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The depleted uranium (DU) awareness for forensic science practices and risk analysis

E. Seyhan*

Jandarma Meslek Yüksek Okulu (JAMYO) Beytepe, Ankara 06835 Turkey

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ABSTRACT

Depleted uranium (DU) came to the fore with its permanent health problems on human after the Kosova and Gulf War. The reason for the rise of congenital defected births and cancers was declared as the use of depleted uranium. Therefore there is a strong need to create awareness for the risks created by depleted uranium munitions usage which might have long period effects as lasting centuries. To take the necessary precautions in the crime scene for nuclear, biological, chemical and physical dangers is the primary responsibility of crime scene officers and all the investigators. But compromising procedures and educating personnel for the awareness are the liability of institutions.

Keywords: Depleted uranium (DU), risk, awareness, crime scene

1. Introduction

As known, depleted uranium (DU) has had a wide range of application venue in industry and medicine for years, it had its notorious allegations for the long term health problems after the Kosovo and Gulf Wars. The health problems which the military personnel, non-governmental organizations (NGO's) and the locals faced in the DU contaminated areas in post war periods still keep its place in the world agenda.

In fact, the amount of possible health hazards of DU usage for military purposes cannot be an issue for discussion. The innocuity of something can only be assured with the results of scientific studies. If there is still suspicion of its credibility, then the amount of risk in the situation can be assessed. Principally, this issue is still a hot topic in the international *vox populi* after the use of DU munitions in the present wars.

Based on the fact that many countries produce depleted uranium and sell it to the countries which are well known with their capacity and power in arms industry, it can be easily presumed that tons of uranium could have been used in the wars of Kosovo, Afghanistan and Iraq. In many studies, increase in congenital defects and cancer cases in these countries was pointed out as the result of DU munition usage. Furthermore, many prominent scientists pointed out that the collapse of immune system; illnesses related with kidney, lung and liver which were not common in the area prior to war started to be prevalent. They also stated that these could be the results of the DU contamination. After the Iraq war, the dramatic rise in the lukemia cases in children, anemia, miscarriage and premature births in women were also linked to the use of DU contamination [1].

In this review article, it was primarily aimed to create awareness in the public for the post-war risks and the long term health effects of depleted uranium which can last hundreds of years. With this

*Corresponding author: Ercan Seyhan, (E-mail:ercnes@yahoo.com)
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perspective, it was also intended to establish awareness for the crime scene investigators and law enforcement agencies who are mostly the first responders to the scene together with first aid personnel.

2. Depleted Uranium (DU) Content and its Production

Natural uranium is a dense and slightly radioactive trace element found in human and nature as in air, water, earth, stone etc. Higher concentrations can be found in ore beds and deposits of the world. [2]. The uranium and its compounds are also valuable elements for trading means for humans. It had been usually used as polishing tiles in history.

The studies on the health effects of uranium date back to 1800s. In 1900's, it was especially prescribed to increase the glucose levels of the diabetics' glucose secretion [3]. But it attracted attention and had been demanded in producing nuclear fuel parallel to the development of nuclear weapons in 1940s. Big discussions on military use of uranium are still going on for the negative health effects on human and possible environmental hazards.

2.1 What is Depleted Uranium (DU)?

Depleted uranium (DU) is produced with ^{238}U which is a natural radioactive isotope [4]. It can also be defined as the by-product of uranium enrichment process. The characteristic properties of depleted uranium can shortly be summarized as; alfa emitting particles with low specific radioactivity, high specific of weight and being easy to obtain compared to enriched uranium [5].

Depleted uranium can easily be distinguished from natural uranium with its changing concentrations of definite uranium isotopes. Natural uranium contains 0.7% ^{235}U. Despite that depleted uranium is an unstable and radioactive heavy metal like natural uranium; it emits ionized alpha, beta and gama radiation. The radioactive nature gives uranium the tendency of decreasing. In other words, it has half life. The required time to decrease the half amount of natural uranium (^{238}U) is around 4.5 billion years [6] .

2.2 Some Characteristics of Uranium

Natural uranium contains three major radioactive isotopes, ^{238}U (99.27%), ^{235}U (0.72%) and ^{234}U (0.0054%). The depleted uranium is a definition of uranium type which has one third of ^{235}U uranium isotope amount existing in nature. Depleted uranium, mostly produced in nuclear power plants and used in nuclear arms, is a type of uranium which is the remnant of uranium enrichment process [7]. Uranium is the heaviest metal and its density is about double of lead's density. Even the radioactivity toxicity of depleted uranium is less compared to enriched uranium, its chemical toxicity is relatively higher. Depleted uranium has very similar chemical, physical and toxicological specialities with natural uranium. But it emits about 40% less alpha radiation and 15% less gamma radiation than natural uranium [8].

To be used as a nuclear fuel or in nuclear weapons, uranium must be enriched in ^{235}U, most commonly by the process of gaseous diffusion. With this process, the concentration of ^{235}U isotope can be obtained to a level of sustainable nuclear chain reaction [9]. Nuclear fuel needs approximately 3-5% of enriched uranium ^{235}U isotope [10]. Highly enriched uranium used for nuclear weapons necessitates an increase to over 90% ^{235}U composition. But many side products are formed disproportionably in the enrichment phase. However, the enrichment process produces a disproportionately large amount of by-product, depleted uranium (DU) [5].

The most important issue is to prevent misunderstanding of "depleted" word in depleted uranium. The difference in radioactivity between natural and depleted uranium is that given equal quantities, the radioactivity of depleted uranium was observed as the half amount of isotopes in natural uranium content. But the uranium concentration in depleted uranium waste is very high level and this makes it more radioactive [11]. With the fact that depleted uranium, 1.7 times denser than lead, is very pyrophoric, it is really valuable in anti-tank assaults.

2.3 The Possible Health Effects of Depleted Uranium

The most sensitive point in the use of these kind of munitions in wars is that the effects remain in nature for years and the fact that there is no method to completely dispose of DU in the environment is extremely problematic. It is a fact that that decontamination of depleted uranium exposure can be done in a limited way which is really expensive

and dangerous for human health. The most common method of DU clean-up simply involves moving the contaminant elsewhere. But even the transfer process has many risks itself.

2.3.1 Radioactivity of DU

Depleted uranium is a radioactive heavy metal. In reality, the chemical toxicity of both natural and depleted uranium is same but depleted uranium radiates 40% less radiation than natural uranium [5]. Uranium isotopes mainly radiate α particle. But it also emits some β radiation and a very small amount of γ radiation. α particles cannot cross the superficial dead layers of skin, but β radiation can penetrate to the basal layer of the skin.

2.3.2 Radiation toxicity of DU

^{238}U emits small amount of α and β particles but its α particle radiation is long lasting. The body is exposed to depleted uranium generally by ingestion and respiration [12,13]. The depleted uranium particles reaching to the lungs reside there for long periods and give tremendous damage. There is still ongoing scientific discussion if this brings the cancer risk together.

2.3.3 Chemical toxicity of DU

There are many articles written about the toxic effects of uranium. In these studies, kidneys are stated as the most sensitive target areas [14].

It is known that uranyl carbonate complexes dissolve into acidic urine in kidneys. This establishes the baseline of the damage which uranium can activate. These kinds of damages in kidneys are very similar to the damages of heavy metals such as lead and cadmium. Wherever uranium penetrates into the body, it ends in the kidneys via blood stream. If the solubility of uranium source is higher, it will reach to the kidneys in relatively shorter periods. The areas which human body holds uranium are approximately 66% in skeleton, 16% in liver, 8% kidneys and 10% other tissues [15].

3. The Military Use of Depleted Uranium

Depleted uranium has multiple uses by military forces. It is also used as balance support in some missiles and aircrafts. Because of its high density (19.0 g/cm^3) and penetration ability into stiff surfaces made it possible to be used in tanks as armor and also an armor piercing weapon as well. But it must be stated that all armor plates are not made of depleted uranium. When depleted uranium rounds hits armour plating, the rods begin to self-sharpen, thereby enhancing their ability to pierce the armour which makes it an excellent armor piercing weapon [16]. The self-sharpening starts with hitting the armor plates and emits depleted uranium particles around simultaneously. The amount of depleted uranium particles emitted around depends on the munition type, impact velocity to the armor and the target whether it is armoured or not [17].

When a depleted uranium munition hits the target, it starts to burn with a temperature of 3000°C. This amount of temperature makes the depleted uranium munition penetrate the armor easily and makes the other metals such as steel, lead, nickel and aluminium burn simultaneously with depleted uranium. Such heat blastwave in the target reaches its maximum value in the contact point and makes these metals aerosol dust. These dusts are vaporized into the air [18]. It was stated that depleted uranium oxidizes about 28-70% while hitting the target. The amount of respirable state is about 50-96% and these amounts can hang on the air [17]. This reality brings together the fact that people near to the targeted area are more susceptible to the uranium exposure than the others. So the first responders and crime scene investigators are potential exposure victims [19]. The curious public and children in post war venues are highly potential victims as well. It is the priority to bear in mind that ingestion or respiration of the depleted uranium dust are the most common way of exposure [20].

Thus, depleted uranium is converted into a fine dust of different sized particles and can constitute a very dangerous situation for human health. The dust particles of depleted uranium can travel to very far distances by wind. Depleted uranium can influence food supply if the particles mix with water sources by taking part in water cycle [21,22]. Most contamination from depleted uranium hits on armoured vehicles is limited to within about 100 metres of the target. But the DU bullets are not as effective as expected when they hit to unarmoured vehicles and the earth. In other words, they cannot produce enough depleted uranium dust [23].

The depleted uranium armour plates are specific for the tanks when considered the abovementioned

advantages. In fact, the most effective tanks of the modern world have depleted uranium armor shields. This enables the tanks to have an effective and active defence against conventional anti tank munitions.

It is a fact that many countries in the world have or is thought to own depleted uranium munitions [24]. The years in which the depleted uranium munitions or armors were used effectively and in large amounts were 1990s [25,26]. These munitions and armours were commonly used in Kuwait-Iraq War in 1991 [27,28]. It was also stated by NATO that these were used in large quantities in both Bosnia (1995) and Kosovo (1999) [29,30,31].

It is stated that 300 metric tons during Gulf War in Iraq and Kuwait which is about 944,000 depleted uranium munitions [32,33]; 3.3 metric tons between the years of 1994 and 1995 in Bosnia [34] and 10 metric tons which is about 30,000 [33,18] were used. It is also known that 100-200 metric tons during Iraq War in 2003 [35] and 500-600 metric tons of DU during Afghanistan War between 2001 and 2002 were used [36].

4. The Effects of Depleted Uranium Dust on Human Health

The basic approach for radiation protection in medicine is the verification of the dose exposed. It is to prevent the exposure amount exceeding the threshold amount [37].

Depleted uranium mainly radiates α particle. But β and γ particles are also radiated. The α particles ends in kidneys by blood stream. Some amount is thrown out but some can settle down for long periods and ruin the DNA configuration of cells. This can lead to gene mutation and cancerous cells. Theoretically, even a single α particle can cause devastating effects in human body. Thus, high high exposure rates can be thought as high risk of getting ill [38]. β particles can mainly damage the eyes and skin. This is important because DU can enter body through the open wounds [5]. When DU enters the body by ingestion, respiration or other means abovementioned, radioactive particles can especially settle in lungs, kidneys or spleen Considering that respiration is a common way of DU exposure, it is important to know that DU particles can be suspended in the air for long period of times [5].

The dust formed after the impact of bullet in the target area can be easily ingested or breathed. The amount of depleted uranium in the blood is relatively higher when ingested compared to breathing particles. The fraction of depleted uranium absorbed by an individual will also depend on the particle size and environmental distribution of DU. If depleted uranium particles are in a compound which can easily dissolve into water, this could lead to more than 20% absorption into the blood [5].

When DU hits the target, uranium oxide particles form with the size of 0.5-5 micron. These particles can suspend in the air for a long time and be carried to long distances by windpower. The particle size varies. Some can be seen but most of them are in a form of dust and undetectable by naked eye. That's why they can easily be breathed or ingested [39]. Regardless of the dust particle, depleted uranium has got solubility levels in different liquids. In other words, it can dissolve in body fluids as well. The amount of depleted uranium, which is approximately 90%, dissolved in blood is thrown out by kidneys between 24-48 hours. The remaining 10 % stays in the body. It is also stated that the amount of undissolved uranium taken into the body by respiration can stay in the lungs for years [40].

The contamination by ingestion generally occurs with the depleted uranium dust contamination of the spring water or food supply [5]. The children playing with the war remnant DU munitions or touching the tanks hit by DU can be dramatically subject to uranium exposure [5].

It was studied on the brain and renal damage, cancer, chromosome aberration and congenital damages to determine the effect of depleted uranium exposure to human. It was also stated that the number of people killed from cancer in Southern Iraq were 34 in 1988, 450 in 1998 and 603 in 2001 [41]. In another study carried out in 39,450 Italian soldiers, it was also determined that there was a dramatic increase in lymphoma cases. According to the study, the expected rate of lymphoma cases was observed 8 times higher than the normal Italian citizens [42].

High level of uranium was determined in the urine of American soldiers took part in the Gulf War. This was indicated itself as law performance levels in the cognitive tests. This study put forward the

relation between depleted uranium and brain damage [43]. A study on the tank repairmen working in Sarajevo, capital city of Bosnia, with the tanks with DU damages states that the chromosome aberration rate was notably high [44]. It was also stated that the malformations in births in Basra city of Iraq increased to 17,6 in every 1000 births while it was only 3,04 in every 1000 births in 1999 [45]. There is also another statement from 2009 that a paediatrician working in a hospital in Felluja, a highly bombed city of Iraq, recorded down 37 births as the congenital abnormality [46].

5. The Environmental Effects of DU

Depleted uranium munitions start to burn out immediate after impact on the target while turning its 70% into aerosol form [24]. The particles in dust of aerosol are less than 5μm and can be easily carried away by wind. DU dust is black in color and leaves a black circle on the impact point at the target [47]. The uranium come out in the attacks after DU munitions were used are stored in the earth or the surfaces as uranium oxide dust [48]. When DU munitions hit the soft ground it goes approximately 50 cm depth and can stay there unexploded for years. But most of the munitions hitting the armor plates turn into aerosol dust, some of them, depending on the impact angle on the target, bounce back and stay on the ground. These pieces can be carried away by rain water, wind or even the insects but most of them stay in the earth. The earth type can differ in one place to another so does the DU munitions. When depleted uranium hits the clay it mostly doesn't explode and stay there without giving any damage. If the DU munition hits the crystal sand it has got the potential of contaminating the underground water supplies. When it hits the rigid earth with granite stones, there will be more worn out on the DU surface and this will lead to more uranium contamination.

In short, the depleted uranium can go down to the bottom of underwater supplies by the effect of rain and stay there for centuries.

6. International Law and Depleted Uranium Munitions

The countries producing or purchasing depleted uranium munitions are slow or ignorant to announce publicly the negative health effects and possible environmental hazards of pre and post use of depleted uranium.

While the current arms control law strictly bans the use of chemical and biological weapons, there is no legal regulation banning the use of depleted uranium munitions. But there is a continuing debate aiming to ban uranium weapons in the international arena within the framework of humanitarian law.

The change made in 1977 at Genova Convention Article 35 banned the methods among 168 countries used in wars which cause excessive and unnecessary pain. *Article 35* also prohibits the countries to own the weapons of war mean which have long term and widely effects to both human health and environment. *The 36th article of Protocol 1* brings obligations to define the weapon's legal statue for the countries which owns, produces or develops a new weapon This binding article also brings obligatory rules for the 168 state parties to declare not violating the international law by using new weapons. It also prohibits using weapons which have long term and long lasting effects on masses. *The 51st article of the same Protocol* prohibits the use of weapons of which the effects can not be limited within the war or have long term and inhuman effects.

The Humanitarian Law Rule 44 strictly states that state parties will be responsible to take precaution for the protection of environment and human health in the case of military operations even there is not definite scientific proof of adverse effect to the environment and human health. The Rule 44 states as; "*Methods and means of warfare must be employed with due regard to the protection and preservation of the natural environment. In the conduct of military operations, all feasible precautions must be taken to avoid, and in event to minimize, incidental damage to the environment. Lack of scientific certainty as to the effects on the environment of certain military operations does not absolve a party to the conflict from taking such precautions."* Namely the warfare methods must be used by considering the natural environment protection. This means that the countries conducting and practicing military operations need to take necessary precautions to minimize or prevent natural environment damages. The rule openly states that the countries using these kinds of war means have got certain obligations to take

effective precautions even if there is lack of scientific certainty.

United Nations has also taken some binding resolutions regarding this issue (1996/16 and 1997/36). These resolutions discussed the inhuman effects of DU usage and brought forward the long term negative effects for both human life and environment. UN stated the potential health and environmental effects of DU munitions with its 2007 and 2008 resolutions. It also called for more detailed investigations for countries in which DU was effectively used.

UN called the countries using DU munitions for being transparent with its *General Assembly Resolution* in 2010. This call was supported by 148 countries. 36 countries were abstained in this voting. *USA, France, GB and Israel which are accepted as the main DU producers opposed in the voting.* In fact, these decisions are the strongest ones taken by international communities. The most important side of these decisions is that DU awareness is rapidly growing in international arena.

7. Threat Assessment and Risk Analysis from the View Point of Forensics Practices

Risk is a daily and often used word with different meaning. This word mostly means the probability of happening an unpleasant and dangerous case. With another definition, risk can be understood as the possible results of a case. Like answering a question of "what could be the results of radiation exposure to the human body" is being cancer. Threat assessment and risk analysis are probability assessment of a chosen method to interfere the current situation with appropriate means.

One of the most valuable issues in threat assessment is the difference between the degree of risk perception and real risk. That is why the scientific quantity of present risk must be stated in an understandable way. Countermeasures can be easily taken in this way. So, quantitative values for depleted uranium munition cases have utmost importance for a healthy risk assessment. It has been generally focused on military personnel by the mass media while considering the health and environmental problems caused by depleted uranium munitions. But the most vulnerable ones, children, are generally overlooked. That is a reality that the tanks travelled in the city streets of occupied cities or abandoned unattended while providing a playground for the children. That is another issue to be considered that the children can be exposed to huge amount of radiation by touching these vehicles [50]. That is also a reality that not only the children's high probability of DU exposure but their probability of being cancer is higher than the adults [51].

In fact, the crime scene investigators in a DU contaminated are under the risk same with the children do. But the probable DU contamination risk does not attract enough and desired interest by the global community while analyzing the risk factors. The scientific data explained gives enough proof that the crime scene practitioners are under the same risk with the military personnel working in the vicinity of DU. Creating awareness for the depleted uranium cases set forward the reality of practicing the same protective measurements as done for the nuclear, biological and chemical contamination. This brings the fact that the crime scene personnel, fire brigades, first aid personnel and the rescue teams working in a DU contaminated area must be strictly considered in the related risk analyses.

Taking necessary and appropriate precautions in crime scene for the nuclear, chemical and biological contamination as well as the physical dangers are under the responsibility of not only the crime scene officer but all the bodies taking part in the crime investigations. But establishing procedures and training the personnel for the related precautions are the responsibilities of the organizations.

8. Results and discussion

There are many scientific studies stating that depleted uranium exposure can cause serious health problems. Additionally there are many scientific articles stating that there happened an increase in the numbers of cancer and congenital defects in the areas which were targeted by the depleted uranium munitions or the tanks with depleted uranium armors.

This indication of the increase in the cancer and congenital problems in the occupied countries are not the findings which can be easily underestimated. It can be thought that there is a highly probable causative relation between the military occupation and the frequency of the abovementioned diseases. The scientific studies aiming to set forth the causative relation can be

thought to be the responsibilities of not only the countries using DU but also the international organizations. Regarding the Humanitarian Law, using such kind of weapons is openly the violation of human rights.

It is the basic responsibility of being constitutional state to preserve the state order as well as to assure the human rights. Because the countries are in a position of maintaining their incumbent duties both for the peace and the crime against humanity; it is also their responsibility to counteracting armed conflict and compensate the damages [52].

It can be given priority to the scientific studies regarding this issue by the international communities. It can also be assessed to take precautions or limitation to DU production for military production, usage, storage or transportation in the try of establishing an ideal world state.

That is the fact that use of depleted uranium in military purposes is in a disputable state in the international arena; that is also another fact that the present danger not only threat the military personnel and the public being exposed to it, but also the first responders, paramedics, fire brigaders, rescue teams, crime scene investigators and the forensic laboratory personnel.

In the region the Country is present; the terrorist actions are mostly related with explosives in most cases munitions are being used as the main charge. The first responders to the case are commonly the crime scene personnel, fire brigades and the paramedics and the first responders. That is why it is an important issue to create awareness for the depleted uranium in both the first responders and the forensic laboratory actions in an accredited method.

Only having trustable and true information about the war enables both the local population and the international personnel to prevent themselves from the possible post war health risks and dangers.

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