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# Engineering solution for Radioactive Waste in IRAQ

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**Abstract**

Depleted uranium (DU) is a by-product of the enrichment of natural uranium for nuclear reactor-grade or nuclear weapons-grade uranium. DU is chemically identical to natural uranium. Depleted uranium is chemically identical to natural uranium. DU is depleted with isotope of $U^{235}$ and its radioactivity is 60% of the natural uranium and increases to 80% after few months and is usually considered as low level radioactive waste (LLW).Iraq experienced two devastating wars in 1991 and 2003, during which massive amounts of new weapons and sophisticated manufactured nuclear weapons were used -called Depleted Uranium (DU).During the second Gulf war in 2003 U.S. and British troops have reportedly used more than five times as many DU bombs and shells as the total number used during the 1991 war for the invasion and occupation of Iraq. It was estimated that more than 1100 to 2200 tons of DU was used. As a consequence the ruminants of wars are affecting the people (30 million) and environment. There are hundreds of sites contaminated with nuclear radiation.There is no Iraqi strategy and/or national program, not even well thought out plans and scientific personnel and technical equipment required to clean Iraq of these wastes. The aim of this work is to high light the environmental implications of the two Gulf wars on Iraq and suggest possible solutions to the problem.

***Keywords*:** Depleted uranium, Iraq, Radioactive waste, Military radioactive waste.

## 1. Introduction

Radioactive waste is an important part of hazardous products. The source of this waste is mainly nuclear power plants, industry, hospitals, research organizations and military nuclear tests and weapons (Abdel Rahman, 2012). IAEA (1995) published the ethics and principles for the management and disposal of these wastes irrespective of their physical and chemical characteristics or origin minimizing the risks to population and environment. Individual countries also have their own policy principles that might include administrative and operational measures based on national priorities, structure and human and financial resources. Declarations and agreements were executed to prevent radioactive pollution (IAEA, 2002, 2010). Nuclear power plants are dangerous facilities put in practical use on the stipulation that they can "completely seal in radiation," while radioactive weapons scattering radioactive materials in the environment (Yagasaki, 2003). Currently there are 441 power reactors in operation and some under construction (IAEA, 2011).The Global radioactive waste inventory reported as storage in 2008 was 17.6 million cubic meters, of these 21% are short-lived, low and intermediate level waste, 77% long-lived, low and intermediate level waste, and 2% high level waste (Yagasaki, 2003). Depleted Uranium (DU) is a by-product of the enrichment of natural uranium for nuclear reactor-grade or nuclear weapons-grade uranium. Depleted uranium is chemically identical to natural uranium. DU is depleted with isotope of $U^{235}$ and its radioactivity is 60% of the natural uranium and increases to 80% after few months and is usually considered as low level radioactive waste (LLW) (Zwijnenburg, 2013, Almuqdadi and Al-Ansari, 2013 a&b).

DU (depleted uranium) had been used in military weapons due to its ability to penetrate armored vehicles, tanks and bunkers during the 1960s (Zwijnenburg, 2013, IAEA, 2011). It is used to make the tips of armor-piercing shells because it is extremely dense: 1.7 times as dense as lead ((Zwijnenburg, 2013, Al-Ansari et al, 2013a&b, Al-Ansari, 2013). In addition, unlike other heavy metals that tend to flatten, or mushroom, upon impact, DU has the ability to "self-sharpen" as material spread out by the impact ignites and burns off as the munitions pierces its target (Bollyn, C., 2004, Wagner, F. and Thurn, V., 2005¸ Rowe, D.G., 2003).On explosion it creates a poisonous radioactive cloud of fine dust that can spread by tens of kilometers (ICBUW, 2008). Anybody who breathes these particles will have a permanent dose; it is not going to decrease very much over time, and cause major problems (Almuqdadi , 2000, Bollyn, 2004).

Though DU is 40 per cent less radioactive than natural uranium, its radiological and toxic effects might combine in subtle, unforeseen ways, making it more carcinogenic than thought. Depleted Uranium is "genotoxic". It chemically alters DNA, switching on genes that would otherwise not be expressed. The fear is that the resulting abnormally high activity in cells could be a precursor to tumor growth. Depleted uranium weapons alloy is 99.8%, U238, emitting 60% of the alpha, beta, and gamma radiation of natural uranium (Wagner and Thurn, 2005 and,Durakovic 2003). When the DU penetrates hits an object it breaks up and causes secondary explosions. Some of the uranium used with DU weapons vaporizes into extremely small particles, which are dispersed into the atmosphere where they remain until they fall to the ground with the rain. As gas uranium oxides, the chemically toxic and radioactive Depleted uranium can easily enter the body through the skin or the lungs and be carried around the world until it falls to earth with the wind and the rain. DU is used in many forms of ammunition as an armor penetrator because of its extreme weight and density. The depleted uranium used in these missiles and bombs is a by-product of the nuclear enrichment process. Experts say the US Department of Energy has 100 million tons of DU and using it in weapons saves the government money on the cost of its disposal (Puppetgov, 2009; Hall, 2006).

DU weapons had been used in several places in the Balkans in 1994-95 (Bosnia Herzegovina) and 1999 (Kosovo, Serbia and Montenegro) ) (Zwijnenburg, 2013). It was also used in Kuwait (1991) and Iraq (1991 and2003-2004), in Chechnya and during and the ten day war in Georgia in 2008(Zwijnenburg, 2013).

Iraq is located between geographic coordinates 33 00 N, 44 00 E, (Figure 1), and occupies a total area of 437 072 square kilometers. Iraq is bordered by Turkey from the northIran from

the east, Syria and Jordan from the west, and Saudi Arabia and Kuwait from the south. The total population in Iraq is about 30, 000,000. This country experienced two devastating wars in 1991 and 2003, during which massive amounts of new weapons and sophisticated manufactured nuclear weapons were used -called Depleted Uranium (DU).
In this research, the environmental implications of DU will be highlighted and solutions will be given to protect the environment in Iraq.

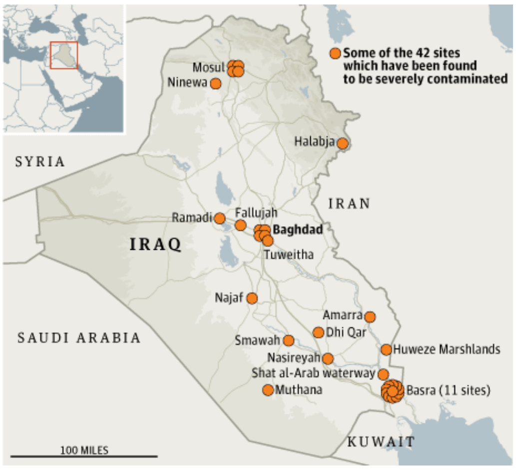


Figure 1: Contaminated sites in Iraq with DU (Chulov, 2010)

## 2. Contaminated sites

The largest single radionuclide contamination occurred in the Gulf during Gulf War II, 1991, where depleted uranium was used as amour-penetrating ordnance, contaminated the countryside of Iraq, and chronically exposed the civilian population and military personnel to DU dust, vapors, and aerosols.

During the second Gulf war in 2003 U.S. and British troops have reportedly used more than five times as many DU bombs and shells as the total number used during the 1991 war for the invasion and occupation of Iraq . It was estimated that more than 1100 to 2200 tons of DU was used. The most conservative estimate is that more than 440 tons of DU was used by tanks, armored vehicles and aircraft (Zwijnenburg, 2013).

This quantity is 400 to 800 more powerful than the ones used in the first Gulf war. According to Okinawa (Almuqdadi, 2007**)** every 800 tons of DU is equivalent to 83 nuclear bombs. Accordingly, about 250 nuclear bombs were fired on Iraq tell 2003 war. Weyman (2003) reported that the Uranium Medical Research Center cited in their report that the published data about the quantities of DU used in Iraq are as follow:
24 Imperial Tons (21.8 Metric Tonnes). U.S. Army data related by U.S. Senator Jon Kyle, U.S. Senator, Chair of the Republican Policy Committee, in a letter to J. Cohen-Joppa, July 14, 2003.
100 – 200 Metric Tonnes – D. Fahey, the Use of Depleted Uranium in the 2003 Iraq War: An Initial Assessment of Information and Policies, June 24, 2003.
68 Metric Tonnes (75 Imperial Tons), representing calculations based on % of DU rounds loaded in total fired rounds of 300,000 by A-10 Thunderbolt. Reported interview of unnamed CentCom spokesperson, Christian Science Monitor, May 15, 2003.

311,597 30-mm rounds, T M Mosley, USAF, By the Numbers, Operation Iraqi Freedom, Assessment and Analysis Division, USAF, April 2003.
1,000 – 2,000 metric tons (1,100 – 2,200 imperial tons), posted in Associated Press article, The Environment in the News, UNEP Environmental Press Release Reports, Communications and Public Information, United Nations Environment Program, Associated Press, April 2003.

The targets where DU weapons were used are spread from south to north Iraq (Figure 1). UMRC (2004) conducted a team to investigate the areas contaminated by DU (Chulov, 2010). The team performed radiation surveys, nuclide analysis, interviewed civilians and community leaders, collected biological and field samples, and investigated the possible health effects of radiological weapons on Iraqi civilians. UMRC's team surveyed bombsite and battlefield investigations, and sample collection activities were conducted in central and southern Iraq, covering major areas of engagement. Operation Iraqi Freedom executed two operational programs: "Rapid Dominance" and "Shock and Awe"; each was investigated by UMRC (Table 1).

More detailed information about the contaminated sites and the quantities of DU ammunition used are given by Zwijnenburg (2013) Al-Taie et al, (2013),Almuqdadi and Al-Ansari (2013a&b), Ali (2013), Al-Daghastani (2013) and Fathi et al (2013). It is evident that the southern part of Iraqi is highly contaminated (Figure 2).


Figure 2: DU contaminated sites in southern Iraq (Zwijnenburg, 2013)

In addition, other targets were located within populated areas were also hit by radioactive weapons in many cities especially the capital Baghdad (Figure 3).

Figure 3: A10 firing DU at the Ministry of Planning inside Baghdad, April 4, 2003 (Zwijnenburg, 2013)

Table1: Bomb sites, battlefields and communities surveyed and investigated by UMRC September 30 to Oct 13, 2003(UMRC, 2004).

| Order of Investigations<br>Areas surveyed and sites investigated | "Overwhelming Force" Order of Battle<br>Operations Iraqi Freedom, Telic and Falconer |
|---|---|
| Baghdad area, heavy-weight bombsites:<br>• Baghdad Central Market<br>• Baghdad Central Telephone Exchange<br>• Al Rashid Air Force Base<br>• Baath Party Headquarters<br>• Ministry of Information<br>• Mansour District – April 7/03 leadership decapitation strike (Sector 613)<br>• Jammah Suburb # 512, Baghdad<br><br>Baghdad combat battlefields, US led:<br>• Haiyy al Mavalemeen – Teachers District<br>• Auweirj Coalition/SRG HQ<br>• Tank-graveyard<br>• Baghdad Gate<br><br>Central Iraqi, U.S. led combat:<br>• Suweirah and Suweirah Air Force Base<br>• Salman Pak Road Battlefield<br>• An Najaf and Diiwaniyah<br>• Karabla and Al Husseiniyah<br>• Al Kut<br>• Al Hillah<br>• An Nasiriyah<br><br>British led combat:<br>• Battle for Al Basra<br>• Az Zubayr (Kuwaiti/Iraq DMZ)<br>• Al Ashar and Abu Khasib<br>• Basra Canal and Shaat al Arabi corridor<br>• Al Faw peninsula<br>• Umm Qasr | Air campaign:<br>U.S. and British "Shock and Awe" Strategic Military and Civilian Demoralization bombing<br>Joint Air-delivered and Ship-launched Bombing Campaign by:<br>• U.S. & UK Royal Airforces<br>• U.S. and British Royal Navies<br>• 15,500 strike sorties<br>• 27,000 bombs<br>•<br><br>Ground force battles<br>Advance and Battle for Baghdad: "Rapid Dominance"<br>Comprised of two main divisions, western and eastern, main columns advancing from Kuwait to Baghdad.<br>• U.S. 1st Marine Expeditionary Force – East<br>• U.S. 5 Corps – West<br>• U.S. 3rd Mechanised Infantry Division<br>• Close-in air support:<br>- 101st Air Assault Division<br>- 82nd Airborne Divisions<br><br>UK Operation Telic & Operation James<br>Combat Joint Special Operations Task Force; including Australia - Operation Falconer<br>• 3rd Commando Division (Desert Rats)<br>• 1st UK Armoured Division<br>• 7th Armoured Brigade<br>• 2nd Close Support Division (Royal Logistics)<br>• 16 Air Assault Brigade & SAS Sabre Squadron |

## 1 Clean-up operations

The soil as well as the military equipment in all these sites are believed to be contaminated by DU used by American and allied forces. Due to the abnormal high radiation rates in these sites and their effect on humans and environment, the Iraqi Government and the American and allied forces (coalition forces) carried out clean up and soil replacement activities. Allied forces carried out major clean-up programs to clear army bases and remove contaminated military scrap metal from these sites, to storage areas in and around Baghdad and Basrah. US government's clearance efforts remain classified (Zwijnenburg, 2013).

Uranium Medical Research Centre (UMRC) carried out a comprehensive survey on the sites where coalition forces tried to clean in Iraq (Weyman, 2003).Some of the cleanup operations as Baghdad sites are concerned, UMRC, first visited the U.S. occupied base in south-western Baghdad in the Auweirj district which is close to the International Airport and hosts one of the largest Coalition bases around Baghdad, occupying the operational headquarters of the Iraqi Special Republican Guard. The area was subject to considerable aerial bombing and rocket fire prior to the Coalition ground forces' arrival. Then it was followed by several ground skirmishes along the main routes to the International Airport and western entrances to the City. This area is very close to Mansour District and the main route to many bridges crossing the Tigris into the downtown core.

They stated that when the UMRC team arrived to the site a cloud was blanketing the Coalition-occupied base, depositing a layer of fresh dust on people, houses, automobiles, and the highway. There was a steady stream of tandem-axle dump trucks carrying full loads of sand leaving the site, heading south away from the city while a second stream of fully loaded dump trucks was waiting to enter the base returning from the south. At the base, bulldozers were spreading soil while front-end loaders were filling the trucks that had just emptied their loads of soil (silt and sand). The arriving trucks were delivering loads of sand into the base while the departing trucks were hauling away the base's topsoil. This operation was going on for months.

The aim of this operation is removing potentially contaminating soils from their living and working areas. Due to this exercise, it was noticed that lofting tones of fine, light dust was going on into the local environment, which was then falling back to inundate square kilometers of residential neighborhoods and Coalition occupied facilities. These clouds are lofting above and spreading over the entire area of at least 5,000,000 residents in Baghdad alone. Other sites in Baghdad and other cities were also visited by UMRC and the situation was not encouraging.

WHO put a plan in 2003 highlighting areas where intervention was required and seeking support and funding due to DU contamination and itt was not implemented due to lack of funding.( WHO, 2003 a&b).

UNEP after the fall of the Iraqi regime was concerned about environmental problems due to DU and oil spills and the lack of effective waste management. It did recieve information from British forces only about contaminated sites in Basrah (UNEP, 2003). Activities of UN organizations in Iraq were significantly constrained after the 2003 suicide bomb attack on the UN's headquarters in Baghdad. IAEA and the US to shift focus to yellowcake uranium oxide from Saddam-era nuclear facilities but Radiation Protection Centre surveyed the contaminated sites and claimed that there were between 300 and 365 contaminated sites, which they are now in the process of cleaning, and 30-35 sites which still need to be cleaned-up (Zwijnenburg, ,2013). The people were unaware of the risks of exposure to DU. Most of the military remains were collected and put in yards very close to residential areas in most of the cases (Figure 4). Civilians, including children, were seen playing and/or removing parts and components from the vehicles these site (Figure 5).


Figure 4: Contaminated military waste in yards.

Figure 5: Children playing with radioactive military waste.

According to the Iraqi Ministry of Environment there are hundreds of sites contaminated with nuclear radiation, and The Center of Radiation Protection in 2005 reported that there are 315 polluted sites (Almuqdadi and Al-Ansari, 2013a&b,Al-Taie et al, 2013), while experts from the United Nations Environment Program UNEP estimated that contaminated sites are thousands (UNEP,2005). But people were afraid to talk about the problems due to these sites, thinking that the government would evict them from their homes and land.

Extremely dangerous acts had been reported concerning the military waste of war that includes hundreds of tanks, armored vehicles and other scrap. Some were exported to Jordan and at the border checks, staff from the IAEA picked up elevated levels of radiation from the scrap metal, raising concerns among government officials in Jordan (Al-salh, 2012). Furthermore, some scrap was recycled and used in buildings while civilians, including children, were seen removing parts and components from the vehicles (Zwijnenburg, 2013, Al-Ansari, 2013).

Zwijnenburg (2013) stated that cleaning up Iraq from contaminated DU sites will cost multi-billion US Dollars and for this reason (Williams, 2004) DU user states refuse to be held accountable for the contamination in Iraq.

## 3. Environmental Implications

As it was indicated earlier that almost all the area of Iraqi was a target for DU weapons, in addition to the radioactive contamination due to military activities in Gulf war II and III, other dangerous source of contamination was from the material and equipment at the Iraqi Energy Authority (Figures 6 ,7,8). After the fall of the Baath regime in 2003, the Iraqi Energy Authority, like all other Ministries and governmental organizations, sustained immense losses due to the turmoil and looting. The Middle East Media Research Institute (MEMRI) (Scherrer, 2003) carried out an intensive interview with formal researchers at the Iraqi Energy Authority and they disclosed the events that took place after the fall of Baath regime at the facilities of the commission. Tons of Uranium (as yellow cakes) as well as byproducts from processing activities in addition to tons of radioactive waste were stored in barrels. Simple citizens stolen these barrels and used they for storing water. The radioactive materials in these barrels were either spread in large quantities on the ground or taken to their homes. Later some of these barrels were used for drinking water while the others were used to sell milk. Some the researchers surveyed homes of some civilians and noticed that the contaminated barrels were used to store food or daily household. When they were told that these barrels are contaminated they throw some of them in the river and others in waste sewer systems. About 4-5 houses were tested for outdoor contamination every day. The level of radioactivity on the walls of one of the houses was 30 billion/hour (the allowed level is 0.2) which means that it was 150 million times more than the allowed level.


Figure 6: Locations of nuclear facilities in Iraq.
(Source http://www-ns.iaea.org/images/rw/iraq/map-images/map_01.jpg)

In other parts of the Iraqi Energy Authority, there were about 200 barrels of isotopes and radioactive materials as well as yellow Uranium Oxides; they were all spilled on the ground. If a strong wind blows, it can carry these quantities to great distances outside.

In addition, insects were kept in 4 labs where these insects were used as biological insecticides. The expected ecological disaster from releasing thousands of flies known as chrysomya bezziana, nicknamed screw worm, which were bred by the Nuclear Authority to be used as biological farming insecticides. They Iraqi police and the Americans were fully informed about these labs but nothing was done to protect the people from these harmful insects. The flies were released by the looters and were expected to harm animals in Iraq and neighboring countries. These flies were to be released after being sterilized (Chulov, 2010). Hall in 2006 reported that with the arid climate of Iraq, sandstorms blow tiny particles of DU away from the blast epicenter, impacting the surrounding environment without geographical limitations. These particles enter the soil, polluting the water table, the Tigris and Euphrates Rivers, and infecting the food chain. Fertile grasslands west of Basra in southern Iraq, contaminated with DU, produce vegetables and grains for livestock that are consumed by American troops as well as Iraqis (Chulov, 2010).


Figure 7: Left, waste barrels comprised of two groups, first; ready to use material (known as yellow cake), second; waste material stored in plastic barrels. Right, decayed solid and liquid radioactive wastes stored at Al-Tuwaitha site - waste silos, (www.iaea.org)


Figure 8: Left radioactive scrap and soil at Adaya site northern Iraq. Right, soil contamination at Al-Tuwaitha site - RWTS Warehouse near Baghdad, (www.iaea.org)

Numerous research had been carried out about the effect of DU in various part of the world (Durakovic, 2003, Durakovic et al 2003, Miller et al 2003, L'Azou et al 2002, Arfsten et al, 2001, Gu et al 2001, Pellmar et al 1999, Kennedy et al 1996, Lehnert et al 1997, Kadhim et al 1994, Kadhim etal 1992). They also analyzed different parts of the body to detect the effect on these parts. Scientists noticed that DU is organotropic and ultimately gets incorporated into target organs, such as the skeletal tissue where it has a long-term retention. It is also slowly soluble, uranium isotopes are gradually decorporated from the retention sites and have been detected in the urine of Persian Gulf War I veterans 10 years after inhalational exposure or shrapnel wounds. Studies of tissue distribution reported DU accumulation in the bone, kidney, reproductive system, brain, and lung, with verified genotoxic, mutagenic and carcinogenic properties, as well as reproductive and teratogenic alterations. Recent studies on animals embedded with DU pellets confirm the findings of previous Biological distribution studies that the kidneys and bones are target organs for uranium isotopes, with other identified sites in the lymphatic, respiratory, and reproductive and central nervous systems (Zwijnenburg, ,2013, Almuqdadi and Al-Ansari, 2013 a&b).

DU isotopes were detected in the British, Canadian, and United States Gulf War veterans as late as nine years after inhalational exposure to radioactive dust in Gulf War I. Autopsy for a Canadian veteran's samples of lung, liver, kidney, and bone showed DU isotopes. They contained high concentrations of uranium, with the isotopic ratios indicating the presence of DU. Early studies performed in 1991 by whole body counting, suggested evidence of the presence of uranium in the body and urine of the contaminated veterans. Research has progressed about DU in veterans' bodies to evaluate the clinical effects of contamination with uranium in Gulf War I veterans, the civilian population of Iraq, military personnel and civilians in the Balkans, and civilians in Afghanistan, and more recently, Gaza and West Bank, Palestine (Zwijnenburg, ,2013, Almuqdadi and Al-Ansari, 2013 a&b).

Recent evidence, from human data reports, about the mutagenic effects of alpha particles on stem cells and alpha-radiation induced chromosomal instabilities in human bone marrow cells are of particular importance(Kadhim et al 1992 and 1994).Low dose of alpha particles can cause sister chromatid changes in normal human cells (Lehnert et al 1997). The lung remains the principal portal of entry of uranium isotopes into the body; the skeletal tissue being the final target organ (Durakovic, 2003).

In 1991 during Gulf War I resulted in 350 metric tons of DU deposited in the environment and about 3 to 6 million grams of DU aerosol released into the atmosphere. This caused later what is known as the Gulf war disease. These methods, identifying 0.2-0.33% of U235 in Gulf War I veterans, demonstrate uranium concentration of 150 ng/L at the original time of exposure, as compared to the non-exposed population in the Gulf who contained 0.7 to 1.0% of 235U, indicating a urinary uranium concentration of only 14 ng/L (Durakoviæ 2003). The long physical and biological half-life, alpha particle decay, and well-established evidence of somatic and genetic radiation toxicity suggest a viable potential role of DU in the genesis of Gulf War and Balkan Syndromes (Durakovic, 2003).

The armor-piercing shells made of depleted uranium which were first used in warfare by US-led troops during the1991 Gulf War and then during the 2003 invasion, turned many parts of Iraq to radioactive toxic wastelands. Many soldiers participated in Gulf war 1 and 2 were sick. A study conducted on nine recently returned soldiers from the New York National Guard showed that nine were found to have "almost certainly" inhaled radioactive dust from exploded DU shells. About one out of every three veterans from the first Gulf War is permanently disabled due to DU effect, and 179,310 veterans of the 592,561 discharged from the 1991 war in Iraq, are receiving disability compensation and another 24,763 cases are pending (Bollyn, 2004).

Two manmade forms of uranium in urine samples from four of the 9 soldiers were revealed by laboratory tests. They are the first confirmed cases of inhaled DU from the second Iraq war. These soldiers were military police not exposed to the heat of battle indicating that other soldiers engaged in combat must have more DU exposure. Over 30000 casualties were reported in Iraq (Bollyn, 2004).

In 2001 it was found that DU, including U 236, in 62% of the sick gulf war veterans, it is believed that particles lodged in their bodies and may be the cause of their illness. They had significant levels of uranium in their urine seven to nine years after the war. In 2003-05, after the first gulf war, the level of radiation was 300 times more than the normal level where more DU bullets were used in that war (Ross, 2008).

Physical abnormality is increasing after the Gulf war where of 13,191 pregnancies among the partners of male Gulf vets, 686, or 5.2 percent, had some form of physical abnormality, compared with 342, or 3.5 percent, of the 9,758 non-Gulf pregnancies (LaForge, 2004). Doctors in Iraq diagnosed severe leukemia in some of the soldiers where 38 of them died a few hours after returning home to Lima, Peru. They had leukemia because they were exposed to DU, even though one of them had served I Baghdad for a short period. He served in the Baghdad Green Zone area (Hall, 2006).

Following the invasion of Iraq in 2003, over 140,000 cases of cancer has been reported, which are believed to be caused by toxic weaponry used by the occupying troops. It is reported that 2,000 tons of (DU) expenditure were used during the invasion ( Press TV, 2010, Ross, 2008).In addition it has resulted in many grossly deformed children born in areas such as southern Iraq where tons of DU have contaminated the environment and local population. An untold number of Americans veterans have also been born with severe birth defects as a result of DU contamination. Babies whose fathers served in the 1991 Gulf war are 50 percent more likely to have physical abnormalities; in addition it was also found a 40 percent increased risk of miscarriage among women whose partners served in the war (Bollyn, 2004, Zwijnenburg, 2013).

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Figure 9. Some disabled Iraqi children (source a-Ross, S., 2008 and b Puppetgov, 2009)

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Near Baghdad the readings of Geiger counter in 2003 were 1000 and 1900 times the normal reading, where bunker buster bombs and munitions had exploded near Baghdad. These bombs contain more than one ton of DU. According to IAEA half million were dead between 1991 and 1997. Furthermore, it was estimated that 700- 800 tons of DU were used in the bombing the military zone south Basrah, this amount is sufficient to cause 500 000 cases which might lead to death (Ross, 2008). Almuqdadi (2000) stated that the United Kingdom Atomic Energy Authority (UKAEA) warned the British Government of the use of DU weapons in the Gulf war. Such weapons lead to cancer and threat the life of humans near the destroyed equipment and even those looking at them (Felicity Arbuthnot, 1991). Almuqdadi (2000) further mentioned that the American Defense Nuclear Agency warned from serious consequences due to the use of DU weapons. Cohen (1991) reported that the amount of DU present in Kuwait and South of Iraq is capable of killing 5000000 people. Almuqdadi (2000) stated that New York Times in 1992 and other researchers confirmed the effect of DU on the people in the Gulf area.

In one of Baghdad hospitals, during seven years they noticed that where babies are born with congenital abnormalities, but very late spontaneous abortions because of congenital defects. Previously, one cased used to be reported per month and now it is two to three cases are reported each day which is equivalent to about 1000 cases per year in one hospital (Ross, 2008). Malignancies in children at Basrah hospital raised 240% from 1990 to 1999 (Paulinson, 2006).

It was estimated by UNICEF that there are about 6,880 deaths of children under the age of five every year in Iraq, with an under-fives mortality rate of 125 per 1,000 live births. In addition, the mortality rate of Iraqi women during pregnancy and childbirth has reached three times the rate reported during the period between 1989 and 2002 (Hassan, 2004).

During 1991 war DU ammunition was mainly used against Iraqi tanks in the desert near Basrah, while in the second war was used all over Iraq even in densely populated areas including the heart of Baghdad, Mosul, Tikrit and other cities. It is believed that the death toll may surpass a million deaths over the next few years. Some Iraqi doctors estimate that more than 40% of the population around Basrah will get cancer i.e. 680000 out of the 1.7 million people living in that area (Ross, 2008). Leukemia in Iraq had been grown up more than 600% since 1990, similar trend was noticed in Sarajevo after American bombing in 1996 where leukemia tripled within 5 years as well as NATO and UN peacekeepers in the region are also suffering from cancer (Ross, 2008).

Cancer has increased dramatically in southern Iraq. In 1988, 34 people died of cancer; in 1998, 450 died of cancer; in 2001 there were 603 cancer deaths (Johanson, 2002). In August 1998, 10 babies were born with no heads, eight with abnormally large heads and six with deformed limbs in Basrah, furthermore, cancer cases raised from 80 cases in 1990 up to 380 in 1997(Ross, 2008). There were photos of cancer patients as well as infants without brains, with their internal organs outside their bodies, without sexual organs, without spines, and the list of deformities went on and on (Johanson, 2002). The rate of leukemia in Iraq has grown by more than 600 percent. Most of the leukemia and cancer victims aren't soldiers. (ST. Clair and Frank, 2004). Scherrer cited in 2003, based on the report of the 48th meeting issued by the UN Committee dealing with effects of Atomic radiation on 20th April 1999, noting the rapid increase in mortality caused by DU between 1991 and 1997, the United Kingdom Atomic Energy Authority (UKAEA) document predicted the death of half a million Iraqis, noting that "...some 700-800 tons of depleted uranium was used in bombing the military zones south of Iraq. Such a quantity has a radiation effect, sufficient to cause 500,000 cases which may lead to death."

All Iraq is not free from radioactive contamination, including what is called “safe” Green Zone in Baghdad where top military officers, civilian occupation authorities, international journalists, and the Iraqi government leaders live and work (Hall, 2006). Almuqdadi, (2012) stated that the future of all Iraqi children is threatened by the radioactive waste of DU in Iraq. It is evident that Iraqi people are suffering from various health problems due to the use of DU weapons. In addition, Iraqi soil and water is considered contaminated (Zwijnenburg, 2013).

It should be mentioned however, that civilian facilities like power plants and refineries were bombed during the two Gulf wars. These actions left a legacy of the contaminants which are either transient or long lived ( Figure 10). Zwijnenburg (2013) listed a long table will all the toxic substances that were exposed to the environment and the inhabitants in Iraq from these facilities.

Figure 10: Unburnt trinitrotolluine (TNT). Iraqi Army ammunition storage depot, Missan Governorate, south eastern Iraq, 2004 (Zwijnenburg, 2013).

## 4. Discussion

Since most of the battered remnants of war are radioactively contaminated. Despite the passage of two decades of the first war and 8 years of the second war these remains are still radioactive and residues are found in farm fields, along roads, near residential areas. This necessities the importance of proper disposal of the radioactive military waste, and other pollutants to save the Iraqi people and environment.

As a first step proper site selection criteria are to be used. Selecting a landfill site is a difficult task. In doing so, we have to take care of several factors. Among these factors is its effect on humans, environment, water resources, air, and soil as well as other utilities like transportation and power supply. In addition the landfill should have sufficient capacity to meet the current and projected waste to be deposited within at least 10 years.

There are no internationally adopted standards to be followed for site selection criteria (Malczewski, 1999; Lin and Kao 1999; Dikshit et al., 2000)Landfill site selection is a complicated process involving several factors like environmental economics and socio economics) (Kao el al.,1997; Tammemagi, 1999). It should be capable of disposing waste in a safe manner that should provide high degree of protection to human health and environment (Siddiqui et al., 1996; Oweis and Khera, 1998; Dikshit et al., 2000). However, despite the differences of the techniques or methods to be followed, the end result is to minimize: the risk of public health, impact on the environment, level of services to the facility users and cost to the facility.

The most important points to be recognized in landfill sitting are:

1. Distance from Cities and Towns: To minimize the effect of landfill o human health it should be located at least 3 km from the nearest town.
2. Distance from Airports: To overcome birds interrupting aircrafts landing and taking off, it is advisable that the landfill should be at a distance of 3km or more away from the runway.
3. Distance from primary Highways: The land fill should not be very close to highways and this depends on the topography of the area and access roads.
4: Distance from Public parks and recreation areas: The distance of the landfill from parks and recreation areas depends on the topography and the prevailing wind direction.
5. Groundwater: Water table should be deep enough to prevent leakage to groundwater aquifers. The landfill should be away from groundwater recharge areas. In cases of failure, the ground water flow direction should be in such a direction causing minimum pollution.
6. Soil: It is preferable that the existing soil has low permeability (106 cm/s).
7. Flood plain areas: Areas that might be flooded should be avoided.
8. Surface water: The landfills should be at least 200 meters away from streams and stream valleys or lakes.
9. Topography: The land fill is to be located in an area where local drainage is running away from its site. In addition the landfill site should not be located in an area where flush flood might take place.
10. Biodiversity: The site should be located at least I kilometer away from protected areas or areas used for breading or living animals. It is recommended that the site should be away from borrowing animals.
11. Geology: Faulted areas and karsts terrains are to be avoided. Sand dune movements should be studied and landfills are to be located away from such dunes. Areas with rocks

having cracks or joints should be avoided, also areas having sinkholes or karsts are to be avoided.

12. Seismicity: The area should be seismically stable. Nearby reservoirs are to be avoided due to possible induced seismicity.
13. Meteorology: Rainfall duration and intensity, temperature, humidity and wind speed and direction must be considered when sitting a landfill.

The priorities of the above conditions will vary from place to another depending on the population distribution, meteorological, geological and hydrological conditions.

In view of the above, it is believed that there are three places inside Iraq that can satisfy the above site selection criteria. Keeping in mind that Iraq covers an area of 438317km$^2$ of which 60% is desert. These deserts are the Western, Southern and Al-Jazira deserts. They are the western desert, southern desert and Al-Jezera desert in the north (Figure 11). It is believed that these deserts fulfill all the requirements for dumping the contaminated waste of war.

The Western desert lies west of Iraq (Figure 11). It covers an area of 104000 Km$^2$. Most of the desert is a flat rising in elevation westward. The general increase in gradient from east to west is 5 m/km. It is dissected by dense valleys. Some of them are canyon-like running for tens of kilometers. Isolated hills are noticed within the area which might be as high as 50 meters. Depressions are also found either erosional or due to solution effect. The annual rainfall is low ranging from 100-150 mm (Sissakian, 2007). The mean annual temperature is ranging from 13 to 300C (Sissakian, 2007).

The southern desert (Figure 11) covers an area of 76000 Km2. This area is generally flat and rising toward the south. It is characterized by few hills and large number of very long valleys. A fault escarpment which runs for few kilometers with a height of 5-15 meters is another feature in this desert. The area is characterized by its low rainfall which range from 75 to 100 mm/year (Ma'ala, 2009b). The mean annual temperature is 24-260C.

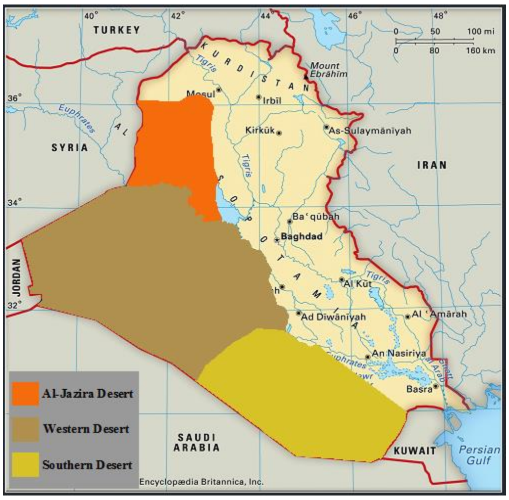


Figure 11. Western , Southern and Jezera Deserts in Iraq

Al-Jazira desert covers an area of 29270 km$^2$ which represent about 6.7% of the total area of Iraq (Figure 13). Al-Jazira desert covers an area of 29270 (Figure 13). It is located in the northern part of Iraq within the area bordered by the Tigris and Euphrates Rivers. The mean annual temperature at Al-Jazira area is (30 – 33) ° C, while the mean annual amount of evaporation (3000 – 3200) mm (Ma'ala, 2009a). Rainfall occurs during winter in the area. It increases from the south to the north within the area. It is 150 mm (in the south), (200 – 300) mm (in the middle) then increases gradually to 400 mm (in the north). The potential of evaporation in the area is several times more than the average rainfall (Ma'ala, 2009a).

From the tectonics point of view, most of Al-Jazira province lies within the stable shelf area (Fouad, and Nasir, 2009).

According to Alsinawi (2006) all the above deserts are within the no damage zone and the rest of it falls within minor damage zone. Historical study of earthquake events in Iraq also indicates that large parts of the desertic areas did not experience any earthquakes in the past and the remainder small area experienced few earthquakes (Alsinawi, and Al Qasrani, 2003).

## 5. Conclusions

The cheapest technique to get rid of the contaminated radioactive military scrap waste is to burry in it to save the civilians and the environment. The climatic, hydrological and geological conditions make the deserts in the western, northern and southern parts of the country suitable for the deposit of DU-contaminated soil and wrecked armour. It is proposed, that the waste should be brought from the fifteen sites that are most heavily suffering from DU-debris to a small number of disposal sites. Here it is proposed sites in the western, northern and southern deserts areas. These disposal sites, can be of different size depending on the amount and type of waste. The largest amounts of waste are located in the Bagdad, Ramadi, Falluja and Tuweitha areas for which two major disposal sites some 300 km west of Bagdad should be constructed. A smaller site in the northeast should be built for the waste from Mosul, Ninewa and Halabja, and a major one in the southeast for the waste from Najaf, Amarra, Dhi Qar, Huweze, Nasireyah, Shat-el-Arab, Muthana and Basra. Some transport of waste from Basra to the proposed two major sites in the western desert area might be necessary. In these sites, site selection criteria suitable for the geology, environment and hydrological conditions of the nature of the waste should be considered.

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