NPRI
NUCLEAR POLICY RESEARCH INSTITUTE

Depleted Uranium: Scientific Basis for Assessing Risk

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The Nuclear Policy Research Institute was founded in 2001 by Nobel Peace Prize nominee, physician, and author Dr. Helen Caldicott. It was established to facilitate a far-reaching, effective, ongoing public education campaign in the mainstream media about the often-underestimated dangers of nuclear weapons and nuclear power programs.

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Emily Dimiero, Marian Park, Nadine Ahmed, Matthew Corley, Eric Lieb, Brett Howe, Elizabeth Dumphy, and Tina Lax.

For more information on the health effects of depleted uranium and other issues critical to NPRI's mission, please visit www.nuclearpolicy.org. Full presentations from the June 14th symposium are accessible on the site.

INTRODUCTION

Depleted uranium and its use by the United States military has become one of the most controversial issues of the past decade particularly following the 1991 and 2003 conflicts in Iraq. Soldiers and civilians in the vicinity of exploded DU munitions are exposed to respirable-size particles of uranium trioxide (UO_3) that may be inhaled or ingested, exposing them both to chemical toxicity and low-level radiation. As the debate has become increasingly politicized and polarized, the rhetoric has gotten in the way of the science, as both activists and military officials have made claims not backed up by science.

Policy-makers and the public must have clear scientific data from which to base decisions, data which has largely been absent from the pronouncements of the Pentagon in defending DU as a weapon. This need for well-considered scientific data prompted the Nuclear Policy Research Institute to endeavor to do what no government, international agency, or academic institution has yet done -- offer a fresh, comprehensive account of the health effects of depleted uranium, considering scientists and positions on both sides of the debate.

On June 14th, 2003, the Institute's inaugural symposium at the New York Academy of Medicine gathered scientists on both sides of the debate to present their data. The symposium was open to the public and the media.

This report succinctly represents both the results of that symposium, and the broad scope of available research on the fundamental biology behind DU's effect. It gives the reader an overview of the various pieces of the puzzle that make up the full picture that is depleted uranium – the history, physical make-up, military and commercial applications, government and independent research – so that they may be fully informed on the science of the issue.

NPRI has found in our research that the health risks of depleted uranium tend to be substantially understated by government bodies, which in some cases have made public statements which directly contradict the results of their own research. The toxic effects responsible for cancers and possible birth defects have latency periods of a few years to possibly a couple of decades. Studies conducted only since the early 1990's have documented the impact of alpha radiation, the bystander effect, genomic instability, mutagenic capabilities of uranyl ions, all issues presenting a very real human health risk.

While most media and government attention regarding the use of depleted uranium has centered on soldiers, with this report, NPRI cautions that the most vulnerable population is children. In conflict areas such as Iraq, where residential areas have been ravaged by tanks and munitions, the DU-contaminated debris has become the children's new playground. Dr. Mike Repacholi, the World Health Organizations coordinator for occupational and environmental health recognizes that "young children could receive greater depleted uranium exposure when playing within a conflict zone because of hand-to-mouth activity that could result in high depleted uranium ingestion from contaminated soil."[1] Not only are they more likely to ingest DU, but they are 10 to 20 times more susceptible to the carcinogenic effects then adults.[2]

Children suffer the greatest risk from depleted uranium exposure, yet they have no voice in the DU debate. Those children, as well as the broader civilian and military population exposed to DU, deserve the utmost consideration when determining the scientific basis for assessing risk.

[1] Environmental News Service *Children Most At Risk from Depleted Uranium* April 26, 2001
[2] Caldicott, Helen, M.D. The New Nuclear Danger The New Press, New York 2002

OVERVIEW

Natural uranium is a dense, weakly radioactive element present in varying trace amounts in rocks, soil, water, air, plants, animals, and even humans. Higher concentrations exist in deposits, or uranium ore, typically found in geological formations in various parts of the world. In the US these occur in New Mexico, Colorado, Wyoming, Utah, and Arizona.[3] The bulk of US uranium comes from this region.[4] Uranium and its compounds have proven valuable to humans for well over a century and served various civilian functions, including colored glazes for pottery. Studies of its health effects date back to the mid-1800's and continued through the 1900's when doctors prescribed it to diabetics in hopes of raising their glucose excretion.[5] The advent of nuclear weapons in the 1940's expanded the demand for enriched uranium, which is essential for the generation of both nuclear fuel and nuclear weapons. Today, the military applications of uranium have provoked a particularly controversial debate about detrimental impacts on the human body and environment.

Properties

Natural uranium contains three major radioactive isotopes, U-238, U-235, and U-234.[6] U-238 comprises about 99.27% of uranium in nature, with 0.72% 235U and 0.0054% 234U. To be used as a nuclear fuel or in nuclear weapons, uranium must be enriched in 235U, most commonly by the process of gaseous diffusion. This process increases the concentration of the U-235 isotope to levels that can sustain the nuclear chain reaction.[7] The U-235 isotope comprises about .72% of naturally occurring uranium.[8] Nuclear power fuel requires enriched uranium composed of 3-5% radioactive U-235.[9] Highly enriched uranium used for nuclear weapons necessitates an increase to over 90% U-235 composition.[10] However, the enrichment process produces a disproportionately large amount of byproduct, depleted uranium (DU). Producing just 1 kilogram of highly enriched uranium creates about 200 kilograms of depleted uranium.[11]

DU closely resembles natural uranium in its chemical, physical, and toxicological properties.[12] "Stripped" of almost all of its radioactive U-234 and two-thirds of its radioactive U-235,[13] depleted uranium emits about 40% less alpha radiation and 15% less gamma radiation than natural uranium.[14] DU qualifies as a low-level radioactive waste (LLRW)[15] and is a heavy metal that requires proper disposal and storage.

Management, Storage, and Disposal

Since the dawn of the nuclear weapons program, the United States has accumulated a stockpile of depleted uranium that exceeds 700,000 tons,[16] making the US the largest generator of DU worldwide.[17] Depleted uranium hexafluoride (DUF6), the form of DU produced by the enrichment process, gives off low levels of both gamma and neutron radiation when held in containers. Should the cylinder leak, DUF6 poses a potential risk because it readily reacts with water vapor in the atmosphere to form chemically toxic uranyl fluoride[18] and highly corrosive hydrofluoric acid.[19] In recognition of DU's potential health and environmental risks, the U.S. Department of Energy (DOE) is responsible for proper management, storage, and disposal of the growing pileup. The DOE stores this waste material in some

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[3] Rotsker, Bernard. Special Assistant of Gulf War Illnesses, DoD *Environmental Exposure Report*: *Depleted Uranium in the Gulf (II*), Chapter 1, Introduction, December 2000, p.1
[4] ibid.
[5] *A Review of the Scientific Literature as it Pertains to Gulf War Illnesses, Vol. 7: Depleted Uranium*, April 1999, Chapter 2: Health Effects p. 1
[6] Repacholi, Dr. Michael H., *NATO's Role in Kosovo: Background Material on Depleted Uranium (DU),* World Health Organization, Geneva, January 2001, p. 1
[7] *Summary Report to Congress: Health and Environmental Consequences of Depleted Uranium Use by the U.S. Army,* U.S. Army Environmental Policy Institute, June 1994, p. 2
[8] *op.cit.,WHO*
[9] Alvarez, Bob. "*The Legacy of Depleted Uranium in the United States*" as presented June 14, 2003, New York Academy of Medicine, Nuclear Policy Research Institute symposium "The Health Effects of Depleted Uranium." Remarks and slides available at www.nuclearpolicy.org
[10] ibid.
[11] ibid.
[12] op.cit. Repacholi
[13] ibid.
[14] Fahey, Dan. *Science or Science Fiction: Facts, Myths an Propaganda In the Debate Over Depleted Uranium Weapons,* March 2003, p. 11
[15] *Summary Report to Congress: Health and Environmental Consequences of Depleted Uranium Use by the U.S. Army,* U.S. Army Environmental Policy Institute, June 1994, p. 2
[16] op.cit., U.S. DOE
[17] op.cit., Alvarez
[18] op.cit., U.S. DOE
[19] Diehl, Peter. *Depleted Uranium: a by-product of the Nuclear Chain* published in *Depleted Uranium: A Post-War Disaster For Environment and Health,* Laka Foundation, May 1999, p. 4

57,700 steel cylinders, each holding about 12 metric tons, located at the three major gas diffusion plants in Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio.[20]

The DOE's Depleted Uranium Hexafluoride Management Program pursues a mission to "safely and efficiently manage the Department's inventory of DUF6 in a way that protects the health and safety of workers and the public, and protects the environment until the depleted UF6 is either used or disposed."[21] The program's commitment to oversee and monitor the waste receptacles and their longer term approach to stabilize DU through chemical conversion for safe disposal is expensive and time-consuming. For "purposes of resource conservation and cost savings compared with disposal," the DOE has explored alternatives to partially relieve its financial burden, most notably in its development of "beneficial uses" of depleted uranium.[22] However, civilian applications of depleted uranium have not caused an "appreciable decrease" of the ever-growing stockpile.[23] At the NPRI symposium on the health effects of depleted uranium, Robert Alvarez, Senior Scholar at the Institute for Policy Studies and former Senior Policy Advisor to the Secretary of Energy ('93-'99), points out that 96% of the DU inventory in the US is stored, suggesting that only a small proportion of DU is put to use.[24]

A HazWat inventories and repackages depleted uranium cores.
Photo Courtesy of Fernald Photography

Commercial/Civilian Applications of DU

Commercially, depleted uranium serves various functions in the fields of medicine, aviation, space, and petroleum exploration.[25] It has a density 1.7 times that of lead, making it effective ballast for commercial aircraft, ships, and even satellites. In the aviation industry, DU is used as counterweights in aircraft elevators, radar antennae, landing gear, and rotor blades.[26] The Boeing Company's 747 airplane program employed more than 200 tons of depleted uranium in the program's first 550 airplanes in the forms of counterweights for aircraft elevators and upper rudder assemblies.[27] But DU's corrosive nature presented Boeing with a maintenance dilemma. In 1983, a Boeing Company letter to the US Nuclear Regulatory Committee revealed that up to 20% of its DU counterweights required replacement or reprocessing every 4-5 years due to corrosion.[28] Another concern regarding DU's commercial use arose in 1992, when an El Al Boeing 747 with counterweights comprised of 282 kg of DU crashed in the Amsterdam

[20] op.cit.,U.S. DOE
[21] ibid.
[22] op.cit.,U.S. DOE
[23] op.cit., Diehl, p.4
[24] op.cit., Alvarez
[25] op.cit., U.S. AEPI, p. 2
[26] ibid.
[27] *Boeing Company Request Concerning Depleted Uranium Counterweights,* U.S. Nuclear Regulatory Commission, Regulatory References: 10 CFR 40.13, Subject Codes: 11.1, 11.6, p. 1
[28] ibid.

suburb of Bijlmermeer.[29] Public outcry and debate ensued regarding health risks posed by burning DU to rescue personnel involved and citizens living in the area.[30]

The medical industry uses DU in radiation shields in radiotherapy units. The petroleum industry has employed DU in some of its drilling equipment. The DOE's Depleted Uranium Uses Research and Development Program continues to investigate the risks and advantages of DU's expanding role in civilian applications, such as its potential as a semi-conductor in electronic devices.[31]

Military Applications

The United States military began exploring, developing, and testing ways to employ depleted uranium in the early 1970's in what were termed "kinetic energy penetrators" and tank armor.[32] DU embodies several characteristics that make it particularly appealing to the military. Physically, DU is extremely dense and pyrophoric, spontaneously igniting and burning upon impact. Its pyrophoricity gives it an edge unlike other metals with similar densities, such as tungsten. When a DU shell hits a hard target, the projectile "sharpens as it melts and pierces heavy armor."[33] Upon impact, it ignites and aerosolizes, forming tiny particles suspended in air and dispersing them over an area. Depending on several conditions, anywhere between 18-70% of the DU penetrator oxidizes to form suspended aerosols comprised of 50-96% respirableDU report 4pm 7,4-size particles.[34]

Alloying DU with a small amount of other metals, such as titanium, reduces its carbon content.[35] This hardens DU to form an even more resistant material. Its unique physical properties enable shells made of DU to penetrate the conventional tank armor of enemies, and when used as plating in tank armor, DU provides an almost impenetrable shield against conventional weapons. Unfortunately, DU rounds can penetrate DU plated tanks, as documented in the friendly fire incidents of the Gulf War in '91.

In addition to its physical properties, DU's relative abundance provides the U.S. military and government with an additional incentive to pursue its development of DU weapons. Depleted uranium is readily available and free because the United States' ever-growing inventory is under the control of the DOE. This eliminates the cost of importing or producing other materials (i.e. tungsten).

HISTORY

Persian Gulf War '91

DU munitions were first used on the battlefield by US and British forces in the 1991 Persian Gulf War. Many believed that these munitions "gave coalition forces a marked operational advantage,"[36] securing the US a quick, decisive victory. However, Dan Fahey, a Navy veteran and expert on depleted uranium, asserts that the US military overstated the effectiveness of DU munitions while downplaying and even ignoring its potential environmental and health risks to exposed civilian populations and US troops.[37]

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[29] van der Keur, Hank. *Uranium Pollution from the Amsterdam 1992 Plane Crash* published in *Depleted Uranium: A Post-War Disaster for Environment and Health,* Laka Foundation, May 1999, p. 44
[30] ibid.
[31] op.cit., U.S. DOE, p.3
[32] Zajic, Vladimir S. *Review of Radioactivity, Military Use, and Health Effects of Depleted Uranium,* July 1999 Ch. 3, p. 2
[33] ibid.
[34] ibid.
[35] ibid.
[36] op.cit., Rotsker
[37] *Health and environmental hazards posed by depleted uranium,* Talk of the Nation/Science Friday (2:00PM) April 18, 2003, National Public Radio (Debate between Dan Fahey, Navy Veteran, and Michael Kilpatrick, Deployment Health Support Directorate of Health Affairs, DoD)

DU penetrators collected at Doha, Kuwait
Photo courtesy of Department of Defense

Questions raised regarding the US military's continuation of depleted uranium munitions in light of its possible link to the Gulf War Syndrome provoked sensationalized remarks and statements from the DoD in defense of the munitions. As Bernard Rotsker, Special Assistant of Gulf War Illnesses (DoD), put it: "DU rounds ripped through [Iraqi] tanks like a hot knife through butter, and their guns were totally…ineffective in penetrating American armor protected with DU shielding. DU did have an effect on the battlefield. It undoubtedly saved thousands of American lives."[38] Such an unverifiable claim should be dismissed, according to analyst Dan Fahey, because "there is not a shred of evidence backing it up."[39] Furthermore, proclaiming DU munitions indispensable through exaggeration and suggestion distorts their role in the US arsenal. Fahey points out that superior fire control systems and guns enabled US and British tanks to stay "out of range of the Iraqi guns."[40] Despite the military's enthusiasm, DU munitions took out only about 500 of the 3,700 (13.5%) Iraqi tanks destroyed during Desert Shield/Desert Storm.[41] He further clarifies that the Maverick missile, and not the DU round, was the "real 'tank killer'" used by the US in the Gulf War.[42]

In the course of the war, the US Army employed DU for both offensive and defensive ends.[43] The M1 series tanks use DU to enhance its protective armor, known as Abrams Heavy Armor (AHA), by inserting a layer of DU into a conventional steel "sleeve." [44] About one-third of the M1A1 series tanks (594 out of 1,772 tanks) deployed by the Army during the conflict were Abrams Heavy Armor variations.[45]

For offensive purposes, Abrams tanks fire both 105mm (M1/M1IP tanks) and 120mm (M1A1 tanks) Armor Piercing Fin Stabilized Discarding Sabot rounds (aka. sabot rounds) with DU penetrators.[46] The Pentagon documented that the Army alone fired 9,552 sabot rounds, a total of about 50 tons of DU.[47] The Marine Corps, in addition to the 76 M1A1 tanks either borrowed or ordered from the Army, deployed the M60A3, an older variation that fires 105mm DU rounds.[48] The exact expenditure of DU tank rounds by the Marines is unknown.

The Air Force is responsible for most of the DU expended. The A-10 "Warthog" jets use GAU-8 Gatling guns loaded with 30mm armor piercing incendiary (API) rounds. Approximately 783,514 30mm DU rounds, each containing about .66 pounds of DU, were unleashed making them the largest contributor to the overall DU dumped in the Persian Gulf region in this brief conflict.[48] (A-10 aircraft fired 782,514 DU rounds fired and A-16 aircraft fired 1,000 DU rounds)[49] The Pentagon estimates that the Air Force's 30mm DU rounds account for about 259 tons of the overall figure of 320 tons (which includes the UK forces' ton) of DU expended in the Gulf region.[50] Since these rounds were fired from

[38] Remarks by Dr. Bernard Rotsker At the American Legion Washington Conference, March 23, 1998, Washington D.C., http://www.deploymentlink.osd.mil/du_library/statements/rostker_032398.htm
[39] op.cit., Fahey, *Science…,* p. 26
[40] ibid.
[41] ibid.
[42] ibid, p. 3
[43] op.cit Rotsker, p.1
[44] op.cit., Zajic
[45] op.cit., Rotsker, p.2
[46] ibid., p. 2
[47] ibid.
[48] ibid., p. 3
[49] op.cit., Fahey, *Science…*, p. 13
[50] op.cit., Rotsker, p. 2

aircraft, many missed the intended hard targets. Therefore, the majority of these rounds did not aerosolize and remain scattered across the landscape in larger fragments or whole.[51]

Armor Piercing Fin Stabilized Discarding Sabot rounds (aka. sabot rounds) with DU penetrators
Photo courtesy of Department of Defense

The Marine Corps AV-8B Harrier aircraft shoots a 25mm DU round that contains about .33 pounds of DU.[52] During the conflict, the Marines deployed 86 aircraft that fired 67,436 DU rounds, for an additional 11 tons.[53]

During the Gulf War, the Navy deployed its shipboard Phalanx cannon (the Close-In Weapons System, or CIWS), which fires a 20mm DU round. With the exception of the rounds expended during cannon testing, the Pentagon states that the Navy launched DU ammunition only once in combat:[54] a friendly fire incident involving the USS Jarret and the USS Missouri.[55] Only 4 or 5 DU shells were fired.[56] The Navy chose to discontinue the use of DU in 2001, opting for non-radioactive tungsten munitions. Col. Clayton Nans, head of the Marines' Advanced Amphibious Assault Vehicle program announced that the Marines are "not considering depleted uranium anymore because of the environmental problems associated with it, be them real or perceived…[We] don't want to be in a position of having someone say, 'You can't bring your armor-piercing rounds on the battlefield.'"[57]

The British Army is the only other confirmed force that fired DU ammunition during the Gulf War in 1991. The British army deployed Challenger tanks armed with 120mm sabot rounds with DU penetrators. According to the UK Ministry of Defense, UK forces fired fewer than 100 Sabot rounds during combat.[58] Taking into account the additional rounds fired during training in Saudi Arabia, the UK expended a scant ton of DU in the conflict.[59]

Friendly Fire

In all armed conflicts, friendly fire is an issue of concern. While the US enjoyed technical and operational advantage over its Iraqi counterparts, the heavily armored Abrams tanks and Bradley Fighting Vehicles could not withstand impact from DU anti-tank ammunition. The DoD noted that "'fog-of-war' situations caused by the rapid advance of American forces, coupled with the use of long-range, highly lethal weapons, led to a number of friendly-fire incidents," in which US systems fired on other US systems involving DU.[60] (There were no incidences of friendly fire accidents between the UK and US forces in the first Gulf War.)[61]

By identifying the distinctive radioactive trace that DU shells leave on both the entrance and exit holes of its impacted targets, US Battle Damage Assessment Teams confirmed that 6 M1A1 tanks and 15 Bradley Fighting Vehicles were destroyed by friendly fire.[62] Many resulted from DU munitions fired from M1A1 tanks; three involved the A-10 DU

[51] op.cit., Fahey, *Science…*, p. 14
[52] op.cit., Rotsker
[53] ibid.
[54] ibid.
[55] ibid. p. 11
[56] ibid.p.3
[57] Eisler, Peter. *Study Flags Radioactive Threat* USA Today, June 25, 2001
[58] op.cit., Rotsker, p.4
[59] ibid.
[60] ibid., p. 1
[61] ibid., p. 12
[62] ibid., p. 1

anti-tank munitions. Only one "ship-to-ship" incident occurred involving the Navy's Phalanx DU rounds, as cited earlier in the report.[63]

Thirteen crewmembers lost their lives due to friendly fire, and about 50 of the 113 survivors suffered injury.[64] Unfortunately, potential DU exposures associated with the friendly fire incidents of the first Gulf War extend beyond these estimates; many personnel entered or came into contact with contaminated vehicles. Several DU-exposed veterans did not know that the damage resulted from friendly fire until after assessment teams investigated the scenes while others endured unnecessary exposure because they were not aware of the potential health hazards associated with DU.[65]

The Balkans

The controversial debate over US and British DU deployments heated up after the 1991 Persian Gulf War and gained momentum in the Balkans conflict later that decade. The 1994-95 conflict in Bosnia and 1999 conflict in Kosovo mark two more armed confrontations in which the United States employed DU munitions.

In a January 16, 2001 news briefing, Kenneth Bacon, Defense Department Spokesman, stated that the US and NATO used DU munitions in Kosovo during Operation Allied Freedom and to a lesser extent in Bosnia, but only in combat and not on a "day-to-day basis."[66] In 1994-95, A-10 aircraft fired about 10,000 30mm DU rounds, a total of about 3.3 tons, at 12 sites in Bosnia-Herzegovina.[67] In Operation Allied Force in 1999, A-10's fired approximately 31,000 DU rounds, releasing a total of 10.2 tons of DU across 85 targets in Kosovo, Serbia, and Montenegro.[68] Rounds fired from aircraft have a miss rate of about 90%; therefore, a relatively small proportion of the DU rounds hit hard targets.[69]

Afghanistan (2001) and Iraq (2003)

To date, information regarding the possible use of depleted uranium munitions in Afghanistan is not available. The Marine Corps deployed two types of weapons capable of firing DU rounds, including their light armored vehicles and AV-8B aircraft, which were used in combat.[70] The US Air Force deployed A-10 aircraft, which fire a mix of DU and non-DU rounds, but lack of documentation leaves the amount of DU expended unclear. [71]

The US Air Force released a preliminary report of "aggregated facts about Operation Iraqi Freedom (OIF)" with data collected and contributed by all US services, the UK, Australia, and Canada.[72] The report timeframe spans from March 19, 2003 to April 18, 2003, or a total of 720 hours.[73] Because more information on deployments and expenditure is readily available for the 2003 Iraq War, more realistic estimates can be figured regarding the expenditure of depleted uranium. Still, the exact quantity of DU expended is unknown and further research will continue to improve the presently available data.

The US Department of Defense and the UK Ministry of Defense have disclosed that US and UK forces utilized DU munitions in combat during Operation Iraqi Freedom.[74] The US deployed several fighting vehicles, tanks, and aircraft capable of releasing DU in Iraq.[75] Based on available information provided by preliminary reports on the 2003 Iraq War, Dan Fahey estimates that the US and UK released between 100 and 200 tons of DU during combat.[76] The Associated Press has published a number ten times that, but the source of their data is unknown.[77] Most battles took place in densely populated settings in or near urban areas. Therefore, US and UK forces released a good portion of their total DU expenditure in locations "where the Iraqi people live, work, draw water, and grow and sell food."[78] The

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[63] ibid.
[64] Fahey, Dan. *Don't Look, Don't Find: Gulf War Veterans, the U.S. Government and Depleted Uranium,* March 2000, p. 3
[65] op.cit., Rotsker, p. 2
[66] Bacon, Kenneth. Defense Department spokesman, DoD News Briefing, January 16, 2001- Pentagon Briefing Room
[67] Clinton, Dr. J. Jarret. Special Assistant to the Under Secretary of Defense for Gulf War Illnesses, Medical Readiness, and Military Deployments, DoD, *Information Paper: Depleted Uranium Environmental and Medical Surveillance in the Balkan,* Section 3- What Is Depleted Uranium and How Was It Used in the Balkans?, October 2001, p. 1
[68] ibid.
[69] op.cit., Fahey, *Science…*, p. 17
[70] ibid., p. 21

[71] ibid., p. 20-21
[72] Moseley, T. Michael, Lt Gen, USAF Commander, *Operation IRAQI FREEDOM – By The Numbers,* 30 April 2003, p. 2
[73] Ibid
[74] op.cit. Fahey, *The Use of Depleted Uranium…*, p. 4
[75] Ibid
[76] Ibid, p. 5
[77] Barbara Borscht. *Depleted Uranium Arms May Pose Risk to Troops, Residents*. Associated Press, June 14, 2003.
[78] op.cit. Fahey, p. 5

likelihood that civilians will come in contact with contaminated areas makes potential DU exposures appear even higher than in past conflicts.[79] Also, several documented friendly fire incidents suggest the UK and US troops may have been exposed to DU. That the US and UK forces have contaminated urban areas that they continue to occupy renders proper assessment and monitoring of DU-exposed soldiers, the Iraqi civilian population and environment increasingly necessary and urgent.[80]

Testing: Okinawa, Japan

On December 5th and again on the 7th, 1995, US Marine Harrier aircraft fired 600 25mm DU rounds on Torishima Firing Range located 16 miles north of Okinawa's Kumejima Island.[81] On January 24, 1996, the Harrier aircraft fired another 320 DU rounds.[82] The total expenditure of DU during this "routine testing incident" was 1,520 rounds.[83] US policy does not permit using this type of DU round in training.[84] According to the DoD, "it was a mistake that the shells were used, they were mislabeled."[85] For training purposes, the Marines use the PGU-33/U made of a powder metal material that does not ricochet when it hits hard targets.[86] These cartridges "provide for a cost effective and safe means to train without concern for hazard to the pilot or aircraft," and their blue color makes them easily distinguishable from the actual 25mm DU rounds that the Marine Harrier aircraft utilize in combat.[87]

Initially, the Marines did not notify the Japanese government because the island was uninhabited and isolated; "they didn't see any threat to the environment…[or] to people." [88] However, the Marines saw fit to clean up but recovered little more than one percent of the rounds.[89] Higher authorities in the US military chain made the decision to report the mishap to the Japanese.[90] At a February 1997 News Briefing, DoD Spokesman, Kenneth Bacon, admitted that an "inquiry from Japanese television" in January 1997 prompted the US military's decision.[91] The US government "expressed regret to the government of Japan for the delay in notifying them."[92]

Testing: Vieques, Puerto Rico

On February 19, 1999, two US Marine Corps Harrier aircraft expended 263 rounds of DU on the Vieques Inner Training Range; the unauthorized expenditure was discovered on March 5, 1999.[93] The Marine Corps took corrective measures including issuing a "naval message" to all ammunition activities "prohibiting firing the 25mm DU munitions for training, testing, or any other non-combat purposes" and disapproving the "manufacturing, reworking, and demilitarizing" DU munitions.[94] The Marine Corps and the Navy conducted a joint investigation and implemented further corrective measures including: placing DU ammunition restrictions in both Navy Instructions and Marine Corps Orders, distributing a "Self-Inspection Checklist" for compliance with the Naval Radioactive Material Permit (NRMP) for DU munitions to all storage facilities, and incorporating DU training in Marine Corps Ordnance Occupation Courses.[95] The Navy conducted an initial clean-up in March 1999 but did not recover all of the missing rounds and recommenced recovery operations and monitoring in August and September of that year.[96]

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[79] Ibid
[80] Ibid, p. 5-7
[81] Tashiro, Akiro. *Special Report:DU Munitions in Okinawa,* The Chugoku Shimbun (http://www.chugoku-np.co.jp/abom/uran/index_e.html)
[82] ibid.
[83] op.cit. Bacon, p. 13
[84] op.cit., Bacon, Tuesday, February 11, 1997, p. 14
[85] ibid., p. 13
[86] *Medium Caliber Ammunition: 25mm PGU-33/U TPF-T Target Practice Frangible Tracer*, General Dynamics Ordnance and Tactical Systems 2000-2003, http://www.gd- ots.com/stie_pages/medium/pgu33u.html
[87] ibid.
[88] op.cit., Bacon, Tuesday, February 11, 1997
[89] ibid.
[90] ibid.
[91] ibid, p. 14
[92] ibid., p. 13
[93] *Expenditure of Depleted Uranium (DU) Rounds at Vieques Inner Training Range, Puerto Rico*, Naval Radiation Safety Committee, Prepare by CDR Farrand, MSC, USN, Slide 2 (available at http://foia.navy.mil)
[94] ibid.
[95] *ibid.*
[96] ibid.

BROADER ISSUES

Contaminated DU

The DOE's production sites not only extract U-235 from natural uranium, but also from spent nuclear fuel, or "recycled uranium,"[97] which contains transuranics--radioactive elements with higher atomic numbers than that of uranium[98]--including plutonium, neptunium, americium, and fission products such as technetium-99.[99] As far back as 1952, four DOE production sites produced "recycled uranium" from spent fuel contaminated with these transuranics; approximately 130,000 tons went to processing sites.[100]

Recycling spent nuclear fuel produces depleted uranium that retains different amounts of transuranics and fission products. The DoD's *Environmental Exposure Report* reveals that the DOE provided the DoD with a DU supply derived from recycled uranium; therefore, the Abrams Heavy Armor and other munitions made from the stock may also contain these contaminants.[101] After testing "representative samples" from different "batches" of its DU stock, the Army concluded that some armor and munitions contain contaminants in trace amounts.[102] According to the DoD, transuranic contamination adds .8% to the internal radiation dose from DU alone.[103]

Despite the attention contaminated DU receives from the media and some DOE facilities, the DoD renders the issue irrelevant, stating that "measures designed to protect personnel from the DU itself are more than adequate to protect them from the trace quantities of transuranics."[104] However, sampled stocks of DU from "recycled uranium" have been found to have inconsistent levels of plutonium, some minimal amounts while others "hundreds of times above established limits."[105]

Proliferation

Although the United States boasts the largest stockpile of DU and has used its DU arsenal most extensively, several other countries have or seek to develop DU munitions for their inventories, including the United Kingdom, Russia, Turkey, Saudi Arabia, Pakistan, Thailand, Israel, and France.[106] The United States, Russia, China, and Pakistan act as DU munitions exporters to several nations.[107] Many countries import US tanks with 120mm tank guns (M1A1, M1A2) and 105mm tank guns (M60 series MBT and variants); however, this is a difficult indicator of DU munitions in country's inventories because the tanks can fire both DU and non-DU rounds.[108] The US has exported 105mm DU rounds to Taiwan and Turkey and 120mm DU rounds to Israel, Jordan, Pakistan, Saudi Arabia, and Turkey.[109]

In recognition of the "steady proliferation [of DU munitions] into the arsenals of allies and adversaries alike," the DoD states that "[t]here is little doubt, therefore, that DU will be used on the battlefield against US personnel in some future conflict."[110] This disturbing fate implies an even more perilous version of what Nobel Peace Prize nominee Dr. Helen Caldicott termed a "radioactive battlefield."[111]

HEALTH EFFECTS

The Pentagon

In January 1993 a study done by the United States General Accounting Office (GAO) stated that "inhaled insoluble oxides stay in the lungs longer and pose a potential cancer risk due to radiation. Ingested DU dust can also pose both a radioactive and a toxicity risk."[112] A 1995 study by the Army Environmental Policy Institute (AEPI) reiterated the negative health effects stating that "if DU enters the body, it has the potential to generate significant medical

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[97] op.cit., Alvarez
[98] op.cit., Rotsker, p. 9
[99] ibid., Rotsker, p. 2
[100] op.cit., Alvarez
[101] op.cit., Rotsker
[102] ibid., p. 9
[103] ibid.
[104] ibid.
[105] op.cit., Fahey, *Don't Look*…, p. 47
[106] op.cit., U.S. AEPI, p.2
[107] op.cit., Fahey, *Don't Look…,* p. 57
[108] Hank van der Keur, *Where and how much depleted uranium has been fired*?, March 2001 update of a workshop held at the CADU conference, Manchester, November 2000, Laka Foundation, Amsterdam, p. 7
[109] Ibid
[110] Bernard Rotsker, Special Assistant of Gulf War Illnesses, DoD *Environmental Exposure Report*: *Depleted Uranium in the Gulf (II)*, Section I-Overview, December 2000, p. 2
[111] Helen Caldicott, *The New Nuclear Danger*, The New Press, NY, NY, 2002 p. 146
[112] *Operation Desert Storm: Army Not Adequately Prepared to Deal With Depleted Uranium Contaminatio.,* United States General Accounting Office, January 1993, pp. 17-18

consequences. The risks associated with DU in the body are both chemical and radiological."[113] In the report, the AEPI went on to more specifically explain that "soluble components migrate throughout the body," and in particular "uranium concentrates in the bone, kidney and liver… [the kidney is the] broadly accepted…critical organ for uranium toxicity."[114]

Despite this research, the *Final Report: Presidential Advisory Committee of Gulf War Veterans Illnesses* released in 1996 stated, "it is unlikely that health effects reports by Gulf War Veterans today are the result of exposure from depleted uranium in the Gulf War."[115]

Just a month before the Gulf War began in July 1990, the DOD stated that "assuming U.S regulatory standards and health practices are followed; it is likely that some form of remediable action will be required in a DU post-combat environment."[116] A 1994 Summary Report to Congress by the U.S Army Environmental Policy Institute (AEPI) echoed this opinion: "DU management should be included as part of any remediation program recommended to a host nation to mitigate environmental damage on the battlefield."[117] In a technical report following up on Congressional concerns, the AEPI affirmed that an array of methods have been developed for DU remediation including "excavation, earth moving, physical separation, chemical separation, and in-place stabilization [though] very few [of these] technologies have actually been used. As early as 1991, Lieutenant Colonel M. V. Ziehmn of the Los Alamos Lab cautioned "if no one makes the case for the effectiveness for DU on the battlefield, DU rounds may become politically unacceptable and thus, be deleted from the arsenal…I believe we should keep this sensitive issue in mind when after-action reports are being written."[118]

Exposure in Brief

Exposure to depleted uranium may be chemical or radiological, entering the body through internal or external routes. The health affects depend on the quantity, degree of exposure, and location of embedded fragments. The chemical effects are most harmful when inhaled, ingested or embedded in the skin. When ingested, up to 90% is expelled by the kidney into the urine. However, the remaining DU may stay in the kidneys and skeleton and may disperse to soft tissue such as liver, lung fat, and muscle over an extended period of time.[119] Depleted uranium is primarily an alpha emitter that upon decay emits beta and gamma radiation, which is able to damage human tissue.[120] Research completed only in the past decade points to the impact of alpha particles on cell biology.

United Nations Environmental Programme (UNEP)

In September 2001, the United Nations Environmental Programme (UNEP) found for the first time depleted uranium in the groundwater of Serbia and Montenegro. The contamination resulted from the corrosion of DU and its subsequent diffusion into the soil. This evidence gave UNEP researchers important information about the behavior and capability of DU over time. The re-suspension of DU particles as a result of wind or human activity was also a significant finding. The DU contaminated air was found at several sights including buildings in use.

World Health Organization (WHO)

The World Health Organization (WHO) has concluded that "[o]nly military use of depleted uranium is likely to have any significant impact on environmental levels…in some instances, the levels of contamination in food and ground water could rise after some years and should be monitored and appropriate measures taken where there is a reasonable possibility of significant quantities of depleted uranium entering the food chain." [121] Additionally, the WHO notes that individuals should seek treatment if they believe they have been exposed to excessive amounts of

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[113] *Health and Environmental Consequences of Depleted Uranium Use in the U.S Army.* Army Environmental Policy Institute, June 1995

[114] *Health and Environmental Consequences of Depleted Uranium Use in the U.S Army.* Army Environmental Policy Institute, June 1995

[115] *Final Report: Presidential Advisory Committee of Gulf War Veterans Illnesses* December 1996

[116] *Kinetic Energy Penetrator Environmental and Health Considerations* (Abridged); Science Applications International Corporation (SAIC); July, 1990; Vol. 1, 4-6.

[117] *Summary Report to Congress: Health and Environmental Consequences of Depleted Uranium Use By The U.S Army* U.S Army Environmental Policy Institute June 1994

[118] *The Effectiveness of Depleted Uranium Penetrators* Los Alamos National Laboratory memorandum; Lt. Col. M.V. Ziehmn; March 1, 1991

[119] Physicians for Social Responsibility *Issues Brief: Depleted Uranium Weapons* July 1999 http://www.ngwrc.org/research/MonAug161000001999_psrbrief.htm

[120] Dr. Jan Olof Snihs *Depleted Uranium in the Balkan States Environment: Experiences and Results of UNEP's Special Studies in 1992-2001* Swedish Radiation Protection Authority Stockholm, Sweden June 1, 2003

[121] *Depleted Uranium Fact Sheet* World Health Organization January 2003 http://www.who.int/ionizing_radiation/pub_meet/DU_Eng.pdf

depleted uranium and that young children could receive greater exposure due to typical hand-to-mouth activity that could result in high depleted uranium ingestion.[122]

British Royal Society

The British Royal Society indicates that the primary exposure is from DU particles which can be inhaled. The main risk associated with DU dust is lung cancer.[123]

Concurring Recommendations

Despite differing short term conclusions, final recommendations from UNEP, WHO and the British Royal Society are strikingly in agreement; more research must be done to reach any verifiable conclusions, and clean-up and precaution are needed in areas where DU is detected.

In addition:

- UNEP calls for constant sampling of the water supply in Bosnia-Herzegovina over several years[124] and suggests that buildings containing DU be decontaminated, penetrators from the ground be collected, areas of contamination be covered with asphalt or clean soil, and the six "missing" coordinates of attack sites in Bosnia-Herzegovina be identified for investigation and clean-up.[125] Pekka Haavisto, chair of UNEP's Iraq task force, warns that "without a clean up, and the Pentagon says they have no plans for one, people returning to DU hotspots might find themselves unwitting volunteers in testing just what effects depleted uranium really has."[126]
- WHO suggests that more research be done and calls for clean-up in impact zones and where DU dust or fragments are concentrated. Furthermore, it advises monitoring water and food and aligning the disposal of DU with national and international recommendations.[127]
- The British Royal Society recommends studies on the role of alpha particle irradiation of the thoracic lymph nodes and the growth of lymphoid and haemopoietic cancer.[128] In addition, the Society calls for epidemiological studies of soldiers exposed to DU aerosols or who sustained DU shrapnel in order to identify any possible incidents of cancer, lung disease or kidney disease as well as long-term sampling of the water supply and milk to detect DU contamination. Furthermore, it advises that because "localized areas of DU contamination provide a risk, particularly to young children [that] areas should be cleared of visible penetrators and DU contamination removed from areas around known penetrator impacts."[129]

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[122] *Depleted Uranium Fact Sheet* World Health Organization January 2003 http://www.who.int/ionizing_radiation/pub_meet/DU_Eng.pdf
[123] *The Health Effects of Depleted Uranium Munitions: Summary* The British Royal Society March 2002 www.royalsoc.ac.uk
[124] *Bosnia-Herzegovina: A United Nations Environmental Programme Post-Conflict Environmental Assessment on Depleted Uranium* United Nations Environmental Programme Post Conflict Assessment Unit May 30, 2003
[125] *Bosnia-Herzegovina: A United Nations Environmental Programme Post-Conflict Environmental Assessment on Depleted Uranium* United Nations Environmental Programme Post Conflict Assessment Unit May 30, 2003
[126] Ian Sample, Nic Fleming *When the Dust Settles* The Guardian April 17, 2003
[127] *Depleted Uranium Fact Sheet* World Health Organization January 2003
[128] *The Health Effects of Depleted Uranium Munitions: Summary* The British Royal Society March 2002 www.royalsoc.ac.uk
[129] *The Health Effects of Depleted Uranium Munitions: Summary* The British Royal Society March 2002 www.royalsoc.ac.uk

11th ACR Soldiers evacuate Doha's North Compound where flames at the motor compound destroyed several tanks and their depleted uranium ammunition. July 11, 1991

US GOVERNMENT

Influence

In reaction to claims made by Gulf War veterans that DU played a role in the Gulf War Syndrome, the Department of Defense commissioned the RAND Corporation to study the syndrome, including how DU in particular may have affected it. RAND, a military contractor, did not actually use DU or veterans in their literature review; they used natural uranium as an equivalent to depleted uranium. According to Fahey's analysis of the report, RAND omitted 62 pertinent sources and ignored studies such as one conducted by the Armed Forces Radiobiology Institute (AFRI) which showed a potential relationship between DU and various damaging health effects.[130]

The RAND report did maintain that more research on DU is necessary. In January 1998, in their only admission of liability to exposed troops, the DOD admitted its failure to disseminate the potential health hazards of depleted uranium at the risk of allowing "thousands of unnecessary exposures."[131] However, the U.S government has made it difficult for international agencies to conduct extensive studies. In November 2001, following a strong US lobby, the U.N General Assembly rejected a longstanding Iraqi proposal for a UN study on the effects of DU in the Gulf War, which had already been approved by the committee on disarmament and international security.[132]

UNEP executive director Klaus Toepfer underscores the importance of early scientific assessments.[133] Because the studies on depleted uranium in the Balkans were not conducted until two to seven years after the use of DU weapons were used Toepfer says "an early study in Iraq could either lay these fears to rest or confirm that there are indeed potential risks, which could then be addressed through immediate action."[134]

The UK Ministry of Defense (MoD) took the initiative to test their soldiers returning from Iraq for depleted uranium; however, the test for examining the veterans' urine for high levels of uranium has been charged by several medical professionals as being scientifically invalid. Malcolm Hooper, an emeritus professor of medicinal chemistry on the British Government's DU Oversight Board says rather than test for uranium in urine which is easily excreted, physicians should be more concerned about the "fine particles that get deep into the lungs and stay perhaps forever."[135] The UK MoD website stresses that there is only a danger from DU dust if service personnel are "close to

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[130] Dan Fahey *DoD Analysis: The Good, Bad and the Ugly* June 1999
[131] Department of Defense as quoted in Dr. Helen Caldicott, The New Nuclear Danger, The New Press, New York 2002
[132] Irwin Arieff *US Wins Defeat of Depleted Uranium Study* Reuters November 30, 2001
[133] Nick Nutall *UNEP Recommends Studies of Depleted Uranium in Iraq* United Nations Environment Programme April 6, 2003
[134] Ibid
[135] *Troops Depleted Uranium Tests 'Invalid'* BBC News June 3, 2003

a vehicle recently hit by DU."[136] However, the UNEP study in Bosnia-Herzegovina shows that DU dust poses a longer-term risk than suggested by the MoD. UNEP found that contamination is still present from DU weapons used in 1994 and 1995.[137]

Research

The Department of Veterans Affairs has conducted the Depleted Uranium Follow-Up Program since 1993 to study the health effects of exposure to depleted uranium. This program has been repeatedly cited by the Pentagon as proof that there are no significant health effects from depleted uranium exposure, and in a recent March 2003 press briefing, claimed that doctors had found no medical effects in the studied veterans.[138] However, the program has come under significant criticism. One key criticism is a public misrepresentation of the results: at the aforementioned briefing, for example, Dr. Michael Kilpatrick stated, "There has been no cancer of bone or lungs, where you would expect them -- to see that. We have seen no leukemias."[139] Dr. Kilpatrick neglected to mention, however, that at least one veteran in the study developed lymphoma.[140] Such omissions significantly call into question any conclusions drawn from Pentagon accounts. Another key criticism of the study is the very small size of the population, which the Veterans Administration itself pointed out, calling it "highly unlikely that definitive conclusions concerning cancer induction will be obtained from the study."[141]

Finally, while the Pentagon points to the Baltimore study to justify the continued use of depleted uranium, any results from the study would necessarily apply to adults exposed in a battlefield scenario. This would not rule out potential harm to civilians who enter vehicles later, particularly children.

Studies by the DoD at the Armed Forces Radiobiology Research Institute (AFRRI) probe deeper into the possible health implications of DU exposure. Their findings are consistent with those documented by independent researchers presented in the next section. The studies noted here are representative of the extensive research completed under the DoD's auspices and offer significant information regarding the medical consequences of DU exposure.

In an ongoing study intended to verify the effects of embedded DU shrapnel on pregnancy and offspring development, female rats with implanted pellets indicated DU in the placenta and developing fetus. The depleted uranium did not have an immediate effect, though. The implanted pellets caused the litter size to decrease, but only if the rats became pregnant six months or more after DU is implanted. If the female rat becomes pregnant less than four months after receiving the DU implant, the size of the litter is not substantially affected. Researchers thus concluded that "the placenta is not a barrier to DU migration."[142]

These results are in line with the CDC's determination that low-level radiation is cumulative. The longer the DU is implanted in the female, the greater the potential for health consequences to the radiation-sensitive offspring. The U.S. Army Environmental Policy Institute (AEPI) also pointed out that the offspring of mothers exposed to high levels of uranium can have low birth weight and skeletal abnormalities.[143]

The most recent results of an ongoing AFRRI study led by Drs. Alexandra Miller and David McClain showed that when cultured human bone cells are exposed to DU, the cells had tumorigenic potential both in their growth and biochemical traits. In one study, DU induced tumor-like transformations in bone cells that are similar in magnitude to that of nickel, a known heavy metal carcinogen.[144] *The Guardian* updated the results of the study in an article describing some of Miller's unusual findings. Not only did the bone cells transform but some underwent instant genetic damage in which "fragments break off chromosomes…and form tiny rings of genetic material." This was not as unexpected as the finding that cells undamaged by DU were dividing into new cells which contained genetic

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[136] Alex Kirby *Depleted Uranium Still Haunts Balkans* BBC News March 25, 2993
[137] *Bosnia-Herzegovina: A United Nations Environmental Programme Post-Conflict Environmental Assessment on Depleted Uranium* United Nations Environmental Programme Post Conflict Assessment Unit May 30, 2003
[138] SFC Doug Sample. USA *Pentagon Officials Say Depleted Uranium Powerful, Safe* American Forces Information Service, March 14, 2003
[139] COL James Naughton, U.S. Army Materiel Command, *News Transcript: Briefing on Depleted Uranium,* U.S. Department of Defense, March 14, 2003
[140] The Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses, "Meeting with Dr. Melissa McDiarmid and her staff on October 15, 1999 to discuss the Baltimore DU Follow-Up Program and the Extended Follow-Up Program," undated. http://www.gulflink.osd.mil/du_ii/du_ii_refs/n52en651/0089_005_0000001.htm.
[141] Dan Fahey *Depleted Legitimacy: The U.S. Study of Gulf War Veterans Exposed to Depleted Uranium*, National Gulf War Resource Center Conference, May 4, 2003
[142] Dr. David E. McClain *Evaluation of the Health Risks of Embedded Depleted Uranium Shrapnel on Pregnancy and Offspring Development* Armed Forces Radiobiology Research Institute December 31, 2002
[143] *Health and Environmental Consequences of Depleted Uranium Use in the U.S Army.* Army Environmental Policy Institute, June 1995
[144] Dr. Alexandra Miller *Carcinogenic Potential of Depleted Uranium and Tungsten Alloys* Armed Forces Radiobiology Research Institute (no start date indicated/ongoing).

damage or broken chromosomes. DU appears to have a "delayed effect;" even a month after the DU was removed new cells exhibited damaged genes. Miller believes that the study which examined "tiny" amounts of DU, small enough to be radioactively and toxically insignificant, shows that it is the radioactive and toxic combination which catalyzes significant genetic damage. "You can get more then an eight-fold greater effect then you'd expect," Miller says. This means eight times as many cells can be genetically damaged then previously foreseen. [145]

The U.S. Army Environmental Policy Institute (AEPI) indicated that DU poses environmental concerns, including local water and soil contamination, which can affect human health. Water is the most effective transporter of all metals, including DU. AEPI states that the groundwater contamination, particularly when DU is spread across a land surface, should be the "principal concern." Soil contamination, an additional concern, has been examined at Aberdeen Proving Ground in Maryland, one of the primary locations for test firing DU penetrators. At Aberdeen researchers found soil contamination below a corroding penetrator which lay at the soil's surface. The contamination went as deep as 20 centimeters indicating that depleted uranium has the capability to become soluble and infiltrate soil, even in wetlands.[146] This suggests a hazard for consumption of local vegetation and could be particularly damaging to agricultural areas.

AEPI also noted the difficulty of calculating the danger DU poses in an uncontrolled environment, such as the battlefield, due to reactions with nearby elements. These uncalculated and uncontainable chemical reactions caused by incidents such as fires and high penetrator impacts "may produce compounds with various chemical toxicities."[147]

Lovelace Respiratory Research Institute (LRRI), a private biomedical research facility specializing in respiratory issues, conducts studies on DU that are both DOD commissioned and independent of the DOD. A DOD-funded study completed in March 2000 assessed the long-term carcinogenetic risk of DU by implanting rats with three sizes of depleted uranium shrapnel. The largest 5x5mm DU fragment caused a "significant increase in fragment associated tumors," the 2.5x2.5mm fragment caused only a slight increase and 2x1 mm fragment caused no tumors.[148]

In a preliminary investigation by the LRRI, independent of the DOD, researchers found that DU may infiltrate the central nervous system. Scientists believe that in a desert warfare environment the combination of constant irritation of the nasal passages and respiratory system caused by desert sand storms and combustion materials from oil field fires can weaken the nose/brain barrier impairing its ability to block depleted uranium from infiltrating the central nervous system. Once DU has reached the central nervous system, it acts as a toxin, damaging or destroying nerve tissue.[149]

INDEPENDENT RESEARCH

Fundamental Measurements

The underpinning of all research lies in accurate measurements. In terms of documenting human exposure to DU, Professor Randall Parrish, Research Professor of Isotope Geology at the University of Leicester and Head of the UK Natural Environment Research Council Isotope Geosciences Laboratory a presentation at NPRI's June symposium said, "[f]inding particles of depleted uranium oxide in lungs would be the 'smoking gun' but {such tests would be] invasive and impractical."[150] Urine tests, therefore, are the most useful tests for documenting DU in the body. The slow dissolution of uranium trioxide in the lungs (time scale of years) would cause DU to enter the blood stream, accumulate in bone and organs, with a portion being excreted through the urine. The quantity measured depends on several factors including the rate of the dissolution of uranium trioxide, the rate of bone remodeling and changes in dietary uranium intake. It is the last factor that makes the need for sensitive measurement critical.

People ingest uranium through their diet on a regular basis, with approximately 2% absorbed into the blood stream. The intake level of natural uranium may dilute the excreted depleted uranium in the urine, rendering the detection of DU even more challenging in measurements designed to document contamination. This dilution effect makes detection increasingly more challenging for individuals exposed in the first Gulf War.

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[145] Ian Sample, Nic Fleming *When the Dust Settles* The Guardian April 17, 2003
[146] *Summary Report to Congress: Health and Environmental Consequences of Depleted Uranium Use By The U.S Army* U.S Army Environmental Policy Institute June 1994
[147] *Summary Report to Congress: Health and Environmental Consequences of Depleted Uranium Use By The U.S Army* U.S Army Environmental Policy Institute June 1994
[148] Dr. Hahn Fletcher *Carcinogenicity of Depleted Uranium Fragments* Lovelace Respiratory Research Institute March 31, 2000
[149] *Scientists Study Depleted Uranium Link to Gulf War Syndrome* Lovelace Respiratory Research Institute Albuquerque, New Mexico www.lrri.org/dustudy.html
[150] Parris, Randall, "*Measuring uranium isotopes in urine: the burden of proof in the DU debate?"* as presented June 14, 2003, New York Academy of Medicine, Nuclear Policy Research Institute symposium "The Health Effects of Depleted Uranium." Remarks and slides available at www.nuclearpolicy.org

Depleted uranium, though, "is distinct from natural uranium due to its very different isotopic composition, which can be measured with sufficient accuracy and precision only using mass spectrometry." [151]Since the mid-1990s a "multi-collector high resolution ICP-MS" mass spectrometer has been available to detect with unprecedented precision very small amounts of DU within urine.[152] This stems from the instrument's ability to measure precise isotopic ratios of uranium (238U/235U, 234U/238U, 236U/238U) on less than a billionth of a gram (nanogram) of uranium extracted from urine. This type of test allows confident identification of DU in urine throughout the spectrum of the human population, not just with highly contaminated individuals. As a result it offers the chance to document residual DU in veterans' urine more than 10 years after exposure. Unfortunately, the medical community has shown little awareness of utilizing these methods. For example, a recent US government inter-laboratory study's near complete failure to accurately measure Uranium 238 and Uranium 235 even when levels were considerably above the normal range of concentration. [153]

Low-level Radiation and Cell Biology

Dr. John Little, professor of radiobiology and chair of the Department of Cancer Cell Biology at the Harvard School of Public Health, has made discoveries regarding the effects of alpha particles, the primary radioactive particles emitted by depleted uranium. Dr. Little's study illustrates the notion of "bystander effect," which implies that the injury of one cell can influence its neighbors rather than the previously held belief that radiation only harms cells expressly by contact.[154] With this evidence Dr. Little points to the possibility of a new danger in low-level radiation and a more widespread mutation of cells. He also points out that "if down at the low doses, you're inducing mutations not only in the cells that are hit but in ten cells around them, you may not be able to predict their effects just by the number of cells that are actually irradiated."[155]

The Department of Defense often justifies the safety of depleted uranium due to its low level of radiation. The "bystander effect," though refutes this position. This phenomenon has significant implications for the nature of low-level radiation alpha particles in DU, and may have even more serious effects on beta and gamma radiation that are produced when DU decays. These effects however, have yet to be studied.

In a presentation at the NPRI symposium, Dr. David Brenner, Professor of Radiation Oncology and Public Health and Director of the Radiological Research Accelerator Facility, College of Physicians and Surgeons at Columbia University, presented more recent research on the 'bystander effect' in greater detail.[156] Research on radon establishes the links between the inhalation of gas, alpha particles and cancer. Since DU is a comparable radioactive aerosol, the studies on radon were used to effectively explain the biological effects of DU.

The main concern related to radon and DU is the inhalation of dust making the primary organ of concern the lungs. Upon inhalation, dust particles containing uranium can get trapped in the lung's mucus lining and, while they are there, an alpha particle can be emitted which has just sufficient range to reach the sensitive basal cells which line the lung. On a dose-for-dose basis, alpha particles are more hazardous than x-rays or gamma rays because they produce DNA damage sites which are extremely close to one another.

Unlike radon particles from depleted uranium also produce comparable doses to the thoracic lymph nodes. This is of serious concern because the lymphoid and hemopoietic progenitor cells that ultimately make red blood cells circulate through this system. Smaller doses are also noted in the extra-thoracic airways, lymph nodes, bone surfaces, kidney, liver and red bone marrow.

Although the number of alpha particles that impact the lungs are actually small, the health risks are surprisingly high. The process is exacerbated by the 'bystander effect." Only in the last ten years has this phenomenon become more fully understood. Scientists knew that alpha particles going through cells caused transformation and damage. The fact that adjacent cells not directly irradiated would mutate and transform was unexpected.

Lung cancer risks associated with low level alpha particle damage have been established through epidemiological studies on radon. The bystander effect explains the risks. Since studies specifically on lung cancer and DU are not available, radon is again the best comparison. The latency period for lung cancer following exposure is 20 years. According to Dr. Brenner, there is quantifiable lung cancer risks associated with DU especially if the person is inside

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[151] ibid.
[152] ibid.
[153] ibid. reference: http://www.deploymentlink.osd.mil/du_library/lab_assessment/index.html
[154] Humphries, Courtney. *Direct Damage from Radiation May Be Passed to Neighboring Cells* Focus: News From Harvard Medical, Dental and Public Health Schools February 9, 2001
[155] ibid.
[156] Brenner, Dr. David. "*The Biological Effects of Very Low Dose Alpha-Particle Irradiation*" as presented June 14, 2003, New York Academy of Medicine at the Nuclear Policy Research Institute symposia "The Health Effects of Depleted Uranium." Remarks and slides available at www.nuclearpolicy.org

a vehicle struck by a DU penetrator. Although not as quantifiable, there are also lymphocytic leukemia risks (latency period of only three years); other cancers are highly speculative.

The critical impact of alpha-particles in the discussion on the health effects of DU cannot be underestimated. Alpha-particles qualify as high-LET (linear energy transfer), a measure of "radiation quality;" a high-LET is "associated with an increasing complexity of damage and a consequent decreasing efficiency of repair."[157] Biological consequences that result from irreversible DNA damage inflicted at the time of ionizing radiation exposure include: gene mutation, chromosome aberrations, malignant transformation, and cell death. [158]

A series of studies conducted by Professor Eric G. Wright, Department of Molecular and Cellular Pathology, University of Dundee, Ninewells Hospital and Medical School, Scotland, and his colleagues show that non-irradiated cells that are the progeny of cells that have been irradiated several generations (or cell divisions) earlier show a high frequency of these aforementioned irregularities.[159] A single surviving irradiated cell that suffers genetic alterations will lead to a "clonal" effect, creating the same chromosomal aberration in its progeny.[160] Studies have also shown "non-clonal chromosome aberrations and mutations," including a higher cell death rate and reproductive irregularities, in the progeny of irradiated cells; these abnormalities may continue to appear for many generations, and "possibly indefinitely in established cell lines."[161] The transmission of genetic alterations from surviving single irradiated cells (incurred at the time of exposure) to its progeny is termed *radiation-induced genomic instability (RIGI).* [162]

Wright asserts that preserving "genome integrity in the face of DNA damage is critical for human survival."[163] Diseases associated with the breakdown of chromosomal stability, "chromosome instability syndromes," include malignancy, immunodeficiency, neurological disorders, and growth and development abnormalities.[164] Wright's studies document radiation-induced genomic instability, "raising questions" regarding potential connections to "human disease processes."[165] Wright hypothesizes that "chromosomal instability, whether genetically-determined or induced by ionizing radiation, produces lesions in the haemopoietic cells of certain individuals that may contribute to the subsequent development of AML," or acute myeloid leukemia.[166]

Dr. Thomas Fasy, associate professor of pathology at the Mt. Sinai School of Medicine, at the Nuclear Policy Research Institute symposium further explained the connection between depleted uranium and potential DNA damage. As is scientifically accepted, inhaled depleted uranium particles created by the explosion of depleted uranium weapons or armor are retained deep in the lungs. These particles of uranium trioxide (UO_3) dissolve into uranyl ions (UO_2^{++}), which are the form that travel around the body, leave deposits in bone and discharge through the urine. Uranyl ions bind to DNA selectively to "clumped chromatin"[167] with high affinity (uranyl acetate is widely used in electron microscopy to stain DNA, chromosomes and nuclei.) This causes DNA damage in a reducing environment such as breaking strands or modifying the bases found in DNA; hence, their mutagenic capability.[168] Dr. Fasy proposes that due to the propensity for uranyl ions to act in this manner and given that the spermatozoa has the highest amount of chromatin in clumped form, it "does not offend reason" to surmise that the uranium found in semen is actually in the nucleus of the spermatid. [169]

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[157] Wright, Eric G., *Inducible Genomic Instability: New Insights into the Biological Effects of Ionizing Radiation,* Medicine, Conflict and Survival VOL. 16, 117-130, Published by Frank Cass, London (2000), p. 117
[158] ibid.
[159] Lorimore, S. A. and Wright, E. G. ,*Radiation-induced genomic instability and bystander effect: related inflammatory-type responses to radiation-induced stress and injury? A Review,* International Journal of Radiation Biology 2003, VOL. 79, NO. 1, 15-25 Taylor and Francis (2003) p. 15
[160] ibid.
[161] ibid.
[162] ibid.
[163] op.cit., Wright, p. 125
[164] ibid.
[165] ibid.
[166] ibid., p. 126
[167] Fasy, Dr. Thomas. "*The recent epidemic of pediatric malignancies and congenital malformations in southern Iraq; the biological plausibility of depleted uranium as a carcinogen and teratogen*." as presented June 14, 2003, New York Academy of Medicine at the Nuclear Policy Research Institute symposia "The Health Effects of Depleted Uranium." Remarks and slides available at www.nuclearpolicy.org
[168] ibid.
[169] ibid.

Studies on Children in Iraq

As a central element to his presentation at the NPRI symposium, Dr. Thomas Fasy reviewed the findings of Dr. Alim Yacoub, an epidemiologist and former Dean of Basra Medical College, Dr. Jenan Hasan, a neonatalogist at the Women and Children's Hospital in Basra, and their colleagues at the University of Basra.

As early as 1995-96, Iraqi doctors suspected a rise in leukemia and birth defects among children born or treated at the Women and Children's Hospital in central Basra, Iraq's second largest city. The hospital diagnoses all children less than 15 years of age in the whole government of Basra with a malignancy or suspected malignancy. In addition, all pregnant women inclined to deliver in a hospital do so in this hospital. The same neonatologist assessed all cases of congenital malformation. Since there was no established system for registering cases of cancer or birth defects, doctors at the hospital created an epidemiological study that integrated the hospital admittance and treatment records with census data to derive incidence.

Dr. Fasy notes that the World Health Organization's request to implement an epidemiological study in 2001 would have provided real data on real people exposed to depleted munitions. In its absence, scientists have to "rely on mathematical models that involve numerous assumptions of uncertain validity." [170] The Iraqi studies, the only population-based studies available, have their limitations including a lack of independent measures of exposure such as tissue and urine samples, no control city for comparison, mobile population so that some exposed individuals moved from the area while unexposed people moved into the area and, as a retrospective study, a question of assessment bias.

Still, key findings presented by Dr. Fasy include:[171]

- 1990 - 2001 – Incidence rate of malignancies per 100,000 children below 15 years of age in Basra has tripled.
- 1993-2000 – Incidence rate of malignant diseases among children in Basra compared to 1990 has quadrupled.
- Children under 5 with leukemia:
    - 2 cases reported in 1990
    - 41 cases reported in 2000
- Congenital Malformations: Incidence per 1000 births
    - 3.04 cases reported in 1990
    - 17.6 cases reported in 2000

One exception regarding the medical care of children in Basra is that those with bone tumors are treated at the orthopedic institute. Bone is a major repository for uranium and, according to Dr. Fasy, research has shown that uranium can "transform human osteoblasts into a malignant phenotype in cell culture." [172] Therefore, studies on the health effects of depleted uranium should also include the rate of osteosarcomas in children.

Dr. Fasy recognizes that it is virtually impossible to prove cause and effect based on epidemiological data. However, "causative agents can be implicated based on epidemiological data established by Bradford Hill" when the issue was 'does smoking cause cancer?' [173] The requirements include a time sequence, biological plausibility, dose response relationship, strength of association and specificity. Regarding the four to five year latency period for the appearance of birth defects, Mr. Fasy suggested that the slow dissolution of insoluble uranium (as explained earlier in this report) is responsible for a slow redistribution of uranyl ions from the lungs to other parts of the body including the testes, ovaries, placenta, embryo and fetus.

Animal Studies

In a joint study between the Armed Forces Radiobiology Research Institute (AFRRI) and the National Institute of Health (NIH), researchers found that human osteoblast, or bone cells, transformed into the tumorigenic phenotype, the expression of a cancer-causing trait. The study exposed mice to DU alpha particles and found that although very few cell nuclei were hit by the alpha particles, the exposure lowered the production of the Rb tumor-suppressor protein, and thus tumors formed. The study concluded that the risk of cancer observed in the mice may be analogous to other biologically reactive and carcinogenic heavy metal compounds. As a result, they call for additional studies.[174]

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[170] ibid.
[171] ibid.
[172] ibid.
[173] ibid.
[174] *Transformation of Human Osteoblast Cells to the Tumorigenic Phenotype by Depleted Uranium-Uranyl Chloride* Environmental Health Perspectives Volume 106, Number 8 August 1998 Bethesda, MD

Another study by the American Association of Cancer Research tested the reaction of rats to the implantation of uranium pellets. They found that over six months there was up to a 1,000 fold increase in the level of uranium. This indicates that DU is the likely initiator of cellular oncogenic expression and subsequently malignant disease in humans.[175]

COMPARISONS

Low-level Radiation, Pregnant Women and Birth Defects

While little research exists regarding the effects of the radiation emitted specifically by DU, there is medical knowledge regarding the effect of general radiation exposure to pregnant women and children. The Center for Disease Control points out that "the human embryo and fetus are particularly sensitive to ionizing radiation, and the health consequences can be severe, even at radiation doses too low to affect the mother." These consequences can consist of "growth retardation, malformations, impaired brain function, and cancer."[176] Because radioactive materials are most harmful when ingested, evidence of DU in water supplies may further explain how radioactive DU is transmitted to a pregnant woman.

The UNEP final report on Bosnia-Herzegovina in March 2003 found that the nine tons of DU munitions fired in 1994 and 1995 "contaminated local supplies of drinking water at one site, and can still be found in dust particles suspended in the air."[177] The CDC points out that "if a pregnant woman ingests or inhales a radioactive substance that subsequently is absorbed in her blood stream (or enters her bloodstream through a contaminated wound), the radioactive substance may pass through the placenta to the fetus…"[178] However, the irradiating effects on the unborn baby continue well after birth and can boost that individuals risk of cancer later in life.[179]

Children and Lead Poisoning

Pentagon medical experts continue to state that Iraqi children would have to "eat enough soil contaminated with depleted uranium to suffocate" in order to suffer DU's harmful effects. However, a report by the U.S Army's Environmental Policy Institute compares the toxicological risks of DU to other heavy metals like lead, cadmium, nickel, cobalt and tungsten that children would clearly be harmed by ingesting in even the smallest amounts.[180] The United Kingdom's Ministry of Defense makes a similar statement in an article about battlefield precautions, stating that DU is no more harmful then lead.[181]

While there is little information about the effect of DU contamination on children, it is widely known that childhood lead poisoning can affect almost every system in the body. According to the CDC, lead poisoning has the potential to cause learning disabilities, behavioral problems and in extreme cases, seizures, coma and death.[182] If the effect of DU is in fact similar to the effect of lead, children are especially at risk of toxic contamination.

INTERNATIONAL LAW

The U.S Army claims that it "complies with established statutes, regulations and procedures."[183] International law suggests otherwise:

- The UN Sub-Commission on Prevention and Protection of Minorities in 1996 passed a resolution banning DU weapons. They stated their concern that "abandoned contaminated equipment [may] constitute a serious danger to life" and noted the "repeated reports on the long term consequences of the use of such weapons upon human life and upon the environment." It urged all countries "to curb the production and the spread of weapons of weapons of mass destruction or with indiscriminant effect, in particular…weaponry containing depleted uranium."[184]

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[175] Miller AC, Whittaker T, McBride S, Hogan J, Benson K, Siu H. *Biomarkers for Carcinogenesis: Oncogenic Activation By Depleted Uranium In Vivo* American Association for Cancer Research 1997;38:462

[176] The Center for Disease Control *Prenatal Radiation Exposure: A Fact Sheet for Physicians* http://www.bt.cdc.gov/radiation/prenatalphysician.asp

[177] United Nations Environment Programme Post Conflict Assessment Team *Bosnia-Herzegovina: A United Nations Environment Programme Post-Conflict Environmental Assessment on Depleted Uranium* March 25, 2003 http://postconflict.unep.ch/actbihdu.htm

[178] op.cit., CDC, *Prenatal Radiation Exposure….*

[179] The Center for Disease Control *Possible Health Effects of Radiation Exposure on Unborn Babies*

[180] *Health and Environmental Consequences of Depleted Uranium Use in the U.S Army*. Army Environmental Policy Institute, June 1995

[181] United Kingdom Ministry of Defense *Depleted Uranium Middle East 2003* http://www.mod.uk/issues/depleted_uranium/middle_east_2003.htm

[182] The Center for Disease Control *Childhood Lead Poisoning* http://www.cdc.gov/nceh/lead/factsheets/childhoodlead.htm

[183] op.cit., US AEPI

[184] United Nations Sub-Commission on Prevention of Discrimination and Protection of Minorities *Resolution 1996/16*, *August 29, 1996 UN Press Release,* September 4, 1996

- An August 2002 report by the UN Sub-Commission stated that the use of DU shells is a breach of the following laws: the Universal Declaration of Human Rights; the Charter of the United Nations; the Genocide Convention; the Convention Against Torture; the four Geneva Conventions of 1949; the Conventional Weapons Convention of 1980; and the Hague Conventions of 1899 and 1907. These laws all ban the use of weapons with indiscriminant effect or which cause long-term and/or unnecessary suffering.

RECOMMENDATIONS

Debate over the use of depleted uranium munitions, sometimes fierce and politicized, has continued since the 1991 Gulf War. The purpose of this report was to review some of the key, and most recent, research applicable to the issue and reach some conclusions and recommendations for the future.

From a review of the research, both independent and government sponsored, several conclusions can be drawn:

- The virtually unanimous conclusion of all investigative and scientific bodies that have looked into this issue is that DU fragments and contaminated equipment should be cleaned up and civilian access, especially from children, should be prevented.
- Lab research on alpha emitters, conducted by several major universities, show unusual levels of cellular and chromosome damage as a result of exposure to even low levels of alpha radiation.
- Animal research involving implanted depleted uranium shows clear health risks, including tumors and reproductive effects.
- Children, because they are extremely sensitive to both chemical and radiation toxicity, are particularly at risk of harm from exposure to depleted uranium.

Based on all the available data, Nuclear Policy Research Institute makes the following recommendations:

- Immediate urine samples should be taken from civilians in affected areas and soldiers who may have come into contact with DU. These samples can be taken at minimal cost and will allow a base for future research.
- The occupying forces must take action immediately to prevent further civilian exposure to contaminated equipment and ordinance, through cordoning off damaged tanks, removing intact fragments, and placing warnings in Arabic.
- The occupying forces must lay out an immediate schedule for the remediation and cleanup of contaminated equipment, buildings and other locations where depleted uranium may be found.
- Independent epidemiological research is urgently needed to address the health problems reported in southern Iraq.
- Long term monitoring must be put in place to monitor for migration of DU into the environment, water supplies and milk; and long term studies must be conducted on the population in areas where DU was used in 2003.

Finally

- Given the potential long-lasting risk to noncombatants, the Pentagon should investigate alternative sources of ammunition (such as tungsten) and immediately halt the production, sale and use of depleted uranium munitions.