HEALTH EFFECTS OF DEPLETED URANIUM

ICBUW

The International Coalition to Ban Uranium Weapons

Compiled on behalf of ICBUW
by Gretel Munroe
Grassroots Action For Peace
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www.bandepleteduranium.org

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Grassroots Actions for Peace

Grassroots Actions for Peace believes that non-violent conflict resolution, nuclear disarmament and serious reduction of arms trading throughout the world constitute this nation's only real security. Grassroots Actions for Peace is an organization of volunteers who work on specific local programs and campaigns with short term objectives that are connected to these national and international principles.

The principle effort of Grassroots Actions for Peace in recent years has been to ban the production, sale and use of depleted uranium weapons, which were manufactured in Concord at Nuclear Metals, Inc. (now Starmet Corp), and first used in the Gulf War in 1991.

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Military Toxics Project

The mission of the Military Toxics Project is to unite activists, organizations, and communities in the struggle against military pollution, to assure it's clean up, to limit the transport of hazardous materials, and to advance the development and implementation of preventative solutions to the toxic and radioactive pollution caused by military activities. The MTP mission is based on mutual respect and justice for all peoples, free from any form of discrimination or bias.

The purpose of the Military Toxics Project is to provide information, education, networking and organizing resources. MTP serves as a bridge and facilitator for organizations concerned with military pollution issues. MTP fosters a relationship of mutual respect and support with its members, networks, and collegiate campaigns around the country. MTP works to assist local communities, not for them but with them. MTP activities focus on both service and organizing efforts. MTP helps member organizations and networks to project their individual voices nationally and internationally.

MTP has been organizing around depleted uranium issues since 1993, when it formed the Depleted Uranium Citizens Network and released "Uranium Battlefields at Home and Abroad", a report by network members Rural Alliance for Military Accountability, Citizen Alert, and Progressive Alliance for Community Empowerment. MTP organized the first international conference on DU munitions, which brought together community activists, military veterans, and technical experts opposed to the use of depleted uranium weapons. MTP has produced a variety of other reports and fact sheets on DU, supported scientific research into the health effects of DU, and founded an email discussion list about DU that serves over 150 activists in two dozen countries. MTP is a founding member of the International Coalition to Ban Uranium Weapons, and continues to support local organizing around DU and network local organizations who want to work together to oppose DU on the national and international levels.

Please visit **www.miltoxproj.org**

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Introduction

This paper is about depleted uranium (abbreviated DU), and the harm it may cause to human beings primarily as a result of its use in weapons. It deals with exposure dose, basic biological considerations and recent research. To date research has been done mostly in animals and cellular studies and to a far lesser extent in humans. The paper discusses the results of fact-finding missions of the UN Environmental Program in the Balkans. It also deals with Iraq, largely post-war 2003. There is controversy now about DU causing cancers and other illnesses; if we wait the 10-30 year latency period of lung cancer, for example, to resolve this issue, irreparable harm may already have been done to people. For instance, in February 2004, a Scottish veteran won a compensation battle based on his exposure to DU while in the British army, where he served as a driver moving tanks destroyed by DU shells during the 1991 Gulf War (1).

Depleted uranium (DU) is a chemically toxic and radioactive heavy metal. It is a waste product of nuclear fuel or nuclear bomb production, during which natural Uranium has been "depleted" of Uranium 235. When made from recycled nuclear fuel, it contains small amounts of plutonium and other transuranics, (heavy, artificial, highly radioactive elements with atomic numbers greater than that of uranium) (2).

DU is similar to purified concentrated uranium ore except that DU has less mass of the isotopes Uranium 235 and 234. Gram for gram, DU is 60 percent as radioactive as pure uranium ore. DU has a half-life of 4.5 billion years. It is classified as low-level radioactive waste, which the Institute for Energy and Environmental Research (IEER) puts in the same category as transuranic waste (3), as its specific activity (radioactivity per unit weight) is about three times higher than that of the lower limit for transuranic waste (4). According to IEER, DU waste should be disposed of in a deep geologic repository (5).

At least 16 different ammunitions contain DU cartridges (6), including machine guns (7). DU is 1.7 times denser than lead making it a highly effective anti-tank weapon; it slices right through the tank. The 120 mm penetrator has a solid cylindrical core of DU weighing 10 pounds (8). The 30mm DU shell fired by the A-10 Warthog jet has a similar solid core made of DU which weighs three fourths of a pound (9). DU shells can be quite small; both the 30mm shell and the 25mm shell (also solid DU) are the size and shape of a cigar or a little smaller (10). About 25 percent of DU shells hit their target (11), leaving DU shells on the ground or beneath the ground.

When a DU shell penetrates through tank armor, it ignites and spews an extremely fine DU dust (including particles 1.5 microns or less (12)) into the air. DU particles can carry for miles (13). DU is also used in the armor of Abrams tanks making it invulnerable to all but DU shells, but exposing the tank operators to increased radiation.

An Exposure to DU: How Much is Harmful

There are no reliable estimates of dose-exposures to DU dust from the 1991 Gulf War (14) making it difficult to do epidemiological studies (15). The RAND report (1999)(16), whose principal finding was that depleted uranium was like natural uranium in its chemical and radiological properties and consequently not harmful, relied on the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) for its estimate for exposure to DU. Based on a single live fire test, CHPPM estimated that two DU shells hitting a tank would expose soldiers within the tank to an average of 24 mg (17) and a maximum of 52 mg of DU dust (18) (The General Accounting Office found this estimate to be "unreliable") (19).
In the Gulf War vehicles hit by DU penetrators in friendly fire incidences generally sustained three or four hits (20). Dan Fahey states that an A-10 aircraft in a single attack might use from 5 to 16 DU shells (of 30mm ammunition) creating 300 to 960 gm. of DU dust (21).

A 120mm DU penetrator contains about 4,700 gm. of DU (22); when a 120mm DU shell hits a tank, Fahey says according to test data, generally 20 percent (23) of the DU in the shell is oxidized into an aerosol (10), creating about 950 gm. (about 34 oz) of DU dust (24). However, up to 70 percent of the DU may be oxidized into an aerosol on impacting a hard target (25). Fifty to 96 percent of the particles in the DU aerosol are of respirable size (26) based on Army data.

The Nuclear Regulatory Commission gives a weekly limit for occupational exposure to soluble uranium at10 mg; additional intake would cause uranium poisoning due to chemical toxicity according to the NRC. (27)

There is no agreement about how much DU dust is inhaled by the lungs. However, some experts believe that even one DU particle lodged deep in the lung can cause damage. An extremely small dust particle (a speck) of 1 mg DU will irradiate cells in its vicinity with several alpha particles each second for as long as the particle remains in the lung (at some time in the future it will be metabolized by the body (28) at which point it will no longer bombard these cells).

DU dust is made up of soluble and insoluble components. The amount of soluble and insoluble dust created by the impact of a DU penetrator varies. However the intense heat from the shell striking a tank forms an insoluble ceramic aerosol. Although DU particles can be carried for miles in the wind or be re-suspended from dust by wind or human movement, the soldier inside a tank hit by a DU penetrator is at far greater risk of being contaminated by DU dust than anyone near the tank.

Some Scientific Information about DU

DU is a chemically toxic heavy metal and as such can lead to kidney and lung damage. As a radioactive substance, it is an alpha emitter which irradiates powerfully for short distances. The alpha particles cannot penetrate skin but if inhaled or ingested they can irradiate lung cells and other cells in the body. DU is composed of 99.8 percent Uranium 238, which decays into two principal daughter isotopes which give off beta radiation that can travel through at least 300 to just under 1,000 cells (29). It is also a weak gamma emitter which can traverse tissue and bone cells (30).

Alpha particles cause cancer

Research from England in Harwell, Oxfordshire and the Mt. Vernon Hospital in London (28), which was reported in the **New Scientist** in January 2001, demonstrated how a single alpha particle damages human white blood cells. Twenty-five percent of the irradiated cells after 12 divisions showed "patterns of broken or bent chromosomes."(29) The study indicated that this was a first step in a series of biological events that could lead to cancer, more specifically leukemia.

Bystander Effect

Cells that are near by cells hit by alpha particles or other sources of low level radiation show signs of damage such as that sustained by the irradiated cells. Miller and colleagues (33) found that although fewer than 5 percent of human cells were traversed by an alpha particle, approximately 14 percent of the DU-exposed cells underwent neoplastic transformation (34). In an experiment at Los Alamos, a low dose of alpha particles caused excessive sister chromatid exchange (SCE), a chromosomal aberration (35) in about 23 percent of human lung fibrobast cells; in this case under 3 percent of the nuclei of the cells were impacted by the radiation (36).

In a study by Belyakov, Malcolmson et al. (2001)(37) a helium ion ("effectively an alpha particle") hit the nucleus of a single human fibroblast cell in a dish 10 by 10 milllimeters (38) in size and populated by 5,000 human fibroblast cells. The targeting of one of these cells typically led to mutations (micronuclei formation (39)in this case) in approximately 100 other cells in different regions of the dish. Damaged cells were often more than a millimeter apart. As the researchers stated, since other bystander effects besides micronuclei formation might have been present, the measurement of the number of cells showing micronuclei formation only may have underestimated the number of damaged cells (40).

Bystander effects include, in addition to neoplastic transformation, chromosomal aberrations including breakage and micronuclei formation, mutations, apoptosis (cell suicide), cell killing or delayed cell death, enhanced cell growth and the induction of genomic instability (see next topic)(41) as well as increased radioresistance (42).

It is thought that damage to the unirradiated (bystander) cells may occur via signaling across gap junctions from an irradiated cell to a non-irradiated cell. However culture medium of irradiated cells when put in a different cell population can cause the same damage as in the original irradiated cells (43). Yet another mechanism that can cause damage to bystander cells such as DNA lesions (44) are increases in intracellular oxygen reactive species (hydrogen peroxide falls into this category (45)) generated by ionizing radiation. Bystander effects can vary with different types of cells (46). However more than one mechanism may impact bystander cells in the same model system (47). The bystander effect is not noticeable in high level radiation as high dose radiation kills cells. The bystander effect has not been taken into consideration by agencies setting safe radiation limits. However research into the bystander effect is in the early stages.

Genomic Instability

Radiation-induced genomic instability occurs with low level radiation. Miller et al (2003)(48) have defined genomic instability as "the induction of a persistent instability in the genome of surviving irradiated cells." (49). That is, mutations caused by low level ionizing radiation are carried forward from one generation to another. The progeny of cells damaged by radiation through the bystander effect may also show this effect (50). Successive generations of cells targeted directly or indirectly by low level radiation show the same (clonal) and also non-clonal chromosomal aberrations as well as a heightened rate of mutation, a higher death rate and "reproductive irregularities" (51). These changes may persist for many generations (52). Miller et al. (2003) showed that DU exposure to human osteoblast cells led to genomic instability (53). They studied the frequency of delayed reproductive death (or yield of lethal events) and micronuclei formation in the progeny of human osteoblast cells over 30 generations. Some of the initial cells in this study were exposed to low levels of gamma radiation leading to genomic instability although to a lesser extent than the DU-exposed cells (54). Although chemical toxicity as in heavy metals can also cause genomic instability (55), in this study, nickel as a heavy metal did not generate genomic instability to any great degree, far less than that generated by either DU or gamma radiation (56).

Uranyl ion an affinity to chromatin (genetic material)

Inhaled particles of DU that lodge in the lung may dissolve into uranyl ions which then pass through the body. Uranyl ions are thought to be the chief form of uranium to be found in body fluids (57).They are attracted to and fasten onto DNA, particularly the genetic material called "clumped chromatin" (58). Spermatazoa have the greatest concentration of chromatin of any cell in the body (59). It has been conjectured that uranium found in semen is probably in the nucleus of the sperm cell (60).

DU is genotoxic

DU like other heavy metals such as nickel, tungsten and even lead, (recently shown to be weakly mutagenic) (61) has proved to be genotoxic. In 1998 Miller et al. found that DU- transformed cells when implanted in athymic nude mice led to the development of tumors within four weeks which they initially conjectured was due to the chemically toxic nature of DU (62). In 2002 a similar experiment with similar results, was done using an insoluble DU compound (63). Again the researchers thought this was due to the chemical toxicity of DU, which like nickel, can be carcinogenic. It is commonly thought that DU's ability to cause damage is due to its being chemically highly toxic.

In 2002 Miller and co-workers showed that DU's chemical toxicity could generate free radical (64) damage to DNA bases, including lesions in the DNA. Gradual accumulation of oxidative damage could occur which is important in the development of tumors (65) or birth defects (66). Using an insoluble DU compound, Miller et al. showed that DU caused single strand DNA breaks in **i**mmortalized human cells (67). Yazzie and collegues found that uranium in a uranyl ascorbate complex also led to single strand DNA breaks in plasmid DNA (68) *in vitro* which also could eventually lead to cancer (69).

Other research by Miller et al. found that the radiological component of DU may be genotoxic. Using a DU compound and two other uranium compounds, all of which were the same chemically, but which differed in specific activity (amount of radiation given off), they showed that DU had the median frequency of neoplastic transformation in immortalized human cells, having a higher frequency of malignant transformation than Uranium 238, but a lower frequency than the third compound, Uranium 235 (which is fissionable uranium) .Uranium 238 lacks the small amounts of Uranium 235 and Uranium 234, which are present in DU. The difference between the two compounds was however statistically significant. Results indicated that radiation may be involved in neoplastic transformation (70). In the same study the researchers showed that DU exposure can cause dicentric chromosomal aberrations in immortalized human cells, an aberration caused by ionizing radiation (71).

Insoluble DU dioxide activated 10 out of 13 "stress" genes in 13 different recombinant cell lines developed from human liver carcinoma cells. Results indicated once again that DU is mutagenic: the DU caused potential damage at the genomic level including DNA strand breaks and/or chromosomal aberrations; one gene influenced the incorrect folding of proteins, thus potentially changing their functions (72).

DU's chemical toxicity and radioactivity may work synergistically

Miller and co-workers found that the chemical toxicity and the radioactivity of DU seemed to work together synergistically to produce more genetic damage than either facet of DU could cause by themselves when the effects were simply added together. Miller said to the **Guardian** (73), "You can get more than an eightfold greater effect than you'd expect"(74). This synergistic working of chemical toxicity and radiation thus results in more than eight times as many cells damaged genetically as expected (75). These new findings have not been taken into account by the experts who set radiation limits.

Animal Studies

Animal research on the effects of DU has centered mostly on the effects of embedded DU in animals, that is, pellets of DU are surgically implanted in animal tissue. This research has largely been done by the Armed Forces Radiobiology Research Institute (AFRRI) in Bethesda, MD.. A summary of their research is listed below:

- Distribution of DU in rats embedded with DU pellets: DU traveled in the body, accumulating primarily in the kidney and bone. DU was also found in the lymph nodes, brain, heart, liver, spleen and testicles (76). DU went to tissues even far from the implantation site within one day of transplantation (77).
- Repeated testing of liver, kidney and muscle tissue after implantation of DU in rodents resulted in changes in the expression of several genes which have been implicated in carcinogenesis (78).
- DU caused electrical changes in rat hippocampal slices. (This area of the brain is important in learning and memory) (79).
- DU crosses the blood brain barrier. Rats with medium (10 DU pellets) and high (20 DU pellets) exposure to DU (pellets were implanted in the thigh) had significant amounts of uranium in the brain including the midbrain, the motor cortex and frontal cortex; rats with high exposure to DU had significant amounts of uranium in the cerebellum (80).
- DU crosses the placenta and is stored in the fetuses of rats with embedded DU pellets. Litter size was reduced (81).
- DU pellets implanted in rats did not lead to functional or histological kidney toxicity (82).
- Soluble DU (uranyl chloride) was taken up by mouse macrophages leading over time to the death (apoptosis) of these cells including fragmentation of the nuclear DNA (83). (Macrophages are immune system scavengers found in the lung, lymph nodes, kidneys and other organs).

Animal research by non-AFRRI groups include:

- Research done at the Lovelace Respiratory Institute, found that some rats with embedded DU showed kidney tumors on autopsy after 500-650 days; the difference was not significant although DU was found in the kidneys of all the rats. The researchers also showed that DU fragments caused cancer in rat muscle (84).
- Duke University researchers found that a DU substitute (uranyl acetate) when given to rats in multiple low doses resulted in reduced coordination and impaired movement in a dose-dependent manner (85).
- Rats whose lungs (lower third of trachea) were instilled with DU dust (86) showed histological evidence of kidney damage at higher lung burdens of from 170-200 micrograms of DU per lung; rats that were injected with DU dust in leg muscle (maximum 65 micrograms DU per leg) did not sustain similar kidney damage. About half the DU in the lung and in the muscle appeared in the urine within the first day after DU was implanted in the bodies of the rats (87). The DU dust used contained both soluble and insoluble components.

Animal and cellular research indicate that DU causes genetic damage and has other harmful effects, that both its chemical toxicity and its radioactivity are involved in this damage although it is not known to what degree radiation is involved. It does lead to the bystander effect and to genomic instability. DU also causes damage in ways which are unrelated to DU's ability to cause genetic changes. In addition it should be noted that biological systems have repair mechanisms so that changes may not necessarily be permanent.

Biological Effects of Radiation

Ionizing radiation breaks molecular bonds. Radioactive atoms give off one or more of four different types of radiation – alpha and beta subatomic particles as well as gamma rays and X-rays (88). Ionizing radiation leads to the formation of ions which are electrically charged particles from particles which were formerly neutral, and creates free radicals (89) which can alter proteins, DNA or lipids (fats) (90). A number of experts believe that there is no dose of ionizing radiation that does not pose a risk of malignancy (91).

DU and Uranium Dust in Mines

Dr. Rosalie Bertell, a leading expert on ionizing radiation, states that the **RAND Report** did not differentiate between soluble and insoluble DU dust (92). Uranium dust found in uranium mining is a soluble uranium oxide. However DU dust when in a ceramic aerosol oxide form as exists on the battlefield, is much more insoluble than the dust particles of uranium oxide found in a uranium mine or mill. They are different forms in as much as the ceramic DU particles are created by very high temperatures (up to and more than 4,000 degrees Centigrade) (93) and are extremely tiny; the dust particles of uranium in a mine or mill are larger and are comparatively soluble and traverse the body quickly. They pass through the kidney within a few days, damaging only the kidneys (94). The RAND study concentrated on studies of uranium miners and millers.

Particles of ceramic DU stay in the deep lungs for 2 (95) or up to 20 years (96). Insoluble ceramic DU particles lodge deep in the lung, in mucus that touches lung tissue where it radiates (97), giving off 2 alpha particles a second (98) (or 7,200 in an hour). Each DU alpha particle gives off approximately 4.2 MeV (million electron volts); only 6 to 10 eV (electron volts) are needed to break DNA or other sizeable molecules (99), causing damage that cellular repair mechanisms may not be able to offset. Monocytes take up DU particles from the deep lung and carry them to the thoracic lymph nodes and the lymphatic system (100). Fine ceramic particles travel through the lung-blood barrier, into the blood stream and take root in bone and body organs where they irradiate neighboring tissue and may even disrupt organ function (101).

DU and Natural Uranium

Natural uranium enters the body through food and water rather than through dust reaching the lungs. It goes through the digestive system, which it may irritate and is excreted in the feces. Up to 99 percent of ingested natural uranium leaves the body within 24 hours in this fashion (102). While 75 percent of the inhaled DU aerosol goes into the digestive system, 25 percent of the ceramic and non-ceramic particles lodge in the lungs, which have no exit portal other than the lung-blood barrier or the lymph system. Soluble DU particles that are trapped in the lungs, are carried by the blood and are excreted through the kidneys. With time, some of the insoluble DU particles also become soluble and follow this route with the DU being gradually excreted in the urine (103). The kidneys may adjust to this slow rate of uranium excretion and not be visibly harmed (104).

Any existing DU radiation caused by ceramic DU will be over and above radiation from natural sources. The Childhood Cancer Research Institute reports that most epidemiologists concur that natural background radiation causes a percentage of childhood cancers (105). In fact, the Childhood Cancer Research Institute states that low-level ionizing radiation is considered to be the "best scientifically established cause of childhood cancer" (106).

Other ways in which low-level radiation causes harm

Bertell (107) has catalogued three ways in which low-level radiation achieves effects which for the most part are not found with high-level radiation. They are based largely on biological mechanisms so that the radiation effect is indirect but present. They indicate that low level radiation injures cell membranes, depresses the immune system and causes chronic fatigue syndrome.

1. **Low–dose radiation damages cell membranes – The Petkau Effect**: At the slow-dose rate of 0.001 rad per minute (a rad is the amount of radiation absorbed by exposed material), it takes only **0.7 rad** to destroy a cell membrane. At a high or fast-dose rate of 26 rad per minute, it takes a total of **3,500 rads** to accomplish this. A further discussion of the biological mechanisms involved can be found in **Appendix A**.

2. **Monocyte depletion, anemia and a depressed immune system**: Monocye depletion causes iron deficient anemia because monocytes recycle 37-40 percent of the iron from dead red blood cells. Low level radiation can reduce the monocyte population by 80 percent. Low level radiation also leads to a depressed immune system as monocytes play a role in activating lymphocytes. (See **Appendix A** for mechanism). In addition, iron transport may be reduced by the binding of uranyl ions to red blood cells (108).

3. **Deformed red blood cells** which cannot easily enter capillaries to bring oxygen and nutrients to muscle and brain cells. (See **Appendix A**). This leads to chronic fatigue syndrome and even short-term memory loss.

Most scientists would agree that more needs to be known about the relationship between irradiation and its effects on biological cells (109). More studies are needed.

Summary of Recent Human Research

Little research has been done on the effects of DU in humans. More research is needed on inhalation of depleted uranium.

A German study published in 2003 (110) found specific chromosomal aberrations known as dicentric and centric ring chromosomal aberrations in the peripheral lymphocytes of 16 Gulf War and Balkans War veterans. The veterans were ill and suffered from chronic fatigue, headaches and muscle and joint pain (111). None of the veterans were heavy smokers. The number of chromosomal aberrations were 5 times greater than expected. Dicentric and centric ring chromosomal aberrations are known to be caused by ionizing radiation. All the veterans in this study suspected that they had been exposed to DU dust on the battlefield

The DU Program at the Baltimore VA Medical Center (112) has followed a small number of Gulf War veterans some of whom have DU shrapnel in their bodies from friendly fire incidences. Begun in 1993 with 35 veterans, the program expanded to 70 or so veterans (113). To date the DU Program has served 3 percent of the approximately 900 Gulf War veterans known to have been exposed to DU in either Level I exposures (friendly fire incidences) or Level II exposures (clean up operations and radiation control (114).

Studies of the veterans in the DU Program have found that veterans with embedded DU shrapnel had high levels of DU in their urine. Veterans with high levels of uranium in their urine did poorly on neurocognitive tests stressing accuracy and performance efficiency (115). Veterans with high levels of urinary uranium also had high levels of prolactin in their urine (116). In addition veterans with high urinary uranium had significantly lower monocyte percentages and lower mean lymphocyte counts than veterans with low urinary uranium as well as significantly higher mean neutrophil percentages (all related to immune function) (117). When 22 veterans with embedded DU had their semen tested for DU, 5 tested positive (118).

McDiarmid et al (2004) (119) reported on a ten-year follow up study done on interviews with 31 Gulf War veterans in the Baltimore DU Program and 8 Gulf War veterans new to the program. In the spring and summer of 2001 researchers gave a battery of tests to the 39 veterans. Ten years after initial exposure to DU all 39 veterans had DU in their urine. The 17 veterans who had embedded shrapnel in their bodies basically had the highest concentrations of uranium in their urine (13 of these were in the high urine uranium group). The other 22 had been exposed to DU through: inhalation (some of these vets had been in or on a tank hit by friendly fire), wound contamination or ingestion of DU through coughing etc.(120). None of the veterans in this group had been involved in clean-up or repair operations on tanks or vehicles destroyed by DU (i.e. no Level II veterans).

There was no difference in frequency of disease including cardiovascular, musculoskeletal, nervous system, or psychiatric conditions between the two groups of veterans (121). None of the veterans had kidney dysfunction and the researchers stated that "there is a clear absence of a 'signature' specific medical problem shared by this cohort of Gulf War veterans"(122). The veterans who did not have embedded shrapnel in their bodies, with one exception, had lower urine uranium concentrations. The cut-off point in uranium urine concentrations between the high uranium urine group (n=13) and the low uranium urine group (n=22) was 0.10 micrograms/gram creatinine (measured over 24 hours)(123) **.** Range of urinary uranium values were 0.001 micrograms/gram creatinine to 78.125 micrograms/gram creatinine (124). The mean urinary uranium concentration in the high uranium group was reported to be 62.2 micrograms/Liter, with levels similar to those seen in a study of uranium mill workers in the mid-1970's (125). (For a discussion of uranium miners and workers, see **Appendix C**).

The veterans had their urine and blood tested. The high urinary uranium group had significantly lower hematocrits (the volume percentage of red blood cells in whole blood, a low reading indicating anemia) than the low uranium group. Renal function differed significantly between the two groups – both urine retinol binding protein (a test for proximal kidney tubules) and urine total protein were higher in the veterans with high concentrations of urinary uranium, suggesting decreased protein absorption or increased glomerular filtration of protein (126), i.e. indicating stress on the kidney.

Genotoxic testing included testing for chromosomal aberrations and sister chromatid exchange (SCE) as well as use of an HPRT assay which detects mutations at the gene level. (HPRT stands for Hypoxanthine-guanine phosphoribosyl transferase which is used to detect mutations at the genetic level. It is extensively used in human research (127)). All testing was done using peripheral blood lymphocytes to measure the frequency of genetic mutations. Although there was no significant difference in SCEs between the high and low urine uranium groups, as had been found in a previous study (128), there was a statistical difference in frequency of chromosomal aberrations between the high urine uranium and low urine uranium groups (129). With respect to this latter finding, researchers stated that the chromosomal aberrations were based on near normal "absolute frequencies of chromosomal aberrations per cell" (130). The HPRT assay showed an association of the HPRT mutation frequency with high urine uranium concentration (131). There was no association with low uranium urinary levels. (132) (The frequency of mutations was significantly higher in the first group). More study was called for. These results demonstrated the mutagenic nature of DU.

Statistical differences between the two groups of veterans were found in free thyroxine levels (an indication of underlying disease unrelated to thyroid function (133)), with the lower urine uranium group having the higher levels. Prolactin levels were also higher in the low urine uranium group although the difference was not significant (134). Thyroid function was within normal range but the prolactin levels were above normal range (135). In immunological testing differences between the two groups were statistically significant in only two of fourteen parameters with all values being within normal range (136). (The percentage of T-lymphocytes was significantly lower in the high uranium group whereas the percentage of monocytes was not quite significant between the two groups with the high uranium group having the higher percentage).

Neurocognitive tests did not find statistical differences between the high level urinary uranium group and the low level group although there was a marginal association (p=.069) between urinary uranium levels and an automated accuracy index, which was not statistically significant. The researchers stated however that two veterans with severe combat injuries and high uranium urine levels "drove" this (137). A result of this sort can occur with small numbers.

Twenty-seven of the veterans had their semen counted. Tests included volume of sperm concentration and indices of sperm motility (138). Differences between the two groups of veterans were not significant, although the mean of sperm concentration (over 20 million/ml) was higher in the high urine uranium group as were the means for total sperm count and total progressive sperm, a measure of sperm motility including sperm moving randomly and others not moving at all (139). Incidences of motility characteristics and subnormal sperm count were below WHO 1987 norms (140). The researchers said that the semen characteristics overall were "based on average values" and that the higher values in the high DU-exposed group "are not considered clinically significant for an individual's fertility, as upper limits of normal do not exist" (141).

In summary, the results with prolactin, though significant, were the reverse of what had been found in other research on the veterans in the program. Results indicated that kidney problems might occur in the future and there was evidence that DU could be genotoxic. With this report as with most of the other reports by McDiarmid et al., the small numbers of veterans involved make it difficult to base policies on these results as the V.A. has itself noted, with regard to the induction of cancer (142).

Gwiazda et al.(2004) (143) using inductively coupled plasma mass spectrometry showed that 8 years after exposure to DU, 2 groups of the Baltimore V.A. DU Program veterans had DU in their urine. Those veterans with embedded shrapnel (n=16) had higher urinary uranium concentrations (with one exception) than the group suspected of having been exposed through inhalation, ingestion or wound contamination. Soldiers in the control group had not been involved in friendly fire incidents in 1991. One veteran with embedded shrapnel did not have any DU in his urine. Only 10 out of a total of 28 had DU in their urine in the group of exposed veterans without embedded shrapnel. In the control group, one veteran had DU in his urine. Overall, veterans with embedded shrapnel had the highest urinary uranium concentrations.

The median value for urine uranium concentrations in veterans with shrapnel was significantly higher than the median values of urine uranium concentrations in either of the other groups (144). The median uranium level in the exposed group without embedded shrapnel was six times higher than the median uranium level in the control group (n=13). The range of values for the second and third groups overlapped, leading the researchers to state that urine testing alone was not sufficient to indicate body contamination with DU (145). Urine uranium values for the group of veterans who had been exposed to DU but did not have embedded shrapnel, were within normal limits for the U.S. population (after work of Ting et. al 1999 who used 500 participants in the NHANES III survey to ascertain urine (natural) uranium levels in a normal population (146). The 50 percentile was 6.32 nanogram/L (or .00632 micrograms/L) whereas the 95 percentile was 34.5 nanogram/L) (147).

A more recent article by McDiarmid et al. (July 2004) (148) studied 446 veterans (including about 100 active duty soldiers) found that 95 percent of the veterans who had suspected that they had been exposed to DU did not have elevated urine uranium levels (149). Testing for DU was done only if a urine sample had a uranium concentration equal to or more than 0.05 micrograms/gm. creatinine; soldiers with urine samples with uranium equal to or more than 0.05 micrograms per gm. creatinine were retested and if the uranium content of their urine was still high, only then were tests for the presence of DU done. Testing for uranium isotopes was done using inductively coupled plasma mass spectrometry. Eighteen samples were tested and the ratios of U235/U238 found for these samples "were consistent with ratios expected for natural uranium (range = 0.0066 to 0.0078)" (150) (DU has a ratio of 0.002).Veterans with embedded DU shrapnel had DU in their urine (151). Three out of 6 veterans with embedded shrapnel had the highest urine uranium levels; the next two highest positive predictive values for DU exposure were for soldiers in or on a vehicle hit by friendly fire or in a vehicle hit by enemy fired (152). As a group, the 446 veterans when compared to the NHANES population, had higher urine uranium levels percentile by percentile but these differences were not significant (153).

Dr. Helen Caldicott states that it may be possible to be exposed to DU and have no evidence of this in the urine at a later time. For instance, DU may have been stored in the bone or other tissues. DU formerly in the body may have caused mutations before passing out through the urine, leaving no trace of the actual injury (154). Gulf War veterans were not tested for DU until some time after exposure to DU. Also as insoluble ceramic DU that may exist in the lung, does not readily solubilize and travel to the kidneys, the DU in the urine does not necessarily represent the total body burden of DU.

Guidelines regarding embedded shrapnel may be changing in part as a result of AFRRI research (155). In August 2002, Col. Wakayama of the Defense Department stated at a DOD conference that new guidelines indicate the advisability of removing embedded shrapnel longer than one cm. unless medically contraindicated (156).

In March 2003, a physician with the Department of Defense reiterated that the Baltimore Program veterans showed no ill effects from their exposure to DU, in particular no visible signs of kidney disease (157). They had made similar statements in the winter of 2001.

However, at least two veterans in the Baltimore program have been ill. One veteran had a bone tumor removed from his arm while another veteran who did not have shrapnel in his body has lymphoma (158), a rare type of cancer (the incidence for Hodgkins Lymphoma in the U.S. is 2.8 cases per 100,000)(159). The fact that this cancer has been largely ignored by the Baltimore DU Program from the point of view of DU exposure, may be partly because the nuclear industry, including the military, makes a distinction between radiation that causes cancer and radiation that promotes or accelerates cancer (they discount the latter) (160).

The veterans who are in the DU Program in Baltimore are a small number compared to other highly exposed veterans who inhaled or ingested DU or had wounds contaminated by DU who are not in the program. Veterans not enrolled in the program have reported having health problems including kidney dysfunction and birth defects (161).

Another VA Program in Wilmington, DE treated 24 Gulf War veterans who had been involved in the clean up and decontamination of 24 U.S. vehicles and tanks destroyed by DU munitions in Saudi Arabia over a three and a half month period. Dr. Asaf Durakovic, an expert in Nuclear Medicine and head of the program from 1991-1997 discussed the illnesses of many of the veterans in the program with a reporter with the World Socialist Web Site in September 1999. Fourteen of the veterans tested positive to DU (162) and they suffered from kidney pathology, as well as lung disease, GI dysfunction and immune system problems. At the time of the interview Dr. Durakovic was Professor of Radiology and Nuclear Medicine at Georgetown University (163).

Of the over 600,000 service men and women who served in the Gulf War in 1991, 100,000 veterans have reported having symptoms of Gulf War Syndrome – including symptoms of chronic fatigue, memory loss, joint pain, headaches, anxiety and depression (164). DU may likely be responsible in part for these disabilities.

A study by Winrow et al. (2003) (165) found that the inhibition of a gene, neuropathy target esterase (NTE), in mice produced neurological problems similar to some of the symptoms of Gulf War Syndrome when mice were exposed to organophosphates present in some chemical warfare agents such as certain nerve gases and pesticides. The organophosphates inhibited the activity of the gene. NTE is involved in neurodevelopment and is active in the hippocampus, important for memory and learning, the cerebellum, site of control of gait and movement, and the spinal cord. Inhibition of the gene killed unborn mice and produced the type of hyperactivity found in attention deficit/hyperactivity disorder (ADHD) as well as some of the symptoms of Gulf War illness (166). The study was partly funded by the Department of Defense.

A group of researchers at Duke University (2004) (167) did a rat study on conditions affecting Gulf War troops in 1991. Rats were exposed to stress for 28 days and were given low doses of chemicals encountered on the battlefield: the anti-nerve gas pyridostigmine bromide, the insecticide permethrin and DEET, an insect repellant. Rats exposed to stress and the chemicals showed significant brain and liver damage. Rats exposed only to stress and rats exposed only to the chemicals did not suffer injury, or in the case of the chemicals, little or no injury to brain or liver.

Areas of the brain damaged by the combination of stress, as on the battlefield, and chemicals, included the cerebral cortex, which controls motor and sensory regulation, the hippocampus, and the cerebellum. Damage included death of neurons and increased destruction by oxygen free radicals (168). The researchers stated that the changes seen in the stressed rats receiving the chemicals “likely explain some of the symptoms such as loss of memory, muscle weakness, and alterations in learning ability observed in Gulf War veterans.” (169). They called for further research.

An editorial on Gulf War illness in the December 13, 2003 issue of the **British Medical Journal (BMJ)** (170) states that “war is incredibly stressful” (171). The writer asserts that the Gulf War veterans are ill but that their symptoms can be found in the general population as well. He refers to an article by Hotopf et al. in the **BMJ** (same issue), which found that Gulf War veterans have experienced poorer health (172) than military personnel who did not serve in the Gulf War in 1991; or had served as peacekeepers in Bosnia (but their level of health was better than that of the Gulf War veterans). The Gulf War veterans suffered significantly more persistent fatigue than the veterans in the other two groups, but were not, however, experiencing new illnesses to a greater degree than the veterans in the other two groups (173). A larger study published in **BMC Public Health** in July 2004 found that British Gulf War veterans reported higher rates of general ill health and higher number of symptoms than military personnel who were not deployed to the Gulf, and were more likely to have reported at least one new medical symptom or disease since 1990 (174).

The writer of the **BMJ** editorial mentioned a large study by Macfarlane et al. (175) also in the **BMJ** which found no difference in incidence rates of cancers between veterans who had served in the Gulf War and soldiers who had not been in the war. The Gulf War veterans sustained 270 cancers as opposed to 269 cancers in the control group (176). Investigation of site-specific cancers suffered by Gulf War veterans showed no excess in numbers of cancers at different sites (177). However, there were 24 cases of lymphoid and hematopoietic cancers in the Gulf War veterans group as opposed to 11 in the Era (not Gulf War) cohort (178).

The researchers commented that exposure to DU or pesticides were self-reported with the most common symptoms including fatigue, poor memory, stiffness, inability to sleep, irritability and sudden mood changes (179). Non-melanoma cancers and cancers where site information was lacking, were not included in the study (180). The study was funded by the U.K. Ministry of Defense.

General Health Effects of Radiation and Low Level Radiation

The effects of low-level radiation on genetic material and the cell as per the cell membrane lead some scientists to believe that low-level radiation affects other disease states, above and beyond cancer (including aging) (181). Persons exposed to low levels of radiation may suffer poorer health than the general population. In Belarus, where fallout from the Chernobyl reactor accident was particularly severe, the percentage of healthy persons fell from 16.6 percent in 1993 to 11.7 percent in 1995 (182).

Data taken from the Belarussian State Registry of the Chernobyl children indicated that the incidence of immune disorders, endocrine system disorders, blood disorders and circulatory disorders among other conditions increased between 1986 and the early 1990's (183). Furitsu et al. who reported on these findings stated that "The health status of the children is deteriorating from the incidence" of these diseases (184).

A study done in 1990 (185) found more disease among adults and adolescents in the Brest region of Belarus who lived in areas contaminated by the Chernobyl disaster than among adults and adolescents in non-contaminated areas in Brest. Adults and adolescents in the contaminated areas of Brest suffered more disease than adults and adolescents living in the non-contaminated areas. The incidence of diseases such as circulatory system, hypertension and ischemic heart disease, cerebrovascular disease, urogenital disease, nephritis and kidney infections as well as infections and parasites were found to be significantly greater among adults and adolescents living in the contaminated areas at p= .001 level **(**that is, there is one chance in 1,000 that these results could happen by chance). (p=.0001 for infections and parasites, in this case there is one possibility in 10,000 that this could have come about by chance (186). (For statistics on atom bomb survivors and general health, and contributing biological factors, see **Appendix A**).

Studies on men who inhaled DU

Horan et al.(2002)(187) took urine samples from 26 British, Canadian and American Gulf War veterans all of whom showed symptoms of Gulf War Illness, and who had inhaled DU dust in 1991. DU was found in the urine of 14 of the veterans. The DU in the urine samples was analyzed by thermal ionization mass spectrometry. The researchers also examined three autopsy samples taken from a dead soldier. They found DU in lung tissue and bone.

Dr. Hari Sharma used delayed-neutron counting and neutron activation methods, checking his results with mass spectrometry, to test the urine of a small number of Iraqis who had lived in Basra. (Heavy bombing during the first Gulf War occurred in the neighborhood of Basra from 1991-1993.) The urine of these Iraqis tested positive for DU years after exposure. Dr. Sharma also analyzed tissues from 38 dead Iraqis (the bodies were taken from a morgue) who in life had lived in Basra from 1990-1993-1994. The youngest was 12 and the oldest 45 (188). Testing revealed that DU was in the lungs, while the thoracic lymph nodes had 10 times the amount of DU present in the lungs. The kidneys also contained a larger amount of DU than was found in the lungs (189). DU was found as well in the livers of some of the dead Iraqis (190).

Sharma also tested Gulf War I veterans from 4 countries in 1998-1999, eight years after exposure to DU on the battlefield. The clearance rate of DU in the veterans' urine averaged 1-5 micrograms of DU (191) per day, a much higher rate than was found in the urine of Iraqi civilians (192); the urine of veterans in a medical unit who were stationed close to the Iraq-Saudi Arabia border contained a clearance rate of several micrograms of DU a day (193). Sharma associated the clearance rate with "a very slow rate of solubilization of accumulated DU oxides aerosols in body fluids" (194), indicating that only soluble DU is excreted in the urine.

The finding of a comparatively large amount of DU in the thoracic lymph nodes of the deceased Iraqis was similar to the finding of very high amounts of DU or enriched uranium in the lymph nodes of Worker Y, who in life had worked at the Oak Ridge National Laboratory. Sharma noted that this finding, of high levels of uranium in lymph nodes, has definite implications for the immune system (195). In his work, Worker Y decontaminated equipment which possibly was covered with or contained DU or enriched uranium. Worker X who also died of cancer, worked at the Paducah Gaseous Diffusion Plant where uranium hexafluoride was the main uranium product. Worker X had 0.02 micrograms of uranium per gram of bone (196).

Kenneth Duncan, the Scottish veteran who won a claims benefit in February, 2004, and who had prolonged exposure to DU dust, suffers from respiratory problems (breathlessness) and painful joints. He was in the German pilot study previously discussed and his lymphocytes show dicentric and centric chromosomal aberrations, indicative of exposure to ionizing radiation. His children have deformed toes and a depressed immune system, which has made them susceptible to asthma, hay fever and eczema (197). Duncan had been involved in transporting Iraqi tanks that had been hit by DU shells and also in cleaning up the destroyed tanks (198).

Another British veteran, a medical technician, had worked with wounded Iraqi soldiers, removing their dusty clothing, at a field hospital near the Iraqi border. Since his return from the Gulf, he has suffered chronic fatigue, headaches, digestive problems and is confined to a wheelchair (199). A third British veteran, whose job in telecommunications exposed him daily to desert dust, is now on kidney dialysis; symptoms that manifested after his return home included chronic fatigue and severe headaches. His urine showed signs of DU but contained a lot of protein, making it impossible to actually isolate the DU (200). All three of these veterans had come in continual contact with DU dust through their jobs.

An Epidemiological Study

At a conference put on by the Nuclear Policy Research Institute at the New York Academy of Medicine in New York City in June of 2003, Dr. Thomas Fasy reported on epidemiological studies (201) done by Drs. Alim Yacoub (an epidemiologist, formerly Dean of the Basra Medical College), Jenan Hassan (a neonatologist) and scientists at the University of Basra. In their retrospective study they used hospital and treatment records combined with census data to develop incidence rates.

The Women's and Children's Hospital where Dr. Hassan works, diagnoses all children under fifteen who live in the governorate of Basra for malignancy or suspected malignancy. Their findings for malignant disease were, an incidence rate of 3.98 cases per 100,000 in 1990 which increased in 2001 to 12.6 cases per 100,000, an increase which had quadrupled. Furthermore, in 1990, 13 percent of leukemia cases in children under five had increased to nearly 60 percent by 2001 (from 2 cases in 1990 to 41 in 2001). In 2002 the number of cases in children under five had risen to 53 (202). Some of the highest incidence rates per department were in areas south and west of Basra where there had been heavy fighting during the first Gulf War (203). Dr. Yacoub and Dr. Hassan and their colleagues determined in their study that incidence rates of congenital malformations in infants had risen from 3.04 per 1,000 live births in 1990 to 17.6 per 1,000 live births in 2000 (204).

Elizabeth Neuffer of the **Boston Globe**(1/26/03) reporting from Iraq wrote in January 2003 that in recent years expectant mothers no longer ask, "Is it a boy or a girl?" they ask "Is it normal?". Pregnant women have resorted to ultrasound to determine if their fetus is normal (205).

Two Studies on Reproductive Anomalies

A large study by Kang et al. (2001) (206) indicated that male U. S. Gulf War veterans had children with birth defects at nearly two times the rate of male non-Gulf War veterans whereas female Gulf War veterans had children with birth defects at just under three times the rate of female non-Gulf War veterans (207). Actual numbers of "likely" birth defects broke down to 120 cases in infants born to male Gulf War veterans in contrast to 47 in infants born to male non-Gulf War veterans. For female veterans, 26 infants with "likely" birth defects were born to Gulf War veterans but just 13 infants with "likely" birth defects were born to non-Gulf War veterans. Numbers of live births varied, with the percentage of birth defects in the Gulf War veterans groups being 5.4 or 5.5 percent and under 3 percent in the non-Gulf War veterans groups. Overall, Gulf War veterans had a significantly higher number of birth defects in their offspring than veterans who had not served in the Gulf War. Male Gulf War veterans also reported significantly more miscarriages by their wives and partners in first pregnancies after the Gulf War than did veterans who had not been deployed in the Gulf (208). The researchers did not pinpoint any one cause (209).

Doyle and colleagues in another large survey (210) found a 40 percent increased risk of miscarriages in pregnancies of spouses and partners of British Gulf War veterans (211); miscarriages occurred especially in the first trimester. Research indicated a probable genetic effect stemming from exposures undergone by veterans while in the Gulf War (212). Male U.K. Gulf War veterans also reported a 50 percent higher prevalence rate of congenital abnormalities than non-Gulf War veterans (213). In particular the risk of malformations of the genital system was 80 percent greater in infants of Gulf War veterans than in infants born to non-Gulf War veterans (214). Risk of malformations of the urinary system and to a lesser extent, the musculo-skeletal system was linked to service in the Gulf War (215). The survey was funded by the U.K. Ministry of Defence.

The Balkans

The United Nations Environmental Program (UNEP) sent teams to: Kosovo in 2000, a year and a half after the conflict; to Serbia and Montenegro in 2001, 2-3 years after cessation of hostilities; and to Bosnia–Herzegovina in 2002, 7-8 years after bombing of that region. DU munitions were used in all three theaters of operation (216).

Sites chosen by UNEP were selected through NATO and national authorities. UNEP visited 11 sites in Kosovo, 7 in Serbia-Montenegro and 14 in Bosnia-Herzegovina. In all they found upwards of 75 DU penetrators (including DU fragments). Approximately 10,000 rounds (a round is a single shot) had been fired in the site areas (217). The teams found comparatively few DU contamination points in Kosovo and Serbia-Montenegro but nearly 300 in Bosnia-Herzegovina. Laboratory analysis of soil samples taken as far away as 200 meters from a DU shell showed signs of DU contamination (218).

Many of the DU shells were found lying on the ground while many others were found a few centimeters below the ground and were covered by grass, leaves and soil (219). Points of contamination, i.e. detectable levels of radioactivity, were found to be mostly within a radius of 1-2 meters from the DU target (220). At a former tank repair facility in Bosnia/Herzegovina, radiation levels ranged from 10 times natural background radiation levels (the usual) to 100 times background radiation levels (221); this site had been heavily targeted.

The British Ministry of Defense sent a team to Kosovo in January 2001 (222). They found that some DU penetrators were as far as 5 meters beneath the ground and so were hard to detect and that many DU shells had not hit their targets. In their report they said, "some hundreds of rounds are used in every air strike, and a significant portion of these arrows penetrate the ground around the target"(223). They also found areas of high intensity alpha radiation related to DU shells (224).

In Kosovo, the UNEP team found DU contamination down to a depth of 10 cm beneath the soil. In Bosnia and Herzegovina where DU had had more time (7-8 years) to penetrate the soil, DU contamination due to corrosion was detected as far down as 40 cm. (225). DU shells just beneath the ground surface were found to have lost 10 percent of their mass to corrosion in Kosovo, whereas in Bosnia-Herzegovina DU shells were found to have dissipated 25 percent of their mass (226). Studies of the corroded DU shells in Bosnia-Herzegovina indicated that the shells had lost 66-93 gm (out of 292 gm. – the weight of one shell) (227). UNEP teams stated that the corrosion situation in Bosnia-Herzegovina indicated a future problem of groundwater contamination, adding that within 25-35 years these shells would be completely corroded (228).

In Bosnia-Herzegovina, the UNEP team found DU contamination of local supplies of drinking water at one site (229). UNEP recommended that local authorities make other water sources available and that water supplies be monitored and tested regularly for several years (230).

Samples of lichens (algae and fungi live symbiotically getting nutrients and pollutants from the air), barks from trees and mosses were taken by UNEP teams in each region visited (231). Samples in each region showed presence of DU, indicating that one or more DU shell had hit a hard target in their vicinity, had shattered into dust with the aerosol so created, filtering up into the air and into the lichens, mosses and tree bark.

The UNEP team discovered DU particles in air-borne dust at two sites and also inside two buildings (232) one a storage barn where the dust particles were nearly 100 percent DU (233). The UNEP report recommended "a precautionary clean-up" of the buildings to prevent human exposure (234).

UNEP teams found that some DU penetrators contained low levels of plutonium (in all three UNEP reports). The UNEP scientists stated that these levels were insignificant (235). Overall the UNEP teams determined that according to established international safety radiation limits, the low levels of radioactivity found at most DU sites were not significant (236).

Recommendations by UNEP in addition to those mentioned above included removing DU penetrators or their fragments, fencing off areas where DU contamination existed, and storing DU penetrators and fragments in well-marked locked storage. They also were concerned about corrosion of DU shells and the subsequent risk of contamination of ground water. In their report on Serbia and Montenegro, they wrote that "it is very difficult to achieve comprehensive detection and complete decontamination of DU at a given site" (237). They also recommended that the public should be informed about possible dangers of DU contamination. In addition, in the

Bosnia-Herzegovina report, UNEP recommended that there be investigation of alleged health claims (238). They were aware too of possible contamination of the food chain through contaminated soil and water (239).

The UNEP Report on Bosnia-Herzegovina includes a WHO Assessment of Information on Cancer. Physicians in the region complained of increases in a number of cancers that people thought might be due to DU. WHO investigated but found “no reliable information on cancer rates and trends” (240) existing in the areas investigated. They were concerned about reports in increases in cancers and recommended improving registration of diseases and doing epidemiological studies (241).

Reaction to Deaths of Soldiers Who Had Served In the Balkans

In 2001 the deaths of 24 European soldiers and peacekeepers who had served in Bosnia (1995) and Kosovo (1999) from leukemia and other cancers stirred controversy over whether these illnesses were linked to exposure to DU. Leukemia has a latency period from 2-10 years (242). Scientists in the U.S. denied that DU exposure could lead to cancers. Dr. Melissa McDiarmid of AFRRI (and who is also head of the Baltimore V.A. DU Program) told the **Boston Globe** that “past studies show that uranium miners and millers do not have a higher incidence of leukemia or other cancers.” (243). Uranium dust particles are much larger than ceramic DU particles and cannot penetrate the deep lungs (244). However, miners have a high incidence of lung cancer, caused generally by radon. (Radon is a very strong alpha emitter) (245).

Rosalie Bertell in “Host Response to Depleted Uranium” states that peacekeepers serving after the war, as well as civilians are not as much at risk of exposure to DU as soldiers or civilians caught up in the fighting (246). After a conflict, DU ceramic aerosol particles will not be in the air to the same extent as they would be immediately after a DU shell has hit a hard target, unless dust particles on the ground are disturbed and go into the air; what could be inhaled would mostly go into the gastrointestinal tract (247).

In a commentary on an Italian study of Italian peacekeepers who served for 7-20 months in Bosnia and Kosovo, Busby (unpublished manuscript) (248) found “a significant excess risk” of lymphoma, a comparatively rare cancer, in the Italian veterans (249). Sixteen out of 35 of the veterans with cancer in the study had lymphoma. Busby estimated that in a 30 month period in an average population such as that of England and Wales, there would be 54 cancers, 7.48 of which would be lymphomas (or a ratio of lymphomas to all other cancers of 0.16). Among the Italian peacekeepers over a 30 month period, (the main period in which most of the lymphomas manifested) there were 14 cases of lymphoma (10 cases of Hodgkins lymphoma) and just 11 cases of all other cancers (including 2 cases of leukemia). The ratio of lymphomas to all other cancers in the small but initially healthy Italian cohort in the 30-month period was 1.27, a ratio which is 7.9 times greater than the ratio of lymphomas to all other cancers in the population of England and Wales. When he compared the total number of lymphomas, 16, to the total number of all other cancers, 19, in the Italian peace keepers, he got a ratio of 0 .84 which is 5.25 times greater than the same ratio (0.16) in the population of England and Wales (250). He stated that other factors connected with the peacekeepers’ tour of duty besides exposure to DU might have contributed to the cases of lymphoma. However Busby noted that very small DU particles in the micron and sub-micron range that are inhaled can reach the lymphatic system. (251). He called for further studies.

In addition to the above-mentioned Italian study which did not find a significant difference between observed and expected cancers in peacekeepers in Bosnia and Kosovo, a Swedish study (2004) (252) also found no significant differences in cancer incidence between Swedish personnel who participated in U.N. missions in Bosnia and Kosovo and the expected number of cancer cases. Over 9,000 military and civilian workers (a total of 438 were women) comprised the experimental group. They served an average of six months in the Balkans. They experienced overall a slightly higher incidence of cancer than existed in the Swedish population. There were 34 cancers (with no cases of acute leukemia) whereas 28.1 cases of cancer were expected. There were 2 cases of Hodgkins’ lymphoma when one was expected. However, there were 8 cases of testicular cancers when only 4.3 were expected (253). None of the peacekeepers were tested for exposure to DU. The researchers did not find evidence of cancers due to depleted uranium exposure.

The U.K. Royal Society in its **March 2002 Report on Health Effects of Depleted Uranium Munitions** stated that an increased risk of lung cancer is the principal risk of low level radiation from DU. Risk of leukemia and other cancers they considered to be much less likely. The report makes a distinction between soldiers exposed to DU aerosol relatively briefly on the battlefield and those in or near tanks or vehicles hit by DU or those involved in lengthy clean-up operations on tanks and vehicles contaminated inside and out by DU dust. They stated that the soldiers most heavily exposed to DU could have approximately a 1 in 15 chance of getting lung cancer as compared to a 1 in 250 chance for non-smokers in the general population and a 1 in 6 chance for smokers in the general population (254).

With regard to peacekeepers in the Balkans, the Royal Society researchers stated that re-suspension of DU particles from the soil would not result in any "detectable increase in any cancer" (255) among peacekeepers or the civilian population although they did not know what conditions would be like in later years. Worst case scenarios might, they stated, cause short-term respiratory problems.

The Royal Society report evidenced a concern about the effect on the kidney of DU's chemical toxicity although it was felt that there was a gap in knowledge about how much exposure to DU would cause kidney damage. A worst case scenario might conceivably lead to kidney failure but they observed, there was no evidence that this had happened (256). The researchers stated that an undefined amount of renal dysfunction as well as lung disease might occur in soldiers inside a struck tank and might lead to ill health in later life from either kidney disease or lung cancer (257). They also noted that the types of uranium dust particles inhaled by uranium industrial workers and those encountered by soldiers on the battlefield might be different so that the lack of increase in kidney disease in workers in uranium plants did not necessarily signify that this would be the case for soldiers exposed to DU (258). (See **Appendix C** for discussion of uranium miners and workers and cancer).

Citing recent research, they stated that "there is a possibility of damage to DNA due to the chemical effects being enhanced by the effects of the alpha-particle irradiation"(259).

The Royal Society made recommendations which included:

- Measurement of urine for uranium isotopes and testing for kidney dysfunction using sensitive biochemical techniques as soon as possible after exposure to DU.
- Research into possible causation of disease by inhaled DU aerosol in lymphoid and haemopoeietic cancers (260).
- Study of the properties of DU aerosols as well as the study of the behavior of DU oxides upon the impacting of a DU shell on a tank.

The Royal Society report was also concerned about the risk of DU contaminated areas where children might play, breathe in DU particles or ingest them by moving hand from soil or vehicle surface to mouth (261).

Iraq

The situation in Iraq differs from that in the Balkans. First the two regions have very different climates and geography. In Iraq the sand and wind leads to the re-suspension of sand and dust (262) which is not the case in the Balkans. In Kuwait Bou Rabee (1995) found DU in soil samples and in the air (DU oxide aerosols were found in the air from 1990-winter 1994 (263)). Bou Rabee's results indicated however that there was "no significant contamination of the Kuwait soil, water or atmosphere" by DU (264).

Another difference between Iraq and the Balkans was the tank warfare in the first Gulf War as well as in the 2003 Iraq war, leading to the creation of DU oxide aerosols and ceramic oxide aerosols. DU shells were also shot from aircraft in these wars. In the Balkans however DU shells were only fired from A-10 Warthog jets, with about 10 percent of the shells hitting their targets; up to 90-95 percent of DU shells ended buried in the ground (265). Civilian populations were also impacted in Iraq to a greater extent than in the Balkans (266). In fact the 2003 Iraq war was the first time that DU weapons were used in urban areas. However there were other toxic pollutants in the air in Iraq, especially in the First Gulf War (267).

Over 127 tons of DU were used by U.S. forces in the Iraq war of 2003 according to Dr. Michael Kirkpatrick of the Department of Defense (268) as opposed to 320 tons of DU used in the 1991 Gulf War. These numbers, particularly for the 2003 Iraq war are not firm.

Scott Peterson of the **Christian Science Monitor** took readings of radioactivity at four sites in Baghdad after the war, most of which registered 1,000 times background radiation levels or higher. Near the Iraqi Ministry of Planning where there were quite a number of small spent DU shells "littering the ground" (269), Peterson's Geiger counter registered close to 1,900 times background radiation levels (270).

On the outskirts of Baghdad, at an intersection, four U.S. supply trucks had gone up in flames during the war, burning DU munitions. The area was bulldozed by U.S. soldiers a few days later, in order to remove contaminated topsoil near the burnt vehicles. Peterson found "black piles of pure DU ash" near the site (271). One such pile of black ash gave a digital reading of 9,839 radioactive emissions in one minute (272). This reading by the Geiger counter was over 300 times average background radiation levels (273). Another pile gave a higher reading (274).

Peterson found tanks destroyed by DU near a vegetable produce stand with children playing in and near either of two tanks close by. A DU fragment the size of a pencil eraser near one of the tanks registered a level of radioactivity on the Geiger counter nearly 1,000 times background levels (275).

In his tour of Baghdad Peterson noticed a warning sign at just one of the sites he visited where U.S. soldiers had written to stay away from a tank in Arabic (276).

In Basra, radiation readings from burned-out Iraqi tanks recorded radiation levels 2,500 times greater than normal background radiation (277). Further away from the tanks radiation readings were 20 times natural radiation limits. Analysis of biological and soil samples from battlegrounds also showed high levels of radiation especially in one Basra suburb where there had been fierce fighting (278). UNEP in their survey of Iraq after the war found that most of the tanks they investigated had low levels of radiation and also the tanks had been painted to show they had been hit by DU shells (279).

A World Health Organization study of health effects of DU was slated to start before the outbreak of the war. In the words of Professor Dr. A. Hadi Khalili, Vice Chair of the Iraqi Cancer Board and Chair of the Department of Neurosurgery at Baghdad University which runs a National Cancer Registry: "We do not know whether there is a statistically significant link between DU and cancer. We were planning to do a proper study with the WHO starting in March 2003 with six projects but it was delayed by the war and now it is on hold. So there is no solid evidence of link, only presumptive evidence, because the biggest increases (in cancers) have been in the areas where the greatest amount of DU was used". (280)

Dr. Jawad Al Ali, Director of the Oncology Center at the Basra Training Hospital in Basra stated at the World Uranium Weapons Conference in October, 2003, in Hamburg, Germany, that some of his patients have 2 cancers and 1 patient has 3 cancers. Five to 8 families in his care have more than one family member with a cancer. Dr. Ali also stated that 300 tons of DU had been dumped on the western part of the Basra governorate (281).

Two members of the staff of the Uranium Medical Research Center have been diagnosed with DU in their urine after 13 days in Iraq, in October 2003 (282).

In November 2003, the **Sunday Mirror** (UK) broke the news (11/30/03) that five British soldiers stationed in Iraq had tested positive for depleted uranium. The tanks they had been in had been hit with DU penetrators in several friendly fire incidents (283).

As of February 15, 2004 Reuters reported that thousands of British soldiers who spent time in Iraq during and after the war would be screened for physical and psychological health. Exposure to depleted uranium munitions will be considered among the possible causes of ill health found as a result of the screening (284). Furthermore British soldiers are being issued DU information cards (285).

On September 23, 2004 the British Ministry of Defense announced that a new, more reliable test for DU would be made available for 500 veterans a year, especially to Gulf War I veterans as well as civilians who were in the Gulf War theater of operation. The test will discriminate accurately between DU in the urine and natural uranium in the urine from food and drink of the person being tested. **The Times** reported also that the test would find small amounts of DU in the urine "if the level were high enough to have caused ill-health" (286).

American troops also are being asked 3 questions on possible exposure to DU in their post deployment health questionnaire (287).

In the meantime, as reported in the **New York Daily News** (288) in early April 2004, four out of nine members of the 442 Military Police Company of the New York National Guard tested positive to DU after serving in Iraq. A 5th member of the company had U236, a uranium compound formed by the nuclear fuel process, in his urine. The 442 Military Police Company had been barracked in an abandoned train depot in Samawah, Iraq. DU shells were on the ground near by and 100 yards away a tank which had sustained many DU shots, along with another tank, was on a flat bed railroad car. There were many sandstorms during the two months or so that the company stayed in the train depot. They ate the dust and slept in it. Men in the Military Police Company complained of ailments including chronic nausea, migraine headaches, skin rashes, frequent urination and kidney stones, the first four of which the 4 tested National Guardsmen suffer from; the other 5 National Guardsmen tested have also been ill. However the nine members of the New York National Guard had been previously tested by the military who stated that they were free of DU (289). The **Daily News** linked them up with an independent source to get properly tested.

While the New York National Guard was still in Samawah, a Dutch company moved into the train depot in late July 2003. They left three weeks later as high levels of radiation were detected. A Japanese journalist who accompanied Japanese soldiers who later came to Samawah also tested the radiation around the train depot with a Geiger counter and found radiation 300 times natural background radiation (290).

The furor created by the **New York Daily News** articles resulted in testing of other members of the 442nd National Guard – and others. After two weeks, the Pentagon claimed that those tested all tested negative for DU. However, the independent investigators, Dr. Durakovic and Dr. Axel Gerdes (of the Goethe University in Frankfurt, Germany) who tested the 9 National Guardsmen questioned the military's testing methods (291). According to the **New York Daily News** the Army only tests urine samples where "the total natural uranium concentration is more than 268 nanograms (or 0.268 micrograms) per liter" (292)

The Department of Defense has stated however that three soldiers with embedded DU shrapnel who had been hit by DU in friendly fire incidents have tested positive for DU (293).

On September 29, 2004 the **New York Daily News** (294) again reported on DU, specifically that Gerard Matthew, an Army National Guardsman, had tested positive for DU. He had returned ill from Iraq, complaining of migraine headaches, blackouts and a burning sensation upon urination. His wife became pregnant not long after his return. Their baby girl was born in June 2004 lacking three fingers on her left hand and almost all of her other hand. Matthew had worked as a truck driver in Iraq taking supplies from Kuwait (some of which may have been contaminated with DU) and on several occasions he moved destroyed tanks and vehicle parts from the front back to Kuwait.

The Matthews saw photographs of deformed Iraqi infants and decided that he should be tested for exposure to DU. The urine sample he provided to Fort Dix got lost and he went to the **Daily News**. They arranged for independent testing through Durakovic and Gerdes, who did the testing. Matthew tested low positive. Leonard Dietz, a physicist and expert in the area of DU said, "Those levels indicate pretty definitely that he's been exposed to DU" (295). According to Army guidelines the total uranium concentration in Matthew's urine sample was within normal range ('acceptable standards') for the majority of Americans. Gerdes challenged the Army guidelines. The **Daily News** quoted Gerdes as saying, "While the levels of DU in Matthew's urine are low, the DU we see in his urine could be 1,000 times higher in concentration in the lungs" (296).

U.S. Legislation

In October 2000 Congress passed an important nuclear-weapons worker-compensation bill (297) allowing workers at three uranium facilities to file for compensation for any of 22 cancers included in the bill. One factor leading to Congress' interest in this area was a Department of Energy (DOE) official review of DOE occupational epidemiological studies to the effect that exposure to radiation and "other substances" at 14 DOE plants had led to heightened death risks from cancer and other diseases. Workers at 6 uranium facilities also suffered excess deaths from cancers and kidney and nonmalignant lung diseases (298). As of June 11, 2001, this bill, the Energy Employees Occupational Illness Compensation Program Act, was expanded to employees at more than 300 facilities and to cover all cancers. The act includes factories "that received radioactive material that had been used in the production of an atomic weapon, or the "back end" of the production cycle, such as waste handling or reprocessing operations". (FEDERAL REGISTER 66(113), June 11, 2001:31219). Starmet in Concord, MA, which made depleted uranium weapons from the mid 1970's until 1999 is among the facilities on this list.

In March of 2003, Congressman Jim McDermott (D-Washington) introduced the Depleted Uranium Munitions Study Act of 2003 (H.R. 1483) which, in addition to studying health effects of DU weapons, would designate contaminated DU sites in the U.S. for clean-up. Congressman McDermott is a physician who has been to Iraq and who has been concerned about the illnesses of Gulf War veterans (299).

A new bill was proposed in May of 2004. Congressman Jose Serrano (New York) introduced H.R. 4463 which would require the identification of members of the Armed Forces who have been exposed to DU, the testing of those exposed and the tracking of all who test positive in order to ascertain long-term health consequences of DU exposure (300).

Summary and Conclusion

Although there is a dearth of epidemiological studies on DU, evidence exists that DU is harmful on the cellular level. Most studies have been done on animals which have also shown that DU can be damaging. Animal models used in biomedical research have been vital in understanding the human model because their biological systems are the same or similar in function and structure to those of humans. These models have made possible discoveries in fields like experimental oncology and the study of tumors, immunology and aging that have solved or helped to solve problems of chronic disease (301).

As an alpha emitter, DU generates changes in the genetic material of human white blood cells. Low-level ionizing radiation also causes bystander effects, leading to genetic alterations and other deleterious consequences such as the induction of genomic instability in cells not directly hit by radiation. The mechanisms behind these bystander effects vary as does the number of cells affected by the bystander effect. Bystander effects may differ according to type of cell. Bystander effects have been demonstrated in numerous *in vitro* studies. However, Goldberg and Lehnert have stated, "Overall, the clinical literature does not provide strong evidence for or against the existence of radiation bystander effects *in vivo*" (302). Still experts setting safe radiation limits may need to take the bystander effect into consideration. Miller and co-workers have said, "The involvement of bystander effects in the mechanism of DU-induced effects could mean that conventional microdosimetry assessment of the radiation dose from DU might be significantly undervalued" (303).

Genomic instability may also lead to the reassessment of safe radiation limits due to DU's chemical toxicity as well as to its radioactivity. Genomic instability with its ability to allow genetic mutations and chromosomal aberrations to be passed on to future generations of cells may lead to cancer (304). In DU-exposed cells Miller et al. showed that DU caused genomic instability through the formation of micronuclei and delayed reproductive death lasting for at least 30 generations in the progeny of the cells first subjected to the low-level ionizing radiation and chemical toxicity.

Both DU's high chemical toxicity and its radioactivity can damage genetic and non-genetic material in the cell. Both are responsible for DU's ability to transform non-tumorigenic human cells to neoplastic cells which in turn cause tumors in athymic nude mice. These two properties, chemical toxicity and radiation, may act synergistically resulting in more damage than either component could cause alone.

Genetic effects of DU include: DU turned on 10 of 13 "stress" genes, leading to chromosomal breaks and potential damage at the genetic level in human liver carcinoma cells. DU or exposure to ionizing radiation (presumably DU) caused dicentric chromosomal aberrations in human cells in an AFRRI study and in the lymphocytes (where centric ring aberrations were also found) of 16 Gulf and Balkan War veterans in the German study. The uranyl ion itself has an affinity to chromatin, the genetic material; sperm have the greatest amount of chromatin in the body.

Non-genetic effects caused by DU's alpha radiation include the breakdown of cell membranes through the Petkau Effect, damage to the immune system by monocyte depletion and anemia as well as damage to the brain through the development of large abnormal red blood cells that have difficulty getting oxygen and nutrients into capillaries going to the brain and muscle.

The insoluble DU ceramic aerosol created when a DU penetrator hits a hard target and penetrates into the deep lung, does not easily leave the body like the soluble uranium oxide dust in uranium mines. Natural uranium tends to be relatively soluble and is generally ingested and passes rapidly through the digestive tract and out. As the Royal Society stated, the situation faced by the soldier in direct contact with DU dust and the situation faced by the miner, are not the same. Research that extrapolates from the miner's situation as similar to that of the person exposed to DU dust is not dealing with equivalent situations. The RAND Report dealt principally with uranium miners and natural uranium in order to show that DU was harmless.

Animal studies have shown that in rats with embedded DU pellets, DU travels to many areas of the body, particularly to kidney and bone, but also to different parts of the brain. DU causes electrical changes in the hippocampus of the brain, the area of memory and learning. DU also crosses the placenta and is stored in the fetus. DU travels to the lymph nodes and the testes. Another study by the Lovelace Institute showed that DU caused cancer in rat muscle and in the kidneys. However, an AFRRI study showed that embedded DU did not lead to kidney dysfunction or toxicity in rats. Yet another study where the lungs of rats were instilled with live-fired DU dust, found that some of the rats suffered kidney damage.

In one animal study, DU was captured by mouse macrophages, which scavenge for bacteria, heavy metals and so forth in the lung and other organs; and was concentrated in the macrophages, killing them. This destruction of the immune system, of which macrophages are a part, helps to allow pathogens to more easily enter the body of the rat. In another animal experiment, exposure to DU led to impaired coordination and movement performance in rats.

With regard to Gulf War Syndrome, several rodent studies (Winrow et al. and Abdel-Rahman et al.) found that a simulation of toxins that had existed on the battlefield during the Gulf War caused neurological and other damage (the latter study) to rodents.

Human studies have varied in indicating whether DU exposure causes harm, with some studies finding that exposure to DU is damaging and others finding no difference in cancer incidence between people exposed to DU and those not exposed.

The group led by McDiarmid by and large did not find that DU exposure was harmful or rather that DU exposure caused disease. The NHANES III Survey results were used by Gwiazda and McDiarmid (2004) to show that veterans in the Baltimore V.A. DU Program who had been exposed to DU through inhalation, ingestion or wound contamination (Gwiazda et al.) or who thought they had been exposed to DU (McDiarmid 2004), had DU urinary levels or urinary uranium levels that were within normal urinary uranium levels or were not significantly different from urinary uranium levels in NHANES Survey participants. In both studies veterans with embedded shrapnel by and large had the highest urinary DU levels. Unfortunately the reader is not given the number of veterans exposed by inhalation of DU. Those veterans who inhaled or ingested DU or had wounds contaminated with DU were lumped together.

Sharma on the other hand found a urinary clearance rate of 1-5 micrograms of DU per day in Gulf War veterans who had been exposed to DU through inhalation.

The methodology used in the McDiarmid and Gwiazda studies, accounted only for soluble DU. Where veterans had inhaled ceramic aerosol DU, with predominantly insoluble DU particles, the extent of contamination by DU in the body would not have been picked up solely by analyzing urine for soluble DU. Insoluble DU will gradually solubilize in the lungs or elsewhere, with the passage of newly solublized DU traveling through the body into the urine very gradually. Insoluble DU will not find its way into the urine (305).

Most of the research by McDiarmid's group has been done on relatively small numbers of Gulf War veterans. Results from one study as compared to another have been contradictory from time to time. However the 10-year follow-up study (McDiarmid et al 2004) on 39 veterans found evidence of genotoxicity, stress on the kidney, reduced percentage of T-lymphocytes and lower hematocrits in the group of veterans with high uranium levels. In this study there was no significant difference between groups in performance on neurocognitive tests although an earlier study had found a significant difference between high and low uranium groups in tests stressing accuracy and performance.

However, McDiarmid et al. have stressed that the veterans they have studied have not suffered ill health from exposure to DU although one veteran has come down with lymphoma and another has had a tumor removed from his arm. Furthermore the Baltimore DU Follow UP Program has served just 3 percent of the 900-odd veterans who were exposed to DU during the Gulf War.

It should be noted that the DU levels of the veteran who has lymphoma, like the DU urinary levels of the 5 National Guardsmen (including the father of the child born with deformed hands) all were low positive. However this does not indicate how much insoluble DU is in the body.

Several studies (McFarlane and Gustavsson) found no difference in cancer incidence rates between British Gulf War veterans and Swedish peacekeepers in the Balkans as compared with British soldiers not deployed in the Gulf War theater and the general Swedish population. The McFarlane study did however have a high number of veterans with lymphoma and haematopoietic cancers compared with the control population.

Although an Italian study found no significant difference in cancer rates between Italian peacekeepers who served in Bosnia and Kosovo and the Italian population, Busby found an unusually high number of lymphomas (14) among the 35 Italian peacekeepers who had developed cancer after serving in the Balkans. Several of these peacekeepers who had lymphoma have died (306).

Dr. Antonietta Gatti has mentioned that “lymph nodes are where lymphomas start”(307). Lymphomas have also been defined as “any neoplastic disorder of lymphoid tissues, including Hodgkins disease” (308). Sharma found 10 times the amount of DU in the thoracic lymph nodes of dead Iraqis as compared to the amount of DU in the lung; inhalation had been the means of DU exposure.

Collectively Sharma’s research and that of Patricia Horan found DU not only in the lung and lymph nodes but also in liver, kidney, and bone.

The veterans like Kenneth Duncan who received compensation for war-time exposure to DU, like several other British veterans who have been ill since their Gulf War service, were in constant contact with DU dust through their jobs. The same was true of the 24 Gulf War veterans treated by Dr. Durakovic through the Wilmington V.A. DU Program. They had been exposed to DU through clean-up and recovery operations in Saudi Arabia; all were ill but 14 tested positive for DU.

With regard to possible teratogenic effects of DU, McDiarmid et al. found DU in the semen of 5 out of 22 veterans in the Baltimore V.A. DU Program (309). Kang and colleagues and Doyle and co-workers found a significant difference between deployed U.S. and British Gulf War veterans and non-deployed controls in the number of infants with congenital malformations born to their spouses or partners.

There is some evidence that low level ionizing radiation may be responsible for the General Health Effect, where persons who have been exposed to low level radiation are more susceptible to disease than populations not exposed to low level radiation. This has been found in three or four studies (310).

The Royal Society, reviewing the evidence for and against DU as a carcinogen, concluded that DU exposure might increase risk of lung cancer, this risk being heightened to 1 chance in 15 with heavy exposure. They also felt that the uranium dust inhaled by workers in industrial uranium plants where workers suffered little kidney disease might be different from DU dust encountered on the battlefield. Certainly the soluble particles of uranium dust in uranium mining are far larger and less apt to travel to the deep lung than the extremely fine ceramic insoluble DU aerosol particles which can lodge in the deep lung irradiating while there. A DU alpha particle while it travels only a short distance, gives off many, many times more than the electron volts needed to break a strand of DNA.

Overall, then, more epidemiological studies are needed, especially studies concerned with the inhalation of DU and subsequent health or lack of health. More animal studies too are needed on exposure to DU through inhalation.

Although UNEP teams in the Balkans stated that levels of radiation detected in soil, air, water, and in buildings were not significant enough to be of public health concern, the UNEP team in Serbia and Montenegro felt that complete detection and decontamination of DU was extremely difficult to do. They recommended that the public learn about the possible dangers of DU contamination. More specifically, their findings were that usually detectable levels of radiation could be found within a radius of 1-2 meters of a DU shell. (However, a team sent by the British Ministry of Defense found high intensity alpha radiation related to DU shells).

In their report on Bosnia and Herzegovina, the UNEP team found that DU shells that had been fired 7-8 years before but had landed intact, had lost 25 percent of their mass to corrosion which could potentially get into the water table. DU particles were found in air-borne dust at two different sites. Dust in the air in one building was found to be 100 percent DU particles.

Also in all three former battlefield theaters in the Balkans, the UNEP teams found DU penetrators that contained trace amounts of plutonium, indicating that these DU shells were made from recycled DU uranium. UNEP did not find significant danger in the presence of the plutonium. They also said that many DU shells did not hit hard targets but landed on or just under the ground.

In Iraq, there may be a problem with re-suspended DU dust; the 2003 Iraq war brought DU contamination into urban areas in a way that the 1991 Gulf War did not. This has not yet been studied to the best of my knowledge. However high levels of radiation (often 1,000 or more times background radiation level) were found at 4 sites in Baghdad after the 2003 war, near ruined tanks or near DU shells. High radiation levels were also detected in or possibly near destroyed Iraqi tanks in Basra. A UNEP team that went to Iraq found low levels of radiation near DU contaminated Iraqi tanks. Clearly scientific studies need to be done on these areas.

Four National Guardsmen stationed in a train depot contaminated we assume by DU, when tested for DU by an independent laboratory, tested positive for DU. They had been breathing in sand and DU dust for two or so months while stationed in Iraq, near at least one destroyed Iraqi tank and like others in their company who had become ill. The other five National Guardsmen who were also tested by the laboratory, tested negative but one had U236 (an artificial isotope of uranium) in his urine. This does not include the National Guardsman who tested positive to DU and has a child with birth defects. Again studies need to be done.

Legislation passed by Congress allowing compensation for cancers sustained through exposure to ionizing radiation, including DU, in nuclear facilities indicate that the U.S. government has concern about the effects of exposure to ionizing radiation, including DU, at least at some level.

Two bills having to do with different aspects of DU – health studies and testing for DU exposure -have also been introduced in Congress over the past two years.

Without more epidemiological studies, those who think DU is not harmful will not be convinced. However there are many signs on the cellular level, in animal models and even indications in some human studies that DU is harmful whether due to DU's chemical toxicity, its radioactivity or both.

Addendum to Health Effects of Depleted Uranium
Some Recent Studies

Three studies published in late 2005 and 2006 deal with depleted uranium as a heavy metal. DU's damaging effects in hamster or mouse cells indicate that DU's high chemical toxicity can create cellular changes which can lead to cancer and other diseases.

The first two studies are by Stearns and colleagues, published in 2005 and 2006.

Diane M. Stearns et al., "Uranyl acetate induces *hprt* mutations and uranium-DNA adducts in Chinese hamster ovary EM9 cells", **Mutagenesis 20** (6) (2005), 417-423.

Stearns and co-workers showed that DU in the form of uranyl acetate (UA), a soluble compound, binds to DNA in Chinese hamster ovary (CHO) cells. This binding, known as an "adduct" is a complex or compound of uranium with DNA; DNA adducts are known to occur between chemical mutagens and DNA and their formation may result in chromosome rearrangements and nucleotide substitutions or deletions (1). The researchers found that uranium-DNA adducts "increased with increasing (50-300uM UA) (2) dose and increasing exposure time for 24 and 48 hours"(3), leading to mutations. In addition UA caused DNA strand breaks which also can result in mutations. UA was shown to be cytotoxic, as seen in a CHO repair-deficient cell line, EM9, where it killed statistically more EM9 cells than parental AA8 cells at doses of 200-300uM UA. The researchers present evidence that these effects are due to the chemical toxicity of uranyl acetate. It should be noted that all uranium isotopes are alike chemically so that these results hold true for DU as well. Previously, the metal platinum had been found to form adducts, used in the anti-cancer drug Cisplatin (4) but this is the first report that DU in its role as a heavy metal can form U-DNA adducts in cultured cells.

Virginia H. Coryell and Diane M. Stearns, "Molecular Analysis of *hprt* Mutations Generated in Chinese Hamster Ovary EM9 Cells by Uranyl Acetate, by Hydrogen Peroxide, and Spontaneously", **Molecular Carcinogenesis 45** (2006); 60-72.

Coryell and Stearns concentrated on the *hprt* locus, used often in genetic experiments (5), in Chinese hamster ovary (CHO) cells in order to compare mutant spectrums induced by the soluble uranyl acetate (UA), the free radical species hydrogen peroxide and mutants arising from spontaneous generation. They did the experiments on the repair-deficient CHO Em9 line. They found a total of 59 UA-induced mutants, 45 hydrogen peroxide-induced mutants and 38 spontaneously generated mutants. Some specifics: UA induced significantly more major genomic rearrangements than occurred through spontaneous generation. All three treatments had mutations in exon 3 (6), the largest coding-region of the *hprt* locus. Exon 3 codes for the *hprt* protein's active site so that small mutations in this exon could alter or destroy the protein's function. (7). Overall, the researchers found significant differences ($p<0.001$) (8) between mutations induced by UA, hydrogen peroxide and spontaneous generation suggesting that UA causes effects above and beyond that of free radical generation. Through the examination of published data, the researchers found that the UA mutant spectrum was also significantly different from either alpha radiation induced or radon induced spectra, research which again zeroed in on the role of DU's chemical toxicity in causing damage in CHO cells.

The third study by Wan and co-workers deals with immune cells in peritoneal (9) and spleen cells in the mouse.

Bin Wan et al., "*In Vitro* Immune Toxicity of Depleted Uranium: Effects on Murine Macrophages, CD4+T Cells, and Gene Expression Profiles", **Environmental Health Perspectives 114** (1) (Jan. 2006); 85-91.

Wan et al. examined DU's toxic effect on the mouse immune system and its ability to alter immune function and kill immune cells. Their findings implicate DU as potentially leading to cancer, allergies and autoimmune diseases.

DU as uranyl nitrate caused cell death in peritoneal macrophages (10) and splenic CD4+T (T lymphocyte (11)) cells at different concentrations, 100uM and 200uM DU in the case of the macrophages and 500 uM DU for the CD4+T cells. The difference in toxicity was thought to be possibly due to the fact that macrophages engulf uranium particles.

DU altered immune function: DU at a concentration of 200uM, in the presence of Concavalin A, transformed macrophages into accessory cells that stimulated T-cell (CD4+T cell) proliferation. Higher quantities of DU led to increased T-cell proliferation. T-cell proliferation was statistically different from controls at DU concentrations of 200uM and over (12).

A mouse cytokine cDNA microassay (13) at non-cytotoxic levels of DU exposure (50uM DU for macrophages and 100uM for spenic T-cells) revealed significant changes in 29 genes in macrophages, and 14 genes in the CD4+T cells. Most of the 29 genes in macrophage cells were up-regulated; these genes were largely involved in signal transduction (14), interleukin (15) production and neurotropic factors (16). NF-alphaB was the most highly expressed gene, a gene which controls key regulators of genes involved in immune activity, inflammatory reactions, cell growth and proliferation and cell differentiation.

Mdk, a neurotropic factor, was highly expressed in both macrophages and splenic T-cells as a result of DU exposure. Mdk levels are often augmented in the early stages of cancer so this finding alone indicates that cancer may be an outcome of DU exposure. This is the first report of such a finding in a heavy metal.

Interleukin 10 (Il-10) in macrophages and Interleukin 5 (Il-5) in splenic T-cells were also highly up-regulated – 1.7 times normal in IL 10 and twice normal levels in Il-5. Both interleukins are part of a T-helper (Th) 2 profile (although Il-5 is also linked to T-cell function). Il-5 is a" signature cytokine" of Th2 cells and leads to the production of Il-10 which in turn fashions a microenvironment promoting Th2 cell development. According to the researchers, a "complex balance between Th1 and Th2 can be disturbed by a variety of factors, including heavy metals; a shift to a Th2 phenotype has been correlated with the development of allergic responses and some autoimmune diseases." (17). A shift from a Th1 profile in the direction of a Th2 profile has been noted in Gulf War syndrome. Elevated levels of Il-10 have also been found in Gulf War veterans whose illness might have resulted from exposure to DU during the war.

In the case of the report by Wan and colleagues as with those by Stearns et al., mutations and other changes caused by DU's chemical toxicity were found to be linked to DU's ability to act as a heavy metal. DU's high chemical toxicity was also shown to potentially lead to disease.

End Notes:

1. See "DNA Adducts" in the Cancerweb on-line dictionary at http://cancerweb.ncl.ac.uk/omd/index.html .
2. uM is short for micromolar, indicating a concentration of one micromole per liter, a substance given in moles rather than in mass per unit – a unit used in chemistry. See Miller-Keane, **Encyclopedia & Dictionary of Medicine, Nursing & Allied Health Professionals**, 5th Edition, Philadelphia/ London: W.B. Saunders Co., 1992, the ultimate definition of "mole" is on p. 929.
3. D.M. Stearns et al., " Uranyl acetate induces *hprt* mutations and uranium-DNA adducts in Chinese hamster ovary EM9 cells", **Mutagenesis 20** (6) (2005), 417-423, p. 420.
4. Mentioned in article by J.P. Leider, "Study rethinks uranium danger", **The Minnesota Daily**, April 21, 2006.
5. See page 7 of text of Health Effects for a brief discussion of the *hprt* locus.
6. An exon, according to the CancerWeb on-line dictionary (see footnote no. 1) is defined by "the sequences of the primary RNA transcript" – or the DNA encoding them that leave the nucleus as part of a messenger RNA molecule.
7. V.H. Coryell and D.M. Stearns, "Molecular Analysis of *hprt* Mutations Generated in Chinese Hamster Ovary EM9 Cells by Uranyl Acetate, by Hdrogen Peroxide, and Spontaneously", **Molecular Carcinogenesis 45** (2006); 60-72, p. 65.
8. **Ibid**, p. 69.
9. Peritoneal has to do with the peritoneum which is a serous membrane which lines the walls of the abdominal and pelvic cavities.
10. Macrophages are immune system scavengers found in many tissues of mammalian bodies. See p. 4 of text of Health Effects for research on DU and macrophages and footnote 83 for citation of article on this research by Kalinich and co-workers.
11. T lymphocytes or T-cells are formed in the thymus gland; they come from lymphoid stem cells that travel from the bone marrow to the thymus. They are involved in cell-mediated immunity and through helping to control the formation of B-cells, assist in the manufacture of antibodies. They assist in surveying and rejecting foreign tissues. (See "T-lymphocyte" in the CancerWeb on-line dictionary mentioned in footnote no. 1).
12. The macrophages in this experiment were exposed to different concentrations of DU for two hours before the experiment.

13. Many cytokines are small proteins – or biological factors that are given off by cells; they have specific effects on interactions between cells, the behavior of other cells and communication between cells. It is a generic term for lymphokines and interleukins etc. This microassay contained 514 different cytokine-related cDNAs.
14. Signal transduction refers to a "cascade of processes" which allows an extracellular signal – a hormone or neurotransmitter - to interact with a receptor at a cell surface leading to a change in the level of a second messenger such as calcium, resulting in for example the initiation of cell division. (See the CancerWeb on-line dictionary).
15. Interleukins are secreted regulatory proteins produced by lymphocytes and other cells; they occur in small quantities and affect the function of certain types of cells. Examples of interleukins (Il) are Il-5 which triggers activated B-cells and facilitates differentiation and activation of certain cells in blood formation. Another example is Il-10 which is manufactured by T-cells and B-cells. It is also a factor formed by Th2 helper T-cells as well as some B-cells. (See CancerWeb on-line dictionary).
16. A neurotropic factor is a protein or molecule which will promote the growth or maintenance of nerve cells.
17. B. Wan et al., "*In Vitro* Immune Toxicity of Depleted Uranium: Effects on Murine Macrophages, CD4+T Cells, and Gene Expression Profiles", **Environmental Health Perspectives 114** (1) (Jan. 2006); 85-91, p. 90.

Notes

1. See Information CADU (Campaign Against Depleted Uranium) web site, “As the Danger of Depleted Uranium is confirmed”, info@cadu.org.uk,, Feb. 10, 2004, p. 1, also Ron Minchin, “Gulf Veterans Hail Uranium Poisoning Ruling”, Scottish Press Association, Feb. 2004

2. Baverstock et al. quote a report of the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) that the presence of transuranics “’adds less than one percent to the internal radiation risks’” but Baverstock et al. question whether this is a maximum. (K. Baverstock, C. Mothersill and M. Thorne, “Radiological Toxicity of DU” (Repressed WHO Document) 5 Nov. 01, p. 4. Available at http://www.mindfully.org/Nucs/DU-Radiological-toxicity-WHO5nov01.htm.)

3. Arjun Makhijani, “Comments of the Institute for Energy and Environmental Research on the proposed uranium enrichment plant in New Mexico”, IEER website, http://www.ieer.org/comments/uenrichnm.html, Jan. 7, 2004, p. 1. DU is more than twice as radioactive, per unit weight, as the lowest limit for transuranic waste; transuranics, like DU, are alpha emitters.

4. **Ibid**, Comments, Jan. 7, 2004, IEER, p. 1.

5. **Ibid** p. 2. Also Dr. Rosalie Bertell, an expert on low-level radiation states that DU is really intermediate level waste. (Letter to Judy Scotnicki, October 2002, p. 4). In addition, Michael Mariotte of the Nuclear Information and Resource Service (http://www.nirs.org) says DU is in a category of its own but should not be in the low-level waste category. (e-mail from Michael Mariotte, Jan.16, 2003).

6. Col. J. Edgar Wakayama OSD/DOT and E/CS, “Depleted Uranium (DU) Munitions”, Presentation at the 5th Annual Testing and Training Symposium and Exhibitions, Defense Technical Information Center and NDIA, Aug. 19-22, 2002, p. 14. http://www.dticmil/ndia/2002training.

7. John T. Eberth, “Unsafe for friend and foe”, **The Times Herald**, (Olean, N.Y.), Jan 31, 2003, writes about a talk given by Dr. Doug Rokke in which Rokke mentions machine-guns as well as other new light weapons all of which can fire DU ammunition.

8. Dr. Doug Rokke, “Learn About Depleted Uranium From the U.S. Army’s Expert on Depleted Uranium (DU)”, speech given by Dr. Rokke in Los Altos, CA, Apr. 21, 2003, recorded and transcribed by Paul Goettlich, p. 3, http://www.mindfully.org/Nucs/2003/Rokke-Depleted-Uranium-DU21apr03.htm.

9. **Ibid**, p. 4. Also see “Depleted Uranium Fact Sheet”:, The National Gulf War Resource Center, Inc., http://www.ngwrc.org.

10. **Ibid**

11. **Ibid**

12. A micron is one millionth of a meter.

13. In 1979, the National Lead Industries plant in Colonie, N.Y. was making DU penetrators; DU particles were found in air filters 10, and later, 26 miles away at air monitors of the Knolls Atomic Power Laboratory. A year later, the State of New York shut down National Lead because the amount of DU particles being released into the air near Albany was 10 times the state regulatory standard. (Akira Tashiro, **Discounted Casualties**: **The Human Cost of Depleted Uranium**, Hiroshima: Chugoku Shimbun, 2001, Interview with Leonard Dietz, pp. 56-57. Also, Dan Fahey, **Case Narrative: Depleted Uranium (DU) Exposures**, Swords to Plowshares, Inc., National Gulf War Resource Center, Inc. and Military Toxics Project, Inc., Sept. 20, 1998, p. 18).

14. Dan Fahey, “Don’t Look, Don’t Find: Gulf War Veterans, the U.S. Government and Depleted Uranium 1990-2000", Lewiston, ME: The Military Toxics Project, Mar. 30, 2000, pp. 20-21 and p. 28. In the Case Narrative, Fahey states that the Department of Defense finally admitted that the Armed Services had not given out information on DU to troops “at all levels”, p. 98. Asaf Durakovic in “Medical Effects of Internal Contamination with Uranium”, **Croatian Medical Journal 40** (1) (1999), 49-66, says that overall, there have been “very few controlled exposures of man to uranium compounds by inhalation”, p. 55.

15. Dan Fahey, “Don’t Look, Don’t Find”. See pp, 14, 19-20 and especially pp. 31-33, and p. 35 which deal with aspects of epidemiological studies and problems estimating exposure doses.

16. RAND, 1999, Harley, N. et al. **A Review of the Scientific Literature As It Pertains to Gulf War Illnesses: Vol. 7 Depleted Uranium**. National Defense Research Institute, RAND. 1999. It should be noted that the RAND Corporation has had a long association with the military as an R & D (research and development) supplier.

17. A milligram (mg) is one thousandth of a gram; there are 28.35 grams in an ounce.

18. Dan Fahey, “Don’t Look, Don’t Find”, p. 21.

19. United States General Accounting Office, **Gulf War Illnesses: Understanding of Health Effects from Depleted Uranium Evolving but Safety Training Needed**, Washington, D.C., GAO, 2000, p.14.

20. John T. Eberth, “Unsafe for friend and foe?”, **The Times Herald**, quoting Doug Rokke, p. 4.

21. Dan Fahey, “Science or Science Fiction? Facts, Myths and Propaganda In the Debate Over Depleted Uranium Weapons”, Mar. 12, 2003, p. 8.

22. Akira Tashiro, **Discounted Casualties**, p. 57. Available at http://www.chugoku-np.co.jp/abom/uran/index_e.html

23. Dan Fahey, “Science or Science Fiction?…” , p. 8.

24. **Ibid**, p. 8.

25. **Ibid**, footnote 26 on p. 8.

26. Dan Fahey, **Case Narrative**, p. 15 (Sources: “Summation of ARDEC Test Data Pertaining to the Oxidation of Depleted Uranium During Battlefield Conditions”, U.S. Army Armament Research, Development and Engineering Center (ARDEC); Mar. 8, 1991; p. .2. **Health and Environmental Consequences of Depleted Uranium Use in the U.S. Army**; U.S. Army Environmental Policy Institute, June, 1995; p. 78).

27. According to the NRC, there are annual radiation dose limits for the lens of the eye and individual organs and tissues as well as for the whole body or skin of an extremity etc. These are the occupational dose limits for adults. Ascertaining the total individual dose limit is complex. However soluble uranium intake which **is in addition** to annual dose limits should, according to the NRC, be limited to 10 milligrams a week “in consideration of chemical toxicity”. See http://www.nrc.gov/reading-rm/doc-collections/cfr/part020-1201.html. Also see footnote 3 of Appendix B (which isn’t there). The above however deals with occupational radiation dose limits not radiation dose limits for individuals in the public which are lower. My original source was Dan Fahey, **Case Narrative**, p. 22.

28. Anne Gut and Bruno Vitale, **Depleted Uranium, Deadly, Dangerous and Indiscriminate,** Nottingham, U.K.: Spokesman, Russell House, Bulwell Lane, Nottingham NG6 OBT, 2003, p. 33. http://www.sppokesmanbooks.com

29. L.A. Dietz, “Penetrating Radiations from Depleted Uranium”, Aug. 18, 1997, p. 1.

30. Asaf Durakovic, “Medical Effects of Internal Contamination with Uranium”, **Croatian Medical Journal 40**(1) (1999), 49-66, p. 59. Dr. Durakovic also says that a milligram of DU “generates over a billion alpha and beta particles per year”. (p. 60).

31. The name of this scientific group is the Medical Research Council’s Radiation and Genome Stability Unit in Harwell, Oxfordshire and Mount Vernon Hospital in London. See “This Week: Science and Technology News”, **New Scientist**, (U.K.), Jan. 20, 2001.

32. **Ibid**

33. Alexandra Miller et al., “Observation of Radiation-Specific Damage in Human Cells Exposed to Depleted Uranium: Dicentric Frequency and Neoplastic Transformation as Endpoints”, **Radiation Protection Dosimetry 99** (2002), 275-278, p. 275.

34. **Ibid**

35. Sister chromatid exchange (SCE) occurs when there is an exchange of segments between the daughter strands of a duplicated chromosome. It is an aberrant event. See http://cancerweb.ncl.ac.uk/cgi-bin/omd?query=sister+chromatid+exchange.

36. Z. Goldbert and B.E. Lehnert, "Radiation-induced effects in unirradiated cells: A review and implications in cancer", **International Journal of Oncology 21** (2002) 337-349, p. 340.

37. O.V. Belyakov, A.M. Malcolmson et al, "Direct evidence for a bystander effect of ionizing radiation in primary human fibroblasts", **British Journal of Cancer 84** (2001), 674-679.

38. A millimeter (mm) is one thousandth of a meter or 0.039 of an inch.

39. Micronuclei formation can occur during cell division; they are nuclei that are separate from and in addition to the main nucleus of the cell. They can come from fragments of chromosomes. See http://cancerweb.ncl.ac.uk/cgi-bin/omd?query=micronuclei.

40. Belyakov, Malcolmson et al., "Direct evidence for a bystander effect of ionizing radiation…", **Brit. J. Cancer** (2001), pp. 674, 675, and 677. An experiment by Lehnert, and colleagues at Los Alamos showed that at the lowest dose of alpha particles (1.8cGy), the area of Chinese hamster ovary (CHO) fibroblast cells affected, i.e. unirradiated bystander cells "was a spatial distance equivalent to about 350 times the area of a typical CHO cell's nucleus"; in this case the marker for the bystander effect was increased frequency of SCE's. (Goldberg and Lehnert, "Radiation-induced effects in unirradiated cells…", **Int. J. Oncol.** (2002), p. 340). (cGy is a centigray, a measure of radioactivity. It is equivalent to a centirad (one hundredth of a rad.)

41. Goldbert and Lehnert, "Radiation-induced effects in unirradiated cells…".**Int. J. Oncol.** 2002, pp. 337, 342.

42. **Ibid** p. 341. This is an example of a benign bystander effect.

43. **Ibid**

44. **Ibid**, p. 343.

45**. Ibid** p. 340. Reactive oxygen species (ROS) are formed in the body but in excess, ROS may attack DNA, proteins (including enzymes), lipids (or fats, which are constituents of cell membranes); ROS can cause oxidative damage leading to the breaking of DNA strands, enzyme deactivation, damaged cell membranes and even changes in proteins. (A.M. Papas (editor), **Antioxidant Status, Diet, Nutrition and Health**, Boca Raton: CRC Press, 1999, p. 5.) The on-line medical dictionary states that ROS have been linked or implicated in a number of diseases including the development of cancer (http://cancerweb.ncl.ac.uk/cgi-bin/omd?query=reacctive+oxygen+species). The on-line dictionary includes free radicals in their definition**. See footnote 89 for definition of free radical.**

46. Goldberg and Lehnert, "Radiation-induced effects in unirradiated cells….", **Int. J. Oncol.** 2002, p. 341

47. **Ibid** p.342.

48. Alexandra C. Miller et al., "Genomic Instability in human osteoblast cells after exposure to depleted uranium: delayed lethality and micronuclei formation", **Journal of Environmental Radioactivity 64** (2003) 247-259.

49. **Ibid** p. 250

50. Chris Busby with Rosalie Bertell et al., editors, **ECRR 2003 Recommendations of the European Committee on Radiation Risk: Health Effects of Ionizing Radiation Exposure at Low Doses for Radiation Protection Purposes, Regulator's Edition: Brussels, 2003**, Green Audit Press, Castle Cottage, Aberystwyth. SY23 1DZ, United Kingdom, 2003, p. 128.

51. Nuclear Policy Research Institute (NPRI), "Depleted Uranium: Scientific Basis for Assessing Risk, July 2003", p. 18 (http://www.nuclearpolicy.org).

52. **Ibid**, p. 18.

53. A. Miller et al., “Genomic Instability in human osteoblast cells…”**J. Environ. Rad.** (2003)

54. **Ibid**, p. 255

55. Miller et al., “Genomic Instability in human osteoblast cells…”, p. 255; Baverstock, et al., “Radiological Toxicity of DU”, p. 5.

56. Miller et al., “Genomic Instability in human osteoblast cells…”, p. 255.
.
58. NPRI, “DU: Scientific Basis for Assessing Risk”, p. 18.

59. **Ibid**, p. 18.

60. **Ibid**, p. 18.

61. A.C. Miller, in her Presentation on Health and DU at Conference, “Depleted Uranium Weapons: Toxic Contaminant or Necessary Technology?” , Massachusetts Institute of Technology, Mar. 6, 2004. Lead can be carcinogenic too. Miller’s presentation can be found at http://mit.edu/tac/www.

62. A.C. Miller et al, “Transformation of Human Osteoblast Cells to the Tumorigenic Phenotype by Depleted Uranium-Uranyl Chloride”, **Environmental Health Perspectives**, **106** (8) (August 1998), 465-471. The mice used in this experiment were nude mice lacking a thymus gland; the thymus gland is involved in the development and functioning of the immune system and is thought to play a part in natural resistance to cancer.

63. A.C. Miller et al., “Potential Late Health Effects of Depleted Uranium and Tungsten Used in Armor-Piercing Munitions: Comparison of Neoplastic Transformation and Genotoxicity with the known Carcinogen Nickel”, **Military Medicine 167** (2002), 120-122.

64. A free radical is a molecule or chemical species with an unpaired electron; it seeks an electron. For further discussion of free radicals, see footnote 89.

65. A.C. Miller et al., “Depleted uranium-catalyzed oxidative DNA damage: absence of significant alpha particle decay”, **Journal of Inorganic Biochemistry 91** (2002), 246-252, p. 251.

66. Mentioned on website of Dr. Glen Lawrence, http://www.phoenix.liu.edu, “Known Toxic Effects Associated with Uranium”, p. 1.

67. A.C. Miller, “Potential Late Health Effects…”, **Mil. Med.**, p. 120.
Immortalized human cells have the ability to reproduce indefinitely whereas normal human cells eventually stop reproducing and die. (Tabor’s **Cyclopedic Medical Dictionary**, Philadelphia: F.A. Davis Co., 2000, p. 1063).

68. Plasmid DNA is made up of cyclic double stranded DNA molecules which replicate independently of chromosomes. Miller-Keane, **Encyclopedia and Dictionary of Medicine, Nursing and Allied Health**, 5th edition, Philadelphia: W.B. Saunders Co., 1992, p. 1167.

69. Monica Yazzie et al., “Uranyl Acetate Causes DNA Single Strand Breaks In Vitro in the Presence of Ascorbate (Vitamin C)”, **Chem. Res. Toxicol. 16** (2003), 534-530.

70. A.C. Miller et al., “Observation of Radiation-Specific Damage in Human Cells Exposed to Depleted Uranium: Dicentric Frequency and Neoplastic Transformation as Endpoints”, **Radiation Protection Dosimetry 99** (2002), 275-278.

71. **Ibid**

72. A.C. Miller et al., “Effect of the militarily-relevant heavy metals, depleted uranium and heavy metal tungsten-alloy on gene expression in human live carcinoma cells (HepG2)”, **Molecular and Cellular Biochemistry 255** (2004), 247-256, p. 254. The term “stress gene” alludes to a gene that is activated as a result of various environmental stressors which include heat shock, or as a consequence of oxygen or amino acid starvation. (Christine Eymann and Michael Hecker, “Induction of Sigma-B general stress genes by amino acid starvation in a

SpoOH mutant of Bacillus subtilis", **FEMS Microbiology Letters 199** (2001), 221-227, p. 221. In the Miller study, the environmental stressor is DU. **With regard to incorrect folding of proteins**, according to Dr. Susan Lindquist, "roughly half of all disease and most genetic disorders are rooted in protein malfunction. Rogue proteins that no longer hold their shape are to blame for cystic fibrosis and a number of cancers". Ellen Ruppell Shell, "Protein origami is her passion", **The Boston Globe**, May 25, 2004, p. C2. **The Globe** also says that proteins changing shape occurs naturally but on the other hand "when a protein changes shape, it changes function, which in turn generates a new trait in the cell". This trait may be passed on from one generation to the next and beyond. "Misfolded proteins behind many diseases", **The Boston Globe** (same issue)**,** p. C2. Linquist is an expert in this area.

73. Ian Sample and Nic Fleming, "When the dust settles", **The Guardian**, Apr. 17, 2003. p. 2 of article. (http://www.guardian.co.uk/life/feature/story/0,13026,937902,00.htm).

74. **Ibid**, p. 2

75. **Ibid**, p. 2. This is not so clearly spelled out in Miller et al.'s research. It may be discussed further in as yet unpublished research.

76. T.C. Pellmar et al, "Distribution of Uranium in Rats Implanted with Depleted Uranium Pellets", **Toxicological Sciences 49**, (1999), 29-39.

77. David E. McClain et al., "Health Effects of Embedded Depleted Uranium", **Military Medicine 167,** Supplement 1 (2002) 117-119, p. 118. Also T.C. Pellmar et al., "Distribution of Uranium in Rats…", **Toxicological Sciences**, 1999, p. 31.

78. **Ibid**, p. 118.

79. T.C. Pellmar et al., "Electrophysiological Changes in Hippocampal Slices Isolated from Rats Embedded with Depleted Uranium Fragments", **Neurotoxicology** 20(x) - no page numbers (Oct. 20, 1999), 785-792. Also see **Science News 160** Dec. 8, 2001, p. 356.

80. T.C. Pellmar, "Distribution of Uranium in Rats…", **Toxicological Sciences** (1999).

81. David McClain, "Health Effects of Depleted Uranium Penetrators", Project Briefing. Armed Forces Radiobiology Research Institute (AFRRI); Bethesda, MD. Presented July 13, 1999 to the Presidential Special Oversight Board, Washington, DC (Cited in Fahey, "Don't Look, Don't Find", p. 40)

82. David E. McClain et al, "Biological effects of embedded depleted uranium (DU): Summary of Armed Forces Radiobiology Research Institute", **The Science of the Total Environment 274**, (July 2, 2001), 115-118.

83. John F. Kalinich et al, "Depleted Uranium-uranyl chloride induces apoptosis in mouse J774 macrophages", **Toxicology 170** (2003), 105-114.

84. Fletcher F. Hahn et al., "Implanted Depleted Uranium Fragments Cause Soft Tissue Sarcomas in the Muscles of Rats", **Environmental Health Perspectives 110** (1), (2002), 51-59.

85. Mohamed B. Abou-Donia et al,, "Uranyl acetate-induced sensorimotor deficit and increased nitric oxide generation in the central nervous system in rats", **Pharmacology, Biochemistry and Behavior 72** (2002), 881-890.

86. R.E.J. Mitchel and S. Sunder, "Depleted Uranium Dust from Fired Munitions: Physical, Chemical, and Biological Properties", **Health Physics 87** (2004) pp. 57-67. The researchers used dust from shells containing DU that had been fired and had hit an "armored target". The dust was collected and used in the experiment (particle size of the DU dust used was under 300 micrometers with about 14 percent being under 10 micrometers). A micrometer is one millionth of a meter and is equivalent to 1 micron. Another study by this group showed that natural uranium ore dust inhaled by rats during half their life-span led to the deposition of uranium in their bones with a decrease in concentration of total uranium in bone gradually after inhalation of uranium stopped. However concentration of Thorium (also a daughter in the DU decay series and a constituent of uranium ore dust) did not decline over time. T. Dewit et al. (including R.E.J. Mitchel), "Uranium and Uranium Decay Series Radionuclide Dynamics in Bone of Rats Following Chronic Uranium Ore Dust Inhalation", **Health Physics 81**(5) (2001), 502-513.

87. **Ibid** p. 59. The diameter of DU particles deposited into the lung was under 50 micrometers while the diameter of DU particle injected into the leg ranged from 50-300 micrometers.

88. Nuclear Information & Resource Service, Radiation Basics http://www.nirs.org/factsheets/WhatisRadiation.htm

89. Anna Gyorgy et al., "No Nukes:Everyone's Guide to Nuclear Power", Boston: South End Press, 1979. Also see David E. McClain, "Depleted Uranium: A Radiochemical Toxicant", **Military Medicine, 167**, Suppl. 1:125 (2002), p. 126. And, Dr. Thomas Fasy in a presentation at the NPRI conference on Health Effects of DU, at the New York Academy of Medicine, June 14, 2003, said that free radicals especially hydroxyl ions are formed by ionizing radicals**. A definition of "free radical":** Free radicals are molecules with an odd number of electrons. A free radical is "highly reactive" as the unpaired electron searches for another free electron, to pair with. Free radicals occur in normal body metabolism but, "Overwhelming evidence indicates that oxidative stress (when there are too many free radicals which aren't neutralized) can lead to cell and tissue injury…they are involved in both human health and aging". E. Cadenas and L. Packer, **Understanding the Process of Aging: The Roles of Mitochondria, Free Radicals, and Antioxidants"**, New York: Marcel Dekker, Inc., 1999, p. iii. Radiation can make free radicals out of water molecules which generate peroxides that injure cells and their membranes, which can in turn create changes allowing invasion of cells and their membranes by bacteria and viruses. Free radicals can also indirectly lead to "the release of an inflammation cascade" etc. which may lead to chronic problems in addition to killing cells or making "subtle changes" in the cellular physiology of surviving cells. (Rosalie Bertell, "Host Response to Depleted Uranium", Nov. 2000, 1-7, p.4. http://www.iicph.org/docs/host_response_to_du.htm.

90. Mohamed Abou-Donia, "Uranyl Acetate-induced sensorimotor deficit…", **Pharm. Biochem. and Behavior** (2002), p. 888.

91. Dr. Karl Morgan, the father of Health Physics, said, "There is no safe level of exposure and there is no dose of (ionizing) radiation so low that the risk of a malignancy is zero". (NIRS, "Radiation Basics"). Dr. Alice Stewart agreed, "Any dose of radiation, however small, is going to have an effect on the body – *any* dose has the potential of damaging a cell". Quoted in Gayle Greene, **The Woman Who Knew Too Much: Alice Stewart and the Secrets of Radiation**, Ann Arbor: University of Michigan Press, 1999, p. 124. Dr. John Gofman also said that there is no safe level of exposure, that low dose radiation exposures carry a greater cancer risk than high-or moderate-dose radiation. (G.T. Davis, M.D. and Bruwer, Andre J., M.D., "Book Reviews", **The New England Journal of Medicine 324** (7), (Feb. 14, 1999). One of the books reviewed is by John Gofman, **Radiation-Induced Cancer From Low-Dose Exposure: An Independent Analysis** published by the San Francisco Committee for Nuclear Responsibility Book Division, 1990. See first page of the review regarding Gofman's findings. Gofman's research is also discussed in **CREW News**, **1** (2), (Dec. 1993). CREW's website is http://www.crewconcord.org.

92. Dr. Rosalie Bertell is a biometrician, i.e. a specialist in the mathematics applied to biomedical problems, who is qualified to design and evaluate epidemiological research. She has worked in the area of the health effects of ionizing radiation, particularly at low dose and slow dose rates, for 30 years; she has published books and professional papers in this area.

93. Rosalie Bertell, "Letter to Judy Scotnicki", Oct. 2002, p. 1. (available through Gretel Munroe).

94. Ibid, p. 1.

95. Rosalie Bertell gives 2 years as the length of time insoluble ceramic DU stays in the lungs, see "Depleted Uranium as a Weapon of War" Brief submitted by Dr. Rosalie Bertell to the DU Human Rights Tribunal, Aug. 1999. Bertell states that RAND did not fully discuss insoluble DU which remains in the lungs and tissues of the body for a long time, and that this is a major difference between the DU encountered in the Gulf War and uranium dust found in the milling or mining of uranium. Bertell's article is available at http://www.bandepleteduranium.org

96. A British scientist at a meeting in 2001 on depleted uranium in Kosovo gave 20 years as retention time for DU particles in the deep lung. This was reported in Dan Fahey, "Meeting Summary: Expert Meeting on 'Depleted Uranium in Kosovo: Radiation Protection, Public Health and Environmental Aspects", Bad Honnef, Germany, June 19-22, 2001, p. 2. (Rosalie Bertell gives the half-life of inhaled or ingested DU as 10 years, based on Dr. Hari Sharma's data, (which would agree with the above. (Dr. Rosalie Bertell, "The Use of DU Weapons in War", Submitted to the Hiroshima World Tribunal on Iraq, 10-11 October 2004, p. 14.

97. David J. Brenner, "The Biological Effects of Very Low Doses of Alpha Particles", presentation at conference, "Health Effects of Depleted Uranium", New York Academy of Medicine sponsored by the Nuclear Policy Research Institute (NPRI), June 14, 2003. See http://www.nuclearpolicy.org for presentation.

98. Anne Gut and Bruno Vitale, **Depleted Uranium,** p. 33.

99. Rosalie Bertell, "Depleted Uranium as a Weapon of War: Brief submitted by Dr Rosalie Bertell", **DU Human Rights Tribunal**, Aug. 1999, p. 2. Also see Dr. Rosalie Bertell, "The Use of DU Weapons in War", Submitted to the Hiroshima World Tribunal on Iraq, 10-11 October 2004, 1-28, p. 12.

100. David Brenner, "The Biological Effects of Very Low Doses of Alpha Particles", presentation at NPRI Conference, "Health Effects of DU", New York Academy of Medicine, 2003.

101. Rosalie Bertell, "Letter to Judy Scotnicki", Oct. 2002, p. 2.

102. Rosalie Bertell, "Host Response to Depleted Uranium", Nov. 2000, The International Institute of Concern for Public Health (IICPH), http://www.iicph.org/docs/host_response_to_du.htm., p. 2.

103. **Ibid**, p. 2.

104. **Ibid**, p. 3 and Bertell, "Letter to Judy Scotnicki", p. 2

105. **Health Risks of Low-Level Ionizing Radiation in Adults and Children: Overview of Epidemiological Studies**, The Childhood Cancer Research Institute, Worcester, MA, May 1999, p. vi.

106. **Ibid**, p, vi.

107. Rosalie Bertell, "Nine-Legged Frogs, Gulf War Syndrome and Chernobyl Studies", **Metal of Dishonor,** John Catalinotto and Sara Founders, editors, New York: International Action Center, 1999, p. 130-131.

108. Rosalie Bertell, "Host Response…", IICPH, p. 3.

109. Dr. Hari Sharma in conversation with the author said that the field of radiation biology was in its infancy (personal communication, Sept. 20, 2000). Also, in his paper, "Report on Depleted Uranium Exposures", he states that biological effects of low-level long-term radiation exposure are not "fully understood", p. 2; L.A. Dietz, "Penetrating Radiations from Depleted Uranium" says more or less the same thing. Dr. Rosalie Bertell, **Metal of Dishonor**, 127-132. Steve Wing et al. (Wing et al., "Mortality Among Workers at Oak Ridge National Laboratory", **Journal of the American Medical Association 265(11):** Mar. 20, 1991, 1397-1402) state that less is known about the effects of relatively long-term low-level (low-dose) ionizing radiation on humans as compared to "acute" high doses. (p.1400). G.M. Kendall et al. state that "There is little direct evidence of the effects of lower doses and dose rates typical of occupational exposures" (p.220); (Kendall et al., "Mortality and occupational exposure to radiation: first analysis of the National Registry for Radiation Workers", **British Medical Journal 304**: Jan. 25, 1992, 220-225.) Also Asaf Durakovic, **Croatian Medical Journal**, 1999, p.60.

110. H. Schroeder et al., "Chromosome Aberration Analysis in Peripheral Lymphocytes of Gulf War and Balkans War Veterans", **Radiation Protection Dosimetry 103** (3) (2003), 211-219. The laboratory control group was composed of 40 healthy volunteers aged 17-57 (p. 213).

111. H. Schroeder, presentation at the "World Uranium Weapons Conference 2003", Hamburg, Germany, Oct. 16-19, 2002.

112. Dr. Michael Kilpatrick, a physician with the U.S. Department of Defense, Health Affairs, said at an MIT conference, that the purpose of the Baltimore VA DU Program was the follow-up of veterans with embedded shrapnel ("Depleted Uranium Weapons: Toxic Contaminant or Necessary Technology?", The Massachusetts Institute of Technology, Mar. 6, 2004,(see http://mit.edu/tac/www). Dr. Melissa McDiarmid stated in "Health Effects of Depleted Uranium on Exposed Gulf War Veterans: A 10-Year Follow Up", (**J. of Toxicol. & Environ. Health**, 2004), that the program, established by the VA and the Department of Defense, was established for the follow up for veterans "involved in the DU friendly fire incidents" (p. 278). The original protocol for the establishment of the program was '"the clinical follow-up of Desert Storm patients with known or suspected imbedded depleted uranium (DU) fragments, DU contaminated wounds or significant amounts of inhaled DU.'"

(The protocol also established a research program to study the toxicological and radiological effects of DU. (Source: Dan Fahey, **Case Narrative**, Sept. 1998, p. 56 (Fahey quotes the protocol setting up the program).

113. Dan Fahey, "The Use of Depleted Uranium in the 2003 Iraq War: An Initial Assessment of Information and Policies", June 24, 2003, pp. 3, 10, has a brief discussion of the Baltimore DU Program.

114. Dan Fahey, "Unresolved Issues Regarding Depleted Uranium And the Health of U.S. Veterans of Operation Iraqi Freedom and Operation Enduring Freedom", Mar. 24, 2004, pp. 5 (regarding the 3 percent of the number of Gulf War veterans who were exposed to DU during the Gulf War in 1991), p. 13.

115. Melissa McDiarmid et al., "Health Effects of Depleted Uranium on Exposed Gulf War Veterans", **Environmental Research 82** (2) (Feb. 2000) 168-180, p. 178, (Also see Fahey, "Don't Look, Don't Find", p. 39).

116. Melissa McDiarmid, "Health Effects of Depleted Uranium…" **Environmental Research** (2000) p. 175 (Also see Fahey, "Don't Look, Don't Find", pp 39-40). Prolactin is a hormone responsible for building breast tissue and for the stimulation of milk production.

117. Melissa McDiarmid et al., "Surveillance of DU exposed Gulf War veterans' health effects observed in an enlarged 'friendly fire cohort', **Journal of Occupational and Environmental Medicine 43** (2001), pp. 991-1000.

118. Melissa McDiarmid, "Health Effects of Depleted Uranium…" **Environmental Research** (2000), p. 172.

119. Melissa McDiarmid et al., "Health Effects of Depleted Uranium on Exposed Gulf War Veterans: A 10-Year Follow-Up", **Journal of Toxicology and Environmental Health, Part A, 67** (2004), 277-298.

120. **Ibid**, p 278

121. **Ibid**, p. 286

122. **Ibid**,, p. 292

123. **Ibid**, 280. A microgram is one millionth of a gram. The researchers used grams creatinine because it allows different samples to be compared to each other. It has to do with the variability in urine samples. The variability can be adjusted for the concentration of urine based on the levels of creatinine in the urine. Grams creatinine is often used in metabolic studies. (See p. 705 of L.M. May et al. "Military Deployment Human Exposure Assessment: Urine Total and Isotopic Uranium Sampling Results", **Journal of Toxicology and Environmental Health, Part A 67** (2004)), pp. 697-714.

124. McDiarmid et al., "Health Effects of DU: A 10-Year Follow Up", **Journal of Toxicology and Environmental Health** (2004) p.285.

125. **Ibid**, p. 291.

126. **Ibid**, p .292.

127. **Ibid** p. 294.

128. **Ibid** p. 291

129. **Ibid** p.293. McDiarmid et al. did not specify what kind of chromosomal abnormality was tested for; they alluded only to "chromosomal aberrations"(see p. 289).

130. **Ibid**, p. 294.

131. **Ibid**, p. 290.

132. **Ibid**, p. 294.

133. Robert Berkow, MD, Editor-in-Chief, **Merck Manual of Medical Information, Home Edition**, (Chapter 145, "Thyroid Gland Disorders"),Whitehouse Station, N.J., Merck Research Labs., 1997, p. 705.

134. Melissa McDiarmid et al., "Health Effects of Depleted Uranium on Exposed Gulf War Veterans: A 10-Year Follow-Up", **J. of Toxicol. and Environmental Health,** (2004), p. 287.

135. **Ibid**, p. 292.

136. **Ibid**, p. 291.

137. **Ibid**, p. 287.

138. **Ibid**, p. 281.

139. The formula for progressive sperm motility (percent) is (a/dx100 where a =steady movement of sperm in one particular direction; b=sperm moving in random directions (including moving in place); c=sperm showing no discernible movement. d=a+b+c. A low percent means a high b or c or both. Normal progressive sperm motility is over 40 percent. Equivocal is 35-40 percent and abnormal is under 35 percent with sperm motility being counted within 60 minutes of ejaculation. If it is under 50 percent , abnormality may be suspected. (R.S. Jeyendran, **Protocols for Semen Analysis in Clinical Diagnosis**, New York: The Parthenon Publishing Group, 2003 p. 32.

140. **Ibid**, p. 288.

141. **Ibid**, p. 293.

142. Dan Fahey, "The Use of Depleted Uranium in the 2003 Iraq War…" (2003), p.10

143. R.H. Gwiazda et al., "Detection of Depleted Uranium in Urine of Veterans from the 1991 Gulf War", **Health Physics 86** (1), (Jan. 2004), 12-18. They x-rayed veterans to make sure that they had embedded shrapnel. Dr. Melissa McDiarmid was one of the researchers in this study.

144. **Ibid**, p. 15.

145. **Ibid**, p. 17.

146. **Ibid**, p. 17. The study cited, Bill G. Ting et al., "Uranium and Thorium in Urine of United States Residents: Reference Range Concentrations", **Environmental Research Studies, Section A 81** (1999), 45-51, p. 49**.** NHANES III (National Health and Nutrition Examination Survey) collected data on the U.S. population for 1988-1994.

147. Bill G. Ting, "Uranium and Thorium in Urine of U.S. Residents…", **Environ. Res. Studies** (1999), p. 49. A nanogram is one billionth of a gram. A liter is 1.06 quarts.

148. M. McDiarmid et al., "Biologic Monitoring for Urinary Uranium in Gulf War I Veterans", **Health Physics 87**(1) (July 2004) pp. 51-56.

149. **Ibid** p. 54

150. **Ibid** p. 53

151. **Ibid** p. 54

152. **Ibid**

153. **Ibid** pp. 53-54. The 50th percentile for the entire DU group was 0.010 micrograms Ug-1 creatinine while the 50th percentile for the NHANES participants was 0.006 micrograms Ug-1 creatinine (pp. 53-54). (U stands for Uranium, g for gram). The NHANES survey collected urine uranium levels from men and women 20 years old or older, in 1999-2000. This NHANES data, which was used by McDiarmid et al., was published in 2003.

154. Dr. Helen Caldicott, **The New Nuclear Danger: George W. Bush's Military-Industrial Complex**, New York: The New Press, 2002, p. 160.

155. Col. J. Edgar Wakayama, "Depleted Uranium (DU) Munitions", Conference Presentation, Department of Defense, Aug. 2002, p. 20.

156. **Ibid**, p. 20.

157. Transcript prepared by the Federal News Service, Inc., Washington D.C. (202-347-1400).

158. Dan Fahey, "Unresolved Issues Regarding Depleted Uranium And the Health of U.S. Veterans of Operation Iraqi Freedom and Operation Enduring Freedom", Mar. 24, 2004, 1-16, p. 8.

159. **Ibid**, p. 9.

160. Rosalie Bertell, "Letter to Judy Scotnicki", Oct. 2002, p. 3. McDiarmid et al did actually mention this case of Hodgkins disease in their article in **J. of Occup. & Environ. Med.** but added in the scientific paper that both the veteran with the disease and his doctor did not believe the Hodgkins lymphoma to be related to DU exposure. (McDiarmid, "Surveillance of Depleted Uranium Exposed Gulf War Veterans: Health Effects Observed in an Enlarged 'Friendly Fire' Cohort", **J. of Occup. & Environ. Med. 43** (Dec. 2001), p. 998. The veteran did believe his Hodgkins Disease was related to DU exposure. McDiarmid noted that he was "a newly identified member of the low urine uranium group" (p. 998). The veteran's Hodgkins lymphoma had been diagnosed 4 years after his service in the Gulf War. Also, regarding promotion of cancer, see Dr. Rosalie Bertell, "The Use of DU Weapons in War", Submitted to the Hiroshima World Tribunal on Iraq, p. 16. (Regarding the stance of the nuclear industry, Dr. Bertell has mentioned it in various communications, her "Letter to Judy Scotnicki" being one of them).

161. Dan Fahey, "Depleted Legitimacy: The U.S. Study of Gulf War Veterans Exposed to Depleted Uranium", National Gulf War Resource Center Conference, Atlanta, GA, May 4, 2002, p. 7. Also see Fahey, **Case Narrative**, 1998, pp. 103-104, 107, 109-112, 140, 150, 274-275.

162. Dan Fahey, **Case Narrative**, p. 130.

163. Phil Gardner, "Casualties increase from use of depleted uranium", **World Socialist Web Site** (http://www.swsw.org), Sept. 8, 1999, interview with Dr. Asaf Durakovic, p. 2. Also see "History of UMRC and Gulf War Syndrome" on the Uranium Medical Research Center website (http://www.umrc.net/umrcResearch.asp.). Dr. Durakovic is head of the UMRC. In the interview with Phil Gardner, Dr. Durakovic said two of his patients had died of lung cancer. Dr. Doug Rokke, a health physicist, and head of the DU Assessment team that supervised the work of the veterans cleaning up destroyed (with DU contamination) equipment in Saudi Arabia also became ill as did other members of his team. He has stated that their illnesses were connected to exposure to DU. See also Dan Fahey, **Case Narrative**, p. 130 where there is mention of the veterans who worked on clean-up of DU-contaminated tanks and vehicles and their being under treatment with Durakovic

164. "Air Force gathering Iraq environmental data from Nellis troops", Associated Press, July 7, 2003, p.1.

165. Christopher T. Winrow et al., "Loss of neuropathy target esterase in mice links organophosphate exposure to hyperactivity", **Nature Genetics 33** (Apr. 2003), 477-485. For a less technical discussion of this research, see "Genetic Link Found for Pesticides, ADHD, Gulf War Syndrome" , **Environmental News Service**, Mar. 17, 2003.

166. Christopher Winrow, "Loss of neuropathy target esterase in mice….".**Nature Genetics**, 2003, pp. 482-483.

167. A. Abdel-Rahman et al., "Stress and Combined Exposure to Low Doses of Pyridostigmine Bromide, DEET, and Permethrin Produce Neurochemical and Neuropathological Alterations in Cerebral Cortex, Hippocampus, and Cerebellum", **Journal of Toxicology and Environmental Health, Part A 67** (2004), 163-192. For a more readable summary see "Mix of Chemicals Plus Stress Damages Brain, Liver in Animals and Likely in Humans", http://dukemednews.org/news/article.php?id=7433. (Feb. 26, 2004).

168. A. Abdel-Rahman, "Stress and Combined Exposure to Low Doses of Pyridostigmine Bromide, DEET, and Permethrin…", **J. Toxicol. And Environ. Health,** (2004), p. 187.

169. **Ibid**, p. 188.

170. Daniel Clauw, "The health consequences of the first Gulf War: The lessons are general (and for many patients) rather than specific to that war", **British Medical Journal (BMJ) 327** (2003), pp. 1357-1358.

171. **Ibid**, p. 1357.

172. M. Hotopf et al., “Gulf War illness – better, worse, or just the same?”, **BMJ 327**: 1370-1372, p. 1371.

173. **Ibid**, p. 1372.

174. Rebecca Simmons et al., “Self-reported ill health in male UK Gulf War veterans: a retrospective cohort study”, **BMC Public Health 2004, 4:27**, at http://biomedcentral.com/1471-2458/4/27. Specifically, the study found that 61% of Gulf War Veterans (GWV) reported at least one new medical symptom or disease since 1990 compared to 37% of veterans not deployed to the Gulf (NGWV). Gulf War veterans also reported higher numbers of symptoms, with the strongest associations for mood swings, memory loss/lack of concentration, night sweats, general fatigue, and sexual dysfunction.

175. Gary J. Macfarlane et al., “Incidence of cancer among UK Gulf War veterans: cohort study”, **BMJ 327** (Dec. 13, 2003), 1373-1375. Information about lymphoid and haematopoietic cancers is in Table 2, p. 1374. A longer version of this study, by the same title and same authors is to be found on bmj.com but although mentioned in the on-line article, the tables are not included.

176. **Ibid**, p. 1374.

177. **Ibid**, p. 1374.

178. **Ibid**, see Table 2, p. 1374.

179. **Ibid**, p. 1375..

180. **Ibid**, p. 1374.

181. **ECRR 2003 Recommendations of the European Committee on Radiation Risk**,, pp. 54, 121. Also Rosalie Bertell, “Host Response….”, IICHP, p. 4.

182. Rosalie Bertell, “Host Response…”, p. 6.

183. Katsumi Furitsu, MD et al., “The Parallel Radiation Injuries of the Atomic-bomb Victims in Hiroshima and Nagasaki after 50 Years and the Chernobyl Victims After 10 Years”, **International Perspectives in Public Health 13**, (2002), 19-32, p. 22,

184. **Ibid**, p. 22.

185. The study was done by Malko (1997) as reported in **ECRR 2003 Recommendations of the European Committee on Radiation Risk** (2003), pp. 125-126.

186. **ECRR 2003 Recommendations of the European Committee on Radiation Risk**, p. 126.

187. Patricia Horan et al., “The Quantitative Analysis of Depleted Uranium Isotopes in British, Canadian, and U.S. Gulf War Veterans”, **Military Medicine 167**(8), (2002), 620-627.

188. Dr. Hari Sharma, “Investigations of Environmental Impacts from the Deployment of Depleted Uranium-Based Munitions, Part I, Report and Tables, Part II Appendices, December 2003”, p. 16 available through the Military Toxics Project, P.O. Box 558, Lewiston, ME 04243 or http://www.miltoxproj.org.

189. Presentation of Dr. Hari Sharma at conference, “Health Effects of Depleted Uranium”, New York Academy of Medicine, Nuclear Policy Research Institute, June 14, 2003.

190. Sharma, “Investigations of Environmental Impacts…” Part I, Table VI, following p. 26.

191. **Ibid** p. iii

192. **Ibid** p. 20

193. **Ibid** p. iv

194. **Ibid.** Dr Sharma has stated, "uranium excreted through urine is the soluble kind. Soluble uranium compounds are aided by the bicarbonate ions to form good complexes. They pass through body compartments readily. There is one point which has not been recognized, namely, ceramic dioxide of uranium is highly insoluble in body fluids. It is stored in the lungs for a long period. It may go to the thoracic lymph nodes and be stored there". He adds that the U.S. and U.K. Department (Ministry) of Defense have not taken this into consideration. (E-mail from Dr. Sharma to Gretel Munroe, September 23, 2004).

195. **Ibid,** p. 18. Lymph nodes are a vital part of the immune system. They are a main supplier of lymphocytes of peripheral blood. They are involved (through special cells), in the trapping and removing of toxins, bacteria and cancer cells. (Miller-Keane, **Encyclopedia and Dictionary of Medicine…"** p. 867; On-line medical dictionary, http://cancerweb.ncl.ac.uk/cgi-bin/omd?query=lymph+nodes.

196. Sharma, "Investigations of Environmental Impacts…", Part II, Appendices p. 3

197. "As the Danger of Depleted Uranium is Confirmed", Campaign Against Depleted Uranium, info@cadu.org.uk, Feb. 10, 2004 p. 1; Martin Williams, "First award for depleted uranium poisoning claim", **The Herald** (U.K.), Feb. 4, 2004, pp. 1-2.

198. Akira Tashiro, **Discounted Casualties**, pp.86-87. (Interview with Kenneth Duncan).

199. **Ibid**, pp. 82-83. (Interview with Ray Bristow. Ray Bristow was too ill to come to the World Uranium Weapons Conference in Hamburg, Germany in Oct. 2003).

200. **Ibid**, pp. 88-89. (Interview with Paul Connolly).

201. Dr. Thomas Fasy in his talk, "The Recent Epidemic of Pediatric Malignancies and Congenital Malformations in Southern Iraq", at the NPRI conference on "Health Effects of DU" at the New York Academy of Medicine, June 14, 2003, mentioned that the Bradford Hill thesis of biological plausibility pertains to these studies as per the issue of tobacco, i.e. does smoking cause cancer. See "DU: Scientific Basis for Assessing Risk: July 2003", NPRI, p.19 for Fasy's brief discussion of components of epidemiological studies. Dr. Fasy is a physician in the Department of Pathology at the Mt. Sinai School of Medicine in New York City. See http://www.nuclearpolicy.org for his presentation.

202. In his presentation at the MIT conference on March 6, 2004, Dr. Fasy mentioned the 53 cases of leukemia in children under 5 in the Basra area in 2002, (an increase of 12 cases over the number of cases in 2001). This was new information not covered in his presentation at the NPRI conference on Health Effects of DU, at the New York Academy of Medicine in June 2003.

203. Children with bone tumors are treated at an orthopedic institute in Basra and should also be included in total numbers.

204. Dr. Thomas Fasy, "The recent epidemic of pediatric malignancies…", NPRI conference on Health Effects of DU at the New York Academy of Medicine, June 2003.

205. Elizabeth Neuffer, "Iraqis trace surge in cancer to U.S. bombings" , **The Boston Globe**, Jan. 26, 2003, p. A11.

206. Han Kang et al., "Pregnancy Outcomes Among U.S. Gulf War Veterans: A Population-Based Survey of 30,000 Veterans", **Annals of Epidemiology 11**(7), (Oct. 2001), pp. 504-511.

207. **Ibid**, p 507. The authors used the odd ratio to adjust the rates for cases of "likely" birth defects. The odd ratio (OR) is an estimate of relative risk when the exposure group is approximately 5 percent of the population – which it was in this case, for Gulf War veterans. The adjusted OR for males in was 1.94, with confidence intervals (CI) at the 95 percent level being 1.37-2.74. For females, the OR was 2.97 with CI at the 95 percent level being 1.47-5.99. The CI gives an idea of the range of values, with a large CI giving less precision to the mean value. (My source on OR and CI is Elaine R. Monson, editor, Research: Successful Approaches, The American Dietetic Association, Chicago, 1992, pp. 134-135, 356 (OR) and CI, p. 353). The discussion of cases of "likely" birth defects is taken from Table

4, “Adverse outcomes among index liveborn infants by Gulf deployment and gender of veterans, Kang et al., “Pregnancy Outcomes Among U.S. Gulf War Veterans….”, p. 508.

208. **Ibid**, p. 507. However, female Gulf War veterans reported more miscarriages than the men did, but the difference was not statistical. That there was a statistical difference between male Gulf War and non-Gulf War veterans in number of miscarriages may have been due to the fact that the numbers reported by the latter group was lower than the expected rate which ranged from 10-15 percent. In this study, the control rate was just 7.7 percent. (Kang et al, “ Pregnancy Outcomes Among U.S. Gulf War Veterans…”,p. 509).

209. **Ibid**, p. 509. The researchers said that the British Gulf War veterans had, during their service in the Gulf, been exposed to “many chemical, biological and physical agents suspected of being reproductive toxins”.

210. Pat Doyle et al., “Miscarriage, stillbirth and congenital malformation in the offspring of UK veterans of the first Gulf War”, **International Journal of Epidemiology 33**, (2004), 74-86. See also Nic Flemming, “Gulf Troops' babies are 50pc more vulnerable”, **The Telegraph** (U.K.), Mar. 24, 2004.

211. Pat Doyle, “Miscarriage, stillbirth and congenital malformation in the offspring of UK veterans of the first Gulf War”, **Int. J. Epidemiology** (2004), p. 79.

212. **Ibid**, p. 84.

213. **Ibid**, pp. 79, 84.

214. **Ibid**, p. 79.

215. **Ibid**

216. United Nations Environmental Programme (UNEP), **Depleted Uranium in Bosnia and Herzegovina, Post-Conflict Environmental Assessment,** Revised Edition: May 2003. UNEP, **Depleted Uranium in Serbia and Montenegro, Post-Conflict Environmental Assessment in the Federal Republic of Yugoslavia 2002.** UNEP, **Depleted Uranium in Kosovo, Post-Conflict Environmental Assessment, 2001.** (All these reports can be found on the UNEP website, http://www.unep.org).

217. Jan Olof Snihs, “Depleted Uranium in the Balkan States Environment. Experiences and Results of UNEP's Special Studies in 1999-2002", as presented at NPRI's conference on Health Effects of DU at the New York Academy of Medicine, June 14, 2003. See http://www.nuclearpolicy.org for presentation.

218. **Ibid**, p.22.

219. **Ibid**, p. 21. A centimeter is .4 of an inch.

220. UNEP, **Depleted Uranium in Bosnia and Herzegovina**. p. 49.

221. **Ibid**, pp. 69-70.

222. Anne Gut and Bruno Vitale, **Depleted Uranium**, pp. 100-101. The British Defense Ministry sent a team to Kosovo because British veterans were concerned about ill effects of DU.

223. **Ibid**, p. 101. A meter is 1.1 of a yard.

224. **Ibid**

225. Jan Snihs, “Depleted Uranium in the Balkan States”, p.22, UNEP, **Depleted Uranium in Bosnia and Herzegovina**, p. 176.

226. Jan Snihs, “Depleted Uranium in the Balkan States”, p. 21.

227. UNEP, **Depleted Uranium in Bosnia and Herzegovina**, p. 217.

228. **Ibid**, p. 218.

229. **Ibid**, p. 50.

230. **Ibid**, pp. 59-60.

231. Sources: (all UNEP): **Depleted Uranium in Kosovo** p. 155; **Depleted Uranium in Serbia and Montenegro,** pp. 140, 151; **Depleted Uranium in Bosnia and Herzegovina** p. 198. There are also tables of findings in each volume.

232. UNEP**: Depleted Uranium in Bosnia and Herzegovina**, p. 51.

233. UNEP in Bosnia and Herzegovina stated that "the concentration was about 50 times normal value for uranium". However they do not give a value for a normal uranium level. **Ibid**, p. 95

234. UNEP, **Depleted Uranium in Bosnia and Herzegovina**, p. 51.

235. **Ibid**, pp. 16-17, 216-217.

236. **Media Room Press Release**, Mar. 15, 2001, "United Nations Environment Programme Recommends Precautionary Action Regarding Depleted Uranium in Kosovo", (it was on the internet in 2001), p. 1; Press Releases March 2002, United Nations Environment Programme, "UNEP Confirms Low-level DU Contamination", p. 1; Post Conflict Assessment Unit, "Bosnia and Herzegovina: A United Nations Environmental Programme Post-Conflict Environmental Assessment on Depleted Uranium", Jan. 8, 2004, p. 1. (http://postconflict.unep.ch/actbihdu.htm).

237. UNEP, **Depleted Uranium in Serbia and Montenegro**, p. 35.

238. UNEP, **Depleted Uranium in Bosnia and Herzegovina**, pp. 59-61.

239. **Ibid**, p. 187. Also Gut and Vitale state that UNEP is not sophisticated in their knowledge about how uranium acts in the environment. They say that more studies are needed on the extent to which a hydrated uranium oxide like schoepite (which is fairly common) is soluble; more studies are also needed having to do with the connection between contaminated water and soil and the food chain and how this relates to human health. (Anne Gut and Bruno Vitale, **Depleted Uranium**, p. 90).

240. UNEP, **Depleted Uranium in Bosnia and Herzegovina**, p. 258.

241. **Ibid**, pp. 252-259.

242. Dr. Helen Caldicott in **The New Nuclear Danger** gives the latency period for leukemia as 2-10 years. (p. 160). Sue Roff, a radiation researcher at the Center for Medical Education at the University of Dundee, Scotland, stated that in her experience, the greatest period of risk for developing leukemia is in the first 2-5 year following exposure. G.M. Kendall et al. in "Mortality and occupational exposure to radiation: first analysis of the National Registry for Radiation Workers", **BMJ 304**, (Jan. 25, 1992), 220-225, state on p. 223, "To allow for latency, doses were lagged by 10 years (**except** for leukemia, for which a lag of two years was used)". Steve Wing et al. cited the National Academy of Sciences – **BEIR V** (see Appendix **B)** as their source for the statement that there is a "considerably shorter interval" between radiation exposure and death for leukemia as compared with solid tumors (p. 1401). Wing et al. made this statement in "Mortality Among Workers at Oak Ridge National Laboratory: Evidence of Radiation Effects in Follow-up Through 1984", **Journal of the American Medical Association 265**, Mar. 20, 1991: 1397-1402.

243. Maggie Fox, "Study finds no ills from depleted uranium", **The Boston Globe**, Jan. 27, 2001.

244. Asaf Durakovic, "Medical Effects of Internal Contamination with Uranium", **Croatian Medical Journal 40**(1), 1999, 49-66, p. 55.

245. David Brenner, "Do low dose-rate bystander effects influence domestic radon risks?"**, Int. Radiat. Biol. 78**(7), 593-604.

246. Rosalie Bertell, "Host Response…", IICHP, p. 3.

247. **Ibid**, p. 3.

248. Chris Busby, “Lymphoma Incidence in Italian Military Personnel Involved in Operations in Bosnia and Kosovo”, Unpublished manuscript. Author may be contacted through Green Audit, Castle Cottage, Aberystwyth, SY23 1DZ, U.K.

249. The title of the Italian study is “Seconda Relazione Della Commissione Institiuta Dal Ministro Della Difesa Sull’ Incidenza di Neoplasie tra 1 Militari impiegati in Bosnia 28 Maggio 2001.”

250. Busby says the value of 7.9 is due to the fact that the number of lymphomas is 7.9 times what would be expected in a healthy population, a population that soldiers belonged to. (Chris Busby, “Lymphoma Incidence in Italian Military Personnel…” , p. 8.

251. **Ibid** p. 6

252. P. Gustavsson et al., “Incidence of cancer among Swedish military and civil personnel involved in UN missions in the Balkans 1989-99”. **Occupational Environmental Medicine 16** (2004), 171-173.

253**.** See J.D. Knoke, “Testicular cancer and the Persian Gulf War”, **Epidemiology 9** (1998), 648-53. This group of researchers found an increase in testicular cancer in the second half of 1991 in soldiers who served in the Gulf War over a non-deployed cohort. Within four years however the difference in incidence of testicular cancer between deployed and non-deployed soldiers had vanished. The study was large but did not include veterans who left service after the end of the Gulf war.

254. The Royal Society, **The Health Effects of Depleted Uranium Munitions, Summary. March 2002**, p. 3. Their website is http://www.royalsoc.ac.uk.

255. **Ibid**, p. 4.

256. **Ibid**, p. 3.

257. **Ibid**, p. 3

258. **Ibid**

259. **Ibid**

260. **Ibid**, p. 6

261. **Ibid**, p. 5

262. Baverstock et al. “Radiological Toxicity of DU” p. 11; F. Bou-Rabee, “Estimating the Concentration of Uranium in Some Environmental Samples in Kuwait After the 1991 Gulf War”, **Appl. Radiat. 46**(4) (1995), 217-220, p. 217.

263. Sharma, “Investigations of Environmental Impacts…”, Part I, p.11 (also Bou-Rabee, “Estimating the Concentration of Uranium…”).

264. Bou-Rabee, “Estimating the Concentration of Uranium…”, p. 220.

265. Baverstock et al., “Radiological Toxicity…” p. 11.

266. Ibid

267. Ibid

268. Dr. Michael Kilpatrick, Department of Defense, MIT Conference, “Depleted Uranium Weapons…”, Mar. 6, 2004. The U.S. has been reluctant to give a figure for the amount of DU used in the 2003 war in Iraq. Dr. Kilpatrick said that the Marine Corps has not yet gone public with the amount of DU they used in the war.

269. Scott Peterson, “Remains of toxic bullets litter Iraq”, **The Christian Science Monitor**, May 15, 2003.

270. **Ibid**, p. 9.

271. **Ibid**. Scott Peterson adds that this form of DU is thought to be “the most dangerous form of DU” if inhaled or ingested. (p.9)

272. **Ibid**

273. **Ibid**

274. **Ibid.** This pile of dust gave a reading of 11,585 emissions in one minute.

275. **Ibid**, p. 1.

276. **Ibid**, p. 8.

277. Anthony Barnett, Public Affairs Editor, “Depleted uranium causing high radioactivity levels”, **The U.K. Observer**, Dec. 14, 2003, p. 1 of article. The exact phrasing was, “2,500 times higher than normal”.

278. **Ibid**

279. UNEP, **Environment in Iraq: UNEP Progress Report, Oct. 2003**, p. 21 (http://postconflict.unep.ch).

280. Jo Wilding Iraq Diaries, “The Cancer Registry”, Jan. 7, 2004 (DU Information List), “The Cancer Registry”, pandora-project@yahoogroups.com. (Jan. 11, 2004).

281. Dr. Jawad Al Ali, presentation at the World Uranium Weapons Conference, Oct. 16-19, 2003, Hamburg, Germany.

282. T. Weyman, Iraq Field Team Leader, “Warning of uranium contamination risks to NGO staff, Coalition forces foreign contract personnel and civilians in Iraq”, UMRC Information Bulletin, Feb. 6, 2004, p. 1, info@UMRC.net104&.

283. **The Sunday Mirror** (U.K.), Nov. 30, 2003.

284. “Troops to be tested for war effects”, **Reuters**, London, Feb. 15, 2003.

285. “Depleted Uranium Safety Fears Continue”, **UN Observer**, Feb. 20, 2004. http://www.unobserver.com/index.php?pagina=layout5.php&id=1461&blz=1
The DU information card introduced in March 2003 for British soldiers contains the following questions:
a)”You have been deployed to a theater where Depleted Uranium (DU) munitions have been used.”
b)”DU is a weakly radioactive heavy metal, which has the potential to cause ill health”
c)”You may have been exposed to dust containing DU during your deployment”.
The soldier is given further information in which he is told that he/she is eligible to have a urine test “to measure uranium”. (Website initially given along with this information is no longer there).

286. Michael Evans, “Sick Gulf War veterans will be tested for depleted uranium”, **The Times** (U.K.), September 23, 2004

287. Rick Scavetta, “Returning Vilseck troops get depleted uranium questions”, **Stars and Stripes**, European Edition, Feb. 6, 2004 (http://estripes.com/article/asp?section=104&article=20287. In a medical questionnaire, U.S. troops are being asked the following questions:
a) “Were you near an armored vehicle that was struck by depleted uranium?”
b) “Were you in or near an Abrams tank when it was hit with depleted uranium munitions?’
c) “Did you routinely enter vehicles with depleted uranium dust to perform maintenance, recovery or intelligence gathering?”

In Scott Peterson’s article in **The Christian Science Monitor** (May 15, 2003) he mentions U.S. soldiers who are aware of depleted uranium and that it might be hazardous. However, members of the New York National Guard, in particular members of the 442 Military Police, seem never to have heard of depleted uranium before, during or after their service in Iraq. Corporal Anthony Yonnone, who felt sick in Iraq and since, and who tested positive for DU said when he filled out his questionnaire he wrote that he had not been exposed to DU "because nobody had even told us what it was back in Iraq". (See article by Jan Gonzalez, "Soldiers demand to know health risks", **New York Daily News**, April 4/ 2004 (http://www.nydailynews.com/04-04-2004/news/story/180339p-156686c.html) (at end of article).

288. There were three articles in the **New York Daily News**. See Juan Gonzalez, "Inside camp of troubles", **NY Daily News**, Apr. 3, 2004. http://www.nydeailynews.com/news/local/story/180340p-156689c.html; Juan Gonzales, "front story", starting "Four soldiers from A New York Army National Guard Company…", **NY Daily News**, Apr. 3, 2004 http://www.nydailynews.com/front/story/180333p-156685c.html and Juan Gonzalez, "Soldiers demand to know health risks", **NY Daily News**, Apr. 4, 2004, http://www.nydailynews.com/04-04-2004/news/story/180339p-156686c.html. It is my understanding that the 4 National Guardsmen who tested positive for DU, tested low positive. My source, Dan Fahey. However these men did not work in battleground areas in Iraq.

289. Jane McHugh, "Sick Guard members blame depleted uranium", **Army Times**, April 9, 2004 (http://www.armytimes.com/story.php?f-1-292925-2810214.php) says that the Army had not in effect found evidence of radiation poisoning through testing the National Guardsmen for DU exposure. National Guardsmen who were tested by the Army at Walter Reed Hospital had difficulty getting their test results. After asking for the results a number of times, an Army colonel called the lab and got the results. Others who asked to be tested were turned away. This occurred before the articles in the **Daily News** came out. See also transcript of the April 4, 2002 TV program, **Democracy Now** (http://democracynow.org/static/uranium.shtml). On this program Amy Goodman and Juan Gonazalez, hosts, interviewed 3 of the National Guardsmen who had tested positive for DU as well as Leonard Dietz, an expert on DU and Dr. Asaf Durakovic, an expert in nuclear medicine.

290. Juan Gonzalez, "Soldiers demand to know health risks", **NY Daily News**, April 4, 2004.

291. Juan Gonzalez, "The war's littlest victim", **New York Daily News**, September 29, 2004. Durakovic and Dr. Axel Gerdes, an expert on uranium isotope analysis, found "significant problems with testing methods". Sharma, "Investigations of Environmental Impacts…", Part I deals with problems and methods for testing for DU exposure.

292. "G.I.s press Army for uranium test", **New York Daily News**, April 19, 2004. Dr. Thomas Fasy of the Mount Sinai Medical Center, who is a pathologist, said that this was a very high cutoff point.

293. Juan Gonzalez, Front story starting "Four soldiers from A New York Army National Guard Company…", **New York Daily News**, April 3, 2004.

294. Gonzalez, "The war's littlest victim", **NY Daily News**, Sept. 29, 2004. http://www.nydailynews.com/front/story/236934p-203326c.html

295. Ibid

296. Ibid

297. **Energy Employees Occupational Program Act of 2000**

298. Robert Alvarez, "DU at Home", **The Nation**, Apr. 9, 2001, p. 24. Alvarez, a senior policy adviser to the Energy Secretary in the 1990's states that workers at a uranium enrichment plant in Paducah, KY handled recycled uranium containing plutonium and neptunium without wearing protective gear. In his presentation, "The Legacy of Depleted Uranium in the United States" at the NPRI conference on Health Effects of DU at the New York Academy of Medicine, June 14, 2003, Alvarez showed a slide on a uranium worker, Joe Harding, who had worked for years at the Paducah, KY plant. He had breathed in uranium hexafluoride gas while working at Paducah; he said it was a haze in the air. An autopsy on his death revealed that his bones contained "up to 34,000 times the expected concentration of uranium". Facilities involved in uranium enrichment have protocols requiring safety measures for their workers. (Dr. Thomas Fasy, presentation at the MIT Conference on DU, Mar. 6, 2004).

299. Two other developments. In 1999 the Physicians for Social Responsibility called for "an immediate moratorium on the production, use and sale of DU in weapons of all types, pending further research to prove the safety of these weapons on the environment and the exposed civilian populations". This motion was passed unanimously by the Executive Committee of the Board of Directors (Sept. 1999) (Personal communication to G.

Munroe from Martin Butcher, Director of Security Programs, Physicians for Social Responsibility. On Feb. 15, 2004, presidential candidate Dennis Kucinich came out against depleted uranium. (See http://www.kucinich.us/issues/depleted_uranium.php).

300. See summary of bill at http://thomas.loc.gov/

301. M.M. Swindle and R.J. Adams (editors) **Experimental Survey and Physiology: Induced Animal Models of Human Disease**, Baltimore: Williams and Wilkins 1998, pp. 1, 3 & 4.

302. Goldberg and Lehnert, "Radiation-induced effects in unirradiated cells…", **Int. J. Oncol.** 2002 p. 345. There is some evidence that some second cancers, especially in Hodgkins lymphoma may be caused by bystander effects but this area has hardly been studied. Ibid, p. 344.

303. A.C. Miller et al., "Genomic Instability in human osteoblast cells after exposure to DU…", **J. Environ. Radiat. 64** (2003), p. 257.

304. Goldberg and Lehnert, "Radiation-induced effects in unirradiated cells:…" **Int. J. Oncol.** 2002 p. 342. Also Baverstock et al. "Radiological Toxicity of DU", p. 9 says that genomic instability is "widely associated with the cancer process".

305. Implied in Sharma, "Investigations of Environmental Impacts…", Part I, pp.iv, 14. Also see footnote 194.

306. In July 2004 two Italian veterans who had served in the Balkans died of Hodgkins lymphoma (Luca Sepe age 27 and Fabio Porru). On June 26 an Italian Court gave a verdict that the Ministry of Defense pay 500,000 Euros to the family of Stefano Melone who died in November 2001 at the age of 40, of a rare malignant vascular tumor (Neoplasia Pleuro-Polmonare Maligna or Maling Cancer of Pleura and Lung, in English). He had served in Kosovo. His doctors stated that Melone's illness was due to "exposure of radioactive and carcinogenic substances". See the website of the International Coalition to Ban Uranium Weapons. http://www.bandepleteduranium.org, and the article by Francesco Iannuzzelli, "Italy: Justice for a veteran's family in Du related case" (July 7, 2004) under "Contents" on the website. Information about Sepe and Porru came through the banuraniweapons list serve and is available through francesco@peacelink.org. The Italian government is funding an epidemiological study on soldiers who will serve overseas presumably regarding DU exposure. Over 20 other Italian veterans have died of cancer after serving overseas.

307. Dr. Rosalie Bertell, "The Use of DU Weapons in War" Submitted to the Hiroshima World Tribunal on Iraq, 10-11 October 2004, p. 17.

308. Miller-Keane, **Encyclopedia and Dictionary of Medicine, Nursing and Allied Health**, p. 871.

309. M. McDiarmid et al., "Health Effects of Depleted Uranium in Exposed Gulf War Veterans", **Environmental Research Section A 82** (2000), 168-180, p. 172.

310. It is impossible to know the mechanisms that might account for the general health effect of DU but excessive increases in reactive oxygen species (ROS) (and free radicals) and their consequences due to the radiation and heavy metal toxicity of DU is one possible mechanism that causes damage to cell membranes, DNA, protein (including the enzymes required for repair of cells), lipids and leads to inflammation and even to chronic problems. Rosalie Bertell, "Host Response to Depleted Uranium" p. 4. See Papas, **Antioxidant Status, Diet, Nutrition and Health**, p. 28, "Oxidative stress (where there are too many free radicals or ROS) **is considered a major factor contributing to development of chronic disease**".). Also see **2003 Recommendations of the European Committee on Radiation Risk**, p. 125 for a discussion of the general health effect of low level ionizing radiation.

Appendices

Appendix A

A Discussion of Atomic Bomb Studies and Low Level Radiation

The Childhood Cancer Research Institute in its overview of epidemiological studies of the health effects of ionizing radiation states that there are an increasing number of worker studies which have associated exposure to low levels of ionizing radiation with adverse health outcomes (1). Depleted uranium falls into the category of a substance which emits low-level ionizing radiation. Low-level ionizing radiation is radiation which breaks apart a healthy molecule and can damage living tissue. Sources of low-level ionizing radiation are nuclear plant releases, natural background radiation, medical x-rays and depleted uranium penetrators.

The field of low-level (or low-dose/slow dose) radiation has been colored by the "classic" atomic bomb survivor studies. Some of the problems with the atomic bomb survivor studies are enumerated by Dr. Rosalie Bertell, an epidemiologist who has studied the health effects of low-level ionizing radiation for 30 years. First, the estimated radiation doses which were assigned to the survivors of Hiroshima and Nagasaki are based only on the actual bomb blast, a one-time event in each city. The high-dose estimates did not take into account the fallout, re-suspended particles in the air which the humans would have breathed in, or the contaminated food and water which the survivors ingested, i.e. internal contamination (2).

Furthermore, the atomic bomb survivor studies only acknowledged radiation risk factors linked to external radiation exposure. Possible internal radiation risk factors such as the incorporation of radionuclides into bone leading to long-term irradiation of nearby tissue were not considered (3). Both the "exposed" group and the "control" group suffered from internal low level radiation which was not studied (4).

Finally, it should be noted that the first data base on survivors of the atomic bomb explosions in Hiroshima and Nagasaki was not developed until 1950. By this time, many people had died since the dropping of the atomic bombs in 1945. Those who died were among the most vulnerable in the population, the very young, the ill and the elderly. The survivors whose data found its way into the data base beginning in 1950 would have been among the healthiest of the population of the two cities. This could be called the "healthy survivor effect". The picture thus developed through the statistical data base could not give a true picture of the situation that existed in 1945 (5).

Furitsu et al. showed that a number of diseases occurred to a greater extent among atomic bomb survivors than among the standard Japanese population (6). The incidence of anemia and leukemia was 13.4 fold greater among the atom bomb survivors (total number of survivors participating in the study was 1,233) compared to the standard Japanese population of the same age group (7). Ischemic heart disease was 4.7 times higher, gastritis was 4.5 times higher, ulcers were 4.7 times higher, and liver disease was 6.4 times higher than in the control population. This area of research, based on low levels of internal radiation was not included in the atom bomb studies. There was no concept of a general health effect of low dose radiation.

The epidemiological studies discussed above are studies of human populations (8). They do not study humans at the cellular level. The biological mechanisms discussed in the text on the second page of Recent Research in the text are cellular studies which show harmful effects of low-level radiation.

1. **The Petkau effect**: With a high-dose radiation (26 rads per minute) it takes a total dose of 3,500 rads to destroy a cell membrane. However, Petkau discovered that at the low dose (low-level radiation) rate of 0.001 rads per minute, it took only 0.7 rad to destroy the cell membrane. With the low dose (slow dose) rate, free radicals of oxygen are produced by the ionizing radiation. There are fewer free radicals produced by the low dose and they are able to reach and interact with the cell membrane in a way that the densely populated free radicals resulting from the high radiation dose cannot. (See reference for further explanation). The free radicals coming from the low dose radiation are attracted to the cell membrane by a small electric charge in the cell membrane early on in the reaction of the total low dose. Petkau found through computer calculations that this attraction is reduced with greater numbers of free radicals (9). The Petkau effect is an indirect effect of low-level radiation. Bertell adds that radiation biologists have tended to only test the strength of cell membranes using high-dose radiation (10). DU causes free radicals both through its chemical toxic effects and its radiation (11).

2. **Monocyte depletion**: Bertell has found this to exist in four different populations (12). Radionuclides like DU are stored in the bone and give off chronic low or slow-level radiation. This can interfere with the manufacturing of normal blood cells. This reduces lymphocytes (which radiophysicists tend to count), neutrophils and monocytes. If the radiation destroys the stem cells in the marrow, reducing the total white blood count by 400 cells per microliter, this would only reduce the lymphocytes by 14.8 percent, leaving their number within normal range. However, there are only 500 monocytes in a microliter of blood and their depletion by 400 cells reduces their number by 80 percent (13). Bertell published an article on this subject, "Internal Bone Seeking Radionuclides and Monocyte Counts", in **International Perspectives in Public Health 9**, 1993, 21-26.

3. **Deformed red blood cells**: Using an electron microscope, New Zealand scientist, Dr. Les Simpson observed misshapen, swollen, red blood cells which are elevated in patients suffering from chronic fatigue syndrome. These red blood cells have difficulty getting into capillaries, thus depriving muscle and brain cells of nutrients and oxygen. The patients with this condition suffer brain dysfunction including short-term memory loss as well as extreme fatigue. This chronic fatigue syndrome was seen at Chernobyl as well as at Hiroshima and Nagasaki (14).

According to the **New York Times** 1/29/01, experts in the field of nuclear medicine in the U.S., France and Britain, are in agreement that "the mechanism of radiation damage is still poorly understood and the debate about what might be a harmful dose is still open"(15).

ICRP Safe Radiation Limits and the European Committee on Radiation Risk

The International Committee on Radiation Protection (ICRP) regulations are used by agencies in many countries. Their risk factors are heavily influenced by findings in studies on acute external radiation (16). The ICRP estimates internal radiation by averaging radiation dose over an organ or tissue (17). Their limits do not take into account the bystander effect, or changes in cell sensitivity, i.e. the cell is more vulnerable when it is dividing (18).

The 2003 Recommendations of the European Committee (ECRR) on Radiation Risk: Health Effects of Ionizing Radiation Exposure at Low Does for Radiation Protection Purposes states, "The critical target for ionizing radiation is the individual cell." (19). Cells that receive irradiation may be highly damaged, a situation which is concealed if an estimate of radiation dose for the entire organ or tissue is used as an indication of damage or lack of damage. The ECRR states that "the complex ways in which the organism responds to low dose radiation both at the cell and organism level have been overlooked" by the ICRP (20). Physicists and radiologists made up limits for radiation doses before DNA was discovered (21). What have been considered to be safe levels of radiation have been lowered over the years. The ECRR states that much has yet to be learned about low dose effects from internal radiation. They note that "what is biologically plausible depends upon the biological knowledge of the day". (22). The ECRR would like to establish the principle that exposures should be assessed "at the cellular level"(23).

The ECRR states that "The health consequences of exposure to ionizing radiation follow damage to somatic cells and germ cells and thus involve almost all illness." (24)

The ECRR writes that known biological mechanisms of the way in which radiation acts "clearly predict general harm to the organism at low doses"(25). New research on microscopic particles less than 2.5 microns in diameter has shown that these particles in pollution, lead to heart attacks and respiratory diseases (26). The tiny particles are conveyed into the lung where they injure the brochioles, where oxygen is first taken out of the air (27). Particles that contain metals for example are especially injurious as they form free radicals (28).

Ceramic DU particles are often smaller than 2.5 microns. DU both through its chemical toxicity and its radioactivity generates free radicals in the body. Increasing the internal free radical burden, which creates hydrogen peroxide among other entities, is not healthy, and is a factor in aging as well as in the development of chronic disease. Antioxidants in fruits and vegetables are factors in reducing the internal free radical burden and their ability to do this, is one reason why it is thought that intake of fruits and vegetables reduces the risk of heart disease and cancer as any nutritionist will tell you.

So far DU has not been found in nanodust particles (29). However when a DU shell strikes a tank, the extremely high temperatures created vaporize metals in the tank generating metallic nanoparticles (30) – the elements of iron, aluminum and silicon have been found in a DU mass (31) which may float in the air and breathed in. Dr. Antonietta Gatti, a nanotechnology expert found inorganic particles in tissues of Balkan and Italian soldiers, including the lymph nodes (32). According to Rosalie Bertell, DU is probably most concentrated in the urine and Dr. Gatti did not examine the urine of her subjects (33).

Notes to Appendix A

1. **Health Risks of Low-Level Ionizing Radiation in Adults and Children: Overview of Epidemiological Studies**, Worcester: The Childhood Cancer Research Institute, May 1999.

2. **Testimony of Dr. Rosalie Bertell before the United States Senate Committee on Veterans' Affairs**, April 21, 1998, p. 5.

3. Ibid, 4. A radionuclide is an isotope of natural or artificial origin which possesses radioactivity. (http://cancerweb.ncl.ac.uk/cgi-bin/omd?query=radionuclide&action=Search+OMD)

4. Rosalie Bertell, "Host Response to Depleted Uranium", The International Institute of Concern for Public Health (IICPH), http://www.icph.org/docs/host_response_to_du.htm p. 2.

5. CREW News, Dec. 1993, p. 5.

6. Dr. Katsumi Furitsu, "The Parallel Radiation Injuries of the Atomic-bomb Victims in Hiroshima and Nagasaki after 50 Years and the Chernobyl Victims after 10 Years", **International Perspectives in Public Health 13** (2000), 19-22, p. 21.

7. **Ibid**. The data of the "standard Japanese people" is from "the basic national life survey" done by the Japanese Ministry of Health and Welfare, 1986. Furitsu et al. stated that over 50 percent of the atomic-bomb survivors in the study had had repeated hospitalizations or had had to visit a hospital often. (**Ibid**, p. 21).

8. A study by the Investigative Committee of Atomic Bomb Victims of Hannan Chuo Hospital, in Osaka, Japan, of 1,233 atomic bomb survivors, indicates that radiation exposure may increase susceptibility to other diseases such as liver disease and ischemic heart disease. Atomic bomb survivors contracted the diseases studied more often than the general population. **Testimony of Dr. Rosalie Bertell before the United States Senate Committee on Veterans' Affair**s, April 21, 1998, pp. 10-11.

9. Rosalie Bertell, "Nine-Legged Frogs, Gulf War Syndrome and Chernobyl Studies", (John Catalinotto and Sara Flounders, compilers and editors), **Metal of Dishonor**, New York City: International Action Center, 1999, p.130. One rad is equivalent more or less to the radiation exposure of a "major diagnostic medical X-ray", p. 128.

10. **Ibid**, pp. 128, 131.

11. This is discussed to some extent in the text. See footnote 89.

12. Dan Fahey, **Case Narrative: Depleted Uranium (DU) Exposures**, Swords to Plowshares, Inc., National Gulf War Resource Center, Inc. and Military Toxics Project, Inc., Sept. 20, 1998, p. 28.

13. Bertell, **Metal of Dishonor**, pp.130-131.

14. **Ibid**, p. 131

15. Marlene Simons, "Doctor's Gulf War Studies Link Cancer to Depleted Uranium", **The New York Times**, January 29, 2001.

16. Chris Busby with Rosalie Bertell et al., Editors, **ECCR, 2003 Recommendations of the European Committee on Radiation Risk: Health Effects of Ionizing Radiation Exposure at Low Doses for Radiation Protection Purposes. Regulators' Edition: Brussels, 2003**, Green Audit Press, Castle Cottage, Aberystwyth, SY 23 1DZ, U.K., p. 66.

17. **Ibid**, p. 37.

18. **Ibid**, p. 44

19. **Ibid**

20. **Ibid**, p. 9.

21. **Ibid**, p. 8.

22. **Ibid**, p. 65.

23. **Ibid**, p. 49

24. **Ibid**, p. 54.

25. **Ibid**, p. 121.

26. Janet Raloff, “How microscopic dust particles cause subtle but serious harm”, **Science News 164**(5), Aug. 2003, pp. 72-74.

27. **Ibid**

28. **Ibid**, p. 73.

29. Antonietta Gatti, Presentation at the “World Uranium Weapons Conference 2003”, Hamburg Germany, Oct. 16-19, 2003.

30. Dr. Rosalie Bertell, “The Use of DU Weapons in War”, Submitted to the Hiroshima World Tribunal on Iraq”, 10-11 October, 2004, pp. 1-28, pp. 5,7, and 15.

31. Ibid, p. 15.

32. Ibid, pp. 16, 17.

33. Ibid, p. 16.

Appendix B

A Discussion of the RAND Report, 1999 and Articles by Drs. S. Fetter and F. von Hippel in The Bulletin of the Atomic Scientist and Science and Global Security

The **RAND Report** (1) purports to be a review of existing scientific studies of uranium compounds, stating that there is little literature on depleted uranium. The **RAND Report** ignores a large body of literature of medical studies and reports on uranium compounds failing to review over 70 studies in this area (2). The **BEIR V Report** (**Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V** (3) was not reviewed although, **BEIR IV**, published several years earlier, was reviewed. As mentioned in the text, the **RAND Report** came to its conclusions that DU is no more dangerous than natural background uranium and that Gulf War veterans could not have sustained illnesses because of exposure to depleted uranium.

One problem with the **RAND Report** is that although there is some discussion of the research done by AFFRI (see discussion of research in Recent Research in the text), RAND did not include the findings of their research in its overall conclusions. RAND did call for more research on depleted uranium. As mentioned above, RAND equated DU with natural uranium and discussed studies having to do with natural uranium in this light. They also discussed studies of uranium miners and millers to show that except for radon, known to cause cancer, there were little excess cancers in this group. (For a discussion of studies of uranium workers and cancer incidence, see **Appendix C**).

The exposure of uranium miners and millers to uranium oxide is quite different from the exposure of troops to DU on the battlefield or in clean-up operations of destroyed tanks or vehicles. As previously discussed in the text, particles of uranium oxide are basically soluble and travel through the lung-blood barrier quite rapidly. If the kidneys are overloaded, the uranium oxide may cause tears in the small kidney tubules, injuring the kidneys. The excretion rate may be high on a week day but low after the weekend when the worker is off. Ceramic DU as discussed in the text, does not leave the body easily. Ceramic DU being almost entirely insoluble, can be taken up by monocytes and circulated by the lymphatic system (rather than the blood; soluble particles travel in the blood). The insoluble DU finds many target organs where radiation can lead to tissue injury and disruption of normal organ functioning. Proof that DU stays in the body for a long time is the fact that 8-10 years after exposure to DU, Gulf War veterans were still excreting DU (4).

The **RAND Report** discusses in some detail exterior exposure to DU, especially for crew inside a tank, and how much rem of radiation members of the crew might sustain while inside the tank. RAND estimated exposure doses to tank crewmen as follows: an M1 driver could receive an average of 0.11mrem (millirem) per hour; his head would receive 0.15mrem per hour and his groin, 0.12 mrem per hour (5). Dr. Rosalie Bertell cites regulatory limits recommended by the International Commission on Radiological Protection (ICRP) for members of the public as being a maximum of 1mrem per year per person (6). The current U.S. Occupational limit is 2,000mrem per year averaged over 5 years or 400 mrem for a single year (7). The Army Environmental Policy Institute stated that “All exposures, regardless of the source or strength, contribute to the risk” (8).

It is difficult to estimate how much time tank crews spend in their tanks. Dan Fahey says in “The Good, The Bad and The Ugly”, that members of a tank crew can spend a lot of time in their tank (9). On a rainy day they may pass time in the tank. In war, they eat and sleep in the tank. He says RAND gives conflicting information about the amount of time crews spend in tanks in a typical non-combat year (10); the Army did not monitor external radiation exposure of tank crew members during Operation Desert Storm. Fahey also states that the dose rates (in mrem) of radiation exposure to DU received by tank crew members cited by RAND are contradictory (11).

RAND relied on dose estimates made by CHPPM and OSAGWI (12) in a 1998 Report by the Office of the Special Assistant to the Secretary of Defense for Gulf War Illnesses (OSAGWI) (13). RAND stated that it was “unreasonable” and “unlikely” that soldiers could inhale doses of 1-2mg of DU dust (14). This is a considerably smaller dose than the maximum dose of 25- 52 mg. that CHPPM estimated would result from the firing of 2 DU penetrators and also smaller than a 9 mg estimated dose mentioned in the OSAGWI report (15). OSAGWI’s report written in the late 1990’s, had a confusing tier of 3 dose levels which the Presidential Special Oversight Board found “incomplete and misleading”. (16)

Dan Fahey says that it is difficult to determine the actual level of exposure of members of a tank’s crew to DU dust (17). In addition to tiny amounts of radiation leaking from DU armor and DU penetrators in a tank, there is residual dust from the firing of DU rounds (18). The RAND report does not discuss potential exposures of U.S. Armed Forces in any other context.

That depleted uranium dust did cause bodily harm during or after the Gulf War is evident. Many of the Depleted Uranium Assessment Team which worked on the decontamination of U.S. tanks and vehicles hit by friendly fire, in King Khalid City, Saudi Arabia, have been ill since their return with symptoms associated with uranium illness (19). They were there about 3 months. Doug Rokke, a health physicist, who headed the team, said that what with the high temperatures, they did not wear masks (20) although they did wear protective clothing. Their superiors told them it was safe (21). He suffered respiratory problems while he was still in Saudi Arabia. (22) According to Rokke, since his return from the Gulf, he has had 15 kidney operations (23). Other members of his team also became ill; some have died (24). Rokke's team worked on the clean-up operations with the members of the New Jersey National Guard who were treated by Dr. Asaf Durakovic through the Wilmington VA, and who too were ill (25).

Another unforeseen situation, which could repeat itself, was the fire at the U.S. Army base at Doha, Kuwait, in July 1991. The fire, which burned for 12 hours burned and oxidized 7,000 pounds of DU munitions. The following day, servicemen were asked to clean up the base without wearing protective clothing. One of these workers after returning to the U.S. started a family. His wife had twins but one of the twins had a limb reduction defect (26).

Bulletin of the Atomic Scientist (27): Fetter and von Hippel use the low figure of 20 percent for their estimate of the amount of DU dust created by the impact of a DU shell. The actual range of DU dust that burns when the DU penetrator hits its target, according to U.S. Army test data, is as high as 70 percent (20-70 percent) (28). Building on their scenario, Fetter and von Hippel state that as the dust created by the impact of the DU penetrator is blown upward, someone standing on the ground would only inhale up to 0.1mg of DU dust (29). This figure would have been considerably larger had Fetter and von Hippel used a mean figure of 45 percent or the maximum of 70 percent.

According to figures extrapolated from an Army estimate, 500-3,200 gms (approximately 2-7 lbs.) of DU dust is created when a DU shell hits its target. Based on combat and test-firing studies, the large part of the DU dust created by the firing of a 120 mm. DU penetrator falls to the ground within 50 meters of the target (30). A man near the target would potentially inhale a lot more than 0.1 mg. of DU dust.

Fetter and von Hippel use a hypothetical situation to make their points. Dan Fahey in his rebuttal to their article (31), states that it is difficult to estimate a dose that fits all wartime situations or the post-war climate, that there are no reliable dose estimates for DU because none were monitored during the Gulf War. He adds that Fetter and von Hippel did not mention or discuss the findings of the AFRRI research, or the poor results of veterans with DU shrapnel on neurocognitive tests.

Fetter and von Hippel admit that there are situations where DU may be a problem, as in contaminated wounds (DU shrapnel), inside tanks at the time of the impact of a DU penetrator, or when recovering or decontaminated vehicles, equipment and tanks.

The calculations on which the article in the **Atomic Scientist** was based are in the Appendix of another article, "The Hazard Posed by Depleted Uranium Munitions" in **Science and Global Security**, 1999 (32). In their work Fetter and von Hippel failed to take into account the long biological half-life (half the amount of time a radioactive pollutant stays in the body after being inhaled or ingested)(33) of ceramic DU particles. For their calculations they used the biological half-life of uranium oxide which must be significantly shorter than that of ceramic DU, which is not known (34). Fetter and von Hippel gave 2-4 years as the amount of time insoluble DU would remain in the body (35). As mentioned in the text, DU survived in the bodies of Gulf War veterans for 8-10 years or longer. Furthermore, Fetter and von Hippel did not take into account multiple exposures to DU not only on the battlefield but also during clean-up and recovery operations (36).

In their article in **Science and Global Security**, Fetter and von Hippel go to great lengths to explain that according to their scenarios and their calculations, exposure to DU including that for populations, amounts to a fraction of the amount of radiation exposure due natural background radiation. As mentioned in the text of this paper, natural background radiation can cause cancer. However it should be noted that such exposures to DU are over and above natural background radiation, radiation being cumulative, thus adding to the overall risk of cancer. In desert areas or near by, DU dust can be easily re-suspended by the wind or human activity as soil and vegetation will not hold it in place. Also, with its long half-life, DU is not going to go away.

Should military personnel be subject to safe radiation limits for occupational workers or to the lower safe radiation limits for the public? Fetter and von Hippel do not discuss this in this article. Soldiers in the 1991 Gulf War did not receive training about the hazards of DU, which, if the occupational safe radiation levels for nuclear workers apply to them, should have been mandatory (37).

Furthermore, in their discussion of the populations of Iraq, Kuwait and Saudi Arabia, they assume a low population density in these areas (38). Their calculations do not take into account that there are large population centers in Iraq and Kuwait; Basra, Iraq is a large city. It sustained heavy bombing in its neighborhood during 1991-1993. As mentioned in the text (see Studies on Men Who Inhaled DU in text), Dr. Hari Sharma tested the urine of a small number of Iraqis years after the Gulf War, who tested positive to DU. He also found DU in the lungs, thoracic lymph nodes and kidneys of 38 deceased Iraqis who had lived in Basra between 1990 and 1993-94.

After the 2003 Iraq war, high levels of radiation were found near tanks destroyed by DU in or near urban areas (see section on Iraq); many small DU shells "littering the ground" just 300 yards from the Republican Palace in Baghdad were found to give off high levels of radioactivity (39).

Fetter and von Hippel base their calculations and models on the International Commission on Radiological Protection (ICRP) model which is followed by many nations. The European Committee on Radiation Risk take issue with this model, targeting the individual cell rather than the whole body or organ in determining exposure to low-level radiation. (This is discussed in **Appendix A**). As for Fetter's and von Hippel's scenarios, some of them have been up-ended by the reality of war and its aftermath.

Notes to Appendix B

1. N. Harley; Foulkes, E; Hilborne, L.; Hudson, A; Anthony, C.R., **The RAND Report: Review of the Scientific Literature As It Pertains to Gulf War Illnesses: Vol, 7. Depleted Uranium**, National Defense Research Institute, RAND, 1999.

2. Dan Fahey, "The Good, The Bad and The Ugly, (DoD Analysis II)", Prepared for The Presidential Special Oversight Board for Department of Defense Investigations of Gulf War Chemical and Biological Incidents and The U.S. General Accounting Office, June 29, 1999, 3-9.

3. **Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V**, The Committee on the Biological Effects of Ionizing Radiation National Research Council, Washington, D.C., National Academy Press, 1990.

4. Rosalie Bertell, "Letter to Judy Scotnicki". I am indebted to Dr. Rosalie Bertell for her explanation of this issue.

5. Fahey, "The Good…", p. 13.

6. Dr. Rosalie Bertell, Gulf War Veterans and Depleted Uranium, Prepared for the Hague Peace Conference, May 1999, p. 3. Bertell uses the term "mSv" or millisievert which is equivalent to a millirem (mrem). See reference 28 in Dr. Rosalie Bertell, "The Use of DU Weapons in War", Submitted to the Hiroshima World Tribunal on Iraq 10-11 October 2004, p. 27.

7. D. Moeller, **Environmental Health**, Cambridge: Harvard University Press; 1997, p. 305. The dose limit for workers in Europe is lower.

8. Fahey, **Case Narrative: Depleted Uranium (DU) Exposures**, Swords to Plowshares, Inc., , National Gulf War Resource Center, Inc. and Military Toxics Project, Inc., Sept.. 20, 1998: 150 (source: Health and Environmental Consequences of Depleted Uranium Use in the US Army, US Army Environmental Policy Institute, June, 1995; p. 106)

9. Fahey, "The Good…", pp. 12, 14.

10. Ibid, p. 14.

11. Ibid, p. 13.

12. Dan Fahey, "Don't Look, Don't Find: Gulf War Veterans, the U.S. Government and Depleted Uranium 1990-2000, Lewiston, ME, The Military Toxics Project, Mar. 30, 2000, p. 21.

13. OSAGWI is the Office of the Special Assistant to the Secretary of Defense for Gulf War Illnesses.

14. Fahey, "The Good…", p. 10.

15. Fahey, “Don’t Look…”, pp. 20-21.

16. Ibid, p. 21

17. Fahey, **Case Narrative**, p. 151.

18. **Ibid**, p. 150.

19**. Ibid**, p. 136.

20. Akira Tashiro, **Discounted Casualties**, Japan: Chugoku Shimbun (Publisher), 2001, 32. Available at http://www.chugoku-np.co.jp/abom/uran/index_e.html

21. **Ibid**, p. 32.

22. **Ibid**, p. 32.

23. “Viewpoint: Editorials: Depleted Uranium Lies”, **The Courier**, Littleton, N.H., Apr. 19, 2001, 5A.

24. See Dan Fahey, **Case Narrative**, 1998, p. 136 regarding illnesses of members of the Assessment Team. Deaths of team members is mentioned by Rokke in “Radiation risk for Aussie troops”, from prop1@prop1.org,, **The Age** (Australia), June 17, 2003, http://www.theage.com.

25. See text regarding interview of Phil Gardner with Dr. Asaf Durakovic, in “Casualties increase from use of depleted uranium”, **World Socialist Web Site**, http://www.swsw.org, Sept. 8, 1999, p. 2.

26. Fahey, **Case Narrative**, 140.

27. Steve Fetter and Frank von Hippel, “After the dust settles”, **The Bulletin of the Atomic Scientist**, Nov.-Dec. 1999, 42-45.

28. Dan Fahey, **Case Narrative**, pp.14-15.

29. Fetter and von Hippel, “After the dust settles”, p. 44.

30. Fahey, **Case Narrative**, p. 15.

31. Dan Fahey, “The DU dispute continues”, **Bulletin of the Atomic Scientist**, Jan.-Feb., 2000, pp. 4-5.

32. Steve Fetter and Frank von Hippel, “The Hazard Posed by Depleted Uranium Munitions”, **Science and Global Security 8** (2) (1999), pp.125-161.

33. Dr. Rosalie Bertell, “The Use of DU Weapons in War”, Submitted to the Hiroshima World Tribunal on Iraq”, 10-11 October 2004, p. 14

34. Rosalie Bertell, “Letter to Judy Scotnicki”, p. 2.

35. Fetter and von Hippel, “The Hazard Posed….” **Sci and Global Security** (1999), p. 151.

36. Rosalie Bertell, “Letter to Judy Scotnicki”, p. 2.

37. Discussed by Rosalie Bertell, “Letter to Judy Scotnicki”, p. 2.

38. Fetter and von Hippel, “The Hazard Posed…”, **Sci. and Global Security** (1999), p. 131.

39. Scott Peterson, “Remains of toxic bullets litter Iraq”, **The Christian Science Monitor**, May 15, 2003, p. 9.

Appendix C

Uranium Miners, Nuclear Workers and Adults and Children Living Near Nuclear Facilities

Studies exist indicating that there is a relationship between working in a uranium mine and developing cancers as well as working at a nuclear facility.

Dr. Asaf Durakovic, whose specialty is nuclear medicine, states that uranium workers seem to have a “significantly higher prevalence of malignant diseases” in most of the recent studies done by the U.S. Transuranium Registry (known also as the National Plutonium Registry) (1). He also says that the higher grades of uranium ore increase the miners’ risk of cancer from beta radiation as well as from inhalation of uranium dust. (2). He says that the average size of uranium dust particles in uranium mining have been thought “too large to reach the micro-bronchiolar and alveolar compartment of the human lung” (3). The DU particles formed at high temperatures upon the impact of a DU shell with a target such as a tank are much finer (4).

Some studies of largely uranium miners where miners contracted leukemia or other cancers or died of cancer or leukemia include the following.

X. Baur et al.,” Systemic sclerosis in German uranium miners under special consideration of antibody subsets and HLA Class II alleles”. **Respiration 63** (1996), 368-374. These miners inhaled uranium dust and had a high incidence of systemic sclerosis. The study also documented changes in the immune system (5).

RE Crowell et al. “Detection of trisomy 7 in non-malignant individuals at risk from lung cancer”. **Cancer Epidemiology Biomarkers and Prevention 5** (1996), 631-636. The uranium mining environment is correlated with squamous cell carcinoma.

A. J. DeVillers et al. “Lung cancer in a fluorspar mining community I. Radiation, dust and mortality experience”. **British J. Industrial. Medicine 21** (1964), 94-99. Cites 51of 142 deaths from lung cancer in miners in Newfoundland who worked for 2,000 hours in a uranium mine.

J. Bigu, “Theoretical considerations regarding the migration of Rn22 and Rn230 from uranium and thorium bearing underground environments”. **Health Phys**. **67**(1994), 60-64. Deals with the incidence of silicosis and lung cancer in a New Mexican uranium mine.

R. Zaire et al “Unexpected rates of chromosomal instabilities and alterations of hormone levels in Namibian uranium miners” **Radiation Research 147** (1997), 579-582.

Akira Tashiro discusses uranium mining on a Navajo reservation where a dam burst in 1979, leaving uranium sludge contamination which was only cursorily cleaned up. Although uranium mining was curtailed in the late 1980’s, there were many mines in the area and many Navajos who had worked in the mines developed lung cancer and other diseases of the respiratory tract. Residents estimate that 350-400 workers have died of cancer and other diseases (6).

Several studies of uranium miners mentioned in **ATSDR**, 1999 (7) indicated that radon exposure was not necessarily responsible for the development of cancers: in one study, radon was found to be not associated with excess lung cancers in uranium miners working underground in Grants, N.M. In the other study, it was determined that exposure to radon progeny might not have not caused lung tumors except for oat cell carcinoma. Many researchers have associated exposure to radon in the mines to lung cancer illness and death.

Nuclear Workers

Fahey discusses a study by Xia of mortality due to lung cancer near the Fernald Materials Processing Center in Hamilton County, Ohio which showed more deaths from cancer in Hamilton County than compared with the rest of Ohio. Xia stated “’Since a 20-30 year lag between uranium dust inhalation and death from lung cancer is consistent with known disease etiology, our results suggest continued monitoring of cancer rates in the area’” (8). H. Xia & B.P. Carlin, “Spatio-Temporal Models with Errors in Covariates: Mapping Ohio Lung Cancer Mortality”, **Statist. Med**. **17** (1998), 2025-2043. The site is now a superfund site.

G.M. Kendall et al., “Mortality and occupational exposure to radiation: first analysis of the National Registry for Radiation Workers”. **British Medical Journal 304** (1992), 220-225. Kendall et al. found that there was an association between exposure to radiation and cancer mortality, especially leukemia (when deaths from chronic lymphatic leukemia were excluded) and multiple myeloma. The workers in this study showed the healthy worker effect so that mortality from diseases in the radiation workers in the study was lower than in the general population. Radiation studied in this research was external radiation.

Also, men's leukemia and multiple myeloma rates from 1982-1986 in Concord, MA where Starmet manufactured DU munitions for 25 years, were statistically significant according to Dr. Richard Clapp, then Director of the Massachusetts Cancer Registry as reported in the **Concord Journal** in January, 1991 (9).

An unpublished report on 11,000 Oak Ridge (TN) uranium workers revealed higher rates of lung cancer and bone cancer (82%) than in the general population. (The report was discovered by the **Washington Post**) (10).

Nuclear Workers and Children and Adults Living Near Nuclear Facilities

Many of the studies in **Health Risks of Low-Level Ionizing Radiation in Adults and Children: Overview of Epidemiological Studies** (The Childhood Cancer Research Institute, Worcester, MA, May 1999) deal with cases of leukemia and other cancers in children or adults living in the vicinity of nuclear facilities. Over 16 studies link the presence of nuclear facilities with increased cases of cancers. Seven other studies found no effect. A few of the studies were done on uranium mining. The rest of the studies cited are reviewed in the above reference.

A.M. McConnell et al. "Population monitoring experience with residents exposed to uranium mining/milling waste". **Mutation Research 405**(2):1998 (Sept. 20); 237-245. Residents exposed to uranium/milling waste lived in an area which had significantly higher levels of uranium 238 in the soil than in control areas. The experimental population showed more aberrations in their chromosomes than in the control population, indicating increased health risks. The difference however was not significant (11).

L.M. Shields et al. "Navajo birth outcomes in the Shiprock uranium mining area". **Health Physics 63**(5):1992 543-551. Mothers lived near tailings/mine dumps with either parent working at the Shiprock electronics assembly plant. 13,320 women had "adverse birth outcomes" with more than 320 types of defective congenital conditions (12).

I. Schmitz-Feuerhake et al. "Leukemia in the proximity of a German boiling-water nuclear reactor: evidence of population exposure by chromosome studies and environmental radioactivity", **Environmental Health Perspectives 105** (Suppl. 6):1997 (Dec.), 1499-1504 (13). This study revealed a significant ("exceptional") increase in leukemia in children which appeared 5 years after the start-up of a nuclear power plant in 1983. There was also a significant increase in cases of leukemia in adults (14).

These 13 studies indicate that low level radiation in uranium mines and at several nuclear facilities are correlated with elevated cases of leukemia or cancer or death from leukemia or cancer.

There is also the case of an army base, the Aberdeen Proving Ground, where DU penetrators have been tested for many years. The Aberdeen Proving Ground Superfund Citizens' Coalition, a grassroots advocacy group, estimates that 66 lbs. of DU was being blown into the air monthly until about 1979. Their conjecture is based on army reports and other information. This is more than 50 times the maximum level allowed by New York state, which led to the closing of National Lead Industries in 1980 where depleted uranium penetrators were being made. (See footnote 13 of text). Harford County, which is near the base has the highest cancer rates in Maryland. Delaware which is east and downwind of the army base has the highest cancer rates in the United States. (15) DU may be responsible.

Notes to Appendix C

l. Asaf Durakovic, "Medical Effects of Internal Contamination with Uranium", **Croatian Medical Journal**, **40**(1):1999, p. 55

2. Ibid, p. 56.

3. Ibid, p. 55.

4. Ibid

5. Information about the articles by Baur et al. (both pp. 55 and 58), Crowell et al., DeVillers et al., Bigu and Zaire et al. may be found pp. 55 and 58 of Durakovic, **Croatian Medical Journal**, **40**(1)1999.

6. Akiro Tashiro, **Discounted Casualties**, Hiroshima, Japan: Chugoku Shimbun (Publishers), 2001, pp. 78-79. Available at http://www.chugoku-np.co.jp/abom/uran/index_e.html

7. These studies are discussed by Dan Fahey in “Don’t Look, Don’t Find: Gulf War Veterans, the U.S. Government and Depleted Uranium”, Lewiston, ME: The Military Toxics Project, Mar. 30, 2000, 42. See **ATSDR**, 1999, p. 211.

8. Ibid, 43.

9. Kyle Nitzache, “Men’s leukemia rate twice state’s for 1982-86", **The Concord Journal**, **62** (50), Jan. 17, 1991.

10. The article in question: Joby Warrik, “Uranium Plant Risks Were Concealed”, **The Washington Post**, Sept. 21, 1999. See Fahey, “Don’t Look, Don’t Find”, p. 43.

11. **Health Risks of Low-Level Ionizing Radiation in Adults and Children: Overview of Epidemiological Studies**, Worcester, MA: The Childhood Cancer Research Institute, P.O. Box 309 Westside Station, Worcester, MA 01602-0309 (out of Clark University), p. 6.

12. Ibid, p. 8.

13. Ibid, p. 4.

14. Ibid

15. Tashiro, **Discounted Casualties**, pp. 68-69.

Books and Websites of Interest

A Shimbun, 2001. Distributed in the U.S. and Europe by Transnet: info@transnet-jp.com - $12 plus shipping. The entire book is available online at http://www.chugoku-np.co.jp/abom/uran/index_e.html

Dr. Rosalie Bertell, “The Use of DU Weapons in War”, Submitted to the Hiroshima World Tribunal on Iraq 10-11 October 2004. http://www.bandepleteduranium.org.

Dan Bishop, “DU Compendium of Scientific Research”, www.idust.net & www.bandepleteduranium.org

Dan Fahey, **Case Narrative: Depleted Uranium (DU) Exposures**, Sept. 20, 1998. The National Gulf War Resource Center, Inc., Swords to Plowshares, Inc., Military Toxics Project, Inc. (P.O. Box 558, Lewiston, ME 04243, http://www.miltoxproj.org).

Dan Fahey, “Unresolved Issues Regarding Depleted Uranium and the Health of U.S. Veterans of Operation Iraqi Freedom and Operation Enduring Freedom, 24 March 2004” http://www.danfahey.org

United Nations Environment Programme (UNEP), **Depleted Uranium in Bosnia and Herzegovina, Post-Conflict Environmental Assessment**, Revised Edition: May 2003. UNEP Reports available through http://www.unep.org.

Hari D. Sharma M.Sc., PhD, “Investigations of Environmental Impacts from the Deployment of Depleted Uranium-Based Munitions, Part 1 Reports and Tables, Part 2, Appendices, December 2003. (A technical report). Available through the Military Toxics Project, P.O. Box 558, Lewiston, ME 04243. http://www.miltoxproj.org.

Chris Busby, Rosalie Bertell et al. (editors), **2003 Recommendations of the ECRR: The Health Effects of Ionizing Radiation Exposure at Low Doses for Radiation Protection Purposed: Regulators’ Edition 2003**. Green Audit Press, Castle Cottage, Abersytwyth, SY23 IDZ, U.K. See http://www.euradcom.org for information about this report and ordering information.

Gayle Greene, **The Woman Who Knew Too Much: Alice Stewart and the Secrets of Radiation**, (foreword by Helen Caldicott), Ann Arbor: The University of Michigan Press, 1999.

Websites

http://www.antenna.nl/wise/uranium - WISE Uranium Project

http://www.bandepleteduranium.org - International Coalition to Ban Uranium Weapons

http://www.cadu.org.uk – Campaign Against Depleted Uranium

http://www.ieer.org – Institute for Energy and Environmental Research

http://www.idust.net – International Depleted Uranium Study Team

http://www.miltoxproj.org – Military Toxics Project

http://www.nirs.org – Nuclear Information and Resource Service

www.nuclearpolicy.org - Nuclear Policy Research Institute

http://www.traprockpeace.org – Traprock Peace Center

About the Author

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Education:

University of Massachusetts, Amherst, MA. M.S. in Human Nutrition, February 1978.

Harvard School of Public Health, Boston, MA. M.S.H. in Demography and Human Ecology 1969.

Harvard University, Cambridge, MA. M.A., Regional Studies, Middle East 1966.

Smith College, Northampton, MA. B.A. cum laude, 1958.

Additional: courses in Nutrition, Physics and Biochemistry at Boston University, Framingham State College and M.I.T.

Experience:

Grassroots Actions for Peace, Volunteer, 1998-present.

Director of Development: Tunefoolery Concert Ensembles, Cambridge, MA. 9/91-12/02. Staff position (part-time) in grantwriting and fundraising.

Certified LifeStyle Counselor: Taught class in weight control and nutrition to clients with psychiatric disabilities, 2001-2002.

Marketing: Worked on production of video, **Supermarket Shopping for Elders**; marketing and hand-outs with the Massachusetts Gerontological Nutrition Practice Group. 3/95-12/98.

Nutrition Consultant: Employed as a temporary dietitian for upcoming inspection; charted in patients records and discussed food preferences with residents. The Masonic Home (Daka Corp.). Charlton, MA, summer, 1993.

Nutrition Coordinator: Counseled clients in WIC and Maternal and Child Health Programs (individuals and groups). Facilitated meetings. Uphams Corner Health Center, Dorchester, MA , 1989.

Dietitian: Counseled and provided nutritional assessments of patients of all ages, developed policies and procedures, planned menus and therapeutic diets, did in-service training and weekly inspections of food service. Also hired

Nutrition Consultant: Counseled clients and advised on food service for a drug-rehabilitation program, Spectrum House, Westborough, MA 1984-1985.

Researcher (Staff Associate): Researcher in demography and population policy. Co-author of *Mobile Units in Family Planning,* a publication of the Population Council. The Population Council, New York, N.Y. 1969-1971.

Associations: Am a Registered Dietitian and a Licensed Dietitian in the State of Massachusetts. Member of the American Dietetic Association, Member of the Massachusetts Gerontological Nutrition Practice Group and the Oncology Nutrition Dietetic Practice Group.

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