and formation of the CERRIE committee and advocates an oppositional structure to science advisory committees in order to allow for cultural bias in science advice. It has now been carried forward by PINCHE in Europe.).

Busby CC, Bramhall R and Dorfman P (2004) *CERRIE Minority Report 2004: Minority Report of the UK Department of Health/ Department of Environment (DEFRA) Committee Examining Radiation Risk from Internal Emitters (CERRIE)* Aberystwyth: Sosiumi Press

Busby CC and others (2004) Report of the Committee Examining Radiation Risk from Internal Emitters (CERRIE) *Chilton, UK: National Radiological Protection Board*

Busby C and Yablokov AV (2006) ECRR 2006. Chernobyl 20 year On. The health Effects of the Chernobyl Accident. Brussels: ECRR/ Aberystwyth: Green Audit

Busby Chris (2006) *Wolves of Water. A Study Constructed from Atomic Radiation, Morality, Epidemiology, Science, Bias, Philosophy and Death.* Aberystwyth: Green Audit

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Busby C.C and Scott Cato M (1999) 'A Planetary Impact index' in Molly Scott Cato and Miriam Kennett eds. *Green Economics- beyond supply and demand to meeting peoples needs.* Aberystwyth: Green Audit

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Busby Chris (2007) New nuclear risk models, real health effects and court cases. Pp 35-46 in- *Updating International Nuclear Law* Eds—Stockinger H, van Dyke JM *et al.* Vienna: Neuer Wissenschaftlicher Verlag

Busby C (2008) Depleted Uranium. Why all the fuss? *United Nations Disarmament Forum Journal UNIDIR, Nov 2008*

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Numerous articles for 'The Ecologist' on low dose radiation effects have been translated into most languages and reprinted.

Numerous articles and reports in *Radioactive Times: the Journal of the Low level Radiation Campaign*

Main Green Audit published papers

Busby C and Scott Cato M (2001) *Increases in leukemia in infants in Wales and Scotland following Chernobyl: Evidence for errors in statutory risk estimates and dose response assumptions. Kiev WHO conference paper.* Occasional Paper 2001/7. Aberystwyth: Green Audit

Busby C C, Bramhall R and Dorfman P (2001) *Environmental risk methodology and Breast cancer mortality near Bradwell nuclear power station in Essex 1995-1999. Occasional Paper 2001/8* Aberystwyth: Green Audit

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Busby C, Rowe H (2000) *Cancer Incidence in Carlingford and Greenore, County Louth: Results of the STAD/ Green Audit Questionnaire* Report 2000/06 Aberystwyth: Green Audit

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Busby C.C. (2002) 'Lymphoma Incidence in Italian Military personnel involved in Operations in Bosnia and Kosovo' Occasional Paper 2002/3 *Aberystwyth: Green Audit*

Busby CC (2000) *From Sellafield to Chernobyl and Beyond: Exposure to man-made ionizing radiation as the primary environmental cause of recent cancer increases*. ASPIS (European Commission DG XVI) Conference: Is cancer predominantly an environmental disease? Kos Island September 2000. Occasional Paper 07/00 Aberystwyth: Green Audit Busby, C (1996) `Childhood Leukemia and Radiation new Newbury', Occasional Paper 96/5 (Aberystwyth: Green Audit).

Busby, C. C. (1996), 'Nuclear waste reprocessing at Sellafield and cancer near the Irish Sea: arguments for an independent collaborative study' *Occasional Paper* 96/1 (Aberystwyth: Green Audit).

Busby, C. C. (1996), 'Cancer and Leukemia in Children born in Wales and Scotland after Chernobyl: Preliminary Note', *Occasional Paper* 96/2 (Aberystwyth: Green Audit).

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(this was the basis for a 40 minute TV documentary by ITV Wales)

Busby C, de Messieres M and Morgan S (2006) Did Chemical Exposures of Servicemen at Porton Down Result in Subsequent Effects on their Health? The 2005 Porton Down Veterans Support Group Case Control Study. First Report. Paper 2006/2 Aberystwyth, Green Audit.

(Shortly after this study was reported in the media the government apologised to the Porton Veterans and gave them £3M compensation)

Busby Chris, de Messieres Mireille (2007) British Nuclear Test Veterans Association/ Green Audit Children's Health Study 2007 Report 2007/5 Aberystwyth: Green Audit

(This was presented to the House of Commons Committee on Test Veterans and is the basis for an ongoing discussion with the MoD about further studies of the veterans children and grandchildren)

Busby Chris, de Messieres Mireille, Morgan Saoirse (2007) Infant and Perinatal Mortality and Stillbirths near Hinkley Point Nuclear Power Station in Somerset,1993-2005. Occasional Paper 2007/6 Aberystwyth: Green Audit

(This was peer reviewed by Derek Pheby of the University of the West of England for the BBC and covered in a short TV documentary by BBC Points West)

BOOK REVIEWS

'Chernobyl: the definitive history', by RF Mould (Bristol: Institute of Physics): reviewed for 'The Ecologist' in 2001

'Animal Pharm' by Mark Purdey (Clairview Books) reviewed for Caduceus in 2008

[dstl]

Assessment of the Possible Risks to Mr Stuart Raymond Dyson from the Use of Depleted Uranium Munitions in the 1990/1991 Gulf Conflict

Executive Summary

This report addresses the suggestion that the death of Mr Stuart Raymond Dyson was due to exposure to depleted uranium (DU) paticulate. It is concluded there is no reasonably foreseeable way in which this could have occurred and noted that Dr Busby's report dated 26 March 2009 represents an extreme view of radiation risk held by a very small minority. It is noted that Dr Busby's description of the scientific debate and his research does not provide a complete picture of the issues or his role.

The size of the battlefield, the proportion of DU used in relation to other munitions and the known pattern of limited and localised contamination from DU impacts all mitigate against UK Forces encountering any DU contamination of recognised health significance. Where contamination exists, the effect of the wind, weather and vehicle movements results in the mixing of DU particulate with much larger quantities of natural soil and reduces the fraction of DU in any inhaled or ingested material.

In Mr Dyson's case, there is no reference to anything other than contact with UK equipment suggested as having been contaminated with DU. This indicates service with support rather than frontline troops and a further reduction in any risk of DU exposure. References to the cleaning of equipment seem most likely to relate to the removal of soil that may harbour pests likely to have an adverse impact on UK agriculture. This is done just prior to repatriation of equipment and generally involves the use of hoses - a method which reduces the risk of resuspension and contact with possibly contaminated surfaces. There is also usually a considerable distance between battlefields and the assembly areas where cleaning occurs. These factors all provide further reductions in the risk and magnitude of any exposure.

The scientific consensus is that DU intakes are only likely to be a concern for those in or on vehicles at the time they are struck by DU munitions or for those who enter immediately afterwards. Doses to personnel such are Mr Dyson are likely to be low or very low and well within the annual limits specified in UK regulations. It is concluded that, even without allowing for the mitigating circumstances mentioned above, the doses for DU intake scenarios more severe than those likely to have been experienced by Mr Dyson are at levels at which the risk is so low that there is no statutory requirement for any health protection measures. The results of battlefield and personal monitoring of veterans support this view. On balance of probabilities, it appears that Mr Dyson is most likely to have been one of those unfortunate people who develop bowel cancer for reasons that are never clear, rather than to have developed cancer as a result of DU exposure during his 3 months in the Gulf.

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18 August 2009

Introduction

1. This report has been prepared for the Ministry of Defence (MOD) and contains information relevant to the suggestion that the death of Mr Stuart Raymond Dyson was due to exposure to depleted uranium (DU) paticulate during the 1990/1991 Gulf conflict. The document also sets the context in which DU ammunition was developed and used by the UK and includes comments on a report by Dr Chris Busby dated 26 March 2009. Where and if necessary, further information can be provided.

Qualifications, Experience and Scope of Report

2. The author graduated in Chemistry from the University of St Andrews and was awarded a Post Graduate Diploma in Radiological Protection by the University of Surrey in 1986. Since this time he has been a MOD Radiation Protection Adviser, Environmental Monitoring and Dosimetry Specialist, so this report focuses on the probability of exposure to DU and the radiation doses arising from exposure as determined by the current scientific consensus. Where comments are made in relation to other topics, further expert advice should be sought.

3. Dr Busby states that his expertise is in epidemiology and cell biology. However much of his report seems related to oncology, particle physics, radiation dosimetry, physiology, biokinetics, medicine, environmental monitoring and radiochemical analysis. It is also difficult to understand how he "was one of the first" to link DU exposure with Gulf veterans illnesses as the author was answering related media and Parliamentary enquiries[1] 3 years before the date on which Dr Busby says he began to research this topic. He acknowledges some criticism of his work but fails to put this in perspective by explaining the nature and extent of this or the international standing of his critics. Further information is provided later.

Literature Review

4. The risks to health posed by exposures to ionising radiation and the possibility that a Gulf veteran may have been exposed to a DU intake are issues that have been studied for years and resulted in a multitude of reports of varying quality. The position taken by the author is that there can be a high degree of confidence in reports which appear in good quality scientific journals (those listed on citation databases such as Medline and the Web of Science) and that reports written by groups of recognised experts named on these databases or nominated by internationally recognised agencies and academic institutions provide a similar level of confidence.

5. With regard to other sources, the significance of the work increases in proportion to the track record of the author(s) in a particular research area and the extent to which a range, rather than just a single, technique and argument is applied to consideration of a particular issue. It is also important to note that some reports simply restate the work and findings of others without any reasoned discussion. This is a practice often adopted by single-issue pressure groups and the importance is that it creates a false impression of the level of the scrutiny applied to a specific topic or the support for a particular view. It is also necessary to consider the extent to which repetition, in experiments with slightly different chemical species, constitutes mounting evidence for a common effect.

[1] Depleted Uranium - Hazards and Monitoring, DRPS Report No 23/93, UK Ministry of Defence, Defence Radiological Protection Service, Gosport, UK (1993)

6. It is important to note that although a number of DU-related reports have been published by agencies such as the Royal Society[2,3,4], World Health Organisation (WHO)[56], United Nations Environment Programme (UNEP)[7,8,9] and International Atomic Energy Agency (IAEA)[10]; reference to these reports shows that the majority of researchers and/or authors were from independent academic institutions. This also applies to key reports published by the US Government, principally the "Capstone Report" which describes and interprets the results of a comprehensive programme of experiments to characterise the particulates formed when DU munitions hit different types of armoured vehicle[11,12]. There are also reports by the US Sandia[13] and Pacific Northwest (formerly Batelle) National Laboratories, the UK National Radiological Protection Board (NRPB) which is now part of the Health Protection Agency (HPA)[14] and the US National Research Council[15]. In addition, there are reports by scientists who appear totally independent of any agency, organisation or country with DU munitions interests[16,17,18,19,20,21]. Dr Busby's report lists only a small number of the many organisations that have researched DU munitions health effects and does not explain why he considers agencies such as the Royal Society, WHO and NRPB to be "so called independent organisations".

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[2] The Royal Society, The health effects of depleted uranium munitions - Summary, Document 6/02, ISBN 0 85403 5753, March 2002

[3] The Royal Society, The health hazards of depleted uranium munitions Part I, Policy document 6/01, ISBN 0 85403 5540, London, May 2001

[4] The Royal Society, The health hazards of depleted uranium munitions Part II, Policy document 5/02, ISBN 0 85403 5745, London, March 2002

[5] World Health Organisation, Department of Protection of the Human Environment, Depleted Uranium Sources, Exposure and Health Effects, WHO/SDE/PHE/01.1, Geneva, April 2001

[6] World Health Organisation, WHO Guidance on Exposure to Depleted Uranium, For Medical Officers and Programme Administrators, Prepared in collaboration with United Nations Joint Medical Staff (2001)

[7] United Nations Environment Programme, Depleted Uranium in Kosovo, Post-Conflict Environmental Assessment, UNEP Scientific Mission to Kosovo 5 – 19 November 2000, Geneva, 2001

[8] United Nations Environment Programme, Depleted Uranium in Serbia and Montenegro, Post-Conflict Environmental Assessment in the Federal Republic of Yugoslavia, 2002

[9] United Nations Environment Programme, Depleted Uranium in Bosnia and Herzegovina, Post-Conflict Environmental Assessment, March 2003

[10] International Atomic Energy Agency, Radiological Conditions in Areas of Kuwait with Residues of Depleted Uranium, Report by an international group of experts, STI/PUB/1164, Austria (2003)

[11] Parkhurst MA et al, Capstone Depleted Uranium Aerosols: Generation and Characterization, Volume 1. Main Text. Attachment 1 of Depleted Uranium Aerosol Doses and Risks: Summary of US Assessments. PNNL-14168, Prepared for the US Army by Pacific Northwest National Laboratory, Richland, Washington (2004)

[12] Parkhurst MA et al, Capstone Depleted Uranium Aerosols: Generation and Characterization, Volume 2. Appendices. Attachment 2 of Depleted Uranium Aerosol Doses and Risks: Summary of US Assessments. PNNL-14168, Prepared for the US Army by Pacific Northwest National Laboratory, Richland, Washington (2004)

[13] Marshall AC, An Analysis of Uranium Dispersal and Health Effects Using a Gulf War Case Study, Sandia Report SAND2005-4331, Sandia National Laboratories, New Mexico (2005)

[14] Bailey MR, A review of the Capstone Depleted Uranium Aerosol Characterization and Risk Assessment Programme, RPD-DAR-04-2005, Health Protection Agency, Chilton, Oxon (2005)

[15] Review of Toxicologic and Radiologic Risks to Military Personnel from Exposure to Depleted Uranium During and After Combat, National Research Council of the National Academies, Washington DC (2008)

[16] Fetter S and von Hippel FN, The hazard posed by depleted uranium munitions, Science and Global Security, Volume 8:2, pages 125-161 (1999)

[17] Bou-Rabee F, Estimating the Concentration of Uranium in Some Environmental Samples in Kuwait After the 1991 Gulf War, Applied Radiation Isotopes, Volume 46, Number 4, 217-220 (1995)

[18] Passchier W F and Tuyn J W N. Depleted uranium report from the Health Council of the Netherlands, Journal of Radiological Protection. Volume 22 Number (2002)

[19] Liolios TE, Assessing the Risk From the Depleted Uranium Weapons Used in Operation Allied Force, Science & Global Security, Volume 8, Number 2, 163-181 (2000)

[20] Meddings DR, Haldimann M, Depleted Uranium in Kosovo: An Assessment of Potential Exposure for Aid Workers, Health Physics, 467-472, Volume 82, Number 4, April 2002

[21] Rao S.S. and Bhat T.B.: Depleted uranium penetrators – hazards and safety, Defense Science Journal 47 (1), 97-105 (1997)

7. From the international perspective, the most recent development is publication of a UN report in July 2008[22]. Worldwide comment was requested but only 15 countries contributed to the report entitled "Effects of the use of armaments and ammunitions containing Depleted Uranium". Of these, only Srpska, Cuba, Qatar and Serbia suggested the possibility of widespread or extreme health risks and only 4 countries (Argentina, Belgium, Qatar and Serbia) specifically mentioned the need for a ban on the use of DU munitions. Canada considered that the subject had been studied extensively and Canada and the Netherlands specifically opposed any ban. WHO and IAEA also contributed and noted that DU risks could be controlled with simple countermeasures conducted by national authorities.

8. The author served with Dr Busby on the Depleted Uranium Oversight Board (DUOB) and considers his reference to this group and his involvement in it to be incomplete and therefore potentially misleading. The DUOB report shows that at the time the report was written the group consisted of approximately 16 members. Three were MOD employees, two were Gulf veterans, two were scientists (Dr Busby and Prof Hooper) nominated by veterans as technical advisers, one was an NHS consultant oncologist who has provided consultancy services to the Royal Navy, one a retired Surgeon General representing the Royal British Legion, one from HPA. The remainder were from what are considered independent institutions, including the British Red Cross and Oxford University. The Board also included Prof Spratt, Chair of the Royal Society's DU Working Group.

9. The DUOB report is unusual as it consists of a main and a minority report. The text explains that the "main report represents the views of the majority of Board members, including all who were appointed as independent scientific experts, and also those who were nominated by the Royal British Legion and the British Red Cross. Four members of the Board, all nominated by the National Gulf Veterans and Families Association, disagreed with some parts of the main report. They were asked by the Chairman to produce a statement, highlighting those aspects of the main report with which they agreed and those with which they disagreed. This minority statement is set out at pages 51-75. Unfortunately, despite constructive discussion, it proved impossible to resolve the differences of opinion that it describes." Dr Busby, Prof Hooper and the two Gulf veterans sponsored the minority report. It is not known, but seems likely, that the Prof Hooper mentioned by Dr Busby in his report is his colleague from the DUOB.

10. The main DUOB report states that "None of the veterans tested had detectable exposure to DU. Total 24-hour excretion of uranium exceeded 30 ng in eight samples, the highest value being 497 ng. These higher than average excretions of natural uranium may have reflected unusual dietary or other environmental exposures." The report also notes that "Biokinetic calculations indicated that the assay was sufficiently sensitive to detect past exposures to DU that (according to mainstream medical and scientific thinking) would have material implications for health." So the Board did not accept the view, stated in Dr Busby's report, that the results of the uranium in urine monitoring of UK veterans were "hard to interpret".

11. With regard to the minority statement, the main report states that "The minority statement is presented in a spirit of openness and fairness. The other members of the Board acknowledge that it advances considered opinions which are genuinely held. However, they take no responsibility for the accuracy of its content, and dissociate themselves from its reasoning and conclusions, which they believe to be

[22] Effects of the use of armaments and ammunitions containing depleted uranium, Report of the Secretary General, A/63/170, United Nations General Assembly (2008)

seriously flawed scientifically." From literature reviews it appears that there was a broadly similar outcome to Dr Busby's membership of the Committee Examining Radiation Risk from Internal Emitters (CERRIE). However in this case the minority report was issued as a separate publication. More information is available in an Editorial by Richard Wakeford published in the Journal of Radiological Protection[23].

12. Dr Busby refers to work by the Institut de Radioprotection et de Surete Nucleaire (IRSN), but his interpretation seems at odds with the content of their report[24]. The IRSN report states that the European Committee on Radiation Risk (ECCR) group raises questions that are valid and deserve a debate and that research is needed to address some data gaps associated with the risks from radioactive material taken into the body. However the report also goes on to say "The ECRR attempted to solve these gaps by proposing to modify the ICRP radioprotection system and to arbitrarily decrease the annual exposure limits. Although the questions raised by the ECRR are fully acceptable, the fact is that the arguments stated to justify this doctrine modification are not convincing, as the demonstration as a whole does not meet the criteria of a strict and consistent scientific approach. A detailed critique of ECRR work on the HPA website endorses and amplifies this view.

Radiation Protection and Radiation Risk

13. Radiation protection is based on recommendations made by the International Commission on Radiological Protection (ICRP)[25,26,27,28]. These recommendations also contain information on radiation risks. ICRP was established in the 1920s and consists of groups of recognised experts who produce reports based on literature reviews and/or their own research. However it is important to realise that this group does not function in isolation. Other groups carrying out broadly similar work are the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the US Nuclear Regulatory Commission (NRC). These groups publish their own reports and operate independently of ICRP.

14. When ICRP recommendations are made, they are scrutinised by a variety of different agencies. The purpose of this is to ensure that the recommendations and their conclusions are suitable for adoption by that agency. These groups include the World Health Organisation, International Atomic Energy Agency, European Union Article 31 Group and, for the UK, the Health Protection Agency (HPA) Radiation Protection Division which was previously known as the National Radiological Protection Board (NRPB). The recommendations are also scrutinised by experts acting on behalf of environmental protection agencies and workers representatives such as Trades Unions.

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23 Wakeford R, Reflections on CERRIE, Journal of Radiological Protection, Volume: 24, Issue: 4 (2004)

24 Health consequences of chronic internal contaminations by radionuclides, Comments on the ECRR report "The health effects of ionising radiation exposure at low doses for radiation protection purposes" and IRSN recommendations, Report DRPH/No 2005-20, Institut de Radioprotection et de Surete Nucleaire, Fontenay-aux-Roses Cedex (2005)

25 International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection, Publication 1, Pergamon Press, Oxford, UK (1959)

26 International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection, Publication 26, Annals of the ICRP 1(3) (1977)

27 International Commission on Radiological Protection, 1990 Recommendations of the International Commission on Radiological Protection, Publication 60, Annals of the ICRP 21(1–3) (1991)

28 International Commission on Radiological Protection, The 2007 Recommendations of the International Commission on Radiological Protection, ICRP Publication 103, Annals of the ICRP 37/2-4, Elsevier (2008)

15. As a result of this process, ICRP recommendations are accepted and used throughout the world to protect employees and others against the potentially harmful effects that may result from radiation exposure. They are also agreed by employers and the Trades Unions as providing a suitable basis for the UK's Nuclear Industry Compensation Scheme. It is the output of this process involving hundreds of scientists worldwide that the author and MOD term "the scientific consensus". This is the basis for the DU risk assessments used by the internationally recognised expert bodies mentioned above and it is the approach endorsed and adopted by the author and MOD.

16. Within the radiation protection community it is known that there is a small minority who believe that the ICRP methodology does not provide an adequate level of protection. These views are often accompanied by charges of bias or acquiescence to government or industrial influence. Such views are often expressed by those with few or no citations in databases of the type mentioned above but there are some scientists (who have considerable standing as a result of being cited in such databases) to highlight areas where more research is needed. With regard to DU, this group includes Dr Alexandra Miller, mentioned below. Conversely, the European Committee on Radiation Risk (ECRR) mentioned by Dr Busby as an organisation critical of ICRP, has been described by the HPA as "a self-styled organisation with no formal links to official bodies. The epidemiological studies cited by ECRR have been investigated in detail by HPA and previously by other experts whose conclusions are generally different from those reached by ECRR. The methodology proposed by ECRR for estimating radiation risks from internal emitters is arbitrary and does not have a sound scientific basis." Furthermore, there are many misrepresentations of the current scientific consensus, misunderstandings, inconsistencies and unsubstantiated claims in the ECRR reports. The ECRR reports therefore provide no scientific basis for changing protection standards."

17. Dr Busby's report places considerable emphasis on what has, for over 40 years, been known as the "hot particle" theory. The premise is that calculations suggest very high radiation dose rates to tissue in very close proximity to radioactive particles and that the ICRP methodology underestimates the associated health risk by many orders of magnitude. Figures as high as 100,000 have been suggested but the author is unaware of any study of patients or workers with demonstrable intakes of radioactive material that suggest any significant underestimation of risk. This includes long-term studies of US Gulf veterans with embedded DU and with the skin "peppered" with barely detectable particulates as a result of them being close to a DU munitions impact. Notes from a lecture in 2006 by Dr Monty Charles of the University of Birmingham indicate that the scientific consensus is that although there is some support from in vitro studies for use of a factor between 2 and 3 and just possibly up to 5, there is much less evidence for any carcinogenic enhancement from in vivo work. Dr Charles also published a review of this topic in 2003[29]. This seems to parallel the situation described by Dr Miller below. Dr Charles also notes that very high radiation doses lead to cell death rather than carcinogenesis.

18. Another major feature of Dr Busby's report concerns what he has termed the "photoelectron effect". This is a relatively recent development and the author is unaware of any serious scientific review of Dr Busby's theories as published on the world wide web and reported in New Scientist. In general terms, it is reminiscent of an earlier attempt to propose a mechanism by which radiation exposures give rise to risks greater than those suggested by ICRP. This was known as the "Second Event

[29] Charles MW, Mill AJ and Darley PJ, Carcinogenic risk of hot particle exposures, J Radiol Prot, 23, 5-28 (2003)

Theory" and its failure to obtain any significant acceptance is described in the article by Richard Wakeford mentioned above.

19. Dr Alexandra Miller is the author of many papers on the carcinogenesis and transgenerationaltoxicity of the DU used in munitions. Her publications appear in high impact journals and her work is often cited by others as proof that the risks from DU are being seriously underestimated. However, as seems obvious from her own comments in a review of DU literature published by CRC Press in 2007[30] and which are reproduced below, this overstates the case. Although this relates to medical matters, its importance is that it demonstrates how secondary sources can either knowingly or unwittingly misrepresent information in good quality scientific literature. It also acknowledges the multi-factorial nature of issues relating to intakes of DU and the existence of conflicting evidence. The author is unaware of any more recent developments that would affect the position described below, but this is an area where it would be prudent to obtain confirmation from other experts.

> "The use of depleted uranium (DU) in armour-piercing munitions remains a source of controversy because of the numerous unanswered questions about its long-term health effects. Although there are no conclusive epidemiological data correlating DU exposure to specific health effects, studies using cultured cells and laboratory rodents continue to suggest the possibility of leukemogenic, genetic, reproductive and neurological effects from chronic exposure. On the other hand medical surveillance studies of US soldiers wounded by DU shrapnel demonstrate that despite persistent uranium urine elevations more than 12 years from first exposure, renal and other clinical abnormalities have not been observed. Continuing surveillance is indicated, however, due to the ongoing nature of the exposure. Until issues of concern are resolved with further research, the use of DU by the military will continue to be controversial."

20. With regard to radiation safety, the most recent major development has been the publication of new ICRP recommendations in 2007. These update the previous recommendations published in 1990. Independent scrutiny of the type described above is now ongoing and it would be inappropriate to speculate on the outcome of this. However it is noted that there are no substantive changes in respect of the ICRP assessment of radiation risks. In regard to recent scientific developments that have been suggested as having a bearing on the need to revise radiation risks, HPA have noted that "ICRP have concluded that the body of information on the health effects of radiation has expanded since 1990 but there are few significant changes to our understanding of such effects.".

Radiation Health and Safety

21. Endorsement of the ICRP recommendations by the European Union leads to the formulation of radiation safety directives which are binding on the UK and reflected in statutory requirements[31][32]. There is, and has been for many years, a well-developed system to ensure the safety of those who might receive external or internal radiation exposures. In general terms, the process begins with a risk assessment which leads to decisions on work procedures, personal and environmental monitoring and the personal protective equipment needed to mitigate

[30] Depleted Uranium Properties, Uses and Health Consequences, Edited by Alexandra C Miller, CRC Press, Taylor & Francis Group, Florida (2007)
[31] UK Statutory Instrument, The Ionising Radiations Regulations 1985, SI 1985 No 1333
[32] UK Statutory Instrument, The Ionising Radiations Regulations 1999, SI 1999 No 3232

any health risk. The regulations relate to what is reasonably foreseeable and/or reasonably practicable and focus most attention on those assessed as being at greatest risk.

22. One consequence of this system is that personnel assessed as being at most risk receive most information, instruction and training on the hazards and the measures needed to mitigate any risk. However the corollary is that personnel at little or no risk receive proportionately less advice. This may account for the fact that concerns about potential DU exposures and the health consequences occur less frequently in those, such as Explosive Ordnance Disposal and Logistics personnel. In 1990/1991, these two groups received specific instructions as it was considered reasonably foreseeable that precautions might be needed to reduce or prevent possible DU exposures during battlefield clearance operations or in the event of accidents involving bulk DU munitions.

23. When work begins and potential exposures may be received, environmental and, in higher risk situations, personal monitoring is carried out to confirm the validity of the assessment and adequacy of the safety arrangements. This is supplemented by investigations to investigate the reasons for and consequences of any accidents that may occur and by monitoring for reassurance purposes if staff assessed as being at little or no risk express concern about the adequacy of safety procedures.

Risk Assessment

24. By intuition and experiment it is known that there are a number of factors that need to be considered when assessing the risk from inhalation or ingestion of any potentially hazardous material. At the most basic level there is the distance from the source of the hazard to the individual and the amount of time spent in any known or potentially contaminated area. Other important factors are the amount of material present, either expressed as a bulk quantity or more generally in terms of concentration per unit area or volume. Breathing rate is important as the body cannot inhale infinite quantities of contaminated air. Particle size is important for assessing whether the material can be inhaled or ingested and chemical form dictates how the material behaves when it is taken into the body. With regard to chemical form and the associated solubility, it is important to consider whether it is gut or lung solubility that is being considered as the biochemical conditions are very different. Particle size also affects solubility as smaller particles are generally more reactive by virtue of their higher surface area to volume ratio.

25. The author is of the opinion that a scientifically robust risk assessment requires, preferably, some quantitative consideration of the above factors and, invariably, a reasoned and fully transparent estimate of intake. This is the approach adopted by the academic bodies and international agencies mentioned above but it is something missing from Dr Busby's report. Similarly, simple detection of a given material in any biological or environmental system is insufficient to allow any estimate of the possible health risk. This is important as some reports imply that a substance is potentially or particularly hazardous by virtue of it being detected at an unspecified concentration at a considerable distance from a supposed point of release.

DU Munitions Development and Deployment by the UK

26. There is documentary evidence to indicate that accepted health and safety principles were applied during the UK's development of DU munitions[33] and that there were considerations of the risks that troops would face on the battlefields[34]. The earliest documents known to the author are US reports from the 1970s[35,36,37]. These and many other US Government reports listed in the Royal Society and other subsequent reviews of the health hazards from DU munitions appear to have been shared with MOD at about the time that Ministers announced that the UK would begin a programme to develop DU munitions. Indeed there was a very strong focus on potential health risks and the measures that would be put in place to mitigate these risks in Ministerial statements.

27. Initial entirely theoretical (ie desk-based) assessments were subsequently updated to take account of the results from personal and environmental monitoring during DU munitions trials. This monitoring focussed on measurement of the air and ground concentrations of DU and the physical and chemical characteristics of the particulates formed when DU impacts on hard surfaces. The distinction between what is a theoretical and/or a desk-based study is often misunderstood. Any study that assesses risk by the application of mathematical models to environmental and/or personal measurements must have a theoretical component. The key point about a desk study is that no experimental data is available when the work is carried out and the inputs are based solely on personal judgement[38]. However, in cases such as the Royal Society reports, which Dr Busby refers to as desk-based, experimental data was available even though it was collected by other agencies. Another important point is that the Royal Society critically reviewed this data before they used it.

DU Munitions Use in the 1990/91 Gulf Conflict

28. As in Dr Busby's report, there is often no distinction between the different types of DU munition and the way in which these and other munitions are used in an armed conflict. Neither is there anything that gives a realistic picture of the size of the area over which a modern conflict occurs. This is of importance as it affects the risk of encountering DU metal or particulates on a battlefield. There is also often confusion over the use of DU in tank armour. In fact the UK has never used DU in this role.

29. In 1990/91, the UK had two types of DU munition. The first is of no obvious relevance to this case as it was only used by ships at sea for close-in missile defence. The second was a 120mm anti-tank round used in Challenger tanks. In this ammunition, the DU is encased inside a non-radioactive metal coating. This prevents corrosion of the chemically reactive DU metal and prevents personnel

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[33] Written Answers, Woodall/Mulley, Depleted Uranium Ammunition, Hansard Official Record, Column 777, 8 March 1979, Her Majesty's Stationery Office, London
[34] RAOC Technical Ammunition Bulletin, Clearance of Depleted Uranium (DU) From Range Areas, TAB No 21/2024, UK Ministry of Defence, Director Land Service Ammunition, January 1991 (UK Restricted)
[35] JTCG/ME, Special Report: Medical and Environmental Evaluation of Depleted Uranium, Volume 1, Joint Technical Coordinating Group for Munitions Effectiveness Ad Hoc Working Group for Depleted Uranium (1974)
[36] Hanson W.C., Elder J.C., Ettinger, H.J., Hantel, L. W., Owens, J.W. Particle size distribution of fragments from depleted uranium penetrators fired against armour plate targets. Los Alamos National Laboratory, USA, LA-5654 (1974)
[37] Hanson WC, Ecological Considerations of Depleted Uranium Munitions, Los Alamos National Laboratory, LA-5559 (1974)
[38] United Nations Environment Programme/United Nations Centre for Human Settlements (UNEP/UNCHS) Balkans Task Force, The Potential Effects on Human Health and the Environment Arising from Possible Use of Depleted Uranium During the 1999 Kosovo Conflict: A preliminary Assessment, October 1999

coming into direct contact with the DU when handling intact ammunition. In development trials, no contamination was detected when this ammunition was dropped onto steel plates from a height of 2 metres.

30. There is generally about 4 – 5 kg of DU in an anti-tank round and only 88 rounds were fired by UK Forces during hostilities in 1990/91. This equates to less than one metric tonne of DU. Some additional rounds were also fired on ranges during initial work-up training to establish the round's Mean Point of Impact. Tank guns fire on an approximately "flat" trajectory and the possible outcomes are that the round strikes or misses the target. When a round strikes a target, some DU particulates are produced. The Royal Society estimate that a realistic upper bound for the efficiency of conversion is 20%. Supporting evidence comes from surveys in which physically large DU fragments have been found in and around targets and from the fact that DU penetrators can exit armoured vehicles after entering the crew compartment.

31. When a tank round misses a target, experience gained during test firing shows that the round either becomes embedded at depth in the ground or comes to rest on the surface. In both cases, there is very little particulate contamination produced and the area affected is of the order of a few rather than hundreds of square metres. Due to the similarity in ammunition design and tactics, information from US sources can be applied to UK munitions and vice-versa. Information from the US Government suggests that about 9500 rounds containing about 43 tonnes of DU tank ammunition were fired by US Forces and that about 780 000 rounds containing about 214 tonnes of DU ammunition were fired from US aircraft in 1990/91.

32. The fact that 80% of the DU ammunition was fired from aircraft is of considerable importance. Firstly, there is a very considerable body of data resulting from the use of this ammunition in the Balkans and subsequent environmental monitoring by UNEP. Secondly, from the fact that DU fired from aircraft "saturates" the area around the target and that US sources have acknowledged that, even in a successful attack, most of the DU will enter the ground and remain embedded at depth. The crucial point is that, when DU is fired from an attacking aircraft, very little contamination is found at ground level and this is generally contained within a few centimetres or tens of centimetres of the point of impact. Furthermore, when DU munitions are used by aircraft, they may impact in areas which are not entered, or are only entered very much later or infrequently, by UK Forces. During MOD surveys in Iraq and in the Balkans, some DU impact locations could not be visited as they were in minefields or areas where there was unexploded ordnance.

33. A further practical consideration is the size of a modern battlefield and the multiplicity of weapons systems used in combat operations. There is often a misconception that any damaged vehicle will have been attacked with DU but this is not the case. Usual practice is to gather together battle-damaged equipment and a MOD survey of vehicles in the UK Area of Operations in Iraq in 2003 found that only a small minority of damaged vehicles were DU contaminated. UNEP also experienced difficulties in finding DU contaminated vehicles in the Balkans. Furthermore it was also necessary to travel considerable distances between sites where DU munitions were known or suspected to have impacted. This reflects the reality that modern battlefields are physically large and that many areas will be unaffected by combat.

34. As a result of these considerations, the expectation is that any sources of DU contamination remaining after an armed conflict will be relatively localised and separated by large areas of essentially uncontaminated land. This does not mean

that DU is not present. It may or may not be detectable, but the essential feature is that the DU will be at or below levels at which it presents a "tolerable" health risk. What is considered tolerable obviously depends on many factors, indeed risk management and risk communication have now become social sciences. One crucial aspect is obviously the degree of acceptance of the estimate of risk from a given radiation exposure and, as mentioned above, this is an area in which there is some disagreement by a small minority. In this report, tolerability is as defined by the Health and Safety Executive and radiation risk is assessed in the manner recommended by ICRP.

DU Intakes and Risks - Environmental Monitoring

35. The popular view of environmental monitoring involves the use of a probe for monitoring surfaces or dust collected onto filter papers by air sampling equipment. In both cases, the presence of contamination is taken as being shown by an increase in reading over some pre-determined background level. For some types of material this is a reasonably valid view, although, as mentioned previously, a "positive" reading is insufficient for quantification of a health risk. This is especially true if, as is often found in DU monitoring, a significant reading at one point is accompanied by little or no detectable increase at other nearby locations. However such basic monitoring techniques are fundamentally flawed for a material such as uranium which is present throughout the environment and in concentrations which vary by orders of magnitude from place to place. Increased readings can result from a simple change in soil type of from a reducing thickness of soil over bedrock. Further complications arise from the fact that there is no instrument that allows 100% discrimination between beta and gamma radiation and the paucity of reliable information on geological conditions in areas where DU munitions have been used in combat. Laboratory confirmation of survey readings by techniques that allow discrimination of the material of interest is essential.

36. As Dr Busby states, the DU used in munitions has a higher specific activity than uranium found in soils and rocks because of the concentration that occurs during processing to form the metal. However it must also be remembered that a DU impact generates fragments and particulates that mix with other material in the environment and so reduce the bulk specific activity. The overall consequence is that simple monitoring of the type described by Dr Busby may well be adequate for the detection of physically large (ie millimetre size) DU fragments, but is insufficient to distinguish between a high concentration of naturally occurring uranium in soil and a surface deposit of DU particulates with smaller particle sizes. It is for this reason that the use, or at least the confirmatory use, of mass spectrometry represents the scientific consensus. Dr Busby refers to use of a sodium iodide detector but it is known that such instruments have little ability to discriminate between different forms of uranic material. For this reason it is germanium (ie high resolution) detectors that are used in the studies reported in high impact scientific journals. The UNEP reports discuss the methods needed for reliable detection of DU in the natural environment.

37. Measurements of bulk uranium and/or DU on former battlefields are available from environmental monitoring by UNEP, IAEA and MOD[39]. MOD practice is to use beta/gamma and total uranium measurements for screening purposes and to use mass spectrometry to analyse high or anomalous results. A random sample of 10% of collected material is also analysed by mass spectrometry for comparison purposes. The results from these surveys show that locations where DU can be

[39] Smith DM, Environmental Surveillance in Kosovo, DRPS Report 240/2001, UK Ministry of Defence, DERA Radiation Protection Services, 28 July 2001

But Nic Priest found DU in Kosovo in urine 6 months after the battle. — Reference?

detected are limited and highly localised and that there is generally a highly non-uniform distribution of DU in these areas. The highest levels of DU contamination found during a MOD survey in Iraq in 2003[40] are shown in Figures 1 - 2. These are particularly relevant as they represent the only known occasion on which systematic surveys have been carried out close to and at increasing distances from confirmed DU impact locations. DU concentrations obviously vary by about an order of magnitude immediately around the target and it would seem reasonable that work would not be confined to just one area. In this case, the average value is about 17000 becquerels per kilogram (Bq/kg) and the maximum value 3 times greater. It is also evident that levels of contamination decrease by about an order of magnitude within a distance of about 10 m. The presence of the minefield in Figure 2 is evidence for the earlier observation that DU contaminated areas may not always be accessible.

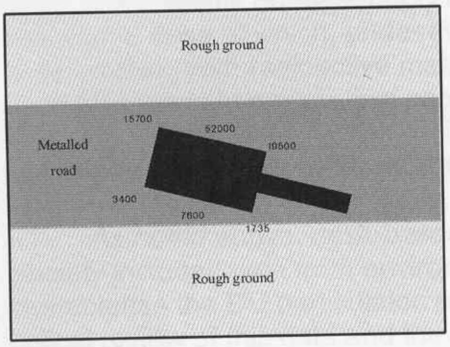

Figure 1 – Uranium in soil (Bq/kg) by high resolution gamma spectrometry

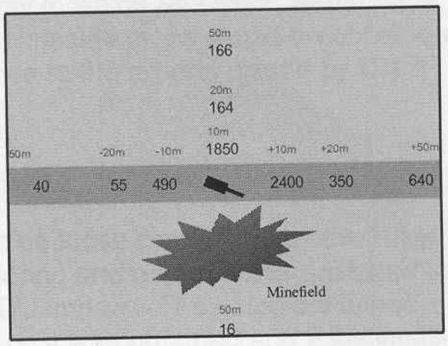

Figure 2 - Uranium in soil (Bq/kg) by mass spectrometry

38. Various benchmark quantities exist for assessing the possible significance of environmental monitoring results. Some are set by environmental regulators and some by expert advisers. Historically, the UK Government has stated that levels of uranium in soil of less than 11000 Bq/kg are below regulatory concern. HPA have established a Generalised Derived Level (GDL) for uranium in soil for measuring the impact of ongoing industrial discharges which give rise to widespread contamination[41]. Their view is that, for the UK environment, an activity concentration of uranium-238 in soil of 20000 Bq/kg would result in a member of the public receiving a radiation dose of 1 millisievert (mSv). This is the current UK statutory annual whole body dose limit for a member of the public. The corresponding dose limit for employees and which would be applicable to Mr Dyson is 20 times greater. Corresponding limits exist for exposure of specific organs and tissues and the significance of this will be discussed later. However application of GDLs to limited areas of contamination obviously represents a very conservative approach as time will be spent in less contaminated areas. The author's view is that, when assessing any possible health impact, the assumption that DU contains 100% uranium-238 leads to a negligible error as the DU used in UK and US munitions contains 99.8% uranium-238.

39. As noted above, GDLs reflect the conditions existing in a particular society and geographical area. So some correction is needed to reflect differing conditions, such as the generally higher dust-loading in air in desert areas. At a meeting of the

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[40] Smith D and Brown R, Radiological Assessment of Depleted Uranium Impact Locations in Iraq, Session TA6 - Radiation Protection of the Public and the Environment, Second European International Radiation Protection Association Congress, Paris (2006)

[41] National Radiological Protection Board, Generalised Derived Limits for Radioisotopes of Polonium, Lead, Radium and Uranium, Documents of the NRPB, Volume 11 Number 2, 2000

International Radiation Protection Association (IRPA) in 2006, MOD suggested that a GDL of 6000 Bq/kg would be appropriate for conditions in Iraq and the author is unaware of any contrary view. This value was also suggested and seemingly accepted at a meeting in Amman in which UNEP, WHO and MOD provided Iraqi scientists with training in DU measurement techniques. UNEP also supplied equipment to allow these measurements to be carried out.

40. From this discussion it is obvious that most of the contamination near a DU impact location is below what most consider to be of regulatory concern and that even continuous occupation of the most contaminated areas would give whole body doses of a few rather than tens of millisieverts per year. Service records indicate that Mr Dyson served in the Gulf for only 3 months and so any radiation dose would be reduced accordingly (ie by 75%). So, in very general terms and in the very worst-case, there seems no reasonably foreseeable way in which Mr Dyson would have received a dose at which, under even peacetime legislation, he would be considered to be working with radioactive material. Reference to the reports issued by UNEP and IAEA leads to an identical conclusion.

DU Intakes and Risks – Desk Studies

41. As noted above, desk-based studies such as those carried out by the Royal Society included data from environmental monitoring and experiments designed to characterise the DU particulates produced in a DU impact. They also contained a critical review of this data and the means by which it was obtained and a justification for the use of parameters based on personal judgement rather than measured data.

42. The author endorses the methods employed by the Royal Society in their work on the potential health hazards from DU munitions. These methods are described in detail in the reports mentioned previously and are not described further here. It is however noted that most of the data used by the Royal Society was obtained from trials in which DU ammunition was being tested for its ability to penetrate the most modern tank armour. However in the conflicts in which DU munitions have been used, older equipment with less effective armour protection has been targeted. The expectation is that this would produce less DU particulate and it is notable that the levels of contamination found in battlefield surveys have been well below those measured in trials. The author therefore considers that application of the Royal Society's methodology will tend to over rather than underestimate risk in regard to the actual use of DU in the 1990/91 Gulf conflict.

43. The Royal Society assessed the risks from several scenarios that were considered representative of the exposures troops might face after the battlefield use of DU munitions. The Royal Society scenarios are designated as Level I, II and III exposures and are categorised as follows:

a. Level I. Personnel in a vehicle struck by DU or those entering the vehicle immediately afterwards, typically to rescue injured colleagues.

b. Level II. Personnel working in or on vehicles struck by DU. Any exposure will be dominated by inhalation from the re-suspension of DU deposited within the contaminated vehicle.

c. Level III. All other personnel.

44. In common with standard procedure in good quality high impact scientific journals, the Royal Society reports acknowledge the uncertainties associated with

their risk assessments and allow for these by calculating a "central" and "worst-case" estimate of intake and dose for each scenario. The central estimate is a representative value, based on likely values of all parameters that determine the intake according to the information available, or where information is lacking, values that are unlikely to underestimate the exposures greatly. The central estimate is intended to be representative of the average individual within the group (or population) of people exposed in that situation. The worst-case estimate uses values at the upper end of the likely range, but not extreme theoretical possibilities. The aim is that it is unlikely that the value for any individual would exceed the worst-case. Thus the worst-case should not be applied to the whole group to estimate, for example, the number of excess cancers that might be induced.

45. The Royal Society approach is intended to be and, in the author's view is, totally transparent. The review by Dr Miller contains a comparison between some of the results obtained by the Royal Society and the results of independent work by Sandia National Laboratory and by the US Army in the Capstone trials. It is considered that results for Level II exposures, which relate to work in a DU contaminated vehicle without respiratory protection, represent an extreme worst case for Mr Dyson's cleaning activities. In general terms, estimates of intakes from the Capstone, Royal Society and Sandia work are in the ratio 0.5 : 1 : 4. Given the large number of different parameters used in these assessments, this is considered very good agreement, with the Royal Society occupying a central as opposed to an extreme position. Although it is ingestion rather than inhalation of DU that is suggested as being the route of intake of importance in Mr Dyson's case, figures for inhalation are included below for comparative purposes. As can be seen, it is inhalation that gives the greatest risk.

46. The Royal Society calculates the central estimate for DU exposure for work in a contaminated vehicle as being 0.1 mg/h by inhalation and 0.5 mg/h by ingestion. If it is assumed that Mr Dyson worked for 8 hours a day throughout his employment, he would have been at risk for a total of 720 hours and would have had intakes of 72 mg by inhalation and 360 mg by ingestion respectively. For DU particulate with a specific activity of 14 900 Bq/g, the corresponding activities would be about 1100 Bq by inhalation and 5500 Bq by ingestion. The cumulative whole body doses are about 3.8 mSv by inhalation and 0.034 mSv by ingestion. This is consistent with the earlier suggestion that any whole body radiation doses to Mr Dyson would be of the order of a few rather than tens of millisieverts. However it should be remembered that the average and maximum levels of DU contamination in the soil immediately adjacent to battle-damaged vehicles were found to be 17 000 and 52 000 Bq/kg rather than the 14 700 000 Bq/kg used by the Royal Society in the reasonable expectation that there would be much less mixing of DU particulate and natural soil inside as opposed to outside vehicles. So there are grounds for suggesting that the intake and dose estimates suggested above, although small in terms of annual limits for workers, are more than 300 times too high. There is obviously a theoretical possibility that one or perhaps more DU particles will be inhaled even when these are mixed with many more particles of naturally occurring soil or dust. However the author considers this risk to be so low that the event cannot be considered reasonably foreseeable. This opinion is consistent with the use of bulk activity in reports which follow the scientific consensus when assessing the risks from contaminated soils. Taking this more realistic approach, the assessed whole body dose would be a few microsieverts and totally negligible.

Organ Doses

total 5500 Bq by ingestion
multiply
dose 0.034 mSv ingestion
3.8 mSv inhalation x 500
=

47. The Royal Society report also calculates the doses to the most highly exposed organs and tissues. For inhalation, the colon is not tabulated. This is consistent with what would be expected as inhalation leads predominantly to irradiation of the lungs, extrathoracic airways and lymph nodes. For ingestion, it is calculated that the ingestion of 1 mg of DU will give rise to a committed dose to the colon of 0.0004 mSv. The lower large intestine receives a larger dose of 0.0006 mSv. For the suggested intake of 360 mg for 8 hours work per day over a 3 month period, the cumulative doses would be 0.15 mSv and 0.22 mSv. Therefore, even without correcting for any possible effect of dilution by soil, the assessed doses are at levels at which any risk is considered to be so low that there is no current statutory requirement for implementation of any health protection measure.

Biological Monitoring and Health Studies

48. The uranium in urine monitoring carried out by the DUOB and the fact that no DU was detected in any of the samples has already been described above. This confirms the expectation that, for the reasons outlined above, the risks of DU intakes for most troops are very low or non-existent. This absence of DU was also consistent with the fact that no UK troops were involved in DU-related "friendly-fire" incidents in the 1990/91 Gulf conflict or in the Balkans.

49. Similar urine monitoring was organised by MOD after the 2003 Gulf conflict[42,43]. However on this occasion some UK troops were attacked with DU munitions and some DU was detected in the urine of a small number, but notably not all of the veterans injured in these incidents. Work by HPA indicated that any risk to these individuals was low – ie considerably greater intakes had been found in US veterans who were injured in the 1990/91 Gulf conflict and who were not showing any ill health related to their prolonged (ie 18 year) DU exposures.

50. As a result of the studies mentioned above, about 1000 UK veterans from a range of services and trades and who were at varying risk of exposure have now been monitored. About 98% of this monitoring was for reassurance purposes. The other 2% were personnel who were offered monitoring on account of their involvement in DU-related incidents in which they may have suffered Level I or II exposures as defined above. Broadly similar measurements have been carried out by government agencies in a number of other countries, including the US[44,45,46], Canada[47] and Germany[4849]. In these surveys, analytical methods have generally followed those recommended by the DUOB. In particular, equipment is calibrated

[42] UK Ministry of Defence, MOD's Policy for Biological Monitoring for DU on operations: a public paper, Gulf Veterans' Illnesses Unit, Ministry of Defence, London, January 2003

[43] United Kingdom Ministry of Defence, Report of a Reconnaissance Visit to Develop an Enhanced Environmental Monitoring Programme in the British-led Sector in Kosovo, London, June 2001

[44] Hooper FJ, Squibb KS, Siegel EL, McPhaul K and Keogh JP, Elevated Urine Uranium Excretion by Soldiers with Retained Uranium Shrapnel, Health Physics, Volume 77, Number 5, 512-519, November 1999

[45] Ejnik JW, Carmichael AJ, Hamilton M, McDiarmid M, Squibb K, Boyd P, and Tartiff W, Determination of the isotopic composition of uranium in urine by Inductively Coupled Plasma Mass Spectrometry, Health Physics, Volume 78, Number 2, 143-146, February 2000

[46] McDiarmid MA, Engelhardt SM, Oliver M, Urinary uranium concentrations in an enlarged Gulf War veteran cohort, Health Physics, Volume 80, 270 – 273, 2001

[47] Ough EA et al, An Examination of Uranium Levels in Canadian Forces Personnel who served in the Gulf War and Kosovo, Health Physics, 527-532, Volume 82, Number 4, April 2002

[48] Roth P, Werner E and Paretzke HG, Research Into urinary Excretion of Uranium, Verification of Protective Measures in the German KFOR Army Contingent, GSF – Forschungszentrum fur Umwelt und Gesundheit, Institut fur Strahlenschutz, Neuherberg, GSF Report 3/01 January 2001

[49] Roth P, Hollriegl V, Werner E and Schramel P, Assessment of Exposure to Depleted Uranium, Radiation Protection Dosimetry, Vol 105, No 1-4, 157-161, 2003

with certified reference material traceable to national standards and there are intercomparison exercises in which samples prepared by one laboratory are analysed by others and the measured and expected results compared. Early work by the DUOB and which is described in their report demonstrated that reliable results could not be obtained unless this level of quality control was maintained.

51. In addition there have been a limited number of very small scale surveys in which DU or excessive amounts of total uranium are reported to have been found in military or civilian personnel who, for the reasons already outlined, are not considered to have been at any great risk of DU exposure[50]. In general there are few if any conclusions that can be drawn because of the lack of information on the analysis procedures used in these studies. In some cases, the sample containers were not cleaned before use and calibration standards appear to have been manufactured locally rather than obtained from traceable sources. Indeed the very fact that bulk DU appears to have been handled in the same laboratories as urine samples containing only trace quantities of natural uranium and/or DU is not good scientific practice. The author has learned of, and is grateful for the honesty of colleagues who have reported, inadvertent cross contamination of urine samples in one of the most capable academic institutions in the UK.

DU and Gulf Veterans Illnesses

52. Dr Busby makes some generalised comments about DU and Gulf veterans' illnesses other than cancer. He mentions the work of Haley, but surprisingly makes no mention of the Congressionally-mandated US Research Advisory Committee on Gulf War Veterans' Illnesses (known as The Binns Committee) or the findings of its most recent work which were published in 2008. The report describes the results of a comprehensive review of Gulf veterans' illnesses and their possible causes[51]. It concludes that there is little evidence supporting an association between DU and Gulf War illness and that DU is not likely to have caused illnesses in the majority of Gulf veterans. Very similar views were expressed recently in the House of Lords[52] when Lord Lloyd of Berwick, who chaired an inquiry into Gulf veterans illnesses and was critical of MOD for its failure to provide witnesses to this inquiry, stated "The [US Research Advisory] committee has gone through all the possible causes [of Gulf veterans' illnesses] in the greatest detail and concluded that only two remain which have been consistently identified by all the evidence — NAPS tablets and OP pesticides. Together, as they say, these causes make a compelling case as the causative factors involved. True, other factors cannot be absolutely ruled out, but there is little or no evidence to support them.".

Conclusion

The scientific consensus is that DU intakes are only likely to be a concern for those in or on vehicles at the time they are struck by DU munitions or for those who enter immediately afterwards to rescue casualties. Doses to personnel such are Mr Dyson are likely to be low or very low and well within the annual occupational exposure limits specified in current UK regulations. Risk assessments in this report show that, even without allowing for mitigating circumstances of the type known to give dilution of particulate within the natural environment, the assessed radiation doses for DU

[50] Durakovic A, Horan P, Dietz L. The quantitative Analysis of Depleted Uranium Isotopes in British, Canadian, and U.S. Gulf War Veterans. Military Medicine. 167, 8:620, August 2002

[51] Research Advisory Committee on Gulf War Veterans' Illnesses, Gulf War Illness and the Health of Gulf War Veterans: Scientific Findings and Recommendations, U.S. Government Printing Office, Washington DC (2008)

[52] Hansard Official Record, Column 847, 5 February 2009, Her Majesty's Stationery Office, London

intake scenarios more severe than those likely to have been experienced by Mr Dyson are at levels at which any risk is considered so low that there is no current statutory requirement for implementation of any health protection measure. The results of battlefield monitoring and the personal monitoring of veterans by urine sampling support this view. It is noted from Dr Busby's report that there is a low but non-negligible risk of bowel cancer within a general population, although it is unclear why he should choose to present historic US rather than more recent UK statistics. On the balance of probabilities, it is suggested that Mr Dyson is more likely to have been one of those unfortunate individuals who develop bowel cancer for reasons that are never clear, rather than to have developed cancer as a result of DU exposure during his 3 months in the Persian Gulf.

The illness of Stuart Raymond Dyson, Deceased and his previous exposure to Uranium weapons in Gulf War I.

Supplementary report on probability of causation
for HM Coroner
Black Country Coroners District
Smethwick, W. Midlands
&
Response to DSTL report:
Assessment of the possible Risks to Mr Stuart Raymond Dyson from the use of Depleted Uranium Munitions in the 1990/91 Gulf War
by
Ron Brown

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SY231DZ

Sept 5th 2009

This report is supplementary to my March 2009 report on the issue of causality in the case of the exposure of Mr Stuart Raymond Dyson to depleted uranium in Gulf War 1 (1991) and his subsequent illness and death from colon cancer at the age of 39. It addresses the arguments advanced by the Ministry of Defence's expert Mr Ron Brown (DSTL 2009) and also includes some relevant material which has appeared since March 2009.

1. DSTL (2009) advances arguments that Mr Dyson's colon cancer could not have been the consequence of exposure to DU because the radiation 'dose' was too low.

2. DSTL (2009) develops its arguments on the basis of a number of platforms. First, there are criticisms of my own expertise and that of the group of radiation experts I represent and base my argument on, the European Committee on Radiation Risk (ECRR). Then DSTL advances its own position relating to the radiological effects of DU exposure on the basis of what it calls a 'scientific consensus'.
It should be noted first, however, that DSTL(2009) is the work of one man, Ron Brown, a person with a Chemistry degree from St Andrews and a diploma in Radiological Protection, an individual with little or no research experience and little scientific publication record in the peer review literature as far as I can determine. Mr Brown's job, has been to work for the Ministry of Defence as a civil servant and to apply there the principles and formulae of the International Commission on Radiological Protection (ICRP), whose risk model is universally employed by national governments and agencies.

It is not my purpose here to belittle Mr Brown, who genuinely believes what he says, and whom I served with on the DUOB, but just to make it clear that he is not a hands-on researcher, but merely an analyst, interpreter and presenter of other people's work. As someone who has been trained in the system of the ICRP he is (and was, on the DUOB) hostile to any suggestion or any evidence that the model he has applied all his life, is flawed. ICRP, as Mr Brown admits, represent the cornerstone of the 'scientific consensus' on which his arguments depend. If it is seen to fail, then all his arguments and those of the bodies he cites, also fail.

3. Apart from a great deal of evidence showing ICRP models to be faulty , this cornerstone has recently been removed by the resignation in April 2009 from the ICRP of Dr Jack Valentin the Editor of the 2007 ICRP report that DSTL(2009) refers to and depends upon (DSTL para.20). Following his resignation, Valentin stated to me in a public meeting in Stockholm that the ICRP risk model 'could not be employed' to predict the health outcomes of exposures to ionizing radiation because for certain internal exposures the uncertainties were as high as two orders of magnitude i.e.100 to 900 times (Valentin 2009). This means that there could be between 100 and 900 times the cancer yield per unit dose than is predicted by the ICRP model. Thus the nuclear site child leukemia clusters, the Chernobyl cancer effects and the effects of uranium are explained. He also stated that since he was no longer the Scientific Secretary of the ICRP he could now say that he believed that ICRP and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) had been wrong in not addressing the many examples of evidence from Chernobyl and from nuclear site leukemias and also other evidence that the ICRP model was unsafe (Valentin 2009).

The meeting in Stockholm where Dr Valentin and I were discussing the validity of the ICRP model was audio and videotape recorded and I have the tapes which can be shown in Court if required.

4. It is worth emphasizing at this point that ICRP is a desk organization with one permanent paid member its Scientific Secretary Jack Valentin. It carries out no research. It depends for its information on the reviews of scientific papers provided by UNSCEAR and so they are not independent of each other as DSTL (2009) states. UNSCEARs reports are selective. In addition, the two committees often have members in common, and also members who have been or are members of the International Atomic Energy Agency (IAEA). One example is Dr Roger Cox, Chair of the UK National Radiological Protection Board (now the HPA) who is ***also*** Vice Chair of ICRP and ***also*** contributing author to the 2000 UNSCEAR report. Another is Mr Abel Gonzalez of the IAEA, who is ***also*** a full member of the ICRP committee and drafted the ICRP 2008 report. Dr Lars Eric Holm of Sweden is the current Chair of ICRP and ***also*** was Chair of the Swedish Radiological Protection organization SSI and ***also*** Chair of UNSCEAR in 2001. Holm has famously gone on record as stating that the total death toll of Chernobyl is limited to 30 seriously irradiated clean up workers, something that is ***also*** stated regularly in public and at conferences by Abel Gonzalez. The point here is that all the organizations that DSTL (2009) depend upon for its scientific consensus argument ultimately interconnect and come back to one risk model: that of the ICRP. The ICRP is not independent of the organizations that it depends upon for its evidence, and they are not independent of it. The system is an internally consistent and epicyclically-maintained fortress of bad science, bias and false conclusions. All the points made by Mr Brown to support his arguments (see e.g. DSTL para.13) are ultimately dependent upon the methodology and modeling of the ICRP. Mr Brown states that the new independent radiation risk committee, the ECRR,has been criticized for being a 'self-styled organization with no links to official bodies' (DSTL para 16). This should, in this context, be a valuable asset.

5. The dispute over the arguments relating to Mr Dyson has become translated by Mr Brown into a dispute about the credibility of two institutions and two models of radiological risk. Thus scientific arguments seem to have been turned into an *ad hominem* argument about credibility.

The ICRP model is based on the universal applicability of the idea of absorbed dose and the application of this concept to the cancer yield of the Japanese A-Bomb survivors, as I have explained in my earlier report. The ECRR 2003 model and its updated publications dispute the applicability of large acute external gamma radiation exposures to Japanese A-Bomb survivors to those internally contaminated and chronically exposed. ECRR employs weighting factors to allow for the effects of certain specific types of such internal exposures.

To address the credibility argument raised by Mr Brown, it might be valuable to ask just which scientists support the ECRR model and what their credibility is. The ECRR held its 3rd International conference at the University of the Aegean in Lesvos, Greece in May 5-7th 2009. At this conference, 20 eminent radiation experts from all over the world made presentations of their original research which showed that the predictions of the ICRP model were totally unsafe. The proceedings of this conference are being prepared. However, at the end of this conference, the current serious state of affairs in radiation protection led to the preparation of a statement which was signed by all the plenary delegates and which demanded the abandonment of the ICRP risk model (ECRR Lesvos Declaration 2009). I attach this statement together with a list of the scientists and their positions/ affiliations. It will be clear that these scientists are extremely eminent individuals with long histories of original research and publications in the area of radiation risk. Theirs are not ‘desktop studies’.

6. I will now turn to some specific arguments contained in DSTL 2009. DSTL(2009) runs to 52 paragraphs. I will not attempt here to respond to all of them and the result would be too time consuming and costly. I will address the most important points by paragraph number (P).

6.1 (4, 5) *multitude of reports. . varying quality. . .simply restate the work and findings of others.* I capture this argument. All of the main reports on DU effects quoted by DSTL are of this nature i.e. desktop studies. Their conclusions are based upon the ICRP model predictions and they quote each others reports for support.

6.2 (6) All of these reports depend for their conclusions regarding health upon ICRP modeling. None carry out any independent epidemiology of exposed populations. There are a very few of these but DSTL has not cited any.

6.3 (7) Belgium has banned DU; the European Parliament has called for such a ban. Canada is a major source of uranium and influenced by the French AREVA company who control the mining.

6.4 (10) As explained in the DUOB final report, there are technical reasons why the results could not be interpreted. The discovery of the existence of enriched uranium in the environment makes it impossible to employ the isotopic ratio to determine DU. More recently I have carried out experiments which suggest that there is significant adsorption of uranium from solution on to the walls of plastic containers. I suggested that this be examined in the DUOB but it was voted in committee not to pursue such an experimental test.

6.5 (12) My point about IRSN is that the 15 French scientists writing the report agreed that the ICRP model was unsafe: in this they agreed with ECRR. They did not agree with the ECRR prescription for a new model. Therefore I think we can both agree, ECRR and IRSN, that ICRP is unsafe, and therefore cannot be used by DSTL or any of the sources they cite in support of their position.

6.6 (13,14) These organisations are not independent in personnel or logical connection from each other and are funded mainly by governments of nuclear States or those employing nuclear weapons. The World Health Organisation WHO is unable to carry out independent research since its 1959 agreement with the International Atomic Energy Agency whose remit is the development of nuclear energy. This disgraceful agreement is the main reason for the absence of any proper research into the Chernobyl accident effects and is part of an on-going international campaign based in Geneva. The WHO has not carried out any research into the effects of DU in Iraq or the Balkans despite many studies showing increases in cancer and congenital illnesses in areas where DU was employed (Busby 2003). Criticism of this state of affairs by the Senior Radiation Advisor to the WHO, Dr Keith Baverstock resulted in his dismissal by WHO in 2005. The European Parliament has recently asked Baverstock to re-open the issue of the Chernobyl effects and Baverstock submitted a presentation to the ECRR Lesvos conference in 2009 on this matter. The only independent epidemiological study of DU effects has been the Italian government study of Italian Balkan peacekeepers (Italian Report 2001). The first study showed a 3 to 7 fold excess of lymphoma. The more recent update showed such alarming increases in cancer in the veterans that it has been suppressed by the Italian government pending a reappraisal of the data. It is truly astonishing that no other proper independent epidemiological study of DU effects has been carried out.

6.7 (16) *formal links to official bodies* i.e. independent. (16) *self styled* what can this mean? How can it differ from the *self styled* ICRP or the *self styled* DSTL?

6.8 (17) *hot particle theory* What Monty Charles and others who have attempted to discount the hot particle anisotropy do is discount any epidemiological evidence that hot particles can be harmful and then say there is no evidence that they are harmful. For example, the childhood leukemia increases near nuclear sites listed in ECRR2003 and now joined by the huge KiKK German study (Spix 2008) are clearly examples of inhalation of particulates from nuclear site releases. But the supporters of the ICRP model deny that they have any causal relation to radiation exposure *one the basis that the model argues that they cannot*. This epicyclical defence of a model by science has been compared by the twice Nobel prizewinning scientist Michael Polanyi to the way in which Azande witchdoctors support their magical models of the world (see ECRR 2003 for a discussion). But note that the 2005 draft of the 2007 ICRP report *did* include a paragraph about the hot particle anisotropy problem saying that under such conditions *the model broke down.* The paragraph was removed in the 2007 publication.

6.9 (18) *photoelectron effect* Contrary to Mr Brown's assertion, this research has been published in a peer reviewed proceedings of an international conference of the German Agriculatural Research Laboratories, Braunschweig in 2008 (Busby and Schnug 2008). Further work by me and my colleagues at the University of Ulster has shown the idea to be correct and indeed it is part of a USA Patent to employ gold nanoparticles to enhance the irradiation of breast tumours. I attach a poster presentation of the initial results of a CERN FLUKA analysis of the photoelectron effect in uranium particles. It will be clear how local tissue receives excess radiation dose from the photoelectrons (Elsaesser et al 2008).

6.10 (18) *The Second Event effect*. This was attacked in the literature by Roger Cox (see introduction for Roger Cox). No research has been carried out into this idea; it is supported by a number of observations in the peer review literature. Richard Wakeford is the Senior Scientist for British Nuclear Fuels based at Sellafield. He described himself in CERRIE as BNFL's *Rottweiler.* He has taken early retirement.

6.11 (19) I list at the end of this supplementary report a number of research reports in the literature that show that uranium is anomalously genotoxic. Miller's work is among these. Large particles are not the problem, it is the sub micron particles that are the cause of the effects for reasons which are clear from the graphs in Elsaesser 2008 and my earlier publications on this issue (surface area/ volume considerations and self absorption).

6.12 (20) *ICRP 2007I*
See my introduction. . . Jack Valentin.

6.13 (29-33) But the USA employed large quantities of DU munitions and it is now accepted that about 350 tonnes were left on the battlefields. This is the radiological equivalent of dropping about 2kg of plutonium. The area contamination has been calculated to exceed the UN levels for radioactively contaminated land (Busby 2004). Much of this will be resuspended and inhalable. I measured it in southern Iraq myself in 2000 when I visited the country with radiation measuring alpha discriminating scintillation counters. It also travels significant distances as I have shown from my work in Kosovo in 2001 and my work on the Aldermaston filters with Saoirse Morgan in 2007. This is original research carried out personally, and not some desktop citation or wishful thinking. To put this contamination is perspective, the table below is taken from Busby 2004.

Event	**Activity released or estimated deposited**	**Mean activity density Bq per square metre (area)**
10 tons of DU in Kosovo	0.37TBq	3700
350 tons of DU in Iraq 1	13 TBq	130,000 (into 100 km^2)
1700 tons of DU in Iraq 2	63TBq	630,000 (into 100 km^2)
Global weapons fallout Strontium-90 (Sr-90) Northern Hemisphere lat. 50-60deg (UNSCEAR, 2000)	73.9PBq	460
Chernobyl 30km Exclusion Zone *measured* Sr-90 (IAEA)		37,000 to more than 111,000
UK North Wales Radioactive Sheep restrictions *measured* Caesium-137 (Cs-137)		15,000 to 30,000
UNSCEAR definition of contaminated area. (Cs-137)		> 37,000
Irish Sea cumulative Plutonium from Sellafield 1952-1996 [Busby, 1995]	1350TBq	20,000

6.14 (36) Neither Sodium Iodide nor Germanium gamma detectors can give any safe information about DU which is an alpha emitter and has to be analysed by mass spectrometry or alpha spectrometry. (Busby 2009 UNIDIR report). UNEP used mostly the wrong equipment and unsafe isotope ratio techniques for looking for DU in Kosovo. The UNEP soil sample analysis showed widespread contamination and published urine analysis work by Nic Priest of Middlesex University for the BBC in 2001 in Kosovo showed widespread contamination into humans.

6.15 (37) The pictures shown in Fig 1 and 2 are of no value in arguing that contamination was local. All the readings significantly exceed the natural concentration of uranium in the area with is less than 20Bq/kg and probably nearer 10Bq/kg. Thus in Fig 2 at 50m downwind from the target, the soil concentration of uranium particles is at least 32 times background. Given the area of the soil in a 50m radius (7800sq metres) a value of 17000Bq/kg soil to a depth of 5cm (surface contamination is the rule as I have discovered) gives an area contamination of 0.5MBqm^{-2}. This is 500GBq km^{-2} and can be compared with the UN definition of radioactively contaminated land of 37GBq km^{-2}. The level of activity is roughly that of the inner Chernobyl exclusion zone where people are banned from living.

6.16 (38) HPA's GDL is based on the ICRP model and is unsafe. Their view that and activity concentration of 20000Bq/kg would be a safe level would allow people to live on top of mine-able uranium deposits with an activity greater that the outer Chernobyl exclusion zone. The ICRP model predicts that the doses in the outer Chernobyl exclusion zone are safe and that no-one should develop ill health there. The astounding levels of ill health and cancer regularly reported (see Busby and Yablokov 2006) are ignored by ICRP and not cited or reported by UNSCEAR. IAEA ascribes these to 'radiophobia'.

6.17 (40-45) *Dose* is irrelevant as it is an unsafe concept here: uranium should be seen as a particular type of inhalation hazard.

6.18 (46-47) A cumulative whole body ICRP dose of 3.8mSv translates into a ECRR dose of 3.8Sv following the application of the recent weighting factor for U-238 particles. For the inhalation ICRP dose of 0.034mSv the ECRR dose is 34mSv. However, for these particulate anisotropic exposures involving photoelectron amplification, the concept of dose breaks down. Causation must be established by comparison with epidemiologically similar exposures tempered by biological plausibility informed by animal and cell experiments.

6.19 (52) *Haley and US Research Committee* I cite Haley's work because it is one of the few experimental research studies to have been carried out: significantly it was independently funded by a billionaire. The results are quite clear: uranium destroys deep brain tissue. The French ENVIRHOM report also shows results in mice supporting this. The US Binns Research Committee referred to is perhaps another desk operation like all the others. I have not read the report Mr Brown refers to. I did give evidence to the US Congressional Committee in 2003 but clearly this is not referred to in the Binns Committee report.

Conclusion

I stand by my arguments which I laid out in my earlier report on Mr Dyson. I attach some references in addition to those I cited in that

C.Busby September 5th 2009

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ECRR - CERI
European Committee on Radiation Risk
Comité Européenne sur le Risque de l'Irradiation

The Lesvos Declaration

6th May 2009

A. Whereas, the International Commission on Radiological Protection (ICRP) has promulgated certain risk coefficients for ionizing radiation exposure,

B. Whereas, the ICRP radiation risk coefficients are used worldwide by federal and state governmental bodies to promulgate radiation protection laws and standards for exposure to workers and the general public from waste disposal, nuclear weapons, management of contaminated land and materials, naturally occurring and technologically enhanced radioactive materials (NORM and TENORM), nuclear power plant and all stages of the nuclear fuel cycle, compensation and rehabilitation schemes, etc,

C. Whereas, the Chernobyl accident has provided the most important and indispensable opportunity to discover the yields of serious ill health following exposure to fission products and has demonstrated the inadequacy of the current ICRP risk model, especially as applied to foetal and early childhood exposures to radiation,

D. Whereas, by common consent the ICRP risk model cannot validly be applied to post-accident exposures, nor to incorporated radioactive material resulting in internal exposure,

E. Whereas, the ICRP risk model was developed before the discovery of the DNA structure and the discovery that certain radionuclides have chemical affinities for DNA, so that the concept of absorbed dose as used by ICRP cannot account for the effects of exposure to these radionuclides,

F. Whereas, the ICRP has not taken into consideration new discoveries of non-targeted effects such as genomic instability and bystander or secondary effects with regard to understanding radiation risk and particularly the spectrum of consequent illnesses,

G. Whereas, the non-cancer effects of radiation exposure may make it impossible to accurately determine the levels of cancer consequent upon exposure, because of confounding causes of death,

H. Whereas, the ICRP considers the status of its reports to be purely advisory,

I. Whereas, there is an immediate, urgent and continuing requirement for appropriate regulation of existing situations involving radioactivity, to protect the human population and the biosphere,

We the undersigned, in our individual capacities

1. assert that the ICRP risk coefficients are out of date and that use of these coefficients leads to radiation risks being significantly underestimated,

2. assert that employing the ICRP risk model to predict the health effects of radiation leads to errors which are at minimum 10 fold while we are aware of studies relating to certain types of exposure that suggest that the error is even greater,

3. assert that the yield of non-cancer illnesses from radiation exposure, in particular damage to the cardio-vascular, immune, central nervous and reproductive systems, is significant but as yet unquantified,

4. urge the responsible authorities, as well as all of those responsible for causing radiation exposures, to rely no longer upon the existing ICRP model in determining radiation protection standards and managing risks,

5. urge the responsible authorities and all those responsible for causing exposures, to adopt a generally precautionary approach, and in the absence of another workable and sufficiently precautionary risk model, to apply without undue delay the provisional ECRR 2003 risk model, which more accurately bounds the risks reflected by current observations,

6. demand immediate research into the health effects of incorporated radionuclides, particularly by revisiting the many historical epidemiological studies of exposed populations, including re-examination of the data from Japanese A-bomb survivors, Chernobyl and other affected territories and independent monitoring of incorporated radioactive substances in exposed populations,

7. consider it to be a human right for individuals to know the level of radiation to which they are exposed, and also to be correctly informed as to the potential consequences of that exposure,

8. are concerned by the escalating use of radiation for medical investigation and other general applications,

9. urge significant publicly funded research into medical techniques which do not involve radiation exposures to patients.

Statements contained herein reflect the opinions of the undersigned and are not meant to reflect the positions of any institution to which we are affiliated.

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NANOPARTICLES AND RADIATION

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Interaction of Radiation and Matter

Electromagnetic radiation and matter interact predominantly by three different mechanisms:
Compton scattering, the photo-electric effect and pair production. Compton scattering basically describes the loss of incident photon energy by the scattering of shell electrons. Pair production is the simultaneous production of an electron and a positron and occurs at photon energies above 1.022 MeV, which is equivalent to the invariant mass of an electron plus positron. With the photo electric effect, electrons absorb the incident photon energy and are either emitted or lose energy in secondary processes. For energies below 1 MeV, the photoelectric effect is the predominant one. The cross section σ for the photo-electric effect is proportional to Z (atomic number) to the power five and roughly proportional the incident photon energy to the power -7/2:

$$\sigma \propto Z^5 E_\gamma^{-7/2}$$

Most of the photoelectrons produced in an absorbing material lose their energy through electron-electron scattering and Bremsstrahlung. Therefore, the escape depth of photoelectrons generated within solids is usually of nanometers[1]. Hence, irradiated particles with diameters in the range of a few nanometers will emit most of the generated photoelectrons without internal reabsorption.
Therefore, nanoparticles are likely to emit the largest quantity of secondary electrons proportional to their mass.
Furthermore, secondary electron emission of high Z materials could provide a partial explanation of the toxicity of various heavy metals.
Due to their size, nanoparticles can penetrate into the human body and some are able to reach the cell nucleus. This may be crucial in explaining the toxicity of incorporated nanoparticles of materials with a high atomic number Z[2,3].

Monte Carlo Simulations

Monte Carlo Simulations are widely used in computational and statistical physics, physical chemistry and high energy physics to model particle transport and particle-matter interactions. We employed FLUKA[4,5], a Monte Carlo code to simulate the interaction and propagation in matter of different particles. FLUKA is capable of simulating particle interactions from 1 keV to TeV for different leptons, hadrons and bosons with high accuracy. We modeled photon absorption and secondary electron production of particles from 1cm to 1 Å for incident photon energies in the keV region. Target materials we used were water, gold and uranium. Fig.1 shows the arrangement of incident photon beam and target, Fig.2 shows secondary electron production energy deposition. Fig.3 illustrates the ratio of secondary electron production to primary incident photons and Fig. 4 shows the same ratio but weighted with the beam projection area and the target volume.

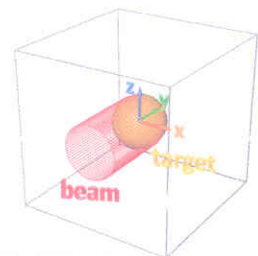
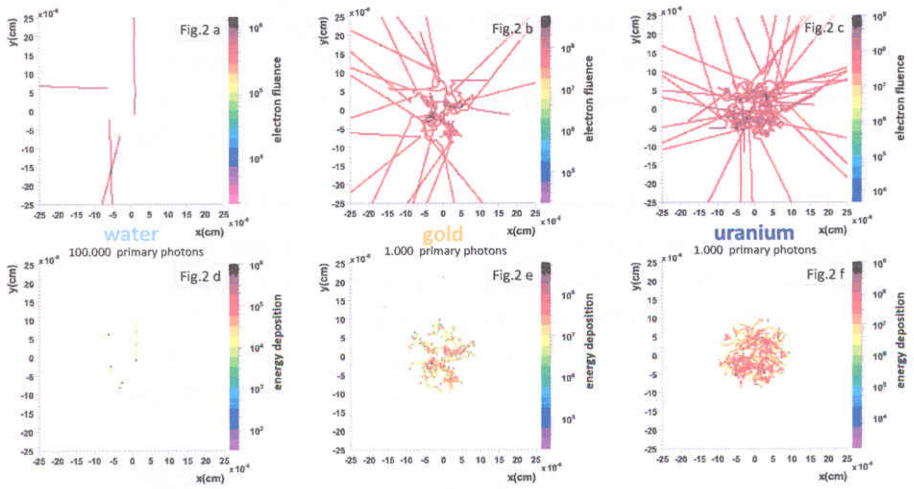


Fig.1: beam and target geometry



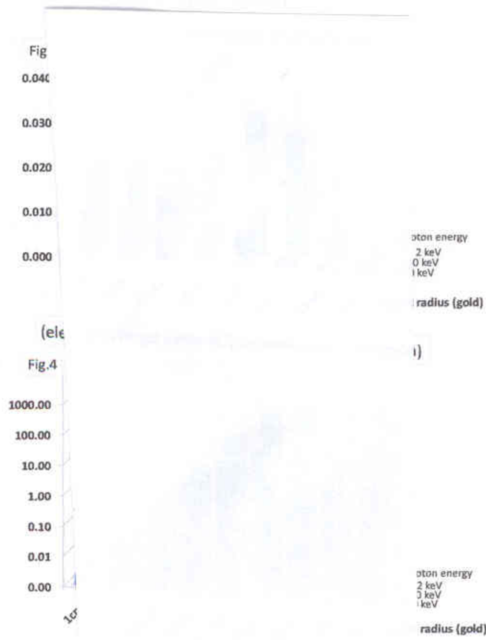


Fig.2: secondary electron production by 100 keV primary photons within the target and escaping electrons overlayed by the target geometry for water (a), gold (b) and uranium (c).Fig.2 (d)-(f) shows the corresponding energy depostion.
Fig.3: ratio of electrons leaving the target material (gold) to incident primary photons (100 keV, 10 keV, 2 keV).
Fig.4: same ratio as Fig.3 but weighted with the perpendicular beam projection area and the target volume.

Conclusion

Secondary electron emission from 1 nm nanoparticles is about 25000 times higher than from the equivalent particle of 1 cm radius. At target sizes of about 10 nm the emission reaches a plateau with no further increase for smaller targets. This is probably due to negligible internal absoprtion within the target material and hence an increased yield of secondary electrons leaving the nano-particle. This "size effect" shows an energy dependent maximum for the ratio of generated electrons to incident primary photons, which shifts for lower photon energies to smaller target diameters. The simulations also show an increase of secondary electrons and energy deposition within high Z target materials compared to a water phantom It also confirmes the energy dependece of secondary electron production as expected by the photoelectric cross section.

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A man who brought the war home with him

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Lancet 2008; 372: 1926

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See Online for webfigures 1–4

Between 1992 and 1996, a man from the UK, in his early 40s, worked in Bosnia. He had been well, except for his longstanding asthma, nasal polyps, and eczema, but developed persistent abdominal pains and periodic fatigue, unrelated to exertion, for which no medical cause was identified. In 1997, the patient had a cholecystectomy for right hypochondrial tightness, and a Nissen's fundoplasty for Barrett's oesophagus. However, his fatigue and discomfort became so severe that he retired involuntarily. In 1999, the patient spent 12 months in Kosovo. By now, he had increasing cramps of the abdominal muscle wall and viscera, altered bowel habit, and weight loss of 19 kg. In 2001, he developed morning stiffness of his back, knees, and elbows, facial paraesthesias, and nocturia. In 2003, the abdominal tightness developed into truncal flexion jerks; later, he developed spasms in his left arm and hips.

In 2004, we observed a stiff gait, abdominal myoclonus, and an enhanced (neurological) startle response. MRI of the head and spine showed nothing of note. Blood tests revealed slightly high concentrations of creatinine (138 μmol/L), bilirubin (20 mmol/L), and γ-glutamyltransferase (121 U/L); the blood film and concentration of C-reactive protein were normal. Ultrasonography and CT of the abdomen, and analysis of CSF, showed no abnormality. Further blood tests showed a normal concentration of angiotensin-converting enzyme, and absence of antibodies to nuclear factor, neutrophil cytoplasm, DNA, endomysium, and neurones; results of electrophoresis were normal. The blood lead concentration was undetectably low. However, we found high concentrations of IgA (5·4 g/L), IgE (475 IU/mL), cardiolipin (62 U/mL), and antibodies to glutamic acid decarboxylase (GAD) (3·3 U/mL; normal ≤1·0 U/mL). Electromyography showed focal continuous motor unit activity, and abnormal exteroreceptive spinal reflexes. We sought further neurological opinions; provisional diagnoses included stiff-person syndrome—given the stiffness, muscle spasms, and antibodies to GAD[1]—and propriospinal myoclonus. Treatment with baclofen, and a trial of intravenous immunoglobulin, provided temporary, symptomatic relief.

We found proteinuria (0·2 g per 24 h) and erythrocyturia ($2{\cdot}4{\times}10^6$ cells per 24 h). Histopathological examination of a kidney biopsy sample showed mesangial expansion and dominant mesangial IgA, without vasculitis—findings diagnostic of (partly autoimmune) IgA nephropathy. In the liver, we found steatosis, and a non-caseating granuloma. Electron microscopy of kidney and liver tissue showed giant mitochondria, without cristae. Even without osmium staining, the mitochondria had high electron densities consistent with heavy-metal deposition (figure); we also saw a nuclear inclusion (webfigures 1–4). Spectrometry showed intense signals from lead-207, lead-208, uranium-235, and uranium-238, distributed throughout the cells, rather than localised in organelles. We gave the patient intravenous calcium sodium edetate; thereafter, we prescribed 2,3-dimercaptosuccinic acid, 250 mg twice daily, which he still takes. Urinary excretion of lead was 50–180 μg per month initially, and 400 μg per month with oral treatment. Nephritis resolved, kidney function and neurological health improved, and concentrations of antibodies to GAD returned to normal. Within 12 months of starting treatment, the patient was able to work. We intend to continue treatment until heavy-metal excretion is undetectable.

Some people in war zones develop unexplained neurological or psychiatric syndromes.[2] Little information exists on tissue heavy-metal sequestration in war zones. Spectrometry allowed us to find substantial metal deposits that would otherwise have been unrecognised. The ratio of ^{238}U to ^{235}U, at about 10:1, was consistent not with depleted uranium from ordnance (99·7% ^{238}U), but with enriched, fissile uranium. Natural lead isotope ratios were found. We suspect that our patient's food was grown in soil contaminated with lead and uranium[3] (many international workers ate food grown outside Bosnia). Heavy-metal toxicity results in part from disruption of cellular metabolism; we surmise that mitochondrial dysfunction in part caused the illness. Heavy-metal poisoning can also induce autoimmunity,[4] which was detected, and resolved with our patient's recovery. Our diagnostic methods may prove pivotal in assessment for metal poisoning.

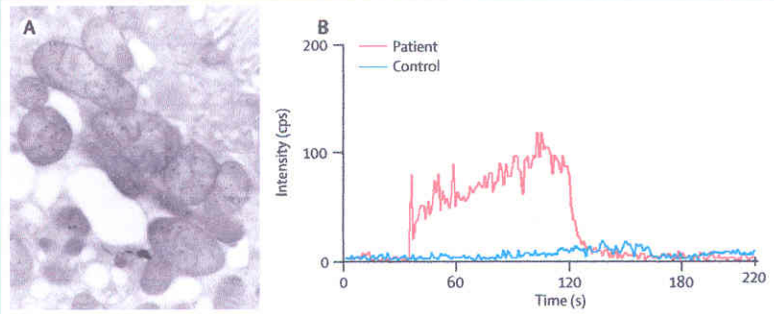

Figure: **Evidence of heavy-metal poisoning**
(A) Electron micrograph, showing metal deposits resembling those caused by staining; magnification ×29 000. (B) Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) of ^{238}U. See webfigures for other isotopes.

References

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