RESEARCH AND DEVELOPMENT

DEPLETED URANIUM ON THE BATTLEFIELD PART 2 – BIOLOGICAL CONSIDERATIONS

by William S. Andrews, Edward A. Ough, Brent J. Lewis, and Leslie G.I. Bennett

As discussed in Part 1 of this article (in Vol. 4, No. 1, Spring 2003), depleted uranium (DU) has a number of ballistic properties that make it an attractive and effective material for anti-armour penetrators. Consequently, DU is likely to be used in operations by the armed forces of a number of countries, including the United States and Russia, for a considerable time. However, one of the significant concerns about the use of DU in armour-piercing rounds is the potential health hazard to combatants and civilians that may result from the oxidization of DU on striking a hard target, and the subsequent precipitation of oxidation products as fine solid particles, which can be inhaled. This paper will examine the potential hazard posed by the use of DU rounds, and will report on studies currently being conducted on troops who may have been exposed to DU.

AEROSOLIZATION

Uranium can exist in three solid forms as well as in liquid and vapour phases. Table 1 below shows the transition points.

Temperature (°C)	Phase	Structure
< 669	solid	α – orthorhombic
669 – 776	solid	β – tetragonal
776 – 1132	solid	γ – body centred cubic
1132 – 4134	liquid	
> 4134	vapour	

Table 1. Physical phases of uranium.

As already noted in Part 1, the impact of a depleted uranium penetrator against a hard target generates local temperatures as high as 1800°C, which result in phase changes to liquid. At these elevated temperatures, uranium is readily oxidized, principally to U_3O_7 (47 percent) U_3O_8 (44 percent) and UO_2 (9 percent). (These proportions are considered to have an uncertainty of 25 percent, and were determined using x-ray diffraction during the analysis of uranium dust generated by DU rounds striking hard targets.[1]) Oxidation is the source of the pyrophoric nature of DU impacts and is not present

Drs. Andrews, Lewis and Bennett *teach in the Department of Chemistry and Chemical Engineering at the Royal Military College of Canada.* Dr. Ough *is a research associate in the same department.*

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with tungsten heavy alloy (WHA) penetrator impacts. This effect enhances the effectiveness of DU penetrators, particularly inside the target. The oxides subsequently condense as solid aerosol particles.

Much work has been conducted in the United States to determine the extent to which DU penetrators are converted to aerosols and on characterizing the aerosol particle-size distribution. Against thick hard targets, it is estimated that some 18 percent of the DU penetrator of a 120-mm tank munition is aerosolized, with virtually all these aerosols (91 to 96 percent) having sizes less than 10 um, i.e., they are readily respirable. These particles can remain suspended in air for a significant period of time (hours to days), most of which will remain inside the target vehicles, but with some likely to escape into the atmosphere through open hatches or remain outside the target. Re-suspension of already settled particles would, of course, constitute a hazard to personnel engaged in entering or inspecting contaminated vehicles. At any distance from contaminated vehicles, it is considered that aerosol concentrations would be diluted to safe levels.

POTENTIAL HEALTH CONSEQUENCES

The human body's natural (aqueous) solutions act as solvents for any uranium with which they may come into contact. The principal oxides generated on aerosolization (UO_2, U_3O_7 and U_3O_8) all dissolve slowly. Once dissolved, however, uranium may react as a uranyl ion with biological molecules to produce cellular necrosis (cell death) and/or atrophy in the tubular walls in the kidneys, resulting in a diminished ability to filter impurities from the blood.

Of the respirable particles resulting from aerosolization, roughly two-thirds have dissolution half-times greater than 100 days, while the other one-third have half-times less than 10 days.[2] (Dissolution refers to the rate at which particles are dissolved in body fluids – principally in the lung.) Once dissolved in blood, some 90 percent of the uranium will be removed by the kidney and excreted in urine within 24 to 48 hours of entering solution. The 10 percent remaining in the blood can be deposited in bones, lungs, the liver, kidneys, fat and muscles. Inhaled insoluble uranium oxides can remain in the lungs for years, especially if the particles are smaller than 2 um and thus more likely to be deposited in the alveoli. Gradually, however, these particles will also enter the bloodstream and eventually be excreted in urine.

Like other stable heavy metals, the principal biological hazard of uranium is felt to be toxicological, rather than radiological, with the organ at greatest risk being the kidney. The radiological hazard itself, via either external or internal pathways, is felt to be negligible. The worst exposures to

Country	Subjects Tested	Comments
Belgium	3580	U in normal range, fewer malignancies than expected
Bulgaria	39	No health problems
Estonia	91	No pathologies
Finland	50	U in normal range, no health effects
France	54	No elevated U, malignancies within expected range
Germany	122	No elevated U, no health effects
Greece	1800	Normal findings
Italy	40	No contamination
Lithuania	68	No leukemia detected
Luxembourg	100	Blood samples, no abnormalities
Netherlands	6	No sign of DU exposure
Portugal	341	No abnormally high levels
Slovakia	63	No DU-related diseases
Spain	6000	Normal U levels, no malignancies
Sweden	110	Normal values

Table 2. Personnel testing by NATO and non-NATO troop-contributing nations.[6]

US Army troops during the Gulf War were less than 10 mSv, i.e., less than one fifth the formal annual occupational dose limit and well below the level known to cause any health effects.

To date only 25 of 20,000 US Army Gulf War veterans have been diagnosed with types of kidney damage for which DU would be a causative agent. None of these individuals, however, was among the 33 veterans who had the highest exposures to DU and are undergoing medical monitoring, and it should be noted that the diagnosis rates are consistent with rates for similar kidney problems among the general American population.[3]

Similar studies have been made of other veteran and civilian sub sets, with similar results, i.e., most servicemen tested through urinalysis showed no evidence of elevated DU (or natural uranium, for that matter) in their bodies, or elevated levels could not be correlated with any specific illness, including renal. A study of veterans belonging to the Mississippi National Guard found no evidence of a general increase in birth defects or health problems among children born to these veterans, in spite of anecdotal claims to the contrary.[4] Urinalysis of 122 German peacekeepers deployed to Kosovo after the air campaign revealed that none had any "incorporated DU".[5] Two cohorts of Swedish soldiers were examined, 200 who had spent six months in Kosovo and another 200 who were yet to deploy. The latter group had four times the average uranium levels in their urine than the returnees from Kosovo had.[6] A summary is provided in Table 2. On the civilian side, 31 employees of the International Red Cross and Red Crescent who were present in Kosovo during the air campaign had urine samples analyzed. In these tests uranium concentrations ranged from 3.5 ng/L to 26.9 ng/L, which are consistent with values found among non-exposed individuals.[7]

All the cases listed above involved transients, that is, the test subjects only spent limited amounts of time in-theatre potentially exposed to DU. For balance, the local populations of Bosnia and Kosovo were sampled by Priest and Thirlwell for BBC Scotland, and in 23 subjects from three different locations they found DU present in all subjects. The measured body burdens, however, were less than the average burden of natural uranium in humans, leading to the conclusion that the radiation dose to the skeleton is likely to be dominated by any natural uranium present, which in turn would be dominated by such alpha-emitters as radon-220 and polonium-210, which are more common in the body than uranium.[8]

MONITORING CANADIAN VETERANS

Canadian Forces (CF) personnel have served in areas where DU munitions have been expended, particularly in the Persian Gulf and Kosovo, where the principal danger from DU would have been in the form of re-suspended aerosols that could have been ingested. Similar to servicemen from a number of countries, some Canadians have developed a variety of debilitating symptoms for which causes have yet to be determined. Some see the significant difference from previous experiences, including other off-shore missions, as being the presence of DU in the environment. To establish or eliminate DU as a causative agent for these symptoms (often termed "Gulf War illness") the CF, along with the military forces of other nations, have instituted a programme of urinalysis of such veterans. The aim has been to determine the extent of uranium in the urine and, where possible, to identify the isotopic ratios of any uranium isotopes present. This latter determination would indicate whether uranium contamination was due to DU or to natural uranium.

In 2000, 103 active and retired CF personnel participated in a uranium bioassay programme. The total uranium concentration in each urine sample was analyzed by two laboratories, with one laboratory using inductively coupled plasma mass spectroscopy (ICP-MS) and the other using instrumental neutron activation analysis (INAA). The mean concentrations found were 4.5 ng/L and 17 ng/L, respectively.[9] These values were consistent with quoted literature values of 1 ng/L to 40 ng/L for non-occupationally exposed individuals.[10] The uranium concentration levels in the urine samples were too low to permit direct isotopic ratios to be determined, so hair assays were also conducted, which showed ratios of uranium-238 to uranium-235 ranging from 120 to 145 ± 20, (± 1 σ). By comparison, natural uranium has a ratio of 137.8 versus a ratio of 498.7 for DU. Finally, a single bone sample was analyzed from a deceased veteran, where the isotopic ratio was determined to be 138 ± 4, again consistent with natural uranium.[11]

Author's collection

DU penetrator strikes on an Iraqi tank, presumably from the 30 mm GAU 8 mounted on A10 aircraft. Some larger penetrator strikes, possibly tank 120 mm APFSDS DU rounds, are also evident.

It is believed that the ICP-MS results were more accurate than the INAA, considering the lower detection limit of 0.5 ng/L for the former. Further, the ICP-MS results are consistent with published data for non-occupationally exposed individuals. However, INAA may well be an appropriate technique for the routine analysis of hair samples.

ENVIRONMENTAL ASPECTS

As mentioned above, on hitting hard targets, a significant portion of DU projectiles will aerosolize and oxidize. These projectiles, along with those that hit the ground and fail to fracture, will result in surface, or slightly subsurface contamination. A post-conflict environmental assessment study by the United Nations Environment Programme of eleven sites in Kosovo (including the most heavily attacked) found that there was no detectable widespread contamination of the ground surface by DU. In other words, the contamination resulting from the use of DU is present in such low levels that it cannot be detected or differentiated from natural uranium. Consequently, it was concluded that the radiological and toxicological risks were "insignificant and even non-existent". Any detectable contamination was localized to within 10 m to 50 m on the surface and 10 cm to 20 cm below the surface of actual munition impact points. Further, the study found no DU contamination in water or milk, nor even any significant increased uptake in plants, with no risk anticipated in the future.[12]

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In Canada, work continues to improve measurement capabilities for bioassay. A round robin comparison has been conducted among a number of university and private laboratories using blind synthetic urine samples (both blank and doped), to be followed by real urine samples. Efforts are also underway to investigate the appropriateness of including high resolution ICP-MS, or HR ICP-MS as a potential measuring instrument.

CONCLUSIONS

Penetrator impact on hard targets generates aerosols, most of which are respirable thereby raising the possibility of human ingestion of DU. To date, no direct linkage has been established between uranium contamination of the body due to DU munitions and "Gulf War illness" symptoms observed among some veterans. In fact, virtually all veterans and comparably-exposed civilians tested for uranium content have been found to have levels consistent with the unexposed general public and were generally symptom-free. Environmental contamination due to the use of DU penetrators is thus considered to be marginal and highly localized, with no long term consequences anticipated.

NOTES

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