Under the radar: identifying third-generation uranium weapons

Dai WILLIAMS

Uranium is a heavy metal: it has a number of properties that make it a strategic material for nuclear and other weapons and a genotoxic hazard.

- Radioactive isotopes: natural uranium contains radioactive isotopes of different energy levels: primarily U-238 (99.28%), U-235 (0.71%) and U-234 (0.005%). Radioactive decay, combustion and nuclear reactions create daughter products, thermal radiation and ionizing radiation (alpha, beta and gamma). High-energy, short-range alpha particles are genotoxic, causing potentially carcinogenic and mutagenic chromosome damage.
- High density: uranium has a density of 19g/cm^3. This is similar to tungsten and gold, 1.7 times the density of lead and 2.4 times that of iron. The use of uranium can increase a weapon's kinetic energy, enabling it to penetrate tanks and bunkers.
- High strength: uranium creates very hard alloys with certain metals (e.g. titanium, niobium or cobalt). These alloys can be used for defensive armour, armour-piercing penetrators and high-impact warheads.
- Low melting point: at 1132ºC, less than half that of tungsten, uranium's melting point makes it suitable for shaped charge liners. When fired, these liners melt to form a focused jet of liquid metal that travels at very high speed to burn through metal or rock.
- Pyrophoric: uranium burns in air. Temperatures at explosion can reach up to 5000ºC (compared with phosphorus at 900ºC, napalm 1300ºC and thermite at 2500ºC). [1]
- Ultrafine dispersal: uranium burns to a black dust or aerosol of mainly insoluble oxides. Due to the minute size of particles, contamination disperses widely, resuspended by the sun, vehicles and wind.
- Toxicity: uranium dust is toxic, and can cause severe skin and lung irritation and damage the kidneys. High doses can cause renal failure within days.[2]

Strategic context and known uranium weapons

The first generation of uranium weapons exploited the fission potential of the U-235 isotope in enriched uranium to create nuclear weapons. Global contamination from nuclear fallout started in 1945 and continued from over 500 atmospheric nuclear tests up to 1996.[3] Highly enriched and depleted uranium and plutonium are the main materials in many nuclear warheads. Testing has added

Dai Williams is a work psychologist and independent researcher in the United Kingdom. He correlates technical, combat, health and environmental data regarding suspected uranium weapons from specialists and verified sources.

several hundred tons of uranium and other oxides to global background alpha radiation sources in soil and oceans as well as gamma-emitting fission products.

The horrors of the use of nuclear weapons in the Second World War made them an arms control priority. Nuclear weapons were classified as weapons of mass destruction (WMD); in 1968 the Treaty on the Non-proliferation of Nuclear Weapons was signed and the non-proliferation regime took root. Concerns over the health effects of nuclear fallout had led to the Partial Test-Ban Treaty in 1963 but testing continued, with global health consequences. The Comprehensive Nuclear-Test-Ban Treaty was signed in 1996, although it has not yet entered into force.

Since the 1970s a second generation of uranium weapons has been developed, which exploits the non-fission properties of uranium. Depleted uranium (DU, a by-product of the nuclear enrichment process) is used to create strong and dense alloys for tank armour and anti-tank ammunition. These solid DU penetrators burn through armour and may fragment inside the target into smaller particles that ignite to cause a high-temperature incendiary explosion. In 1991, 286 metric tons of DU ammunition were used in the First Gulf War; 3 tons were used in Bosnia in 1994–1995; 11 in Kosovo and Serbia in 1999; and over 75 in Iraq in 2003—in total over 375 tons reported since 1990.[4]

Penetrators that hit their targets and burn cause airborne uranium oxide dust contamination. Unburned penetrators contaminate soil and groundwater. Official reports from the North Atlantic Treaty Organization (NATO)[5], and for governments and military in the United Kingdom[6], United States[7] and Europe[8] have consistently minimized radiological health risks from DU weapons. But complex health problems for civilians in recent conflict zones (Bosnia, Iraq) and illnesses known as Gulf War Syndrome for veterans of the First Gulf War have caused widespread concern.[9] This has led to investigations such as environmental testing by the United Nations Environment Programme and urine testing of veterans by the United Kingdom's Depleted Uranium Oversight Board, but no official testing of civilians in conflict zones. Almost all the investigations have focused on analysis and testing for depleted uranium.

Growing concern about the hazards of DU weapons are slowly seeing some response from the international community: the European Parliament has voted for a moratorium on DU ammunition in 2001, 2003 and 2008.[10] In October 2007 a United Nations General Assembly resolution requested the Secretary-General to submit a report on the "effects of the use of armaments and ammunitions containing depleted uranium" for its Sixty-third session.[11] However, the latest European Union and United Nations resolutions have been carefully restricted to the use of DU, excluding other non-nuclear uranium weapons. By restricting debate and scientific testing to depleted uranium weapons the arms control agenda has been diverted from a third generation of undisclosed uranium weapons developed to meet more recent strategic concerns—guided weapons enhanced with undepleted uranium.

Enhanced weapons and warheads

In the 1980s and 1990s the threats of large-scale tank warfare, and of chemical and biological weapons, led to the desire to modify or enhance a wide range of conventional weapons. These included retrofitting AGM-86 nuclear cruise missiles with non-nuclear warheads[12] and developing new bomb and missile warheads designed for hard or deeply buried targets, some with agent defeat (to burn up chemical or biological warfare agents) and anti-personnel effects. The United States Air Force (USAF) Mission Plan of 1997 included nine upgrades of bombs and missiles using "dense metal" warheads.[13] The possibility that these dense metal warheads might exploit uranium (or depleted uranium) for its high-density and incendiary properties was put forward in 2001 to explain radiation anomalies in the Balkans.[14] Jane's web site states that "some guided weapons used depleted uranium to increase the penetration effect".[15]

Data on these warheads are publicly available on military research and manufacturers' web sites,[16] but the high-density metals used are classified. Three different conventional warhead technologies can be enhanced using uranium components: shaped charge warheads and submunitions can use uranium in their liners; hard-target bomb and missile warheads can exploit uranium in their casings or as ballast; and high-density, reactive metal or thermobaric explosives can use the pyrophoric property of uranium. While tungsten alloys are also strong and dense, uranium has added advantages regarding its incendiary properties, and penetrates better.

Uranium-enhanced shaped charge warheads

The 1980s saw the development of increasingly complex and powerful anti-tank missiles, including small guided weapons with tandem warheads (which detonate twice or more), some of which used shaped charges. Short-range guided weapons were developed with a range of shaped charge warheads that could be used on many tactical targets, e.g. tanks, vehicles and bunkers. Shaped charge technology is now widely used in modern weapons from landmines, demolition charges and submunitions up to advanced multistage warheads used for hard-target penetration.

There is evidence to suggest that uranium is being used in shaped charge warheads. Civilian research into shaped charges for oil well perforation in the 1980s showed penetration increased fivefold when copper shaped charge liners were replaced with uranium.[17] The United Kingdom's Ministry of Defence web site reported tests for an "Anglo-French tandem warhead with DU rear liner" in 1999.[18] Upgraded shaped charge weapons (judging from the extra letters used in their names, e.g. AGM-65G) were deployed in the First Gulf War in TOW, Hellfire and over 5,000 Maverick missiles.[19] These systems were used again in the Balkans in 1995 and 1999, and in Afghanistan, Iraq and Lebanon.[20] It is not known how many used, or use, uranium-enhanced warheads, or the levels of contamination they have caused, because uranium liners would have burned or vaporized into fine oxide dust. Weapons manufacture and target inspections and casualty testing are needed to verify the extent to which uranium liners or casings are used in shaped charge weapons.

Uranium ballast in hard-target warheads

The threat that WMD may be hidden in hardened concrete bunkers or deeply buried in tunnels or caves resulted in the development of hard-target or "Bunker Buster" warheads. The 2 metric ton GBU-28 Bunker Buster was first tested in combat in Iraq in 1991.[21] These weapons tend to be much heavier than those using shaped charges, and are used for deep impact on larger targets.

The 1997 USAF Mission Plan and Hard and Deeply Buried Target Defeat System Program defined a new generation of guided weapons with short- and long-range warheads capable of penetrating up to 5m of reinforced concrete or over 20m of soil.[22] These warheads range in size from 250lbs to 20,000lbs. All are intended to achieve at least twice the penetration effect of previous weapons by using smaller diameter warheads and replacing steel with high-density metal casings or ballast. Some are also intended to function as agent defeat warheads.

These warheads are of standard sizes and compatible with existing weapons and delivery platforms. Combined with smart laser or satellite guidance units, e.g. JDAM and Paveway, they become guided bomb units (GBU). Some warheads can be delivered in air-to-ground missiles or sea-launched missiles. Enhancement projects include converting existing Air Launched (ALCM) and Tomahawk cruise missiles (TLAM) to be able to carry new hard-target, Advanced Unitary Penetrator warheads instead of tactical nuclear warheads.[23] Most of the warheads defined in the 1997 USAF Mission Plan became operational between 1999 and 2003 except the 20,000lb Direct Strike Hard Target Weapon (DSHTW).[24]

US patents published in 1999 and 2002, including one for upgrading the 2000lb BLU-109 warhead, confirm that hard-target warhead upgrades could use tungsten or uranium as the "heavy metal" mentioned in the USAF Mission Plan.[25] In November 2001 the UK Government claimed that DU could not be used in guided bombs because it was too soft, although it acknowledged that titanium may be used.[26] But as the new technologies are more clearly understood, the potential advantages of using uranium in hard-target warheads—its high density, its high-strength alloys, and the very high temperatures at which it burns—become clear.

In 1999, an analysis was published of the likely impact of weapon systems deemed to have been used in the Balkans if, as some suspected, they carried depleted uranium warheads (Tomahawk, BLU-109/B, GBU-28 Bunker Buster, BLU-107 Durandal, AGM-114 Hellfire and armour piercing incendiary ammunition).[27] The worst-case scenario estimated that with 400kg of DU in a Tomahawk warhead and 651kg in a BLU-109/B, attacks using 1000 of each could involve 1000 tons of DU. Of this at least 200 tons may be respirable. The study only considered the use of depleted uranium, since at the time there was no suspicion that weapons could be using any other form of uranium, but it is possible these weapons were in fact using undepleted uranium. Such use could explain the increased uranium dust levels observed by neighbouring states at the time (see below).

Uranium-enhanced explosives and thermobaric weapons

Thermobaric explosives produce intense heat and a blast wave that suffocates humans in the blast area (if they are not incinerated).[28] Uranium alloys can be engineered to produce hard but brittle bomb casings or ballast that can fragment and burn at very high temperatures, enhancing conventional weapons to create a blast with a fireball and fragments of burning uranium shrapnel. Video reports from Iraq and Lebanon show explosions with these effects.[29]

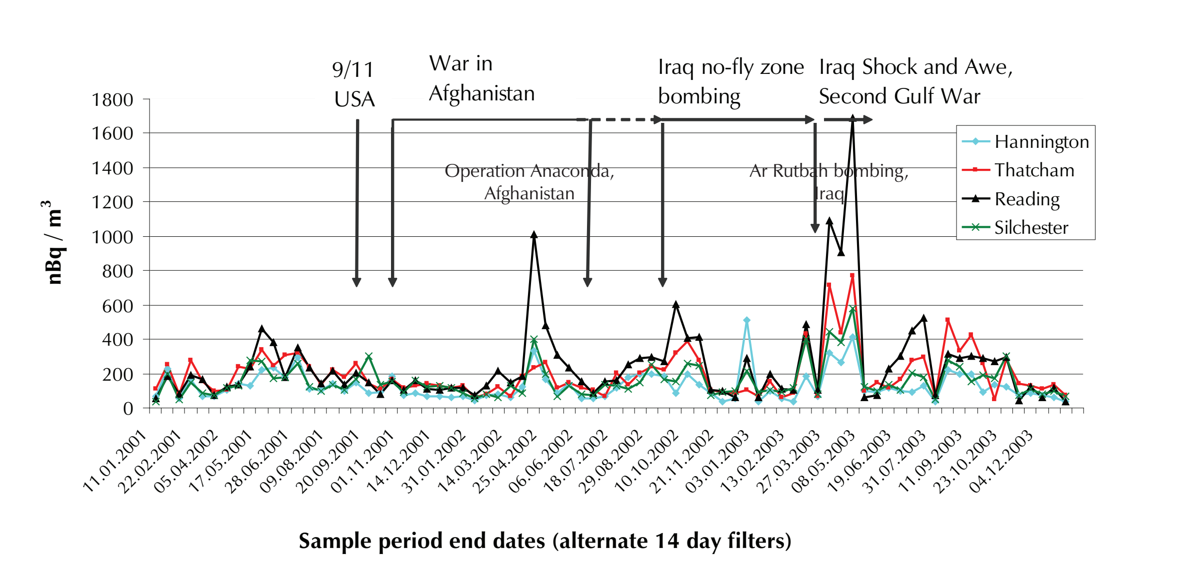
In March 2002 a thermobaric warhead was used on underground targets in Afghanistan. Designated the BLU-118/B, it used the new high-density warhead casings of the BLU-116.[30] The GBU-28 has been upgraded with the BLU-122—another dense metal warhead with a new explosive warhead—to become an enhanced Bunker Buster, EGBU-28 or EGBU-37. Thermobaric and high-density explosives have also been adapted to much smaller guided weapons, such as the AGM-114N Metal Augmented Charge Thermobaric Hellfire and the SMAW-Novel Explosive shoulder-mounted weapon used in Fallujah.[31]

Dense Inert Metal Explosive (DIME), officially using tungsten powder, is another development of concern, anticipated from an examination of US patents.[32] Operationally, tungsten and uranium alloys could be interchangeable. If suspected DIME casualties suffer severe burns, or burning shrapnel injuries, then this raises questions over whether uranium is being added or substituted to make a more reactive high-density explosive.

Evidence of uranium use in recent conflicts

Since the 1986 Chernobyl accident many countries have airborne radiation monitoring facilities. In May 1999 scientists in The former Yugoslav Republic of Macedonia detected an 8-fold increase in airborne uranium levels soon after US bombing attacks began in the Balkans.[33] In southern Hungary Kerekes et al. detected a 14-fold increase in airborne uranium dust (particles less than 2µm in size, with almost normal, not depleted, U-235/U-238 ratios) during the bombing of Belgrade.[34] Kerekes et al.

Figure 1. Uranium in high-volume air sampler filters of the Atomic Weapons Establishment, United Kingdom



Source: Adapted from C. Busby and S. Morgan, 2006, *Did the Use of Uranium Weapons in Gulf War 2 Result in Contamination of Europe? Evidence from the Measurements of the Atomic Weapons Establishment, Aldermaston*, Aberystwyth, Green Audit.

were testing for DU and concluded that what they had detected was natural uranium from soil disturbed by the bombing, an explanation reported by the UK Royal Society in 2002.[35]

In 2000, UNEP conducted an environmental assessment of DU contamination in the Balkans, when it received the necessary data from NATO regarding how much DU had been used and where (this had been initially requested by the UN Secretary-General in October 1999). NATO reported that their forces used 30,000 rounds (10 metric tons) of DU ammunition in about 100 locations in the Balkans in 1999.[36] UNEP did not test bomb or missile targets: it was looking into known DU use. UNEP published its report in January 2001, indicating no detectable contamination more than 10–20m from known DU targets.[37] This represented a major anomaly considering the uranium detected in Hungary and The former Yugoslav Republic of Macedonia. DU contamination from A10 bullets that only travelled 20m does not explain the detection of airborne uranium dust in two different places over 150km away.

Many of the 12,000 guided weapons used in Afghanistan between October 2001 and June 2002 were targeted at suspected caves and bunkers, thus it follows that many employed hard-target warheads. Suspicions of the use of uranium in these warheads were hard to verify: the United Kingdom and the United States have denied that the weapons used contained DU, therefore UNEP's post-conflict assessment of Afghanistan excluded any uranium testing.

But suspicions remained, and from 2002 several independent technical investigations into suspected new uranium weapons began. The Uranium Medical Research Center (UMRC) in Canada arranged two field missions to Afghanistan in 2002 and another to Iraq in 2003. The UMRC collected urine samples from civilians in bombed areas near Jalalabad. These showed no DU, but very high levels of undepleted uranium (80–400ng/l: the normal level among the United Kingdom population is 5ng/l).[38]

In 2004, Chris Busby used air sampling data from the Atomic Weapons Establishment (AWE) in Aldermaston, United Kingdom, from 1998 to 2003 to identify a major increase in airborne uranium dust less than two weeks after bombing in Baghdad (see Figure 1). This correlated with wind tracks from Iraq to the United Kingdom derived from the United States' National Oceanic and Atmospheric Administration (NOAA) modelling system. I ran further NOAA tests and correlated other AWE peaks in uranium levels with Operation Anaconda in Afghanistan (March 2002) and air strikes in Ar Rutbah, Iraq (5–10 March 2003).

Multiple testing verifies uranium contamination in Lebanon

During the 2006 conflict between Hezbollah and Israel in Southern Lebanon, unusual explosions and extreme injuries during the conflict caused Lebanese communities, media and non-governmental organizations to question whether Israel was using DU weapons or other new weapons. The United Nations Human Rights Council voted for an inquiry into the suspected use of DU and other illegal weapons in the conflict, which reported in November.[39]

I visited Lebanon in September and November 2006 and met Lebanese physicist Dr M.A. Kobeissi. I witnessed his radiation reading of 726nSv in Crater A, Khiam. I collected samples of soil and water from Khiam as well as water, dust and urine samples and an ambulance's air filter from south Beirut. These were tested by Chris Busby at Green Audit, by the Harwell laboratory in the United Kingdom and by the School of Oceanographic Sciences' laboratory at the University of Wales. Two samples contained high levels of undepleted uranium and four samples contained low-enriched uranium.[40] Dr Kobeissi continued his studies in 2007: 15 urine samples from Beirut were tested; two were found to contain low-enriched uranium and one a high level of undepleted uranium.[41]

UNEP's first post-conflict survey of Lebanon, undertaken in October 2006, tested 32 locations for DU only, and all were negative, so we met UNEP personnel in Geneva and returned to Lebanon to retest craters in Khiam on 21 November. UNEP did not test Crater B, where my soil and water samples were found to contain low-enriched uranium. But the results of their soil tests in Crater A matched Kobeissi's, with medium and high (26–52mg/kg, where normal is 2–3mg/kg) levels of undepleted uranium. UNEP's statements and final report reflect the results of their first survey, smear tests for DU only. [42] Their more precise soil test results are available on their web site.[43]

Levels and isotopic ratios of uranium contamination distinguish between man-made and natural sources. Bringing together the test results available for Lebanon—those from UNEP, Kobeissi and Busby/Williams—suggests the use of two different types of weapon, one containing undepleted uranium (Khiam Crater A) and one low-enriched uranium (Khiam Crater B); both types of contamination were found in Beirut.

Since 2002 several independent uranium weapons researchers have been collecting combat reports and uranium contamination reports and test results; combining these would create a valuable metadata resource. It has been suggested that the International Atomic Energy Agency (IAEA) should have an international databank of nuclear explosives to allow the identification of the source of nuclear materials following an explosion.[44] A similar facility is necessary for non-fissile uranium sources, weapons and contamination incidents, to build a clearer and more reliable picture of the possible development and use of new weapons and their effects.

Casualty reports

Conflicts are used to combat-test new and prototype weapons. The first warning of the use of new weapons often comes from combat reports of unusual deaths, injuries or destruction. These may not constitute legal or scientific evidence but they serve as early warnings to the possible use of either new and unknown or outlawed weapons, and to the need for operational vigilance and technical investigation.

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Deaths and injuries involving extreme burns indicate the use of high-temperature weapons. In 1945 the heat from nuclear weapons used in Japan carbonized casualties. In Iraq in 1991 casualties in tanks and vehicles hit by second-generation DU ammunition were carbonized; civilians in the Al Amiriya shelter in Baghdad were carbonized by a high-temperature explosion from a bomb or missile. In 2001 US troops bombed by accident in Afghanistan suffered extreme burns. In 2003 Iraqi troop casualties at Baghdad airport were extremely burned on one side but unburned on the other. In one case near Baghdad a child, partly protected by a wall, survived extreme burns that charred his exposed limbs and torso indicating brief, very high-temperature flash burns. In Fallujah, Iraq in 2004[45] and Lebanon in 2006 there were further reports of casualties with extreme burns.[46]

Since 2001 occasional reports from Afghanistan and Lebanon describe victims who died immediately, or within 24 hours, without external injuries, sometimes covered with black dust, sometimes with severe vomiting or internal bleeding;[47] civilian medical personnel would be unaware that these casualty reports match the effects of new thermobaric weapons.

Eyewitness and media reports of explosions

Photographs and television reports of combat situations give direct images of blast, explosions and the size, colour and dispersal of explosion plumes. They also indicate effects such as crater size, penetration and blast damage. Military personnel will recognize most types of explosion, plumes and craters, and which weapons cause them. Some journalists and media teams are also skilled observers of the effects of weapons and the casualties in combat zones, collating eyewitness reports and scientific or photographic data for public information.[48]

Pictures from Baghdad in 2003 and Beirut in 2006 (see above) all show explosions with a brilliant white flash (brighter than lightning) followed by a large fireball (up to 50m diameter). Fragments of burning shrapnel are blown 100–200m or more from the target, indicating high-density pyrophoric metal. Photos of explosions in Lebanon in 2006 often showed two explosions on targets—one from a high explosive and one fireball. Eyewitnesses several hundred metres from targets reported "silent" explosions and brief asphyxia "as if all the oxygen has gone". It appears that very large incendiary bombs are being used frequently, and their difference from high explosives is clear when looking at a mixed strike.[49]

Unusual illnesses and deaths

International and regional organizations involved in emergency response and post-conflict recovery must be alert for unusual health problems after an attack, not to forget the peacekeepers or coalitions that might also be exposed, and national emergency response, health and arms control agencies. Health reports from combat zones are quickly forgotten among the many other urgent concerns, but they may be early indications of communities contaminated by the use of new weapons and deserve investigation.

However, acute exposure to toxic, biological or radioactive sources can be fatal within hours or days. In chaotic conflict situations medical personnel able to assess the cause of death are likely to be scarce and victims are often buried quickly for health, cultural or religious reasons. Medical assessments for the most acute casualties are rare in remote locations so eyewitness reports of unusual deaths are important in trying to establish the cause of death.

Even for well-resourced populations like the United Kingdom and the United States, health anomalies among troops may be undiagnosed, misdiagnosed or not reported. In 1991 US troops in Iraq reported early onset symptoms of nausea, numb hands and feet, joint pains, weakness etc. These symptoms were widespread and also affected non-combatants e.g. technicians. In 2000 several NATO personnel from Italy and Portugal died after post-conflict deployment to heavily bombed areas in the Balkans.[50] Most died of rapid onset leukaemias or lymphomas, and classified investigations are ongoing.

In July 2003 a US soldier was evacuated from Baghdad with a mysterious, non-bacterial pneumonia after hauling contaminated soil from targets in Baghdad to the desert. He died three days later of renal failure. Nineteen other troops were reported with similar conditions.[51] Severe lung irritation and toxic effects could be symptoms of exposure to large amounts of uranium oxide dust. This possibility was recognized in the United Kingdom's Royal Society report on DU in 2002, but as the investigation was on known uses of uranium in combat, there was no expectation of possible lethal toxic exposure from uranium or depleted uranium in large warheads.[52]

In Afghanistan there were several reports of unusual illnesses and fatalities in combat regions: doctors reported several undiagnosed deaths within 2–3 days of bombing incidents that they suspected were due to non-conventional weapons.[53] In November 2001 the World Health Organization's Epidemic and Pandemic Alert and Response web site reported a major epidemic of leishmaniasis in the Kabul region. In February 2002 it reported 30 deaths from Crimean-Congo haemorrhagic fever out of season.[54] In April 2003 visceral leishmaniasis was reported in northern Iraq soon after bombing and an influenza epidemic in western Iran, downwind of bombing in Iraq. Perhaps understandably, symptoms and injuries are being explained by "known" possible causes, as medical experts are not looking for the possible effects of the use of new weapons. However, these explanations can seem far-fetched.

Health problems that may be delayed onset effects of weapons use (three to five years or more after attacks) were reported in Iraq in the mid-1990s, Bosnia in the late 1990s, and more recently in Afghanistan and Fallujah, Iraq. Reported problems include severe birth defects, leukaemias, lymphomas and a range of other chronic or fatal health conditions.[55]

Comprehensive public reports about overall post-conflict health and mortality for military personnel in Europe and North America are rare. Rigorous uranium testing for veterans only started with the United Kingdom's Depleted Uranium Oversight Board project after 2002.[56] Most veterans who have served in locations presumed or known to have been contaminated by uranium have not been fully tested for uranium contamination. There has been no systematic national uranium testing of civilians from recent conflict zones since 1991. The search of veterans and civilians involved in the First Gulf War for answers to their long-term health problems remains far from over in 2008.

Conclusion

Undepleted uranium dust is effectively invisible to conventional field and laboratory tests. It gives no gamma radiation indication in the field and shows an almost normal isotopic ratio in laboratory tests. This is perfect camouflage for large quantities of radiological contamination—it appears to be natural background uranium.

Recent public and scientific discourse has been restricted to depleted uranium, mainly because this is the only form of uranium that has been admitted as used in weapons. However, as long as it is suspected that new weapons are being developed and used that contain other forms of uranium, scientific assessments of veterans' and civilians' health, and of the post-conflict environment, must consider the use of any combination of uranium isotopes.

The borderline between conventional, radiological and nuclear weapons is increasingly blurred.

This paper describes warhead enhancements planned over 10 years ago. If these weapons are using uranium, the levels of contamination could be massive. Moreover, what developments have there been in the meantime? The borderline between conventional, radiological and nuclear weapons is increasingly blurred, both technically and legally. In 2004 the United Nations Advisory Board on Disarmament Matters noted that:

> The nuclear non-proliferation and disarmament regime does not address the issue of radiological weapons and warfare, as it is strictly devoted to nuclear weapons and the respective fissile materials. No international instrument is available in the realm of radiological weapons.[57]

The board recommended that the Conference on Disarmament begin negotiations on a convention for the prohibition of radiological weapons. International debate and far wider health studies and scientific review are needed to uncover the full scope of radiological weapons technology, their use, and hazards for civilians, troops and global contamination.

Notes

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16. See, for example, the Boeing and Lockheed Martin web sites (www.boeing.com and www.lockheedmartin.com) for descriptions of hard-target and penetrator weapons. The Federation of American Scientists' (FAS) Military Analysis Network and the web site *GlobalSecurity.org* are also useful sources.
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