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# Radiation doses arising from depleted uranium shells

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## ABSTRACT

This paper is mainly theoretical surveying the use and the reported effect of DU on human body. The DU has been used in the Gulf War of 1991, during the bombings of NATO / UN over the Serbian Republic of Bosnia in September 1995, against Yugoslavia in spring 1999; during the attack on Afghanistan and then further in Iraq in 2003. DU has been used in Lebanon in 2006 and Gaza- strip in 2008. Furthermore; there are reports that NATO has been using depleted uranium in Libya in 2011. Recently, international reports from hospitals in Fallujah Province in Iraq, blamed depleted uranium for birth defects and cancers in Iraq. The calculated dose in this work arising from the exposure of human to DU dust after the explosion of the DU shell would reach more than $1.6\times10^{6}$ rem/hr.


## KEYWORDS

Depleted uranium;
Dose, effect on human.

## INTRODUCTION

Depleted uranium (DU) is a man-made, radioactive, heavy metal derived from uranium ore. Naturally occurring uranium ore is mined and processed to yield a much more concentrated substance called the yellow cake[1]. Natural uranium exists in three isotopic forms and contains 99.274% U238, 0.72% U235, and 0.0057% U234 by weight. DU, a by-product of uranium enrichment, has an isotopic content of 99.75% U238, 0.25% U235, and 0.005% U234. As part of the effort to secure fissile uranium, many thousand tons of DU have been generated. Since DU is about twice times denser than lead, it penetrates hard surfaces easily. Thus DU can be used in military ammunitions and shells against armors and different targets Depleted Uranium shell can also contain the remains of nuclear waste arise from spent fuel of the nuclear reactors and the reprocessing plants of this fuel, thus can contain traces of transuranic elements.

It has been reported by U.S. Office of the Secretary of Defense that some of these transuranic elements have been reported to be present in some US tank armors[2,3] The aria of the Arab World, particularly Iraq, Palestine, Lebanon and recently Libya[4]was a live theatre and an experimental field of DU war. During the Golf wars between 1991 – 2001, Allies forces had dropped on Iraq a total of about 350 Tons of Depleted Uranium[5-10].

DU was used during the bombings of NATO / UN over the Serbian Republic of Bosnia in September 1995, against Yugoslavia in spring 1999; during the attack on Afghanistan and then further in Iraq in

2003. In Balkan war cases of cancers of blood of soldiers were reported[3].

Depleted uranium used by Allies forces blamed for birth defects and cancer in Iraq[11-13] where reports coming from hospitals in Iraq still talking about malformations of new porn babies and toxicological data reported there.

To date, human epidemiological data include case examples, disease registry records, a case-control study and prospective longitudinal studies.[12,13] A new plant was a appeared in military operational area in southern Iraq. Recovery from cancers in Iraq does not exceed 10 %, while in the rest of the world this ratio is 70 %.

The shell of DU contains about 1-5 Kg of $UO_2$ (U-238 & U-235), which equals about TWICE the quantity of uranium used in nuclear bomb ![1], some of other waste products are existed with these oxides.

About 40 % of the shell of DU is converted into UO dust that spread into air causing pollution that would extend to about 40 km away from target area. Reports talk about fallout due to DU shell explosion[10].

In this paper, I had calculated radiation doses caused by DU shell; the dose would reach more than $1.6\times10^6$ rem/hr. The estimations of radiation hazards expected that the pollution of an area with activity of about 2Ci / $m^2$ would kill all living beings.

After the explosion of the shell inside the target, the DU dust spreads into air, then winds and other corrosion parameters will carry this dust to air, soil and water, thus causing local and general radiation pollution. Finally when this dust reaches human beings it will cause radiation sickness.

Since DU contains several long lived radionuclide, thus its effect will extend to millions of years. Thus, one may conclude that the use of radioactive materials in classical wars will cause pollution in the four dimensions (space & time).

## DOSE CALCULATIONS

As stated previously the DU shell is a general name of that shell which may contain DU and / or spent fuel and nuclear waste. Thus to calculate the dose arising from this shell, one may calculate separate doses arising from different types of shells.

### Doses produced by U-235 and /or U-238

Uranium decays by emitting α particles with energy equals about 5 MeV, followed by γ rays emitted with energy equals about 1 MeV[14]. The activity is given by the relation[15]:

$$\mathcal{A} = \frac{0.693}{\tau}.\frac{m\,N_A}{M} \quad (1)$$

Where τ half – life of U (~ $10^8$ y); m mass of U in the shell (~ 5 kg), $N_A$ Avogadro's no; M atomic mass of U (235 or 238); Substituting these values in Equation 1, we get :

$$\mathcal{A} \approx 30 \times 10^8 \text{ Bq} \quad (2)$$

### Doses produced by alpha particles[1,16]

The exposure dose (D) is given by the relation :

$$D = \mathcal{A}\ E \quad (3)$$

Where: E energy of radiation (for α particle about 5 MeV), thus we have:

$$D = 30\times10^8 \times 5 = 150 \times 10^8 \text{ MeV / s}$$

$$= 240 \times 10^{-5} \text{ J/s} \quad (4)$$

The absorbed dose () by air, water or man can be calculated[16], since:

$$1 \text{ rad} \approx 0.87 \times 10^{-2} \text{ J/Kg} \quad (5)$$

Thus, we have:

$$1 \text{ J/kg} \approx 115 \text{ rad} \quad (6)$$

Then, from Equation 4, we have:

$$D_a = \frac{240 \times 10^{-5}}{m}\ J/kg\,.s \quad (7)$$

Substituting Equation 6 in Equation 7, we have:

$$D_a(\alpha) = \frac{240 \times 10^{-5}}{m} \times 115\ \frac{rad}{s}$$

$$= \frac{0.276}{m}\ \frac{rad}{s} \quad (8)$$

Hence,

$$D_a(\alpha) = \frac{993.6}{m} \text{rad / hr} \quad (9)$$

If a human of 70 kg (standard man) is subjected to radiation for one hour, then the absorbed dose is given by:

$$D_a(\alpha) = \frac{993.6}{70} = 14.2\frac{rad}{hr} \quad (10)$$

### Doses produced by γ – rays

The energy of γ – rays is about 1 MeV, then using Equation 3, one can have :

$D = 30\times10^{8} \times1 = 30\times10^{8}$ **MeV/s**

$= 48 \times10^{-5}$ **J/s**

Using Esq. (8, 9 and 10), one can have :

$D_a(\gamma) = 2.8$ **rad/hr (for 70 kg man)** **(11)**

## Doses produced by nuclear waste and spent fuel

In TABLE 1 we show the activity of the fission products and actinides presented in fuel of nuclear reactor after a period of 150 days of cooling[1,17]. Here, we will focus on two main wastes:

## The actinides (αlpha and gamma emitters)

In a shell of mass equals about 5 kg, the activity) from TABLE 1 is about 963 Ci, which gives $963\times3.7\times10^{10} = 3.57\times10^{13}$ Bq.

Comparing with Equation 2 and using the results in Equations : 10,11, one can calculate the absorbed doses in case of alpha and gamma emitters as:

$D_a(\alpha) = 1.68 \times10^{5}$ **rad/hr** **(12)**

$D_a(\gamma) = 0.33 \times10^{5}$ **rad/hr** **(13)**

## Solid fission products (β,γ) emitters of half – life greater than one year

**TABLE 1 : Fission products and actinides presented in fuel of nuclear reactor after a period of 150 days of cooling**

| Type of Nuclei | Isotope | Half-life (Y) | Mass (g/te) | Activity (Ci/te) |
|---|---|---|---|---|
| Gaseous fission products | $^{3}H$ | 12.3 | 0.083 | 800 |
| | $^{85}Kr$ | 10.7 | 27 | 10500 |
| Volatile and semi volatile fission products | $^{103}Ru$ | 0.11 | 880 | 15 |
| | $^{106}Ru$ | 1.01 | 5.7 | 180000 |
| | $^{129}I$ | $17\times10^{6}$ | 250 | 0.04 |
| | $^{131}I$ | 0.02 | 0.01 | 2.0 |
| | $^{134}Cs$ | 2.05 | 77 | 100000 |
| | $^{135}Cs$ | $3\times10^{6}$ | 1400 | 1.2 |
| | $^{137}Cs$ | 30.2 | 1200 | 106000 |
| Solid fission products | $^{89}Sr$ | 0.14 | 3.5 | 100000 |
| | $^{90}Sr$ | 28.9 | 430 | 6000 |
| | $^{91}y$ | 0.16 | 7.8 | 190000 |
| | $^{93}Zr$ | $0.95\times10^{6}$ | 490 | 2 |
| | $^{95}Zr$ | 0.18 | 19 | 400000 |
| | $^{95}Nb$ | 0.10 | 21 | 800000 |
| | $^{141}Cr$ | 0.09 | 2.8 | 8000 |
| | $^{144}Ce$ | 0.78 | 250 | 800000 |
| | $^{147}Pm$ | 2.62 | 220 | 200000 |
| | $^{155}Eu$ | 5.01 | 87 | 4000 |
| Actinides in uranium fuel | $^{237}Np$ | $2.14\times10^{6}$ | 600 | < 1 |
| | $^{238}Pu$ | 86 | 230 | 4000 |
| | $^{239}Pu$ | 24400 | 8100 | 600 |
| | $^{240}Pu$ | 6580 | 2900 | 650 |
| | $^{241}Pu$ | 13 | 1300 | 150000 |
| | $^{242}Pu$ | 279000 | 510 | 2 |
| | $^{241}Am$ | 458 | 230 | 750 |
| | $^{243}Am$ | 7800 | 100 | 20 |
| | $^{242}Cm$ | 0.45 | 10 | 3500 |
| | $^{244}Cm$ | 17.6 | 25 | 2000 |
| Total | | | 19376 | 3154400 |

In a shell of mass equals about 5 kg, the activity from TABLE 1 is about 2030 Ci, which gives 2030 $\times$ $3.7\times10^{10}$ = $7.5 \times10^{13}$ Bq. Since β and γ are emitted with energies of the order of 1 MeV, then as we have done in previous section, the dose absorbed due to β and γ emitters is given as:

**$D_a$ (â, ã) = 0.7 $\times10^5$ rad/hr** **(14)**

## The equivalent dose

In order to find the total dose arising from different types of radiations, one may need to define the equivalent dose for each type of radiation. Hence the total dose can be calculated by adding the individual doses.

The equivalent dose (DE) measured in rem is given by[1,16] :

**DE = $D_a$ (rad) × RBE** **(15)**

RBE is an abbreviation of: Relative Biological Effect and is given in TABLE 2 for different types of radiation.

In the SI units, the absorbed dose is given in Gray (Gy) and the equivalent dose is expressed in Sievert (Sv), where :

**1Gy = 100 rad, 1Sv = 100 rem**

Thus, we can use Equation 15 to calculate this dose; hence we obtain the following values:

1- Dose produced by α -particle from U – 235/238 (see Equation 10)

**$D_E$ (α) = 142 rem/hr**

2- Dose produced by γ- rays from U – 235/238 (see Equation 11)

**$D_E$ (γ) = 2.8 rem/hr**

3- Dose produced by actinides (α – emitters) (see Equation 12)

**$D_E$ (α) = 1.68 $\times10^6$ rem/hr**

4- Dose produced by actinides (γ – emitters) (see Equation 13)

**$D_E$ (γ) = 0.33 $\times10^5$ rem/hr**

5- Dose produced by Solid Fission products (β, γ) emitters of half – life greater than one year (see Equation 14)

**$D_E$ (β, γ) = 0.7 $\times10^5$ rem/hr**

In TABLE 3 we show a summary of radiation doses produced by DU shell.

In Figure 1 we show doses calculated in this paper, that arise from the explosion of DU shell as a function of distance from the target. The dose produced in an area 50 meters away from the target is about 540 rem / 5 hr /$m^2$, while it is about 135 rem / 5 hr /$m^2$ for an area 100 meters away. These doses are quite high and will produce a noticeable effect of radiation on human.

Generally, the contamination will be spread over a distance of about 40 km from the target, depending on winds and other corrosion parameters.

The effect of radiation on human is reported in literature[1, 16], it was reported that a dose of a value

**TABLE 2 : RBE for different types of radiation[1]**

| Type of radiation | RBE |
|---|---|
| γ, β | 1 |
| α | 10 – 20 |
| Neutron | 10 |

**TABLE 3 : A summary of radiation dose produced by DU shell**

| Type of radiation produced by the DU shell | | Activity ($\times10^{10}$ Bq) | Dose rem/hr | Dose rad/hr |
|---|---|---|---|---|
| U-235 /238 | α | 0.30 | 142 | 14.2 |
| | γ | 0.30 | 2.8 | 2.8 |
| Waste | 1-Actinides: | | | |
| | α-emitters | 3750 | $1.68\times10^6$ | $1.68\times10^5$ |
| | - emitterγ | 3750 | $0.33\times10^5$ | $0.33\times10^5$ |
| | 2-Solid products (β, γ) | 7511 | $0.7\times10^5$ | $0.7\times10^5$ |

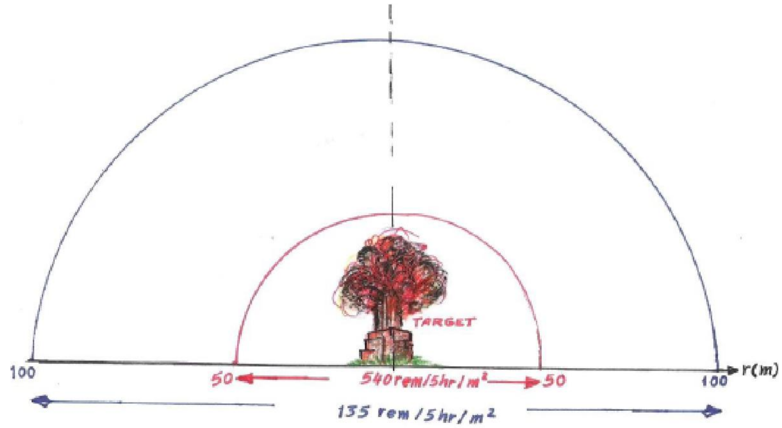


**Figure 1 : Doses arise from target hit by DU shell as a function of distance from it**

lies between 500 and 700 rem is a lethal dose. You can see from TABLE 3 that the doses resulted from the absorption of α – particles are huge, thus these represent extreme danger to mankind. Note that the maximum permissible dose (MPD) must not exceed 5 rem/year[1, 18].

## CONCLUSION

DU shells used in recent classical wars are some sort of dirty wars by all means, they do not kill only man and animal but also extend to kill life itself, they do not kill just the environment, but also extend to destroy time itself, Since radioactivity of some radioactive elements extends for millions of years. The calculated doses produced by DU shells in this work are of the order of $10^6$ rem/hr, which can kill or cause a severe damage to human, and give a chronic dose on the long run. The next generations will be affected on the near and the long run future! These wars affect every one, the near and the far away. These wars must be totally forbidden, no excuses are accepted!

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