Depleted Uranium

All of the Questions are not yet answered

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Abstract: For fourteen years now the debate about depleted uranium and its detrimental effect on the health of the veterans of Gulf War I, the Iraqi people and military, (and subsequently Kosovo, Afghanistan and Gulf War II) continues to be unresolved. Meanwhile the number of first Gulf War U.S. veterans who have developed the so called Gulf War Syndrome (GWS) has risen to about one third of the 800,000 deployed Uncounted civilians and personnel of other nations that fought in Iraq I and wars since 1991 have also been afflicted. The veterans have suffered from multiple serious physiological disorders, and have had little or no official recognition, medical relief, or compensation. It seems important to take another look at this issue and identify the roadblocks to resolving the scientific questions and finding appropriate medical and political responses. Some answers involving the complex interaction of toxic chemicals and radiation are given.

The Problem:

One of the novel exposures of the Gulf War I was the depleted uranium bullets, rockets and armament. Uranium is a heavy metal, one which has no positive biological use. Exposure to uranium occurred along with exposure to other heavy metals well known to cause havoc with the cellular immune system. Heavy metals, especially mercury, lead, arsenic, and cadmium, were contained in pesticides, herbicides; vaccines, including anthrax, botulinum toxin, and nerve agents: sarin, cyclo-sarin, tabun, soman, VX, multiple seven, and novachuks, including chemicals released from the Kamasiah toxic chemical depot which was destroyed by bombing. Many veterans were also subjected to petroleum products and the horrendous oil well fires. [Ref. 1]. Most had very little training for handling these hazardous materials, and no protective clothing or respirators.

A focus of the GWS dispute has been whether or not the use in battle of DU (depleted uranium) weaponry could be one of the principal causes of the syndrome. The first roadblock has to do with focusing on one item to which the veterans were exposed in battle, and attempting to "prove" that it was or was not one of the main causes of their serious illness. One could attempt to do this for each pesticide, vaccination, toxic chemical and heavy metal separately, one at a time, pretending to "prove" for each that it was not the cause. Such reductionist discourse confuses the true issues and delays research into treatment and legal recognition of harm caused. It leads one to the absurd conclusion that the veterans are not really sick, but the problems are all in their imagination. Since the U.S. Research Advisory Committee for Gulf War Veteran's Disease has ruled out psychiatric illness as a cause, [Ref. 2] it would be important to look at all of the circumstances associated with the use of DU, including uranium's heavy metal as well as radiological properties, and their combined effects, on the immune and hormone systems of the exposed veterans and civilians. A damaged immune system leaves one vulnerable to all sorts of viral, bacterial, electromagnetic, and toxic metal exposures. The hormonal system regulates homeostasis, the nocturnal resting cycle (for repair) and kidney clearance rate of heavy metals. When evaluating DU use in war, it must be within this toxic matrix.

Analyzing the Radiological Hazard:

The widely accepted scientific methodology for analyzing radiation dose-response includes a mathematical model predicting damage to the cellular DNA resulting from a homogeneous spreading of ionizing radiation over the critical organ(s), weighting the organ dose to approximate whole body exposure, and using a risk formula to estimate the expected number of fatal cancers due to that dose. If the expected number of cancer deaths is small, the hazard is declared to be trivial. This methodology assumes that the persons care only about cancer death, have normal physiological health and an intact cellular repair system.

Whether or not homogeneous spread of the energy over the organ in question is reasonable under the circumstances, or whether or not the estimates of the amount of radiation inhaled are accurate in the battlefield, whether the cellular repair system is working, whether the clearance rate for heavy metals in the kidneys is normal, or even whether cancer is meaningful as the biological endpoint of concern for the veterans, makes no difference. These details appear to be irrelevant when applying this "objective" methodology.

We will show that this trusted methodology is especially inappropriate and misleading in the case of Gulf War Syndrome. The mathematical equation contains no terms for dealing with a cellular repair dysfunction, damage to the mitochondrial DNA and synergistic effects with toxic metals, halogens and complex nano debris. Airborne nano debris is especially difficult to measure since it can theoretically remain in the air forever by Brownian motion, or can suffer multiple resuspension events if it does fall to the ground.

Origin of the Physics Methodology:

Erwin Schrodinger, physicist, published, in 1944, what became one of the most influential monographs of the incipient atomic age. Schrodinger, in his monograph: "What is Life", [Ref.3] gave the central and primary informational role in life to the nuclear DNA. He found it to be the basis of all organic existence, and he explained it well in terms of fundamental physical and quantum principles. This was a brilliant paper, and it was followed later by the Watson and Crick discovery of DNA's method of replication (1953). DNA was spectacular news in the scientific world at the time. However DNA, while central to protein production and human reproduction, failed to describe the many unrelated life support mechanisms, including the tasks of the mitochondrial DNA, which also go into making the cell functional.

The developing science of radiobiology accepted the thesis that nuclear DNA was the essential molecule of radiosensitivity, and this focus has continued to strongly influence decisions about the potential hazard of exposures to ionizing radiation, even in 2005 when nations are called upon to deal with the complex Gulf War syndrome. We now know that cellular organelles, cell membranes and biochemical reactions within the cell are crucial when assessing the simultaneous damage caused by internal radiation, heavy metal contamination, and nano particles.
This dose-response methodology, developed from studies of high level radiation, appears to work by masking the low dose effects. It is not appropriate for understanding low dose DU exposures because radiation, heavy metals and other toxic chemicals can destroy the functionality of the cellular respiratory system (the mitochondria), disrupt the chemistry of enzymes and hormones, frustrate normal cellular detoxification and repair, and leave the person alive but chronically ill. Also at low doses, many other toxic agents become potentially synergistic or significant

confounding variables for any radiation toxic effect. A system approach is more fruitful, and the two most important systems to examine are the cellular immune and hormonal systems

The ionizing radiation exposure in Gulf War I, actually includes, in addition to DU, the exposure to nuclear debris caused by the bombing of the Iraqi experimental nuclear reactors, and spent fuel pools, and radiation from the Doah explosions and six day fire which consumed the DU ordnance stored at the U.S. military depot near the border of Kuwait. There was no one magic radiation dose which comprised all of these many levels of radiation exposure experienced by the military personnel. These various exposures would be cumulative.

Details Chemical and Radiological Damage to Cells:

DU powder is pyrophoric, and spontaneously creates an invisible metal fume (often called an aerosol) when exposed to air friction or impact on a hardened target. The nano particles, when inhaled, can cross the lung-blood barrier, penetrate the cells and provide the maximum dose (contact dose with little self-shielding) causing free radicals and oxidative stress in the cells. Some believe that the oxidative stress caused by uranium's heavy metal properties is even more damaging than its radiological properties. Total oxidative stress causes failure of the cells protective enzymes, leaving the cells vulnerable to viruses and mycoplasma. Damage to the cellular communication system, over-working the mitochondria, heavy metal replacement of magnesium in molecules which are normally anti-oxidants and destruction of the body's repair mechanisms have serious consequences for the body, including tumorogenesis.

Some cellular mechanisms are of interest here. For example: after a protein, sequenced by the DNA, is properly produced by the RNA, it has to undergo a process of folding. This gives it the proper three dimensional shapes that support the functions and chemical reactions in which it will have to participate. Biochemists now believe that proteins do not fold spontaneously into their final, active conformation [Ref. 4]. Proteins destined to be embedded in the cell membrane, or to secrete, are synthesized in the endoplasmic reticulum of the cell where templates, enzymes and sugars promote some conformations and inhibit others. This is a delicate work with sequential rounds of intricate modifications, overseen by the cell's quality control system. Free radicals can totally disrupt this process, forming unusual molecules, and in the presence of heavy metals, using trace amounts of toxic metals to replace the normal zinc and manganese.

Improperly folded proteins can fail to be routed to the cell membrane or to some gland where, as hormones, they are needed to signal a secretion. Some diseases caused by misrouted proteins include: cystic fibrosis, diabetes insipidus, and cancer.[Ref 5]

Widespread misfolding of proteins can lead to cellular stress, clogging of the system and an accumulation of imperfect proteins. Many scientists now believe that accumulation and aggregation of misfolded proteins, is responsible for neurodegenerative diseases, as well as early onset Alzheimer's, Parkinson's and type II diabetes. In these diseases proteins or protein fragments convert from normal, soluble, conformations to insoluble, sticky fibers called amyloids. These amyloids coalesce into fibrillar aggregates that have a characteristic structure. The insoluble clumps can form either inside or outside of cells. Misfolded proteins are a central pathogenic mechanism, and Gulf War I veterans have manifested many of these symptoms of neurodegenerative diseases.

The Problem of ALS (Lou Gehrig's Disease):

ALS (Lou Gehrig's disease) is being diagnosed at about two times the expected rate in young Gulf War Veterans relative to veteran's who did not serve in the first Gulf War (confirmed in September 2004 by the Research Advisory Committee for Gulf War Veteran's Disease). Normally ALS is diagnosed after age 55 years, but most of these cases were young. Two thirds of the 40 cases are between 20 and 54. ALS is officially listed as "of unknown cause". However, it seems clearly related to failure of anti-inflammatory and anti-oxidant enzymes, together with mitochondria dysfunction.

Amyotrophic Lateral Sclerosis (ALS) was thought to have been caused by the death of motor neurons. Recent data suggests, however, that neurons don't die, so much as they are killed by surrounding cells called glia. The glia usually support and nourish neurons but they can become dysfunctional and toxic in certain diseases. This process is called "neuro-inflammation". Cytokines are small proteins used to communicate between neurons, and glia cell types [Ref. 6]. Recent data suggests that neuro-inflammation in a mouse model of ALS is caused by dysregulated cytokine signaling. The cytokine signaling is, in turn, regulated by major lipid metabolic pathways. Michael Vickers has documented that even microGray doses of ionizing radiation cause inflammation of the blood vessels, and can initiate the arachidonic cascade with its well known sequel of damaging effects on the body. The lipid arachidonic acid is produced when fatty acids in various states of oxidation mediate inflammatory reactions in the blood and other cells.[Ref. 7] This certainly merits further study since the ALS is a very serious and unexpected outcome for these Gulf War veterans.

An unusually high incidence of Lou Gehrig's and Parkinson's diseases in indigenous populations in Guam and New Guinea suggests a possible correlation between the diseases and local environmental conditions, including high levels of aluminum and low levels of calcium and magnesium in soil and food. As with Alzheimer's, humans with these disorders tend to have high levels of aluminum in some areas of their brains, although it has not been demonstrated that the presence of aluminum in the brain initiates the onset of the diseases. It has been suggested that other possible contributing factors need to be examined more closely including the diet of the Guam population - in particular, the seeds of the false sago palm, which contain a toxic amino acid that causes a condition similar to Lou Gehrig's disease in monkeys - as well as the possibility that the dementia is caused by genetic rather than environmental factors [Ref. 8] Both potential confounding factors were absent in the Gulf War, but exposure to aluminum and depletion of calcium and magnesium were present. Guam is also likely to have received some fallout from Pacific nuclear bomb tests.

Immune and Hormonal Systems Damaged in the Gulf War:

The DNA of the mitochondria is 16 times more sensitive to radiation then is the DNA of the nucleus. This is because it has no protective histone proteins, like those within the cellular nucleus. [Ref. 9]

It is well known and well accepted in the scientific community, that radiation produces free radicals in a living cell, which is composed mostly of water. It does this because of its ionizing energy deposit, which creates an atom or molecule with at least one unpaired electron. Because another molecule can easily pick up this free electron, causing a chemical reaction, the free

radicals can effect dramatic and destructive changes in the cell and in the intercellular fluid. Karl Z. Morgan described this effect as: “a mad man in a library”.

All cells of the body contain an endogenous antioxidant in the water soluble part of the cellular fluid which normally deals with free radicals. It is called Glutathione (GSH) and it repairs most cellular structures that are damaged and oxidized by the free radicals. It is also able to detoxify many electrophilic mutagenic threats to the cell. This anti-oxidant function of GSH is normally credited as having cancer protective power since it neutralizes free radicals. Cellular repair mechanisms depend heavily on the presence of GSH in the cells. Another function of GSH is to rid the cells of toxic heavy metals. Heavy metals bind with the GSH, and are carried out of the cell and to the gall bladder, for excretion in bile. This process is a mechanism for depleting the GSH, as well as a mechanism for ridding the cells of heavy metals. Hence heavy metals deplete GSH at the same time it is most need for its protective cell repair and anti-oxidant work.

Individuals may have more or less GSH by nature or exposure history. Yet this is one of the main repair mechanisms on which the physics methodology for calculating radiation dose-response depends for its applicability.

Superoxidase dismutase (SOD) is another chemical, produced by the liver and in the mitochondria of each cell, which acts as an anti-inflammatory, antioxidant enzyme. The body needs zinc, copper and manganese in order to produce sufficient functional SOD. Toxic metals can replace the manganese, making the SOD dysfunctional, or the cell can merely run out of SOD because of over-demand for antioxidants in the mitochondria. Over demand for antioxidants can deplete the manganese needed for protective enzymes in the cell body, leaving it open for viral or bacterial invasion. SOD also has variations in abundance, and can be damaged by a variety of chemicals.
Thus the heavy metal exposure causes oxidative stress that weakens the cellular repair mechanism, which would normally have provided some protection for the military from low dose radiation exposure. Mercury and arsenic are found in pesticides and fungicides, and in vaccines. Nickel is a component of steel, and it can deplete the body’s zinc stores, compromising the SOD cellular immune system. These also play parts in the breakdown of cellular functions.

Trace amounts of inhaled or ingested aluminum, from inoculations, aluminum food wrappings, cooking utensils, salt, baking powder, beer and soft drink cans, or other Gulf War sources, can combine with fluorides from hydrogen fluoride released from oil well fires, drinking water, soft drinks (made with fluoridated U.S. water), toothpaste or foods, to form a pseudo hormone, which mimics the thyroid stimulating hormone (TSH),.even confusing medical testing for thyroid dysfunction Hormonal damage to the thyroid and pituitary glands, which regulate the body metabolism, has severe repercussions for every organ system in the body, including the brain. The aluminum fluoride compounds act like the TSH hormone, which regulates the thyroid hormones T-3 and T-4. When persons are subject to trace aluminum and fluoride they exhibit the same symptoms as hyperthyroidism. This pseudo-TSH bypasses the pituitary control of cell metabolism, drives up the mitochondria activity and depletes the Se-GSH in all the cells [Ref. 10] Aluminum fluoride compounds provide another mechanism which interferes with cellular repair of radiation damage.

The aluminum-fluoride compounds do not clear as does the normal TSH. The highly electronegative effects of the fluorides cause them to bond long term (almost permanently)

to TSH receptor sites of cells. This process highly disturbs the normal pulse and amplitude processes of the pituitary control via TSH, and damages the cellular nocturnal repair processes, over-working GSH within cells. Authentic TSH provides for the normal sleep cycle.

Aluminum-fluoride complexes have been widely used in laboratory investigations for stimulation of various guanine nucleotide-binding proteins. These complexes are able to simulate phosphate groups in many biochemical reactions. Aluminum fluoride compounds are formed in water solutions containing fluoride and traces of aluminum. It is evident that the aluminum fluoride complex is a molecule giving the false information amplified by cell processes of signal transmission, influencing the G-proteins which carry signals from numerous receptors to the cell interior [Ref. 11].

Serious aluminum-fluoride problems have been reported at the St. Regis Akwesasne Indian Reserve, on Cornwall Island, New York State, downwind from the Reynolds Metal Company aluminum smelter; the Marathon Refinery, in Texas City, Texas; Mobil's oil's refinery in Torrance, California (where it involved an oil fire); Sonoco Refinery fire in Tulsa, Oklahoma; Portland, in Victoria, Australia where Alcoa built one of its most modern facilities; and at Oak Ridge Nuclear Laboratory in Tennessee.[Ref. 12] At Oak Ridge, there was an added uranium component. Victims of these environmental disasters reported muscular and skeletal problems, nervous system disorders, anemia, rashes, irritability, high blood pressure and thyroid problems.
Heavy metal exposure (including uranium) can cause loss of cellular immunity, autoimmune diseases, joint diseases such as rheumatoid arthritis, and diseases of the kidneys, circulatory system and nervous system. Metals supplant the normal calcium and other minerals in enzymes, and cause these molecules to lose their important functions in the body. Peroxynitrite, a toxic product of the free radicals nitric oxide and superoxide, can also degrade the functions of respiratory enzymes [Ref. 13]] and inactivate mitochondrial superoxide dismutase (Mn-SOD) enzyme. [Ref. 14]. Decline in functional mitochondria is most damaging to those organs that have the highest energy demands per gram of tissue, namely: the heart, kidney, brain, liver and skeletal muscle, in that order [Ref. 15]. These organs become poorly protected from irradiation from circulating uranium particles, as well as various other pathogens.

Failure of cellular immunity leaves the organism vulnerable to virus, bacterial and mycoplasma invasion. Mycoplasma, are small bacterial organisms. Lacking cell walls, they are capable of invading several types of human cells and are associated with a wide variety of human diseases. Three separate laboratories in the United States have identified mycoplasma organisms in patients with Chronic Fatigue Syndrome, and Gulf War Syndrome. The percentage of positives findings for mycoplasma, ranged from 60 to 80%. Research done by Drs. Garth and Nancy Nicolson of the University of Texas M.D. Anderson Cancer center resulted in the discovery of mycoplasma incognitus as the one cause of the symptoms of Gulf War syndrome. Normal laboratory blood tests do not detect mycoplasma incognitus. The only way to detect this mycoplasma is to use a sensitive genetic marker analysis. Even with this method it is still difficult to detect because mycoplasma is found mainly inside the cells and not in body fluids like a conventional bacteria.

Mycoplasma incognitus causes chronic fatigue, recurring fever, night sweats, joint pain, stomach upsets, stomach cramps, headaches, skin rashes, heart pain, kidney pain, thyroid problems, and in extreme cases, autoimmune-like disorders.

Certainly there was nothing normal about the metabolic response of the Gulf War veterans to the radiation injuries from DU. While it is credible that uranium was not responsible for all of the sickness experienced by the veterans, it clearly was not as minimal a component as would be indicated by the mathematical approach used in physics. The mathematical approach cannot predict what DU exposure would cause in this situation, since the chemical reactions are very interdependent, and find no accommodation in the mathematical formula.

DU in battle vs. Uranium Oxide in a mine or mill:

Uranium oxide, as found in uranium mining and milling, has provided most of the information used for official understanding and evaluation of the exposures to DU in first Gulf War [Ref. 16]. DU exposure in war differs, in that uranium oxide in the mining and milling situation is dust, visible particles of, on average, five microns aerodynamic diameter. The aerosolized uranium oxide from a metal fume, produced through air friction or impact on a hardened target in battle, is on the contrary, invisible, of aerodynamic diameter between 1 nanometer and 2.5 micron. Size is an important factor for inhalation. Particles of aerodynamic diameter less than 2.5 micron are able to penetrate into the deep lung alveoli. When the aerodynamic diameters are in the nanometer range, particles easily penetrate the lung-blood barrier.

Another difference between the two situations is that mine uranium is contaminated with radium and radon, while these have been eliminated in DU.

Mine dust is produce at ambient temperatures, while the metal fume is produced at temperatures between 3000 and 6000 degrees Centigrade. Subjecting uranium oxide to more than 3000 degrees Centigrade produces what the UK National Radiation Protection Board (NRPB) refers to as ceramic uranium oxide, which is highly insoluble in the body fluids [Ref. 17]. These high temperatures will also sublimate all other metals and materials which happen to be nearby, caught in the powdered uranium fire: steel, nickel, aluminum, iron, etc. These other debris will also aerosolize and produce nanometer size debris, which can be inhaled. [Ref. 18]

The small size of these particles facilitates uptake into cells and transcytosis across epithelial and endothelial cells into the blood and lymph circulation to reach potentially sensitive targets. These targets include lymph nodes, spleen and heart. Access to the Central Nervous System and ganglia via translocation among axons and dendrites of neurons has also been observed. The greater surface area per mass, compared to larger particles, renders nano size particles more biologically active. [Ref. 19]

The differences in the receptor or host in the mining vs the battlefield environment, has already been discussed.

Human ability to screen out uranium:

The human body is normally exposed to uranium in food and water at a rate of about 1.9 micrograms a day, but only about 1 to 2%, between 0.019 and 0.038 microgram (19 to 38 nanograms), is absorbed through the intestines. The output of natural uranium in feces is 1.862 to 1.881 micrograms daily. The entire gastro-intestinal tract is considered by physiologists to be external to the body (like the hole in the donut), so this fraction of ingested water and food is not considered to be internal contamination.

The 19 to 38 nanograms of natural uranium, which are absorbed by the intestinal wall, are considered to be internal to the body. They pass through the hepatic portal and are screened by the liver, then are sent either directly to the kidneys to be excreted in urine, or circulate in the blood. Circulating uranium is usually stored in bone, to be excreted at a later time. These results vary according to the solubility of the chemical compounds of uranium in food and water. However these estimates are typical for natural uranium

The human body has an excellent screening system for natural uranium, reducing the ambient average environmental concentration of 1 ppm to 1 ppb internally to the body. However, this GI tract and liver screening system does not operate to screen the uranium or other metals that enter the body through the lungs, are ceramic, and have an aerodynamic diameter in the nanometer range. Gulf War exposures to inhaled DU were likely well above the normal the 19 to 38 nanograms per day, and added considerable stress to the body, regardless of the other stresses present in this toxic war.

Nano particles (whether uranium, steel, iron, or aluminum) pose an especially difficult problem for the body's screening and filtering ability. They pass through the lung-blood barrier, the blood-brain barrier and the placenta, and they are too small to be captured by the kidney filter and excreted from the body [Ref. 20]. They take a long time to dissolve in the body fluid, and only the dissolved portion can be chemically active or eliminated in urine. Because of the variable times needed for dissolving the ceramics, the negative effects of the heavy metals are ongoing. Ceramic uranium does not lose its radioactive properties.

Another biochemical reaction, namely aluminum fluoride compounds which interference with the thyroid gland as has been noted, will also delay the clearance rate of metals through the kidneys.

Uranium oxide and all nano particles are able to cross the placenta, and these are particularly toxic to the rapidly developing embryo or fetus. At low doses, they damage the fetal brain, causing behavioral problems such as aggressiveness and hyperactivity, congenital malformations and diseases. The under-developed immune system of the fetus is more easily compromised than the immune system in a fully mature adult.

The Encyclopedia of Occupational Health:

The chemical toxicity of chronic uranium contamination has been described in the ILO (International Labour Organization) Occupational Health Encyclopedia as:

> " pulmonary fibrosis, pneumoconiosis, and blood changes. The red blood count; hemoglobin, erythrocytes and reticulocyte levels in peripheral blood are reduced. Leucopenia may be observed with leukocyte disorders (cytolysis, pyknosis and hypersegmentosis). There may be damage to the central nervous system. Morphological changes in the lungs, liver, spleen, intestines, and other organs and tissues may be found, and it is reported that uranium exposure inhibits reproductive activity and effects uterine and extra-uterine development in experimental animals. Insoluble compounds tend to be retained in tissues and organs for long periods." [Ref. 21]

The temperature of the spontaneous metal fume produced by DU is between 3000 and 6000 degrees Centigrade. This is in contrast to ambient temperature of 35 to 45 degrees

Centigrade, or the 575 degree centigrade fire produced by TNT in other wars. At this high temperature the uranium oxide becomes ceramic-like, and insoluble in body fluids. For this reason, once inhaled, it provides a chronic source of uranium irradiation and poisoning within the body.

One microgram (1000 nanograms) of pure U_{238} has 12.4 atomic transformations (sub-microscopic explosions) every second, each giving off one alpha particle with energy between 4.15 and 4.2 MeV [million electron volts] in random directions. It only requires 6 to 10 eV [electron volts] to break the nuclear DNA strand in a cell. In one day, one microgram of DU would release 1,071,000 alpha particles, each with more than four million electron volts of energy; into whatever organ or tissue it was lodged. Assuming that this energy deposit causes an occasional direct hit on nuclear DNA, at a rate thought to be less than that required to increase caner rate, and causes no other damage, is foolish.

Calculating Internal Radiation Dose from Ceramic Uranium Oxide:

I do not believe that the dose from nano particles can be estimated using the physics methodology described above. For one thing, these ceramic nano particles cannot spread homogeneously in an organ. They remain point sources of internal (contact) dose until they dissolve in body fluid. Their small size provides no self-shielding, and the direction of the spray of alpha particles is random. Dose is determined by the strength of the source, distance from the source and duration of exposure. For nano particles exposure may well last a lifetime. Ceramic particles will not bind to the bone, but will continue to circulate in blood and lymph fluid, irradiating blood and lymph vessels. If the ceramic DU does dissolve, it can bind to the phosphate in the DNA, or be stored in bone, irradiating the stem cells for blood formation. DU can easily penetrate the blood-brain and reproductive barriers, contaminating brain tissue, being found in seminal fluid, or in the uterus, damaging the developing embryo or fetus. It is not likely to be filtered out by the kidneys. .

Dr. Hari Sharma, Professor Emeritus from the University of Waterloo, tested some U.S., Canadian and U.K. veterans and Iraqi civilians from Bosra and Baghdad for urine DU about eight to ten years after the 1991 war. His findings, when DU was estimated from an isotopic analysis of the uranium present in a 24 hour urine sample, ranged from 81 to 1340 nanograms DU [Ref 22]. This was surprising to those who trust ICRP (International Commission on Radiological Protection) guidelines predicting a three year biological half-life for insoluble uranium oxide. It was eight to nine years after the exposure to DU had terminated for the military, about three biological half-lives of uranium oxide.

In this prolonged exposure picture, one cannot assume that cellular repair systems and hormonal systems will remain intact and function satisfactorily. Failing repair, radiation damage will be increased, and cancer may well follow.

Damage to the individual person will occur not only from the inhaled DU aerosol but also from all of the other toxic debris which was generated by the DU metal fume. Metal debris in the body, like pieces which come from deteriorating hip implants, dental amalgams, or a breast implant, have clearly been shown to be detrimental. Hence the variety of symptoms reported by the Gulf War I veterans derives from the complexity, variety and persistence of the foreign body invasions from their battlefield environment, not least of which was the DU ordnance.

Conclusion:

The problems of Gulf War Syndrome are too complex to use a reductionist methodology to extract the toxic effect of one single component, even DU. This is true for several reasons, not least of which is increased free radicals, heavy metal toxicity, the complexity and sensitivity of cellular reactions, damaged organelles, dysfunctional enzymes and hormones, all occurring simultaneously. The mathematical methodology used by physicists is inappropriate for an insoluble nano particle such as the ceramic DU imbedded in this toxic soup. Mathematical calculation of the risk of cancer death, is likely irrelevant given the various cancer mechanisms not incorporated into the mathematics. For veterans, with illnesses resulting from internal contamination and multiple cellular dysfunction problems, trying to live normally and support their families, this radiation physics prediction of low cancer death risk is likely irrelevant. However, regulators will take the mathematical prediction very seriously when awarding compensation! Veterans need to understand what happened to them and what can be done to improve their situation. They need medical, financial and political help.

I hope that some remedies will soon be found, but while waiting, I would suggest nature's own detoxifying method be used. Nature cleanses the soil with distilled water, evaporated by the sun and condensed in the clouds, falling as rain. Using distilled water for drinking could provide some relief to Gulf War veterans, as it did for many atomic veterans in the 1950s and 1960s. Re-supplying the body's protein loss would also be helpful. Undenatured whey products can be taken to replace proteins, and stressing zinc, calcium and magnesium products in the diet would clearly help.

Serious questions about the legality of DU as used in war, will also need answers. These cannot be answered by a mathematical calculation of the risk of cancer as a first cause of death. In other words, a "trivial" number of cancer deaths caused, will not make this weapon acceptable to the Geneva Protocols.

DU powder produces an invisible metal fume. It is a violation of the **Geneva Protocol on the use of Gas** (metal fumes constitute a gas) **in War**, Geneva 1925, which was ultimately signed, with reservation (i.e. use for crowd control) by President Ford for the U.S. 22 January 1975. This Protocol was proclaimed in the U.S. on 29 April 1975. The U.K. signed this Protocol on 9 April 1930. The commitment to this Geneva Protocol was clearly known by the U.S. and U.K. prior to the 1991 war against Iraq.

The legality arguments can be left to lawyers. However, biochemical processes and not mathematical formula must be the foundation of the legal claim of harm.

Clearly DU is partially responsible for a series of biochemical events which are significantly harmful to human beings. The damage is indiscriminate, mindless of national affiliation, age or gender. In other words, DU is a weapon of indiscriminative destruction which even destroys ones own military. It renders the post-war civilian environment hazardous for many years to come, similar to land mines.

I will close with the wise words of Nicholas Lemann:

> "The preferred method of the reductionist project is analysis into component unit parts. Reductionism ignores or under-rates interactional processes apart from billiard ball-

like encounters between two or more distinct bodies. So, it ignores dynamic, interactional processes which entail reciprocal or mutual determinations. It prefers linear explanations of phenomena like "the central dogma" of modern biology that DNA determines RNA which determines protein, a process represented by a series of arrows. Reductionism stands opposed to field and systems theories which are concerned with the properties of the whole and which consider the whole more than the sum of its parts. It tends to side-step scientific problems involving functional interrelationships, for example, phenomena best explained as the result of a confluence of forces, or as the result of contingency rather than an iron-clad causality. [Ref. 23]

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