DEPLETED URANIUM

A scientific approach to the hazards of military use of depleted uranium

Prof. Dr. Massimo Zucchetti

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The postponed BAN

Depleted Uranium (DU) is not found naturally. It is radioactive waste, produced as a result of enriching uranium for use in nuclear power plants or for the production of weapons. In natural uranium 0,7 % is fissionable, in enriched uranium 2-3,5 % and in depleted uranium 0,2 %. This radioactive and chemical toxic waste should be kept in bunkers for billions of years, which requires stable and sustainable surroundings and an enormous amount of money. However, if one uses DU as contra weight in air-crafts, or in armour-piercing penetrators on the battle-field, one can *make* money with it. This happened first in Iraq and later on the Balkans in Afghanistan and elsewhere.

Military use of DU is profitable for the arms industry, but no solution to the nuclear waste problem. In Iraq, that was first targeted in 1991, 70 % of the soil is now polluted with invisible DU dust. Once inhaled or swallowed, DU is a permanent threat to people's health and that of new generations. Military veterans and civilians alike have given birth to baby's with monstrous malformations. Not only in Iraq but also on the Balkans and wherever DU was used, young children die from leukaemia and lymphomas. They are ten times more sensitive than adults to radiation. Foetuses are even fifteen times more sensitive.

Troops that served in missions where DU was used are developing cancers. In Italy alone some 2500 soldiers became ill, out of whom over 170 died. It was Italy that sent troops to "clean" Kosovo after the bombardments in 1999. In a historic decision on December 17th 2009 the Italian Court recognized the link between cancer and depleted uranium (DU) and forced the Ministry of Defence to compensate half a million euro's to a sick veteran, who had been exposed in Somalia.

In the political world there is growing awareness. Last December 2008 the UN General Assembly passed, by a huge majority, a second resolution on uranium: 141 states called on the WHO, the IAEA and the UNEP to update their positions on the health and environmental effects of uranium weapons. In May 2008 the European Parliament urged in a joint resolution for investigations that might lead to a ban.

It is obvious that there are great interests. Those involved in nuclear power keep silent about the unavoidable links between military and civil uses of nuclear energy, as well as about the fact that dose limits for exposure neglect the much higher sensitivity of children and foetuses. Radiation protection experts admit

with difficulty that the radiation effects of small uranium alpha-emitting particles need new models and investigations, since the actual ones lack of accuracy. And military authorities hide the wide and costly research programs for the development of radioactive weapons. DU, their raw material is cheep, the effects are not.

But the increase of cancers and deaths and the rapidly increasing number of scientific reports about the health effects of DU, with its interaction between chemical toxicity and radioactivity, catches up with the cynic propaganda of interest groups. The Institute of Medicine no longer excludes the link, the United Nations Environmental Program expressed its deep concern and from the Pentagon alarming reports are coming. The International Coalition to Ban Uranium Weapons (ICBUW) is worldwide collecting, coordinating and giving information. No doubt there will be a ban. The vital question is when. How much more irrevocable damage should be done to people and nature? It took forty years to admit that asbestos is carcinogenic: how much time will we need for uranium?

About the author, Prof. Dr. Massimo Zucchetti:
Massimo Zucchetti (Turin, Italy, 1961), is a full Professor of Radioprotection and Safety and Risk Analysis at the Politechnical University of Engineering in Turin. He took his degree in Nuclear Engineering in 1986, and Doctorate in 1990. His research interests deal with depleted uranium, radioprotection, nuclear fusion technology, nuclear safety and radioactive waste management. He is coordinator of the "Italian anti-war scientist committee" and he has been scientifically studying DU since 1999. Furthermore he has been advisor of the Italian Parliament for the Depleted Uranium question. He is referee of several International Scientific Journals, and author of over 80 papers in peer-reviewed journals and several books.
This publication is a compilation of material available in two previous recent Italian books by the author: "Uranio Impoverito", CLUT, Turin (Italy), 2006, and "L'atomo militare e le sue vittime", UTET, Turin (Italy), 2008, with recent new materials and findings.

About the artist who made the cover:
This painting, called "Transmutation", was donated by the Serbian artist Natasja Karanović. Natasha Karanović, who is living in Italy, is referring to the 10 years that passed since the aggression in (former) Yugoslavia started, ending with bombardments and shelling with DU.

MEP Els de Groen

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Introduction

This book is intended as a short reference book concerning the Depleted Uranium (DU) question.
It does not pretend to be complete, however reflects the studies that the author has made since 1999 about this argument.
The first chapter is a sort of extended summary of the main facts concerning the DU question, plus an up-to-date report of the Italian case, a most peculiar one. It can be read independently from the third one, that tackles the Depleted Uranium question into more deep.
The second chapter deals with a technical assessment of the composition and radioactive hazards of DU and it is mainly intended for experts.
The fourth chapter is a review of the huge amount of evidence about the DU effects on Iraqi population, that unfortunately could not emerge on peer-reviewed international journals.
The fifth chapter brings the conclusions. The series of pictures does not need any further comment.
The author wishes to thank some beloved persons. Els de Groen, a Dutch member of the European Parliament, without whom this book would not exist. Dr. Jawad Al-Ali, Oncology Center, Basrah, Iraq. Domenico Leggiero, Osservatorio Militare (Italy). Prof Souad N. Al-Azzawi, author of the review in section 4. And, last but not least, Elena Grassa, much more than just a wife.

1. A Depleted Uranium Quick Reference and the Italian Case

Depleted Uranium Facts

Depleted uranium (DU)[1-3] is mostly composed by the natural radioactive isotope U-238 and it is a by-product of the enrichment process, that part of the nuclear reactors fuel cycle that produces the nuclear fuel ("enriched uranium") to be used in nuclear power plants like Light Water Reactors and other ones[4,5]. DU characteristics are: low specific radioactivity (with emission of alpha particles), high specific weight, low cost, wide availability[3].

Military use of DU for "penetrators" (i.e., bullets with high capability of penetrating shields) has widely spread during the nineties[6,7]. U.S. Army tested it during the seventies and eighties[8,9], and DU-based weapons were first used in the "Desert Storm" War in Kuwait-Iraq (1991)[10, 11]). Since then, DU weapons have been used in the Mediterranean area during the Balkan wars[12] (Bosnia 1995, and Kosovo 1999). During the last war in the Balkan area (Kosovo-Serbia War, spring-summer 1999), NATO forces admitted the use of weapons containing Depleted Uranium[13,14]. In particular, 30 mm bullets being fired by A-10 anti-tank aircrafts. Most probably, also some Tomahawk cruise missiles in those wars had depleted uranium reinforced heads. DU was used again in more recent Afghanistan (2001) and Iraq (2003) campaigns: in particular, the second Iraq war has seen the largest use of DU ever, approximately 1000 tons.

It is widely held that the weak radioactivity of DU – 60% lower than natural uranium – makes its radiological dangers slight. However, DU radiation is indeed "feeble" (i.e. low specific radioactivity, and radiation with low penetration capacity) as compared to several other sources, however its biological effects (chemical and radiological) cannot be neglected if its concentration is sufficiently high – like for any other pollutant. The radiological effects of uranium are well known since fifty years due to its civilian use[15-26], while also US army studies have studied those effects before use[8,9, 27].

In fact, the first study of the military use of radioactive powders[28] is as old as nuclear age: the Report "Use of Radioactive Materials as a Military Weapon" was compiled by James Conant, a member of the Manhattan project, and transmitted to general Leslie Groves, the head of the Manhattan project, in 1943.

When DU bombs detonate, uranium oxide is formed in particulates of between 0.5 and 5 microns. These can be windborne several hundred miles or suspended electro statically in the atmosphere. The size of the particles varies greatly; larger fragments can be easily observed, while very fine particles are smaller than dust ("nano-particles") and can be inhaled and taken into the lungs.[29,30] Whether large enough to see, or too small to be observed, DU particles and oxides contained in the body are all subject to various degrees of solubilisation: they dissolve in bodily fluids, which act as a solvent. Once dissolved in the blood, about 90% of the uranium present will be excreted by the kidney in urine within 24-48 hours. The 10% of DU in blood that is not excreted is retained by the body. Insoluble uranium oxides can remain in the lungs for years.

Concerning chemical toxicity, Uranium, being an heavy metal, is known to have toxic effects on specific organs in the body[29-32] in particular, the organ that is most susceptible to damage is the kidney. The uranyl-carbonate complexes decompose in the acidic urine in the kidney. This reaction forms the basis for the primary health effects of concern from uranium. The effects on the kidney from uranium resemble the toxic effects caused by other heavy metals, such as lead or cadmium.

Concerning DU radio-toxicity, U-238 is a long-lived alpha-emitter, with a weak emission of beta and gamma rays. External exposure hazards mainly regard military personnel using tanks with DU shields, while it is negligible in other occasions. The most important pathways for DU exposure are therefore in case of ingestion or inhalation[15-27].

Personnel in or near an armoured vehicle at the time these vehicles are struck by depleted uranium munitions can receive significant internal DU exposures. On the other hand, army officials believe that DU-related health risks are greatly outweighed by the risks of combat. This is not the case, however, for the exposure of public due to DU contamination, or for peace-keeping actions after war.

Recent studies have demonstrated the so-called "bystander effect", in which unirradiated cells close to irradiated cell populations can exhibit genetic alterations. The bystander effect is predominant at low tissue doses, where few cells experience an alpha particle passage. At higher doses, recipient cells increasingly experience alpha passages themselves, with a high probability of cell killing and almost certainty of inducing other changes, thus reducing the relative effectiveness of the bystander effect. For this reason, uranium particles, which emit few

alphas, would have a greater chance of inducing effects through the bystander mechanism than "hotter" particles. It may, therefore, be prudent to examine the question of whether focal sources of irradiation could induce a spectrum of effects that differs from that induced by more uniform irradiation. In the specific context of uranium, it is of interest also to consider whether the enhanced soluble uranium concentrations that could exist in the vicinity of individual particles or aggregates could interact synergistically with the localised irradiation of tissues, particularly if some of the effects of irradiation are mediated by substances released from the irradiated cells. In considering whether such effects could occur, it is appropriate to recognise that particles could accumulate or aggregate in interstitial tissues of the lung, in pulmonary lymph nodes or in reticulo-endothelial tissues.

This is not a situation that has been experienced in any exposure situation for an alpha or any other emitter in the lung. It is therefore difficult to extrapolate the risk of such an exposure from human experience. In particular the risk to the lung of exposure to DU dusts cannot be easily inferred from the experience gained from uranium miners, or from survivors of Hiroshima and Nagasaki, upon which the current ICRP radiological protection standards are based.

Alpha particle radiation is known to be a potent cause of bystander effects, particularly in the form of genomic instability and, since heavy metals can also cause instability, there is a strong case that the mixed radio-chemical exposure may be acting in this context.

The implication of the combined chemical and radiological transforming capability of uranium and the bystander effect, means that, in estimating its significance in causing cancer, the simple assumptions, based on committed effective dose, i.e. (committed absorbed dose to the lung, modified by a radiation weighting factor for the fact that the radiation arises from alpha particles) would probably underestimate risks.

The DU bullets were used in the Gulf War. Many publications and studies have put into evidence that, subsequently, the incidence of leukaemia's, cancer, neurological diseases and birth defects have risen sharply in that area and in other DU-polluted battlefields during the nineties[29, 33-37]. About 90,000 allied-army Gulf War veterans now suffer from the so-called Gulf War syndrome[38-40]. However being probably only a concurring cause, it is probable that this syndrome could be partially due to DU radiation exposure.

1.2 The Italian Case

A similar syndrome ("Balkans syndrome") is now being suffered by Italian Army soldiers that served in the Balkans during the 1995 and 1999 campaigns[41-42]: Italian soldiers were widely employed by Italy in many recent war and post-war missions abroad: (not relevant, just some aviators, 1991, Iraq); Somalia 1992/3; Bosnia 1995; Kosovo 1999; Afghanistan 2001; Iraq 2003

In all those missions (except Iraq 1991) the Italian soldiers were in the conditions that could expose them to DU contamination, even if they arrived just for the "peacekeeping" phase and not during combat.
Possible exposure pathways, for instance, could have been:

- Particle re-suspension and inhalation due to helicopters and trucks use on battle sites
- Clean-up of battle sites after war operations (e.g. in Kosovo) with handling of contaminated warfare and relics and inhalation of dust. Italian soldiers were completely unaware of the risks due to DU exposure, unlike for instance their US colleagues within the same NATO missions.

So Italian soldiers did not take any precaution against DU contamination: no masks, no gloves, no respirators, no anti-radiation robes, no frequent clothes washing, use of short trousers and so on. Many pictures and testimonies document this.

The Italian Government and Military Commands were advised of the DU risks by many NATO communiqués and reports, but did not take any action to inform their soldiers about this risk. first warning message about DU from Italian military authorities dates to December 1999, while Kosovo occupation began on June 1999 and many soldiers served in Somalia 1992/93 and Bosnia 1995. The consequences of this situation were rather obvious: a rise of tumours, especially some special kind of tumours (Hodgkin lymphoma), in the Italian soldiers occupying the Bosnia and Kosovo areas after the war end.

In Kosovo, for instance, the DU contaminated zone was mostly assigned to the Italian soldiers, while US and UK occupation zones where mostly uncontaminated. At the end of the nineties many cases of tumours among the Italian solders that served in the Balkans began to be signalled in the newspapers and by the military associations.

In that period begins the monitoring and support activity of the "Osservatorio Militare"[43], and of the ANAVAFAF association[44] and the scientific research activity of the Italian "Anti-War Scientists Committee"[45]. Osservatorio Militare began its activity in 1998. It is an association of military men and policemen, their families and their friends, to document, support and help soldiers and families in difficult situation (e.g., ill, lack of assistance, etc..). AVAFAF is a similar association of military men and their relatives, with a particular attention to the case of service victims. Anti-War Italian Scientists Committee is active since 1999 and began its research activity on DU in December 1999, published scientific papers and held several conferences and meetings in Italy and Europe[46-48].

DU was soon identified as a possible exposure hazard for Italian soldiers by many scientists. Initially, both civilian and military Italian denied any possible DU exposure of Italian soldiers. Finally, December 2000, Italian Minister, Mr. Mattarella, admitted the DU exposure in Kosovo. Then, authorities simply denied that DU was a danger (supported by many experts) saying that DU was only "weakly" radioactive and the actual contamination in the Balkans practically negligible.

Public opinion pressure forced the Italian Government to launch the so-called "Mandelli Commission", a tumours epidemiological survey among the Italian soldiers that served in the Balkans. Strong political pressure and important technical mistakes made the scientific results of the Commission very questionable. It was assessed that Italian Balkan soldiers were dying of H and NH Lymphoma 3,5 times more frequently than the expected normal rate. Tumours and dead soldiers kept raising in number in the early 2000's. Newspapers could not avoid talking about that widely, while the action of our and other associations was putting pressure on Authorities and Government. The Italian Parliament finally nominated two "Uranium" investigation Commissions. Conclusions of the last Commission, whose work was interrupted due to anticipated new elections, were the following:

- No certain connection between DU exposure and soldier pathologies can be demonstrated, due to lack of data, too few exposed persons, and so on.
- Further investigations on this subject are urgently necessary, with better epidemiological assessments on the soldiers population.
- The military use of DU should be avoided.

According the precaution principle Osservatorio Militare has gathered and cleaned up data coming directly from the Italian Ministry of Defence. Those data are official ones: they were given by the experts of the Ministry of Defence during the auditions of the Italian Parliament DU Commission.

The records show 2.358 tumour cases among Italian soldiers that served in the Balkans, period 1995-2009. Of these ones, 167 soldiers died[49].

Such a high number of casualties is far higher than the normal tumour occurrence in that population (young men, physically selected). However, a complete and scientific epidemiological treatment of those data needs a research program, serious dedicated researchers and funding. The author, together with Dr. Valerio Gennaro, an internationally known epidemiologist - consultant of the DU Parliament Commission - asked several times resources to start this program, but in vain.

Many legal actions have been initiated during the past years by the ill soldiers and their families, to obtain some compensation from the Italian Government and from the Ministry of Defence. Osservatorio Militare assisted them. Usually, the success of those actions was little or none.

In December 2008, the Italian Firenze Court accorded to a tumour-ill soldier a high money compensation, the Ministry was declared guilty of his exposure, and Depleted Uranium was identified by the Court scientific consultants as the assured exposure cause that determined the tumour in the ill soldier[50]. His name is Gianbattista Marica, he served in Somalia 92/93. He got Hodgkin Lymphoma, luckily now almost completely healed. Reimbursement was around € 550.000 i.e. US $ 800.000. A very first result for such legal actions. In December 2008, Italian Defence Minister, Mr. Ignazio La Russa, officially declared the following[51]:

1. Depleted Uranium kills
2. The Italian Government is ready to financially compensate the dead and ill soldiers families, victims of depleted uranium and nano-particles, and adequate funding (30 billions of euro's in three years) has been destined to that.

It is the first case in the world that a member of a western government makes so clear statements about DU hazards. It must be pointed out that Mr. La Russa belongs to the right government. For many years, the previous centre-left government practically did nothing about the question, with Government-connected experts that refused to even listen to the requests of soldiers associations and scientists.

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2. Characterization of Depleted Uranium

This chapter makes the assumption that the reader has the suitable scientific background contained in Ref. 1 [M Cristaldi, A. Di Fazio, C. Pona, A. Tarozzi, M. Zucchetti "Uranio impoverito (DU). Il suo uso nei Balcani, le sue conseguenze sul territorio e la populazione", Giano, n. 36 (sett-dic. 2000), pp.11-31, Ed. Odradek (Italia)]

We will address the specific problem of the characterization of Depleted Uranium (DU). The following basic assumptions will be made:

- The DU is a mixture of radio-nuclides (U-238, U-235, U-234) with some well known concentrations.
- There have been during the last years contradicting news about the dangers arising from DU for the presence in it of Plutonium.

If DU comes out from the cycle of enrichment of uranium, it is not possible to find in it U-236 nor Pu-239, since only "fresh" uranium is used, that is uranium which is freshly extracted from the mines or coming from processing of natural uranium. If, on the contrary, DU arises from an enrichment progress which employs as rough material also uranium coming from the reprocessing cycle of spent nuclear fuel, then all these and other nuclides can be present in DU.

We will name the first one as "**Clean DU**", and the second as "**Dirty DU**", without, by this, considering the clean DU as a safe material. The fact that DU used in the Balkan area is, at least partly, "dirty" has been confirmed by UNEP (United Nations Environmental Program) which has verified the presence of U-236 in DU. (http://balkans.unep.ch/press/press0101116.html).

The necessary starting point will be a correct information about composition of DU. Far beyond the mixture of the 3 major nuclides, we should know, in the case of dirty DU from which particular nuclear plants originates the uranium to "reprocess" and its characteristics. Eventually, even if we know exactly the original composition of clean DU and dirty DU, we should know also in which amount they have been mixed to produce DU ammunitions.

We will refer to a document published by WISE Uranium Project Fact Sheet (WISE), which exhibits some calculations based on the data given by the U.S. Dept. of Energy.
http://www.peacelink.it/tematiche/disarmo/u238/documenti/durepe.pdf)
We will hence refer to these news:

- The dirty DU used comes from the enrichment plant of Paducah (source: DOE).
- The compositions of clean DU and dirty DU are those reported in the cited document, excluded the presence of some decay products not cited, for which, as we will see later, we will make some assumptions.
- The presence of some other fission products in dirty DU (as Cs-137, Sr-90 and so on) although it cannot be excluded "a priori", it is not considered, because these elements are very easily separated from uranium.

It will obviously be possible to discuss these assumptions, but we will refer to them for simplicity, and to illustrate the method with which we can characterize DU and its hazards.
We will make hence a comparison between clean and dirty DU following these assumptions. Every radioactive nuclide (or radionuclide) decades in an other nuclide, which can be radioactive on its own or stable. These decay products, if they are radioactive, contribute, when present to the total radioactivity of the material where the "father" radio-nuclides are.

- In this way, U-238 brings with itself their decay product Th-234, which decays in Pa-234m, which decays in U-234 and so on (see below for the following of the chain).
- Similarly, U-235 generates Th-235, which generates Pa-231, which generates Ac-227, which decays in Th-227, which decays in Ra-223, which again generates Rn-219. But Rn-219, as it is a noble gas, is removed from the solid matter, and the chain stops here.
- U-234, eventually, produces Th-230, which decays in Ra-226, which decays in Rn-222, which is gaseous and escapes from the solid and the chain stops here.

Therefore in the clean DU, in addition to U-238, U-235 and U-234, we must take into account for the presence of the whole radioactive chain "not gaseous" consisting of Th-234, Pa-234m, Th-231, Pa-231, Ac-227, Th-227, Ra-223, Th-230, Ra-226.

One should ask what would be the concentration of these "daughter" nuclides. Luckily there is an easy answer: at equilibrium its radioactivity will be the same of the "father" nuclide. For example, 1000 Bq/g of U-238 means also 1000 Bq/g of Th-234, 1000 Bq/g of Pa-234m and so on.

As uranium is present in nature since ever (billions of years), all its daughter nuclides are present at equilibrium. Let us have a look now to the table for clean

DU in the WISE document, and we will see that some of these nuclides are missing.

Regarding the dirty DU, we will consider the table in the WISE document at which we will must nevertheless add the following:

- U-236 decays in Th-232, from which generates a radioactive chain which is non relevant for our purposes, as we will se later.
- Np-237 decays in Pa-233, and this in U-233, from which another non relevant chain originates.
- Pu-239 decays in U-235 and from here with the already mentioned chain.

If now we have a look at the table relative to dirty DU in the WISE document, we will note that here also some nuclides are missing. On the other hand, the missing nuclides are characterized by very long half-life (more than 1000 years) or which in the chain are generated by such a nuclide. Nuclides with very long half lives reach the equilibrium after a lap of time comparable with their half-life.

During the enrichment (or depletion) process of uranium, it is theoretically separated from all other chemical species and hence also from its radioactive descendants, even some loss of efficiency in the process may leave some of these isotopes). Uranium would become again "new", as just created, and it would start again from zero, to create its daughters. Those ones with a long half-life (for example Th-230) do not reach the activity of the father in the few decades of life of this new uranium (before it is employed somewhere), and hence their concentration at the moment of utilization should be very little and negligible.

Other nuclides, as all the long lived daughters of U-236, Np-237 and Pu-239 (for example Th-232 and U-233), are originating from a "new" nuclide (born during the utilization as fuel in the reactor), and hence it is certain that their presence is negligible in dirty DU, when it becomes a DU bullet.

On the other hand, we must also take into account that:

- The chemistry of some actinides such as thorium is very similar to that of uranium, and therefore we cannot say that thorium is totally absent in "new" uranium. Nevertheless, if we consider that the separation between the various isotopes of uranium is based on physical properties (such as weight) instead of chemical properties, it is more likely that thorium is found in the enriched fraction.
- DU, after fired, "in situ" (in the environment of Balkans or in the body) starts

generating daughter radioactive isotopes, but many of them are long lived radioisotopes and hence they do not represent a problem for human beings.
- The last contribution will become relevant after centuries and thousands of years and it is non considered here.

Summarizing, we can look at tables 2.1a and 2.1b, 2.2a and 2.2b. Tables 2.1a and 2.1b characterize an "old" DU, either "clean" and "dirty", both considered at equilibrium with their descendants, included the long lived, non gaseous, ones, generated by the primordial isotopes such as U-238, U-235 and U-234.

Tables 2.2a and 2.2b characterize the "new" DU, either "clean" and "dirty", both at equilibrium with their non gaseous decay short lived products. We will consider the latter for our dose calculations.

Table 2.1a: characterization of clean DU. Specific activity in Bq/g. Initial concentration: U-238 (99.8%), U-235 (0.2%), U-234 (0.000821%). All the non gaseous nuclides have reached the equilibrium ("old" uranium), except U-234 generated by U-238, for which we assume the activity shown in the document of the WISE.

Nuclide	Specific activity (Bq/g)	Note
U-238	1.243e+4	Nuclide father
Th-234	1.243e+4	At equilibrium with U-238
Pa-234m	1.243e+4	At equilibrium with U-238
U-235	1.6e+2	Nuclide father
Th-231	1.6e+2	At equilibrium with U-235
Pa-231	1.6e+2	At equilibrium with U-235
Ac-227	1.6e+2	At equilibrium with U-235
Th-227	1.6e+2	At equilibrium with U-235
Ra-223	1.6e+2	At equilibrium with U-235
U-234	1.9e+3	Nuclide father
Th-230	1.9e+3	At equilibrium with U-234
Ra-226	1.9e+3	At equilibrium with U-234
(TOTAL)	4.4e+4	

Note that: 1.243e+4 = 1.243 104

Table 2.1b: characterization of dirty DU. Specific activity in Bq/g. Initial concentrations: U-238 (99.57%), U-235 (0.2%), U-234 (0.001939%), U-236 (0.22%), Pu-239 (4.401e-07%), Np-237 (2.469e-05%). All the non gaseous nuclides have reached the equilibrium ("old" uranium), except U-234 generated by U-238, for which we assume the activity shown in the document of the WISE.

Nuclide	Specific activity (Bq/g)	Note
U-238	1.240e+4	Nuclide father
Th-234	1.240e+4	At equilibrium with U-238
Pa-234m	1.240e+4	At equilibrium with U-238
U-235	1.6e+2	Nuclide father
Th-231	1.6e+2	At equilibrium with U-235
Pa-231	1.6e+2	At equilibrium with U-235
Ac-227	1.6e+2	At equilibrium with U-235
Th-227	1.6e+2	At equilibrium with U-235
Ra-223	1.6e+2	At equilibrium with U-235
U-234	4.48e+3	Nuclide father
Th-230	4.48e+3	At equilibrium with U-234
Ra-226	4.48e+3	At equilibrium with U-234
U-236	5.43e+3	Nuclide father
Np-237	6.44e+0	Nuclide father
Pu-239	1.01e+1	Nuclide father
(TOTAL)	5.7e+4	

Note that: 1.240e+4 = 1.243 104

Table 2.2a: characterization of clean DU. Specific activity in Bq/g. Initial concentration: U-238 (99.8%), U-235 (0.2%), U-234 (0.000821%). Only the short lived non gaseous nuclides have reached the equilibrium.

Nuclide	Specific activity (Bq/g)	Note
U-238	1.243e+4	Nuclide father
Th-234	1.243e+4	At equilibrium with U-238
Pa-234m	1.243e+4	At equilibrium with U-238
U-235	1.6e+2	Nuclide father
Th-231	1.6e+2	At equilibrium with U-235
U-234	1.9e+3	Nuclide father
(TOTAL)	3.95E+4	

Note that: 1.243e+4 = 1.243 104

Table 2.2b: characterization of dirty DU. Specific activity in Bq/g. Initial concentrations: U-238 (99.57%), U-235 (0.2%), U-234 (0.001939%), U-236 (0.22%), Pu-239 (4.401e-07%), Np-237 (2.469e-05%). Only the short lived non gaseous nuclides have reached the equilibrium.

Nuclide	Specific activity (Bq/g)	Note
U-238	1.240e+4	Nuclide father
Th-234	1.240e+4	At equilibrium with U-238
Pa-234m	1.240e+4	At equilibrium with U-238
U2-35	1.6e+2	Nuclide father
Th-231	1.6e+2	At equilibrium with U-235
U-234	4.48e+3	Nuclide father
U-236	5.43e+3	Nuclide father
Np-237	6.44e+0	Nuclide father
Pa-233	6.44e+0	At equilibrium with Np-237
Pu-239	1.01e+1	Nuclide father
(TOTAL)	4.74e+4	

Note that: 1.240e+4 = 1.240 104.

Regarding dirty DU, we have to consider too, as noted by the WISE document, that the composition is based on the assumption that all Pu-239 and Np-237 are not separated from uranium during the reprocessing of nuclear fuel. This obviously overestimates the real amount of such isotopes in DU.

For our purposes, this is not really a problem: the higher danger of dirty DU is not related to Pu or Np, but to the higher amount of U-234 and U-236 (not present at all in clean DU).
Even if we assume that Pu and Np are completely separated because they represent a different chemical compound than uranium, it is not possible to separate U-234 and U-236, which are chemically undistinguishable from U-238.

Hence, we assume that Pu and Np are present in the maximum amount. We will verify that this fact implies only a negligible contribution to the total dose (and to the global risk) of less than 1%. Their presence, is not relevant, except in one case (see later).

Plutonium may generate fears non only for its radiological toxicity, but also for its chemical toxicity. But, following the statements contained in the WISE document (that we have shown are overestimated), we can easily calculate that the

amount of Pu in dirty DU is about to 4.4 mg every tonne of DU. This is not, absolutely, a small quality, but when it is spread over a large territory it is diluted to very low concentration. Even though the lethal dose for a human being is about 1 microgram, this quantity is not likely to be ingested by a single person because it corresponds to a mass of 225 g of DU, which is much more than the lethal dose (for chemical toxicity) for uranium.

Radio toxicity does not have, for delayed and stochastic effects to happen, any threshold: we must calculate the risk due to an higher exposure to radiation and then evaluate if this is relevant or negligible. In order to evaluate the danger for a specific nuclide, we must evaluate the Effective Dose Equivalent (EDE) to man. Referring to the analysis already reported in this work, to obtain the values of dose, it is enough to multiply the figures already given by the amount of DU.

In this section we only wish to make a comparison between clean and dirty DU.

The base scenario will be:
- immediate inhalation of uranium aerosol during attack (1 hour).
- release of 1 g of DU at the level of the soil.
- atmospheric dispersion evaluated by the Pasquill model (non-homogeneous dispersion) and most unfavourable direction (highest exposure).
- distance: 1 km from explosion
- human body modelled following ICRP recommendations.

The calculation of the dose to population is made using the program called GENII, which is a software elaborated by an US laboratory, internationally acknowledged and utilised. [B.A. Napier et al (1990), GENII – The Hanford Environmental Radiation Dosimetry Software System, PNL-6584, Pacific Northwest Laboratories (USA)].
The main result is the following:
- Dirty DU: 1.1 10-7 Sv/g
- Clean DU: 6.9 10-8 Sv/g

These values represent the EDE which is committed for life (50 years) after 1 hour of inhalation at 1 km from the site of release of DU. Obviously, when the distance is different, also the values change. Obviously the highest committed dose is given during the first year after inhalation:

- Dirty DU: 2.3 10-8 Sv/g
- Clean DU: 1.4 10-8 Sv/g

It is also easy to verify that the external exposure to the radiation of DU is negligible, because these are essentially only alpha emitters.
We now wish to answer a couple of important questions:
- Which nuclides contribute most to the dose?
- Which are the organs most exposed?

The answer to the first question is given in tables 2.3.1 and 2.3.2 (single nuclide) and 2.3.3 (nuclides grouped for "families"). Table 2.4 wishes to answer to the second question.

Table 2.3.1 – Clean DU. Contribution from single nuclides to the EDE. Sv/g released.

Nuclide	Sv/g	%	Note
U-238	5.8e-8	84%	Nuclide father
U-234	1.0e-8	15%	Nuclide father
U-235	8.3e-10	1.2%	Nuclide father
Th-234	1.7e-11		daughter of U-238
Pa-234	1.0e-12		daughter of U-238
others	negligible		
Total	6.9e-8		

Table 2.3.2 - Dirty DU. Contribution from single nuclides to the EDE. Sv/g released.

Nuclide	Sv/g	%	Note
U-238	5.7e-8	52%	Nuclide father
U-236	2.8e-8	25%	Nuclide father
U-234	2.5e-8	23%	Nuclide father
U-235	8.3e-10		Nuclide father
Np-237	1.7e-10		Nuclide father
Pu-239	1.2e-10		Nuclide father
Th-234	1.7e-11		daughter of U-238
Pa-234	1.0e-12		daughter of U-238
Total	1.1e-7		

Table 2.3.3 - Contribution to the EDE from "families". Sv/g released

Nuclide father	Clean DU		Dirty DU	
	Sv/g	%	Sv/g	%
U-238 and daughters	5.8e-8	84%	5.7e-8	51%
U-235 and daughters	8.3e-10	1.2%	8.3e-10	0.8%
U-234 and daughters	1.0e-8	15%	2.5e-8	23%
U-236 and daughters	—	—	2.8e-8	25%
Np-237 and daughters	—	—	1.7e-10	0.2%
Pu-239 and daughters	—	—	1.2e-10	0.1
TOTAL	6.9e-8		1.1e-7	

Table 2.4. – Dose to single organs. Comparison between clean and dirty DU, Sv/g released.

Targeted Organ	Clean DU Sv/g	Dirty DU Sv/g	Ratio: (dirty)/(clean)
Lungs	5.7e-7	9.3e-7	1.6
Kidneys	1.1e-10	1.8e-10	1.6
Bone Surface	3.7e-11	5.1e-9	140
Bone Marrow	3.7e-12	4.1e-10	11
Gonad	8,7e-13	4.6e-11	53
Gut	1.3e-10	3.4e-10	2.6
Other organs	—-	—-	
Total *	6.9e-8	1.1e-7	1.6

* to obtain the total EDE, multiply the dose to a single organ by the correspondent weighting factor.

We can conclude that: the risk for inhalation of dirty DU is about 1.6 times the clean. The increase is almost totally given by the increase of the dose to lungs.

For Clean DU:
- 84% of the dose arises from U238 and its daughters.
- 15% of the dose arises from U-234 and its daughters. As a consequence U-234 is not negligible.

For Dirty DU:
- the increase of the dose is highly due to the presence of U-234 and U-236 (48% of the total).
- 51% of the dose arises from U-238 and its daughters.

The contribution of Pu to the dose in negligible. It is not relevant for the dose calculations to know weather it has been or not completely removed during reprocessing of nuclear fuel. What is relevant is the presence of U-234 and U-236. only for the dose to bone marrow Pu is not negligible.

Np-237 and daughter contribute only for 0.2%. we can do the same considerations as for Pu. Also in this case its contribution to bone marrow is not negligible.

Concerning the most targeted organs: the target organs for inhalation are obviously the lungs. Kidneys and gut are also exposed to dose, because this is the pathway uranium walks during the excretion from human body.

There are some other organs which are exposed, in particularly the surface of bones and the bone marrow.

The value of dose to these organs is relatively small. This is not surprising because only a small fraction of DU is retained in bones and irradiates the bone marrow.

Comparing the values for dirty and clean DU, we can see a very big increase of the dose to some organs, such as bones, bone marrow and gonads (relevant for the genetic consequences).

Regarding the bone marrow, we can see that the main contribution (73%) comes from Np-237 (dirty DU), which is as a consequence relevant. The contribution of Pu is 24%, which is also not negligible.

These results, in particular the value of the dose to bone marrow, are proof that at least in principle there can be a link between DU inhalation and the insurgence of leukaemia.

3. A broader approach to the Depleted Uranium Question

(This chapter is mainly taken from:http://en.wikipedia.org/wiki/Depleted_ uranium with re-elaboration by the author).

Depleted uranium (DU) is uranium primarily composed of the isotope uranium-238 (U-238). Natural uranium is about 99.27 percent U-238, 0.72 percent U-235, and 0.0055 percent U-234. U-235 is used for fission in nuclear reactors and nuclear weapons[1]. Uranium is enriched in U-235 by separating the isotopes by mass. The by-product of enrichment, called depleted uranium or DU, contains less than one third as much U-235 and U-234 as natural uranium. Because U-234 accounts for about half the radioactivity of natural uranium, the external radiation dose from DU is about 60 percent of that from the same mass of natural uranium.[2] DU is also found in reprocessed spent nuclear reactor fuel, but that kind can be distinguished from DU produced as a by-product of uranium enrichment by the presence of U-236.[3] In the past, DU has been called Q-metal, deplet-alloy, and D-38, but those names are no longer used.

DU is useful because of its very high density of 19.1 g/cm^3. Civilian uses include counterweights in aircraft, radiation shielding in medical radiation therapy and industrial radiography equipment, and containers used to transport radioactive materials. Military uses include defensive armour plating and armour-piercing projectiles.

The use of DU in munitions is dangerous because of numerous questions about potential long-term health effects. Normal functioning of the kidney, brain, liver, heart, and numerous other systems can be affected by uranium exposure, because in addition to being radioactive, uranium is a toxic metal.[4]

DU is chemically toxic being an heavy metal, even if less heavily than arsenic and mercury. It is radioactive and remains so because of its long half-life. To be exposed to radiation from uranium, you have to eat, drink, or breathe it, or get it on your skin.[5] The aerosol produced during impact and combustion of depleted uranium munitions can contaminate wide areas around the impact sites or can be inhaled by civilians and military personnel.[6] In a three week period of conflict in Iraq during 2003 it was estimated over 1000 tons of depleted uranium munitions were used mostly in cities.[7, 8] Studies using cultured cells and laboratory rodents continue to show the evidence of leukemogenic, genetic, reproductive, and neurological effects from chronic exposure.[9] In addition, the UK Pensions

Appeal Tribunal Service in early 2004 attributed birth defect claims from a February 1991 Gulf War combat veteran to depleted uranium poisoning.[10,11] Also, a 2005 epidemiology review concluded: "In aggregate the human epidemiological evidence is consistent with increased risk of birth defects in offspring of persons exposed to DU."[12]

3.1 History

Enriched uranium was first manufactured in the 1940s when the US and USSR began their nuclear weapons and nuclear power programs. It was at this time that depleted uranium was first stored as an unusable waste product. There was some hope that the enrichment process would be improved and fissionable isotopes of U-235 could, at some future date, be extracted from the depleted uranium. This re-enrichment recovery of the residual uranium-235 contained in the depleted uranium is no longer a matter of the future: it has been practised for several years.[13]

In the 1970s, the Pentagon reported that the Soviet military had developed armour plating for Warsaw Pact tanks that NATO ammunition could not penetrate. The Pentagon began searching for material to make denser bullets. After testing various metals, ordnance researchers settled on depleted uranium.

As a by-product of uranium enrichment, DU became less expensive than other high-density ordnance candidates including tungsten in the 1960s. As the next best candidate, tungsten had to be obtained from China, a potential enemy of United States. With DU stockpiles estimated to be more than 500,000 tons, it was more economical to use depleted uranium than store it. Thus, from the late 1970s, the U.S., the Soviet Union, Britain, and France began converting their stockpiles of depleted uranium into kinetic energy penetrators.

The US military used DU shells in the 1991 Gulf War, the Bosnia war,[14] bombing of Serbia in 1999, and the 2003 invasion of Iraq.[15]. Rumours about the use of DU in Somalia (1992/93) and Afghanistan (2001) have also been reported but not confirmed yet.

While clearing a decades-old Hawai'i firing range in 2005, workers found depleted uranium training rounds from the formerly classified Davey Crockett tactical battlefield nuclear delivery system from the 1960-70s.[16] These training rounds had been forgotten because they had been fired before DU came to the news media's attention, more than 20 years before the Gulf War.

3.2 Production and availability

Natural uranium metal contains about 0.7 percent U-235, 99.28 percent U-238, and about 0.0054 percent U-234. In order to produce enriched uranium, the process of isotope separation removes a substantial portion of the U-235 for use in nuclear power, weapons, or other uses. The remainder, depleted uranium, contains only 0.2 percent to 0.4 percent U-235. Because natural uranium begins with such a low percentage of U-235, enrichment produces large quantities of depleted uranium. For example, producing 1 kg of five percent enriched uranium requires 11.8 kg of natural uranium, and leaves about 10.8 kg of depleted uranium with only 0.3 percent U-235 remaining.

About 95 percent of the depleted uranium produced is stored as uranium hexafluoride, a crystalline solid, (D)UF6, in steel cylinders in open air storage yards close to enrichment plants. Each cylinder holds up to 12.7 tonnes of UF6. In the U.S. 560,000 tonnes of depleted UF6 had accumulated by 1993. In 2008, 686,500 tonnes in 57,122 storage cylinders were located near Portsmouth, Ohio and Paducah, Kentucky.[17, 18] The storage of DUF6 presents environmental, health, and safety risks because of its chemical instability. When UF6 is exposed to water vapour in the air, it reacts with the moisture to produce UO2F2 (uranyl fluoride), a solid, and HF (hydrogen fluoride), a gas, both of which are highly soluble and toxic. The uranyl fluoride solid acts to plug the leak, limiting further escape of depleted UF6. Release of the hydrogen fluoride gas to the atmosphere is also slowed by the plug formation.[19] Storage cylinders must be regularly inspected for signs of corrosion and leaks and are repainted and repaired as necessary. The estimated life time of the steel cylinders is measured in decades.[20] The DOE is constructing two facilities to convert the UF6 to a more stable chemical form for long term storage. These facilities are expected to be in operation by early 2009 and take around 20 years to process the entire US government stock of UF6.

There have been several accidents involving uranium hexafluoride in the United States, including one in which 31 workers were exposed to a cloud of UF6 and its reaction products. Though some of the more highly exposed workers showed evidence of short-term kidney damage (e.g., protein in the urine), none of these workers had lasting kidney toxicity from the uranium exposure.[22] The U.S. government has been converting DUF6 to solid uranium oxides for use or disposal.[23] Such disposal of the entire DUF6 inventory could cost anywhere from $15 million to $450 million.[24]

Table 3.1 - World depleted uranium inventory

Country	Organization	Estimated DU stocks (tonnes)	Reported
United States	DOE	480000	2002
Russia	FAEA	460000	1996
France	Areva NC	190000	2001
United Kingdom	BNFL	30000	2001
Germany Netherlands United Kingdom	URENCO	16000	1999
Japan	JNFL	10000	2001
China	CNNC	2	2000
South Korea	KAERI	200	2002
South Africa	NECSA	73	2001
TOTAL		1,188,273	2002

Source: WISE Uranium Project

3.3 Military applications

Depleted uranium is very dense; at 19050 kg/m³, it is 1.67 times as dense as lead, only slightly less dense than tungsten and gold, and 84% as dense as osmium or iridium, which are the densest known substances under standard (i.e., Earth-surface) pressures. Thus a given mass of it has a smaller diameter than an equivalent lead projectile, with less aerodynamic drag and deeper penetration due to a higher pressure at point of impact. DU projectile ordnance is often incendiary because of its pyrophoric property.[25]

Because of its high density, depleted uranium can also be used in tank armour, sandwiched between sheets of steel armour plate. For instance, some late-production M1A1HA and M1A2 Abrams tanks built after 1998 have DU reinforcement as part of the armour plating in the front of the hull and the front of the turret, and there is a program to upgrade the rest.

Most military use of depleted uranium has been as 30 mm calibre ordnance, primarily the 30mm PGU-14/B armour-piercing incendiary round from the GAU-8 Avenger cannon of the A-10 Thunderbolt II used by the United States Air Force and M230 Chain Gun of the AH-64 Apache helicopter used by the United States Army. 25 m DU rounds have been used in the M242 gun mounted on the U.S.

Army's Bradley Fighting Vehicle and LAV-25. The United States Marine Corps uses DU in the 25 mm PGU-20 round fired by the GAU-12 Equalizer cannon of the AV-8B Harrier, and also in the 20 mm M197 gun mounted on AH-1 Cobra helicopter gunships. The United States Navy's Phalanx CIWS's M61 Vulcan Gatling gun used 20 mm armour-piercing penetrator rounds with discarding plastic sabots which were made using depleted uranium, later changed to tungsten.

Another use of depleted uranium is in kinetic energy penetrators anti-armour rounds, such as the 120 mm sabot rounds fired from the M1A1 and M1A2 Abrams.[26] Kinetic energy penetrator rounds consist of a long, relatively thin penetrator surrounded by discarding sabot. Two materials lend themselves to penetrator construction: tungsten and depleted uranium, the latter in designated alloys known as stab-alloys. Stab-alloys are metal alloys of depleted uranium with a very small proportion of other metals, usually titanium or molybdenum. One formulation has a composition of 99.25 percent by mass of depleted uranium and 0.75 percent by mass of titanium. Stab-alloys are about twice as dense as lead and are designed for use in kinetic energy penetrator armour-piercing ammunition. The US Army uses DU in an alloy with around 3.5 percent titanium.

Stab-alloys, along with lower raw material costs, have the advantage of being easy to melt and cast into shape; a difficult and expensive process for tungsten. According to recent research,[27] at least some of the most promising tungsten alloys which have been considered as replacement for depleted uranium in penetrator ammunitions, such as tungsten-cobalt or tungsten-nickel-cobalt alloys, also possess extreme carcinogenic properties, which by far exceed those (confirmed or suspected) of depleted uranium itself: 100 percent of rats implanted with a pellet of such alloys developed lethal rhabdo-myosarcoma within a few weeks. On more properly military grounds, depleted uranium is favoured for the penetrator because it is self-sharpening and pyrophoric.[25] On impact with a hard target, such as an armoured vehicle, the nose of the rod fractures in such a way that it remains sharp. The impact and subsequent release of heat energy causes it to disintegrate to dust and burn when it reaches air because of its pyrophoric properties.[25] When a DU penetrator reaches the interior of an armoured vehicle, it catches fire, often igniting ammunition and fuel, killing the crew, and possibly causing the vehicle to explode. DU is used by the U.S. Army in 120 mm or 105 mm cannons employed on the M1 Abrams and M60A3 tanks. The Russian military has used DU ammunition in tank main gun ammunition since the late 1970s, mostly for the 115 mm guns in the T-62 tank and the 125 mm guns in the T-64, T-72, T-80, and T-90 tanks.

The DU content in various ammunition is 180 g in 20 mm projectiles, 200 g in 25 mm ones, 280 g in 30 mm, 3.5 kg in 105 mm, and 4.5 kg in 120 mm penetrators. DU was used during the mid-1990s in the U.S. to make 9 mm and similar calibre armour piercing bullets,[citation needed] grenades, cluster bombs, and mines, but those applications have been discontinued, according to Alliant Techsystems. The US Navy used DU in its 20 mm Phalanx CIWS guns, but switched in the late 1990s to armour-piercing tungsten.

It is thought that between 17 and 20 countries have weapons incorporating depleted uranium in their arsenals. They include the U.S., the UK, France, Russia, China, Turkey, Israel, Saudi Arabia, Bahrain, Egypt, Kuwait, Pakistan, Thailand, Iraq and Taiwan.[citation needed] DU ammunition is manufactured in 18 countries. Only the US and the UK have acknowledged using DU weapons.[28]

The Iranian Government TV news channel Press TV claimed on January 4, 2009, that evidence of depleted uranium exposure has been found in wounds of casualties of the 2008–2009 Israel–Gaza conflict.[29]. Urgent request from all countries of the Arab League has been made, in order that UNEP sets up a fact-finding mission about the use of DU in Gaza.

3.4 Legal status in weapons

The Sub-Commission on Prevention of Discrimination and Protection of Minorities of the United Nations Human Rights Commission,[31] passed two motions[32] the first in 1996[33] and the second in 1997.[34] They listed weapons of mass destruction, or weapons with indiscriminate effect, or of a nature to cause superfluous injury or unnecessary suffering and urged all states to curb the production and the spread of such weapons. Included in the list was weaponry containing depleted uranium. The committee authorized a working paper, in the context of human rights and humanitarian norms, of the weapons. The requested UN working paper was delivered in 2002[35] by Y.K.J. Yeung Sik Yuen in accordance with Sub-Commission on the Promotion and Protection of Human Rights resolution 2001/36. He argues that the use of DU in weapons, along with the other weapons listed by the Sub-Commission, may breach one or more of the following treaties: the Universal Declaration of Human Rights, the Charter of the United Nations, the Genocide Convention, the United Nations Convention Against Torture, the Geneva Conventions including Protocol I, the Convention on Conventional Weapons of 1980, and the Chemical Weapons Convention. Yeung Sik Yuen writes in Paragraph 133 under the title "Legal compliance of weapons containing DU as a new weapon":

Annex II to the Convention on the Physical Protection of Nuclear Material 1980 (which became operative on 8 February 1997) classifies DU as a category II nuclear material. Storage and transport rules are set down for that category which indicates that DU is considered sufficiently "hot" and dangerous to warrant these protections. But since weapons containing DU are relatively new weapons no treaty exists yet to regulate, limit or prohibit its use. The legality or illegality of DU weapons must therefore be tested by recourse to the general rules governing the use of weapons under humanitarian and human rights law which have already been analysed in Part I of this paper, and more particularly at paragraph 35 which states that parties to Protocol I to the Geneva Conventions of 1949 have an obligation to ascertain that new weapons do not violate the laws and customs of war or any other international law. As mentioned, the International Court of Justice considers this rule binding customary humanitarian law.

In 2001, Carla Del Ponte, the chief prosecutor for the International Criminal Tribunal for the Former Yugoslavia, said that NATO's use of depleted uranium in former Yugoslavia could be investigated as a possible war crime.[36] Louise Arbour, Del Ponte's predecessor as chief prosecutor, had created a small, internal committee, made up of staff lawyers, to assess the allegation. Their findings, that were accepted and endorsed by Del Ponte,[37] concluded that:

There is no specific treaty ban on the use of DU projectiles. There is a developing scientific debate and concern expressed regarding the impact of the use of such projectiles and it is possible that, in future, there will be a consensus view in international legal circles that use of such projectiles violate general principles of the law applicable to use of weapons in armed conflict. No such consensus exists at present.[38]

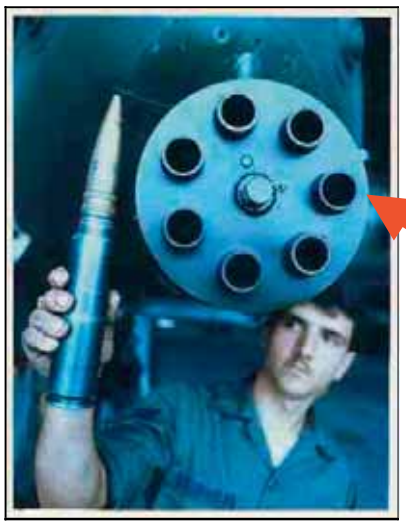
3.5 Requests for a moratorium on military use

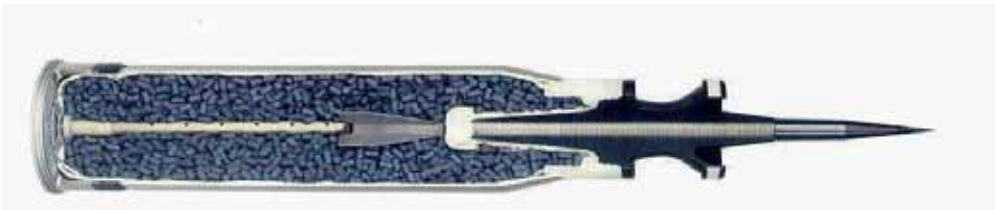
Some states and the International Coalition to Ban Uranium Weapons, a coalition of more than 100 non-governmental organizations, have asked for a ban on the production and military use of depleted uranium weapons.[39]

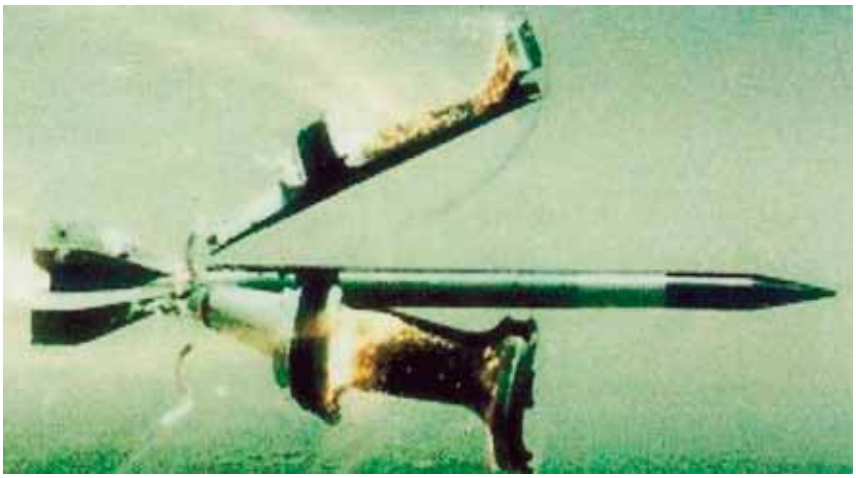
The European Parliament has repeatedly passed resolutions requesting an immediate moratorium on the further use of depleted uranium ammunition,[40, 41] but France and Britain – the only EU states that are permanent members of the United Nations Security Council – have consistently rejected calls for a ban,[42] maintaining that its use continues to be legal, and that the health risks are entirely unsubstantiated.[43]

MILITARY USE OF DU

30 mm BULLETS:
AIRPLANE A-10 Warthog e
120 mm bullets and armour for
M1 (A1 e A2) tanks





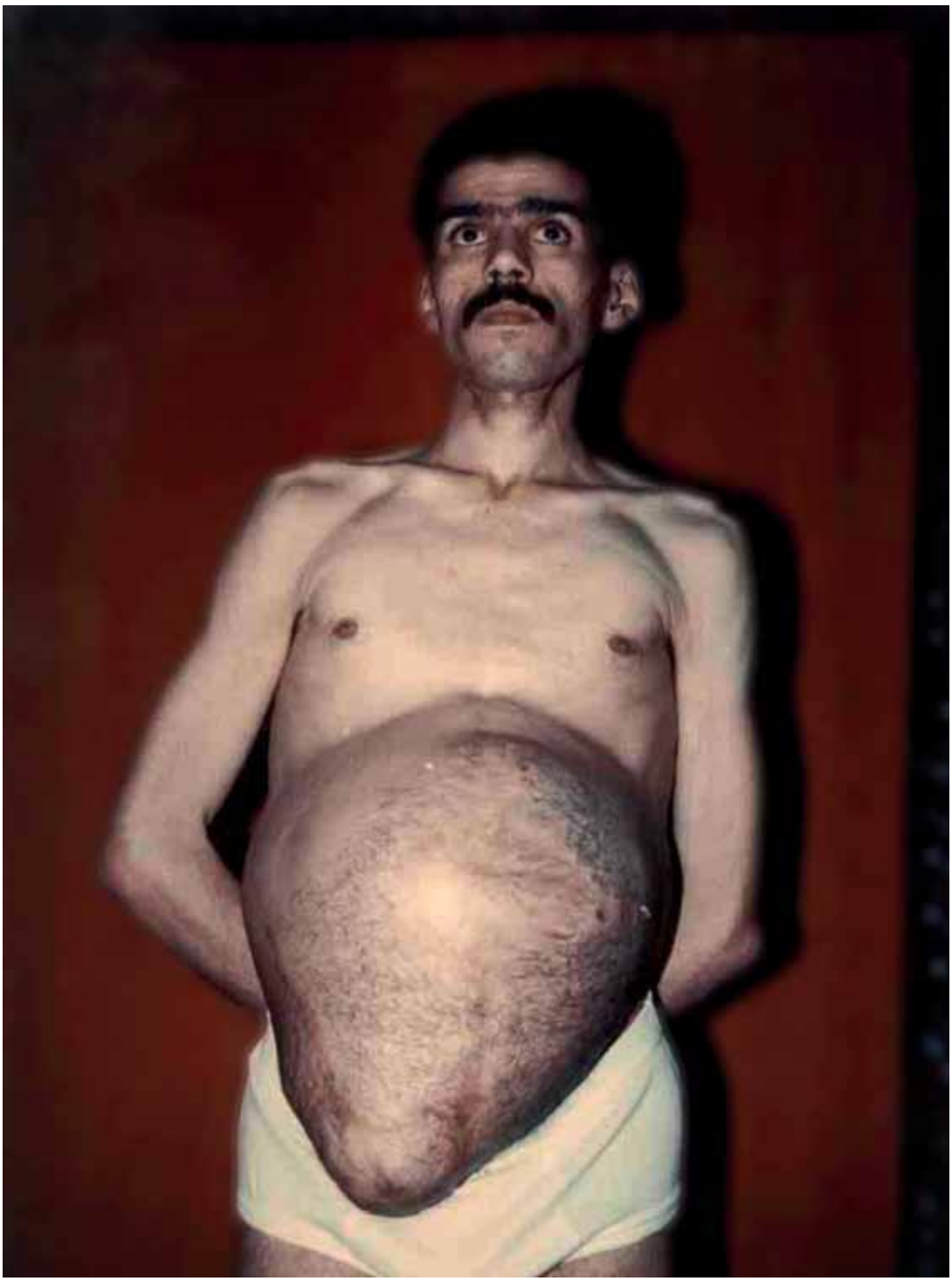


DEPLETED URANIUM CHARACTERISTICS x MILITARY USE

- NUCLAER INDUSTRY SCRAP
- WIDE AVAILABILITY

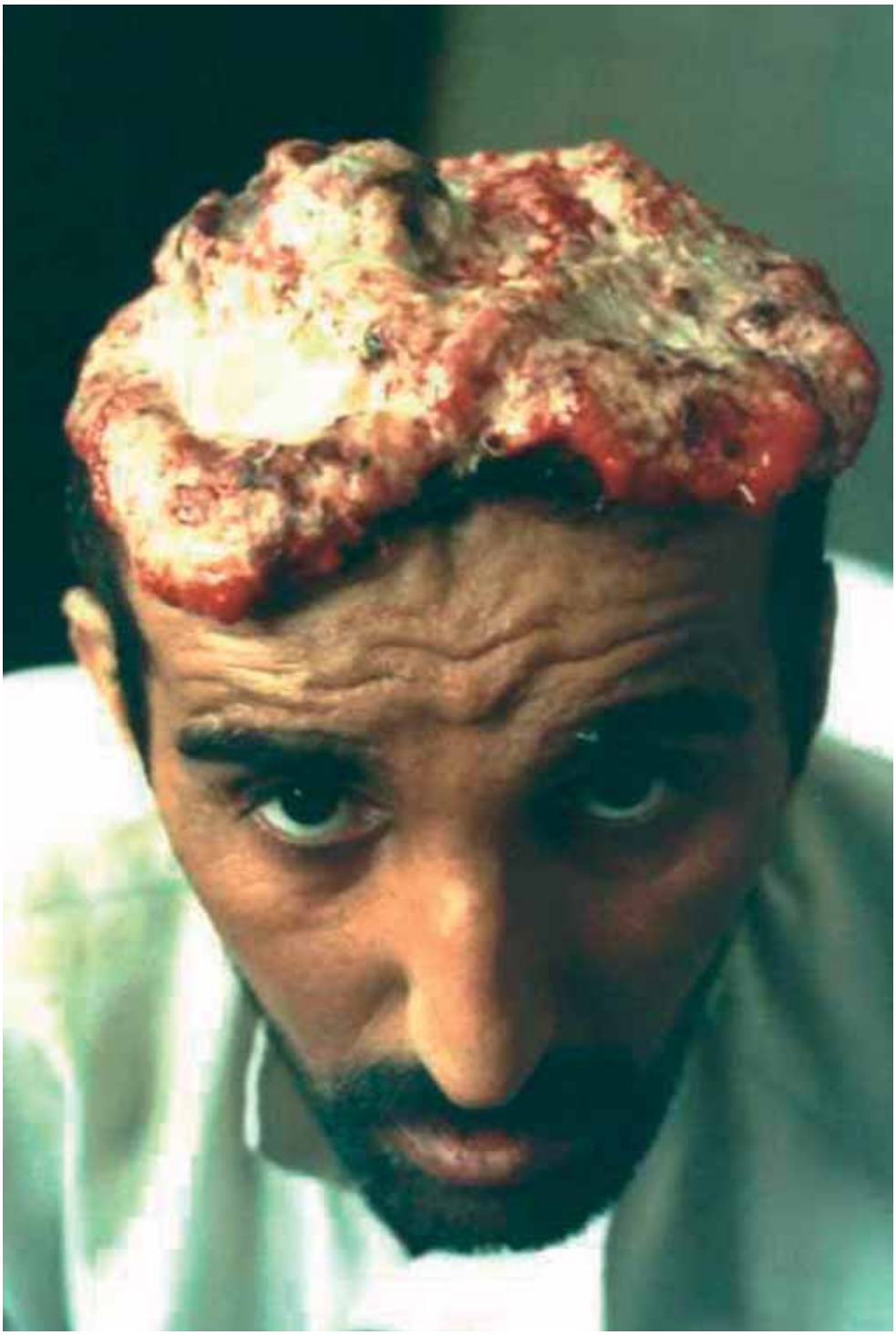
} LOW COST 2 $ / KG

- HIGH DENSITY (One liter = 19 kg)
- PYROPHORIC
- SELF-SHARPENING PROPERTIES
- RADIOACTIVITY

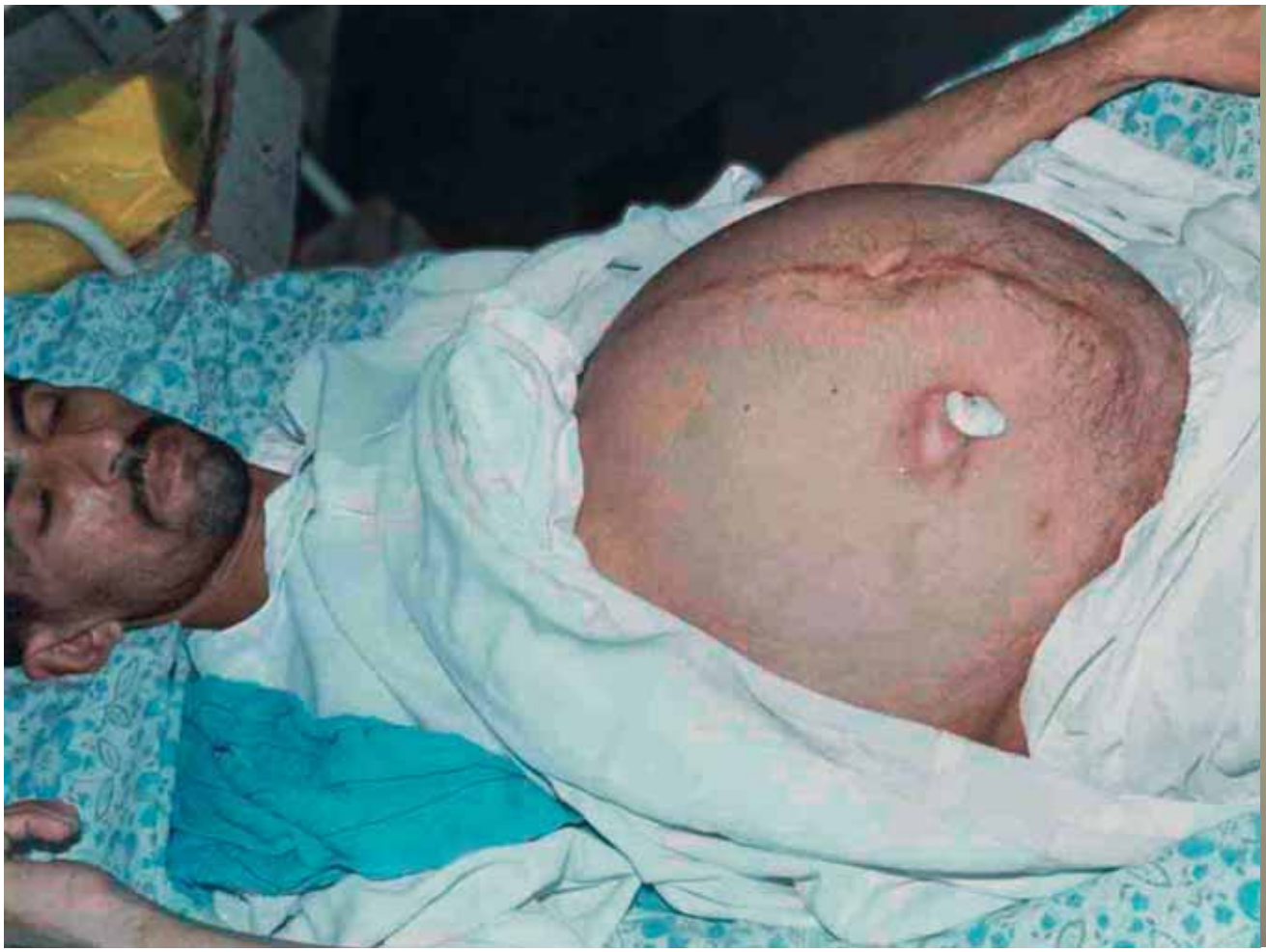


Malignant fibrous histiocytoma

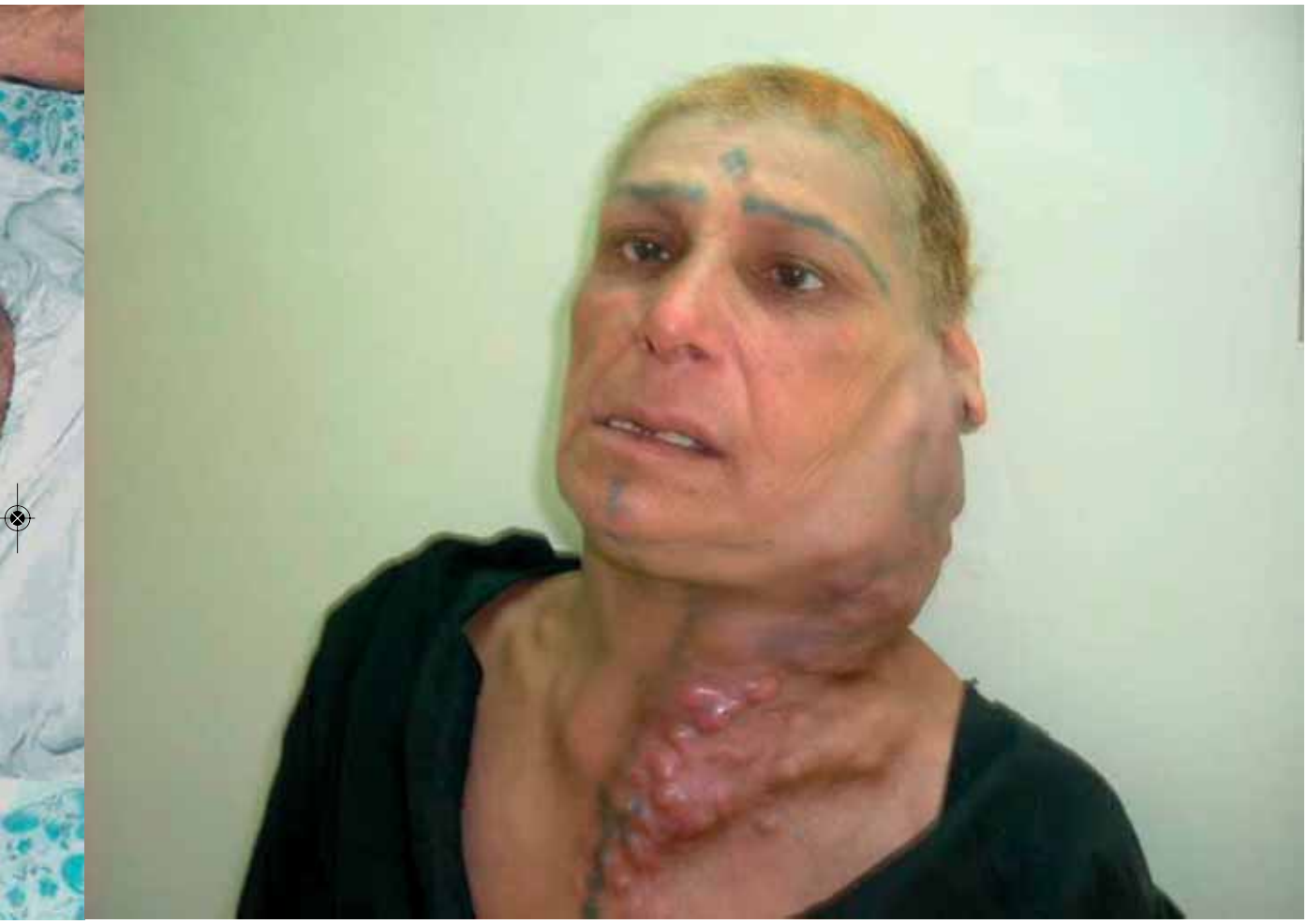
Parotid tumour



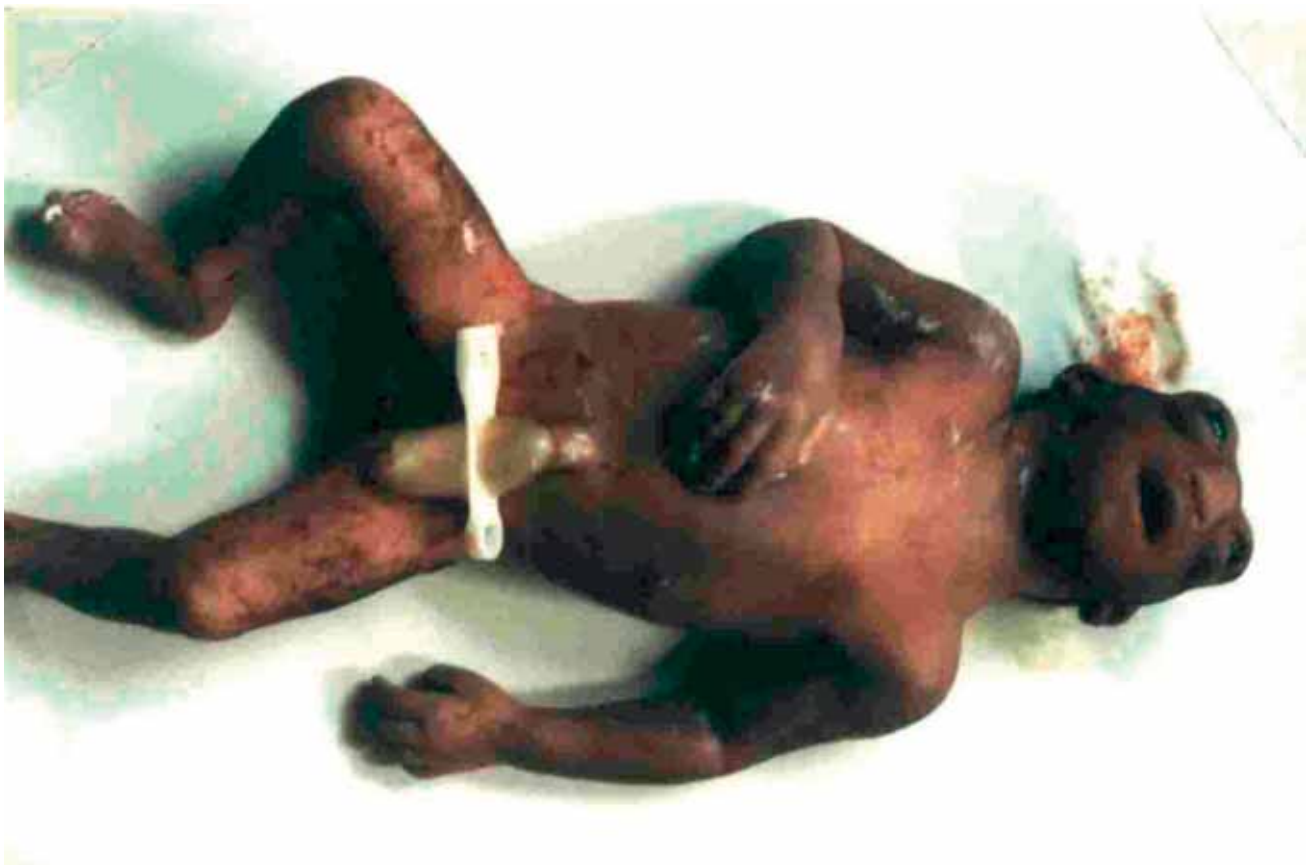
Squamous cell ca.



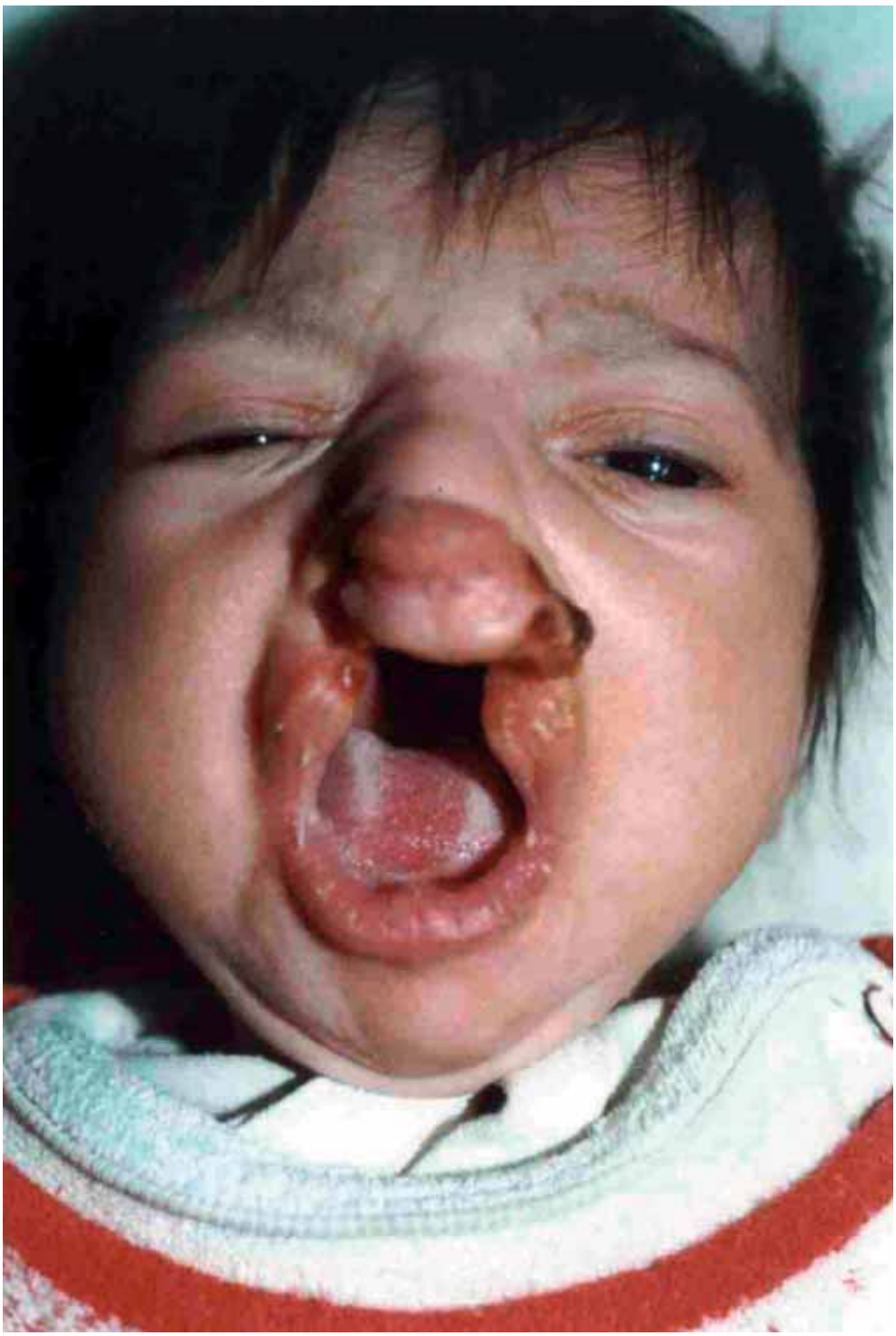
Liposarcoma



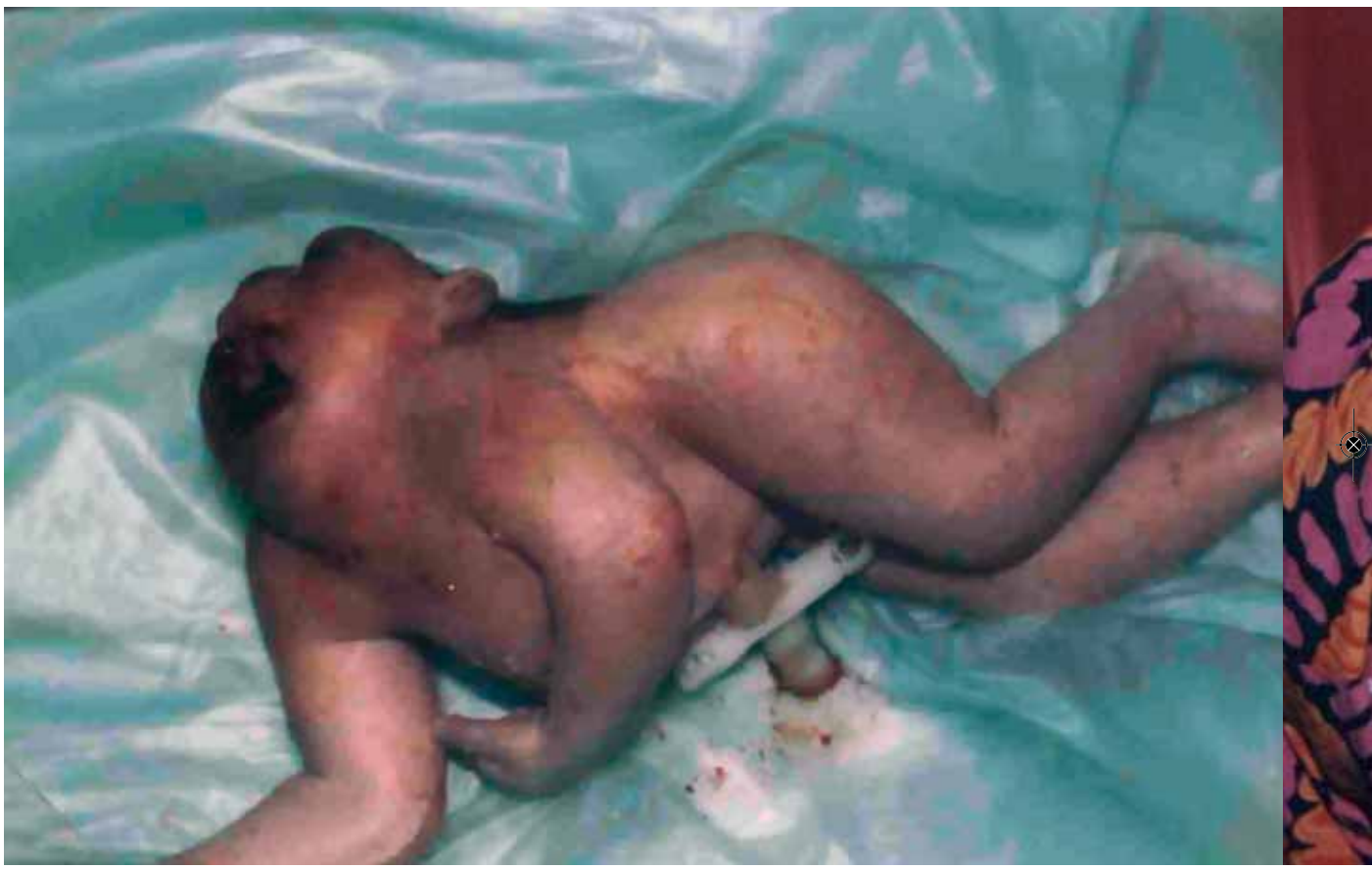
NHL = Non Hodgkin Lymphoma



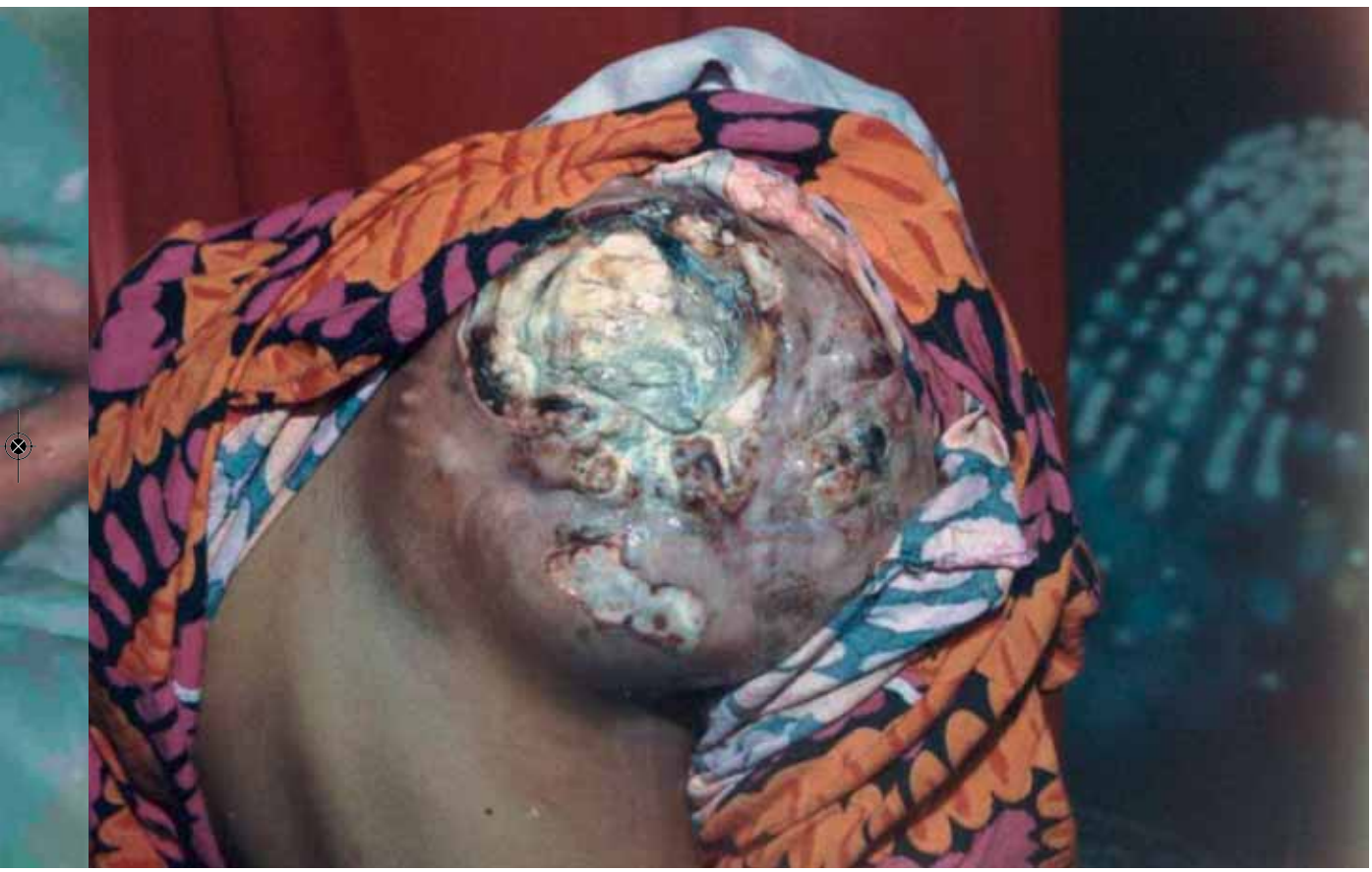
congenital malformation or "birth defects"



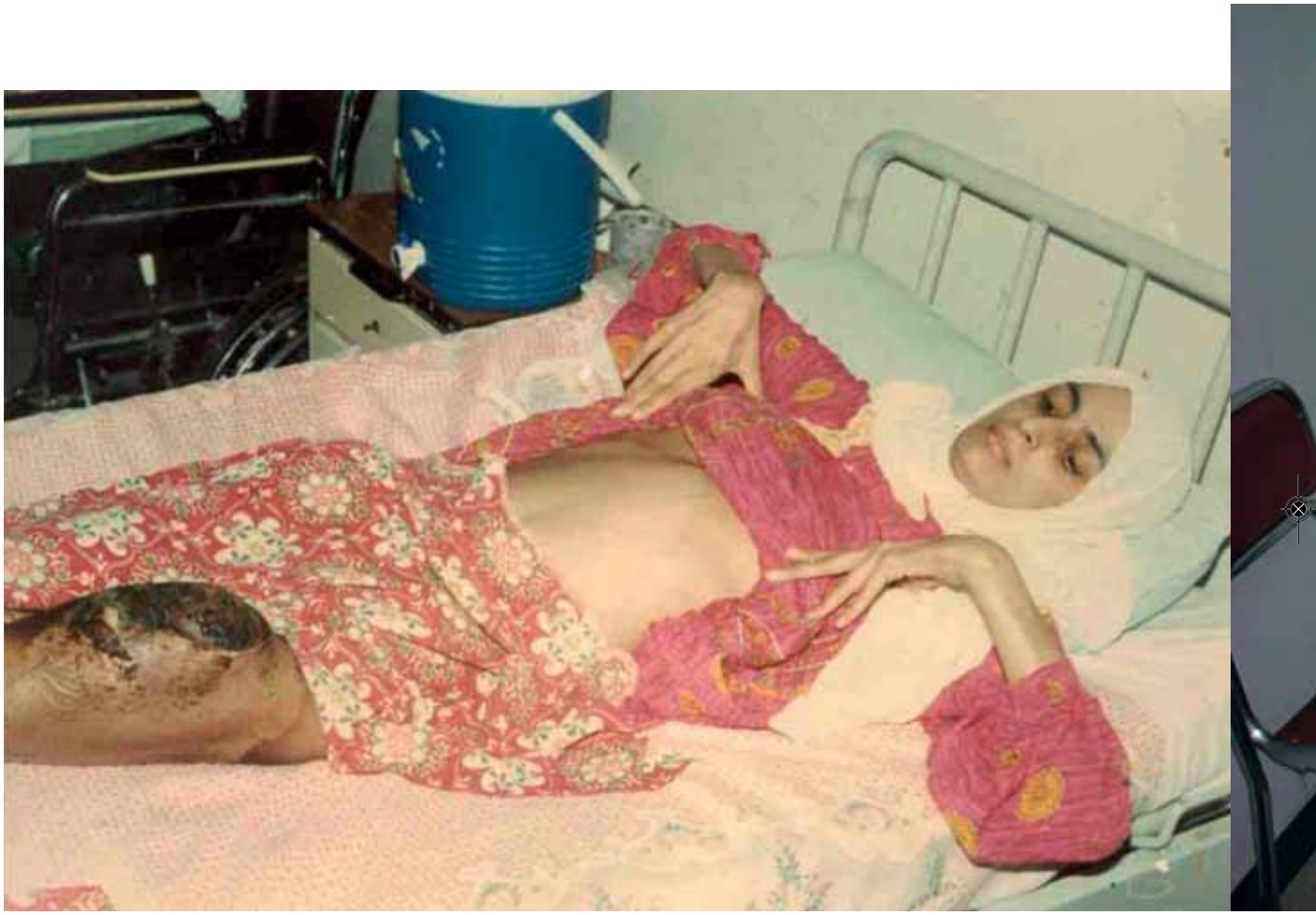
congenital malformation or "birth defects"



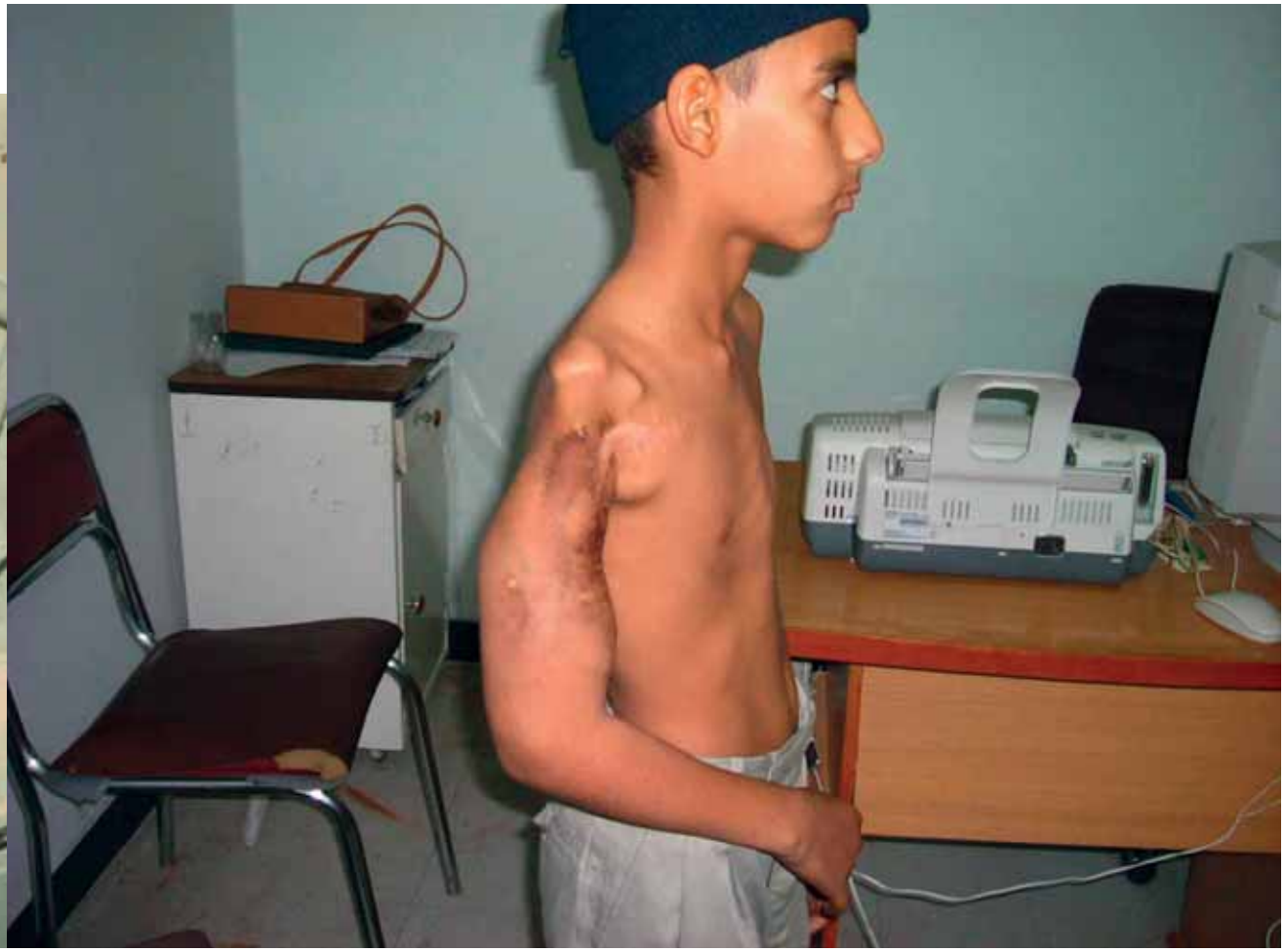
congenital malformation or "birth defects"



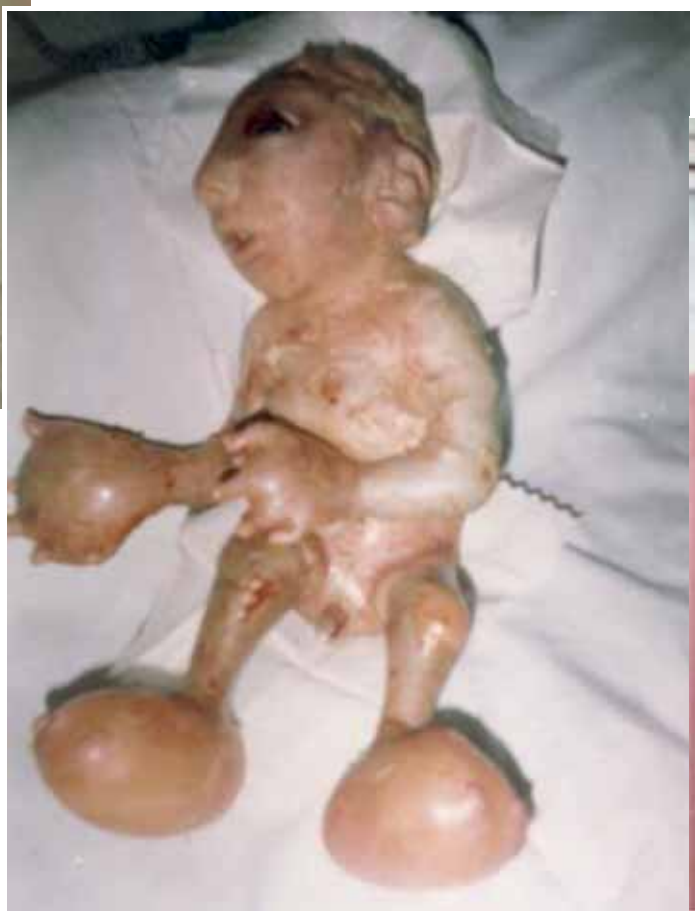
Malignant fibrous histiocytoma



rhabdomyosarcoma

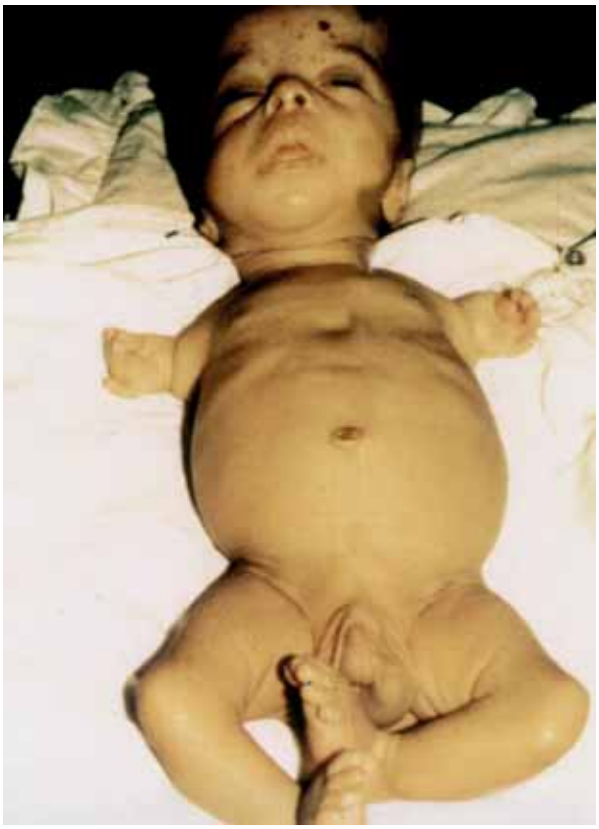


Osteogenic sarcoma (Bone Cancer)



congenital malformations or "birth defects"

congenital malformations or "birth defects"



congenital
malformations
or
"birth defects"

In 2007 France, Britain, the Netherlands, and the Czech Republic voted against a United Nations General Assembly resolution to hold a debate in 2009 about the effects of the use of armaments and ammunitions containing depleted uranium. All other European Union nations voted in favour or abstained.[44] The ambassador from the Netherlands explained his negative vote as being due to the reference in the preamble to the resolution "to potential harmful effects of the use of depleted uranium munitions on human health and the environment [which] cannot, in our view, be supported by conclusive scientific studies conducted by relevant international organizations."[45] None of the other permanent members of the United Nations Security Council supported the resolution as China was absent for the vote, Russia abstained and United States voted against the resolution.[44]

In September 2008, and in response to the 2007 General Assembly resolution, the UN Secretary General published the views of 15 states alongside those of the International Atomic Energy Agency (IAEA) and World Health Organization (WHO). The IAEA and WHO evidence differed little from previous statements on the issue.[46] The report was largely split between states concerned about depleted uranium's use such as Finland, Cuba, Japan, Serbia, Argentina and predominantly NATO members who do not consider the use of depleted uranium munitions problematic.[46]

In December 2008, 141 states supported a resolution requesting that three UN agencies: United Nations Environment Programme (UNEP), WHO and IAEA update their research on the impact of uranium munitions by late 2010 - to coincide with the General Assembly's 65th Session, four voted against, 34 abstained and 13 were absent[47] As before Britain and France voted against the resolution. All other European Union nations voted in favour or abstained: the Netherlands, which voted against a resolution in 2007, voted in favour, as did Finland and Norway, both of which had abstained in 2007, while the Czech Republic, which voted against the resolution in 2007, abstained. The two other states that voted against the resolution were Israel and the United States (both of which voted against in 2007), while as before China was absent for the vote, and Russia abstained.[47]

3.6 Civilian applications

Civilian applications for depleted uranium are typically unrelated to its radioactive properties. Depleted uranium has a very high density and is primarily used as shielding material for other radioactive material, and as ballast. Examples in-

clude sailboat keels, as counterweights and as shielding in industrial radiography cameras.

Industrial radiography cameras include a very high source of gamma radiation (typically Ir-192.) Depleted uranium is used in the cameras as a shield to protect individuals from the gamma source. Typically the uranium will be surrounded by polyurethane foam to protect the uranium from the elements, and stainless steel will be used to house the device.[48]

Consumer product uses have included incorporation into dental porcelain, used for false teeth to simulate the fluorescence of natural teeth, and uranium-bearing reagents used in chemistry laboratories (e.g. uranyl acetate, used in analytical chemistry and as a stain in electron microscopy). Uranium (both depleted uranium and natural uranium) was widely used as a colouring matter for porcelain and glass in the 19th and early to mid 20th century. The practice was largely discontinued in the late 20th century. In 1999 concentrations of 10% depleted uranium were being used in "jaune no. 17" a yellow enamel powder that was being produced in France by Cristallerie de Saint-Paul, a manufacturer of enamel pigments. The depleted uranium used in the powder was sold by Cogéma's Pierrelatte facility. In February, 2000, Cogéma discontinued the sale of depleted uranium to producers of enamel and glass.[49]

Aircraft that contain depleted uranium trim weights (Boeing 747-100 for example) may contain between 400 to 1,500 kg of DU. This application is controversial because the DU may enter the environment if the aircraft were to crash. The metal can also oxidize to a fine powder in a fire. Its use has been phased out in many newer aircraft. Boeing and McDonnell-Douglas discontinued using DU counterweights in the 1980s. Depleted uranium was released during the Bijlmer disaster, in which 152 kg was lost, but an extensive study concluded that there was no evidence to link depleted uranium from the plane to any health problems.[50]. Counterweights manufactured with cadmium plating are considered non-hazardous while the plating is intact.[51]

3.7 Health considerations

Normal functioning of the kidney, brain, liver, heart, and numerous other systems can be affected by uranium exposure, because in addition to being weakly radioactive, uranium is a toxic metal.[4] DU is toxic, being an heavy metal, however is less toxic than other heavy metals such as arsenic and mercury. It is radioactive and remains so because of its long half-life. The Agency for Toxic Substances and

Disease Registry states that: "to be exposed to radiation from uranium, you have to eat, drink, or breathe it, or get it on your skin."[52] However, the Institute of Nuclear Technology-Radiation Protection of Attiki, Greece has noted that "the aerosol produced during impact and combustion of depleted uranium munitions can potentially contaminate wide areas around the impact sites or can be inhaled by civilians and military personnel."[53] In a three week period of conflict in Iraq during 2003 it was estimated over 1000 tons of depleted uranium munitions were used mostly in cities.[7] While any radiation exposure has risks, no conclusive data have correlated DU exposure to specific human health effects such as cancer.[54] Yet, studies using cultured cells and laboratory rodents continue to show the evidence of leukaemogenic, genetic, reproductive, and neurological effects from chronic exposure.[55] In addition, the UK Pensions Appeal Tribunal Service in early 2004 attributed birth defect claims from a February 1991 Gulf War combat veteran to depleted uranium poisoning.[56, 57] Also, a 2005 epidemiology review concluded: "In aggregate the human epidemiological evidence is consistent with increased risk of birth defects in offspring of persons exposed to DU."[12]

DU is considered both a toxic and radioactive hazard that requires long term storage as low level nuclear waste in very large quantities. Its use in incendiary ammunition is dangerous because of adverse health effects and its release into the environment.[58, 59, 60, 61, 62, 63] Besides its residual radioactivity, U-238 is a heavy metal whose compounds are known from laboratory studies to be toxic to mammals.

Although slow, metallic uranium is prone to corrosion and small pieces are pyrophoric at room temperature in air.[25] When depleted uranium munitions penetrate armour or burn, they create depleted uranium oxides in the form of dust that can be inhaled or contaminate wounds. Additionally, fragments of munitions or armour can become embedded in the body. However, 98% of the depleted uranium ingested is filtered and excreted by the body.

3.8 Chemical toxicity

Normal functioning of the kidney, brain, liver, heart, and numerous other systems can be affected by uranium exposure, because in addition to being weakly radioactive, uranium is a toxic metal.[4] The chemical toxicity of depleted uranium is about a million times greater in vivo than its radiological hazard.[64] Health effects of DU are determined by factors such as the extent of exposure and whether it was internal or external. Three main pathways exist by which internalization of uranium may occur: inhalation, ingestion, and embedded fragments

or shrapnel contamination. Properties such as phase (e.g. particulate or gaseous), oxidation state (e.g. metallic or ceramic), and the solubility of uranium and its compounds influence their absorption, distribution, translocation, elimination and the resulting toxicity. For example, metallic uranium is relatively non-toxic compared to hexavalent uranium(VI) uranyl compounds such as uranium trioxide.[65, 66]

Uranium is pyrophoric when finely divided.[25] It will corrode under the influence of air and water producing insoluble uranium(IV) and soluble uranium (VI) salts. Soluble uranium salts are toxic. Uranium slowly accumulates in several organs, such as the liver, spleen, and kidneys. The World Health Organization has established a daily "tolerated intake" of soluble uranium salts for the general public of 0.5 µg/kg body weight, or 35 µg for a 70 kg adult.

Epidemiological studies and toxicological tests on laboratory animals point to it as being immunotoxic,[67] teratogenic,[68, 69] neurotoxic,[70] with carcinogenic and leukaemogenic potential.[71] There has been no definite link between possible health effects in laboratory animals and humans.[citation needed] A 2005 report by epidemiologists concluded: "the human epidemiological evidence is consistent with increased risk of birth defects in offspring of persons exposed to DU."[12]

Early studies of depleted uranium aerosol exposure assumed that uranium combustion product particles would quickly settle out of the air[72] and thus could not affect populations more than a few kilometres from target areas,[73] and that such particles, if inhaled, would remain undissolved in the lung for a great length of time and thus could be detected in urine.[74] Burning uranium droplets violently produce a gaseous vapour comprising about half of the uranium in their original mass.[75] Uranyl ion contamination in uranium oxides has been detected in the residue of DU munitions fires.[76, 77]

3.9 Radiological hazards

External exposure to radiation from pure depleted uranium is less of a concern because the alpha particle emitted by its isotopes travel only a few centimetres in air or can be stopped by a sheet of paper. Also, the low concentration of uranium-235 that remains in depleted uranium emits only a small amount of low-energy gamma radiation. According to the World Health Organization, a radiation dose from it would be about 60 percent of that from purified natural uranium with the same mass. Approximately 90 micrograms of natural uranium, on aver-

age, exist in the human body as a result of normal intake of water, food and air. The majority of this is found in the skeleton, with the rest in various organs and tissues.

However, in a matter of a month or so, depleted uranium generates amounts of thorium-234 and protactinium-234 which emit beta particles at almost the same rate as that of the alpha particles from the uranium-238. Two beta particles are emitted for each alpha particle.

The radiological dangers of pure depleted uranium are lower (60 percent) than those of naturally-occurring uranium due to the removal of the more radioactive isotopes, as well as due to its long half-life (4.46 billion years). Depleted uranium differs from natural uranium in its isotopic composition, but its biochemistry is for the most part the same.

3.10 Gulf War syndrome

Increased rates of immune system disorders and other wide-ranging symptoms, including chronic pain, fatigue and memory loss, have been reported in over one quarter of combat veterans of the 1991 Gulf War.[78] Combustion products from depleted uranium munitions are being considered as one of the potential causes by the Research Advisory Committee on Gulf War Veterans' Illnesses, as DU was used in 30 mm and smaller calibre machine-gun bullets on a large scale for the first time in the Gulf War. Veterans of the conflicts in the Gulf, Bosnia and Kosovo have been found to have up to 14 times the usual level of chromosome abnormalities in their genes.[79, 80] Serum-soluble genotoxic teratogens produce congenital disorders, and in white blood cells causes immune system damage.[80]

Human epidemiological evidence is consistent with increased risk of birth defects in the offspring of persons exposed to DU.[12] A 2001 study of 15,000 February 1991 U.S. Gulf War combat veterans and 15,000 control veterans found that the Gulf War veterans were 1.8 (fathers) to 2.8 (mothers) times more likely to have children with birth defects.[82] After examination of children's medical records two years later, the birth defect rate increased by more than 20%:

"Dr. Kang found that male Gulf War veterans reported having infants with likely birth defects at twice the rate of non-veterans. Furthermore, female Gulf War veterans were almost three times more likely to report children with birth defects than their non-Gulf counterparts. The numbers changed somewhat with medical records verification. However, Dr. Kang and his colleagues concluded

that the risk of birth defects in children of deployed male veterans still was about 2.2 times that of non-deployed veterans."[83]

In early 2004, the UK Pensions Appeal Tribunal Service attributed birth defect claims from a February 1991 Gulf War combat veteran to depleted uranium poisoning.[84, 85] Children of British soldiers who fought in wars in which depleted uranium ammunition was used are at greater risk of suffering genetic diseases such as congenital malformations, commonly called "birth defects," passed on by their fathers. In a study of U.K. troops, "Overall, the risk of any malformation among pregnancies reported by men was 50% higher in Gulf War Veterans (GWV) compared with Non-GWVs."[86]

The U.S. Army has commissioned ongoing research into potential risks of depleted uranium and other projectile weapon materials like tungsten, which the U.S. Navy has used in place of DU since 1993. Studies by the U.S. Armed Forces Radiobiology Research Institute conclude that moderate exposures to either depleted uranium or uranium present a significant toxicological threat.[87]

One particular subgroup of veterans which may be at higher risk comprises those who have retained internally fragments of DU from shrapnel wounds. A laboratory study on rats produced by the Armed Forces Radiobiology Research Institute showed that, after a study period of 6 months, rats treated with depleted uranium coming from implanted pellets, comparable to the average levels in the urine of Desert Storm veterans with retained DU fragments, had developed a significant tendency to lose weight with respect to the control group.[88] Substantial amounts of uranium were accumulating in their brains and central nervous systems, and showed a significant reduction of neuronal activity in the hippocampus in response to external stimuli. The conclusions of the study show that brain damage from chronic uranium intoxication is possible at lower doses than previously thought. Results from computer-based neuro-cognitive tests performed in 1997 showed an association between uranium in the urine and "problematic performance on automated tests assessing performance efficiency and accuracy."[89]

In 2003 Professor Brian Spratt FRS, chairman of the Royal Society's working group on depleted uranium, said: "The question of who carries out the initial monitoring and clean-up is a political rather than scientific question," and "the coalition needs to acknowledge that depleted uranium is a potential hazard and make in-roads into tackling it by being open about where and how much depleted uranium has been deployed." [7]

Since 2001, medical personnel at the Basra hospital (Iraq) claimed [90] that they observed a sharp increase in the incidence of child leukaemia and genetic malformation among babies born in the decade following the Gulf War. Photographs of birth-defected newborns were shown to foreign reporters. Iraqi doctors attributed these malformations to possible long-term effects of DU, an opinion which was echoed by several newspapers[91, 92, 93, 94] But no peer-reviewed study has been undertaken in Basra. The International Coalition to Ban Uranium Weapons (ICBUW) has made a call to support an epidemiological study in the Basra region, as asked for by Iraqi doctors[95].

3.11 1999 NATO bombing of the Federal Republic of Yugoslavia

In 2001, Doctors at the Serb-run hospital in Kosovska Mitrovica say the number of patients suffering from malignant diseases has increased by 200% since 1998.[96] In the same year, The World Health Organization reported that data from Kosovo was inconclusive and called for further studies.[97] A 2003 study by United Nations Environment Programme in Bosnia and Herzegovina stated that low levels of contaminate were found in drinking water and air particulate at DU penetrator impact points. The levels were stated as not a cause for alarm. Yet, Pekka Haavisto, Chairman of the UNEP DU projects stated, "The findings of this study stress again the importance of appropriate clean-up and civil protection measures in a post-conflict situation."[98]

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4. A review of Iraqi "gray" literature about DU

Depleted Uranium (DU) weaponry has been used against Iraq for the first time in the history of recent wars. The synergetic impact on health due to the post Gulf War I economical sanctions and DU related radioactive contamination raised the number of casualties in contaminated areas as in southern Iraq.

Continual usage of DU after Gulf War I on other Iraqi territories through the No-Fly Zones and the major DU loaded Cruise Missiles attack of year 1998, all contributed in making the problem increasingly complex.

During 2003, military operations conducted in Iraq by the invading forces used additional rounds of DU in heavily populated areas such as Baghdad, Samawa and other provinces. It is only fair to conclude that the environment in Iraq and its population have been exposed continuously to DU weaponry or its contaminating remains, since 1991.

Accordingly millions of Iraqi's have received higher doses of radioactivity than ordinary background levels. As a result a multi-fold increase of low level radiation (LLR) exposure related diseases have been registered since 1995. An increase of children's leukaemia, congenital malformations, breast cancer etc…

The shift of leukaemia incidence rates towards younger children during the recent years, and its association with geographically distributed contaminated areas, offers strong evidence of the correlation between LLR exposure and resulted health damages.

Through this section, an overview of major scientific DU conclusions will be presented, drawn from investigations and research conducted since the year 1991 by Iraqi researchers and MDs. Schemes of these researches can be classified into three categories:

- DU contamination detection and exploration programs.
- DU effects on human body cells.
- DU related epidemiological studies.

Most of these researches could not find their way to international peer-reviewed journals because of the comprehensive sanctions imposed on Iraq, even though they have been published in Iraqi universities scientific peer-reviewed journals.

4.1 Detection and modelling of DU contamination through site measurements and laboratory tests

In 1993 the first Iraqi team of researchers from the Iraqi Atomic Commission and the science college of Baghdad University[7, 13] investigated the increase of DU related radioactivity in selected areas west of Al-Basrah where destroyed tanks and vehicles with DU ammunition were still laying around. The areas were: Northern Rumaila oil fields, Al-Shamia, Kharanje, Rumaila and Jabal Sanam. Exposure measurements revealed the existence of DU contamination in the studied areas. Tables 4.1, 4.2, and 4.3 show the results of these measurements.

Table (4.1) Field Measurements at North Rumaila Area[7]

	Type of Chose Sample	Background	Chosen Sample
1	Armoured Personnel Carrier BMB-1	8.1	24.6
2	Armoured Personnel Carrier MTLB	8.2	9.7
3	T-72 Tank	8.7	15.1
4	Rescue Tank	7.2	13.2

Table (4.2) Field Measurements at Shamia Airfield /Gudairat al-Audhaimi Area[7]

	Type of Chose Sample	Background	Chosen Sample
1	T-72 Tank	7.0	60.8
2	Armoured Personnel Carrier (Watercan)	7.2	60.3
3	Far away area from chosen sample (1)/ T-72	7.1	7.3
4	Far away area from chosen sample (2)/	7.3	7.2
	Watercan		

Table (4.3) Field Measurements at DMZ and Surrounding Area[7]

	Type of Chose Sample	Background	Chosen Sample
1	Unexploded DU Warhead (near Karrange Oil Pumping Station on the Iraqi-Saudi border	7.4	83
2	Tank/T-55 (between crossroads Nos. 13 and 14)	7.6	21
3	Tank/T-72 (No. 16107)	7.2	23
4	Tank/T-55 (left of crossroads No. 9)	7.4	67
5	Tank/T-72 (near international observation post between crossroads Nos. 12 and 13)	7.6	69
6	Tank/T-72 (south west on Mount Sanam)	7.0	65

Exposure measurements (Micro Roentgen/hr)

In 1996 Al-Azzawi and her team conducted a comprehensive exploration program through the Environmental Engineering Department in Baghdad University[14, 15, 16, 17, 18, 19] (Al-Azzawi et al). The program involved taking hundreds of exposure measurements, soil samples, surface waterway channels, sediments and bio-samples from vegetation cover, fish and grazing animal tissues from areas of heavy military engagement during the first Gulf War like Safwan, Jabal Sanam, al-Zubair, Northern Rumaila oil fields, and Southern Rumaila Oil Fields. Scintillation counters were used for exposure measurements and high purity germanium detectors for soil and sediment samples, surface and ground water samples and bio-samples. Selected measurements from exploration program results are shown in (Table 4.4). Modelling pollution transport from hundreds of destroyed artilleries to surrounding areas showed the following extensions of DU contamination in the area from 1991 – 1996[17, 18, 19]:

- 1718 km^2 of soil contaminated with DU oxides and particles,
- 140,000 m^2 of channel sediments,
- 845, 100 tons of vegetation cover

Table 4.4 : Selected Exposure and Soil Radioactivity Measurements[15]

				Activity Concentration in Soil (Bq/Kg)		
Sample Symbol	Location	Type of Sampled Target	Expo-sure µR/hr	Th-234	U-235	U-235 / U-238
S-2-2	Northern Jabal Sanam	A1	28.6	3918	41.9	0.01069
S-2-9	Northern Jabal Sanam	T13	30.5	4401	57.1	0.0129
SN-1-2	Jabal Sanam	T1	36.8	11400	183	0.0167
SN-2-3	Jabal Sanam	T2	17.1	2550	47.3	0.0185
S-4-1	NW Jabal Sanam	T4	15.3	3408	30.9	0.009
S-5-3	North Safwan C.	T5	16.3	7310	79	0.010
S-6-2	North Safwan C.	T6	14.4	2019	36.3	0.017
R-1-6	Northern Rumeila Oil Field	T7	75.5	27800	375	0.013
R-3-2	Northern Rumeila Oil Field	T8	58	79100	119	0.014
R-4-3	Northern Rumeila Oil Field	A4	43	9700	70.3	0.007
RK-1-1	Southern Rumaila Oil Field	T9	80.8	55700	901	0.0161
RK-2-2	Southern Rumaila Oil Field	T10	51.9	40900	531	0.013
RK-3-2	Southern Rumaila Oil Field	T11	42.1	21700	198	0.009
RK-4-1	Southern Rumaila Oil Field	T12	43	31600	229	0.007
S-7-3	Jabal Sanam	A2	48	3120	25.1	0.008

T: Destroyed Tank A: Destroyed Armoured Vehicle

Risk assessment related to previous measurements showed that people in the western part of Basrah City, and the Iraqi and American troops received a total whole body radioactive dosage of (442 – 577) mSv[20, 21], mostly in the first six months of 1991 Gulf War military operations.

In 1999 – 2000 a follow-up exploration program in the same area was done by the Environmental Engineering Department (Al-Azzawi et al) through which site exposure, and soil sediments, water samples, and laboratory tests were also conducted in previously studied areas plus areas where most of the DU contaminated tanks were gathered, on the banks of Wafaa Al Qaied waterway causing further contamination[22, 23].

Results of this program indicated the existence of slightly higher radioactivity in some of the areas, but generally sand storms and the weathering process con-

tributed to the dispersion of these contaminants to nearby populated areas. Table (4.5) shows conclusions of the results of these tests and measurements.

Table (4.5): Conclusion of (1999 – 2000) Exploration Program in Basrah

Type of Measurement	No. A *	No. B **	Range of Measurements	Back-ground Levels	Units
Exposure	120	17	8.2 – 11.6	4 – 7	μR/hr
Soil	120	22	80 – 788	42 – 70	Bq/Kg
Surface and Ground Water	75	—	Not detected	Not detected	Bq/l
Waterway Sediment Samples	13	10	50 – 85	30 – 40	Bq/Kg

* No. A: Number of Samples

** No. B: Number of Samples with Higher Activity

Also in 1999-2000 Al-Azzawi, Maarouf and Al-Mousori investigated the possibility of radiological contamination in Ninevah Governorate and its center Mosul City [Northern Iraq] after being attacked during 1999 by new generations (AGM 154 J50W) of Cruise missiles on three targets on the eastern bank of Tigris River in Mosul city. The program also involved checking the extension of Chernobyl plume on Iraqi territories after 13 years[24].

Results of this program (Table 4.6) showed slightly higher radioactivity in and around destroyed targeted areas than other areas of Mosul and Ninevah governorate These results proved that Cruise Missiles also contain DU.

Table (4.6): Conclusion of Ninevah and Mosul City Exploration Program of 2000[24]

Type of Measure-ments	Area	No. A *	No. B **	Range of Measure-ments	Back-ground Levels	Units
Exposure	Ninevah	48	18	8.5 – 14	7	µR/hr
Exposure	Mosul City	62	21	8.5 – 14	7	µR/hr
Soil	Ninevah	29	5	80 – 107	—	Bq/Kg
Soil	Mosul City	48	18	100 – 142	—	Bq/Kg
Water	Mosul City	4	None	—	—	—

* No. A: Number of Samples

** No. B: Number of Samples with Higher Activity

Tawfiq, N. F. et al in 2000[25] measured alpha-emitters concentrations in soil samples from different Iraqi cities using Solid State Nuclear Track detectors CR-39 and CN-85. Her team found out that high concentration radioisotopes of (7.8) ppm was measured in Muthana governorate. The Dutch troops later in 2003 refused to camp in the centre of Muthana, Samawa City, due to high DU related radioactivity detection by those troops. After a few days they finally moved to a nearby desert area[26]. It was also confirmed by Dr. Durakovich that New York Guardsmen serving in Samawe during 2003 were exposed to DU[27]. Other cities with high radioisotope concentrations are Basrah (7.2) ppm, Nasria(Al-Shatra)(6.2) ppm. Generally, locations where the Iraqi withdrawing tanks were intercepted by US troops, and where the massacre of February 27 occurred- and Iraqi POWs were buried alive under the order of General Macaffery[28].

In 2000, Al-Gurabi, S. and her team measured DU related increases in radioactivity along the areas bordering Kuwait and Saudia Arabia. They also measured Northern Rumaila Oil Field areas and northwest Basrah City[3]. Results showed higher activity concentrations of DU related radioisotopes in all investigated areas except the center of Basrah City.

In 2001-2002 Butras, Wartan and Butras[29] measured radioactivity in three different areas of Basrah using Alpha and Beta measuring LB1200 detectors. The measured areas:

- A: Iraqi-Saudi-Kuwaiti borders
- B: Qurna, Zubair, Faw and Umm Kasir seaport.
- C: Shatt Al-Arab district in Basrah

Results proved the existence of higher radioactivity measurements than background levels in the areas[34].

In 2000, Al-Kinani, et al[30] collected (11) soil samples from Safwan, S. Rumaila and unarmed border zone using gamma radiation detector. Results indicated that (7) of these samples were contaminated with DU radioisotopes. Sample (SSI) U235/U238 ratio was found to be (0.00351) which indicates highly DU contamination under that destroyed tank. Other ratios ranged between (0.0041-0.0037).

Dozens of other studies were made and published in Arabic or English peer-reviewed scientific journals of various Iraqi universities. The published investigation programs were all conducted by well-known professors and researchers who followed the IAEA and other international scientific standards procedures. All research and radiological laboratory tests that were done in conjunction of the environmental department of the Iraqi Atomic Commission were searched and reviewed by periodic inspection teams of the IAEA who were checking the IAEC activities throughout the nineties until the invasion of Iraq in 2003.

A UNEP report in 2005 specified the existence of 311 sites related to DU contamination without any measurements[43].

4.2 Epidemiological Studies Related to (DU) Contamination Health Effects

Epidemiological studies about the correlation between (DU) radioactive contamination and the increase of malignancies incidence rates in Basrah Governorate have been noticed and studied by Al-Basra college of Medicine faculty members since 1995. Some of these studies were published in the University of Basrah Medical Journal. Others were presented in the two Iraqi conferences about the effect of economical sanction and the (DU) weaponry use against the human and environment in Iraq, held in 1998 and 2002 respectively.

Results of these studies pointed out very important facts concerning the direct correlation between DU radiological contamination and the resulted increase of the related diseases in geographically contaminated areas. Among others, the following studies are specifically important:

In 1998, Alim Yacoub et al[31, 32] presented an analysis of recorded cases of registered malignant diseases among children under 15 years of age in Basrah for the period (1990 – 1997). This analysis showed a rise of 60% in children's leukaemia from 1990 to 1997. Also, a 120% increase in all malignant cases among children under the age of 15 for the same period were registered. The study also showed the shift of age distribution of leukaemia cases towards younger, than 5 years of age from 13% in 1990 to 41% of total cases in 1997.

In 1998, Al-Sadoon, et al[33] showed a three fold increase in congenital malformations registered cases in 1998 compared to 1990. Congenital heart diseases, chromosomal aberrations, and multiple malformations all indicate exposure to teratogenic environmental factor.

In 1998, Alim Yacoub et, al[34] also introduced an analysis of the incidence and pattern of malignant diseases in Basra from the analysis of the histo-pathological reports of Basra University Teaching Hospital for the period 1990-1997. The study indicated that there was a rise of about 160% in reported cases of uterine cancer in 1997 compared to 1990 and an increase of 143% in thyroid cancer cases in 1997 compared to 1990 recordings. Also a 102% increase in breast cancer and 82% rise in lymphomas in 1997 compared to 1990. The shift in the types of the five major leading malignancies in Basrah in 1997 were malignant diseases such as breast, bladder, lymphomas, uterine, and skin cancers. While those of 1990 were malignant diseases of bladder, skin, breast, lung and larynx.

In 2002, Alim Yacoub, Imad Al-Sadoon and Jenan Hasan presented a paper[35] that examines the association between exposure to DU radiation and the rising incidence of malignancies among children in Basra through time sequence criteria, and dose-response criteria through the geographical shift of the increase of incidence rates in Al-Zubair and other western areas from less than 5/100,000 prior to 1993 to 22/100,000 in 2000 compared to only Al-Hartha area (north of Basrah) only prior to 1993 (with highest incidence rates of > 10/100,000 in 1993). They also tested the biological plausibility criteria through the shift of the increase of leukaemia incidence rate towards younger ages of less than 5 years old after 1995.

Yacoub et al, 2002, couldn ft explain the reason for the constant increase of malignancies incidence rates among children in Al-Hartha district in northern Basrah City, figure 2, from (10 incidents / 100,000) to (42.7 / 100,000) in the year 2000.

This can be explained by the existence of the largest electrical power generation and transformation facilities in Iraq of 800 MW. This power plant was destroyed during air raids several times in 1991. Nobody measured the radioactivity in Al-Hartha, which might also have been destroyed with DU bombing.

In 2002, Abbas Ali & Jawad Ali[26] presented an evaluation of chronic myeloid leukaemia (CML) annual incidence which started to rise from 1995 up to the year 2000, when the increase began to plateau.

4.3 DU Effects on Human Health Pathological Studies

1998: Huda Ammash- Professor of Molecular Biology in the Science College of the University of Baghdad-presented a paper on the mechanisms of toxicity induced by free radicals resulting from irradiation with DU and ionization of the atmosphere in Iraq[37, 38]. This paper pinpointed the need for DU toxicity researches on enzymes (SOD), Caralase, hydrogenates and Glyceraldehydes Dehydrogenates levels. She also presented the multi-collaborative cases on the DNA level where out of 50 studied cases, 29 cases were found with DNA abnormalities (with no hereditary evidence). Other multi-collaborative cases investigating the toxoplasmosis effect showed that out of 130 cases, over 65% more were infected than those recorded in 1989.

2002: Muhammed, Z.T. et al [39] published a paper about the effects of DU radiation on the human immune system enzyme. A group of (26) Iraqi veterans who were exposed to DU radiation with (43) control individuals were all subjected to tests for Adenosine DA Amines (ADN) enzyme activity. Results indicated mean activity of the enzyme of the exposed individuals of (0.184 ± 0.016) U/g protein, while the unexposed individuals enzyme activity (0.291 ± 0.022) U/mg protein. ADA enzyme activity in the exposed individuals were found to be significantly lower than the control group. $P<0.05$ significant correlation coefficient was found between ADA activity as an important immune enzyme and related clinical signs and symptoms related to defective cellular immune functions.

2002: Ammash, H., Alwan, L. and Marouf, B.A. published a paper (in Arabic)[40] about the results of Genetic haematological analysis for a group of individuals lives in DU contaminated areas southern Iraq. Blood tests for the (47) individuals who lived in Basra contaminated areas and other (30) individuals as a control group who lived in Baghdad were conducted with the study of other clinical and correlated factors. Blood tests included haemoglobin concentration, packed cell

volume test (PCV), total count (WBC) test and chromosomal changes and defects tests. Factors such as exposure type and exposure time due to nature of work were taken into consideration (45% of the studied groups are from Iraqi troops who were involved in military engagements of the Gulf War 1). The others were civilians who lived in contaminated areas.

The test results of the study clearly showed that a 21% of the studied individuals in Basrah group suffered a reduction in haemoglobin concentration of (9-13) g/dl.

The other 79% of the individuals from Al-Basrah studied groups with normal haemoglobin concentrations of (12-15) g/dl and (13-18) g/dl for males and females in the group respectively.

The blood Packed Cell Volume (PCV) test results showed that 25.5% of the Basrah study group showed abnormal (PCV) rates of (30-39)% less than the normal rate. One male's individual blood (PCV) was 3% higher than normal. Other individuals' blood (PCV) in the studied group had normal rates ranging between (40-54)%.

Total count of white blood cells (WBC) test results showed that 8% of the individuals in the Basrah study group have (WBC) less than normal which is 4000 c/ml or higher than the normal rate or (11000) c/ml. Control group individuals all had normal (WBC).

Compound chromosomal changes in the lymphocytes of periphal blood of the individuals of the Basrah studied group have been found at a ratio of (0.1118)% which is significantly higher than that of the control group. The ratio of di-centric and ring-centric chromosomal abnormality fraction was found to be (0.04479) which is also higher than ordinary ratio. Chromosomal damages were mostly in male veteran individuals. One case was that of a 13-year-old at the time of exposure in Al-Zubair contaminated area.

In 2000: From the Veterinary College of Basrah University, Khadier, A.A. et al[41] conducted a study to detect levels of DU related radioactivity in pastures and animals within the contaminated areas of Safwan, Al-Zubair, N. Rumaila, Jabal Sanam, Kharanje Village, etc. Blood samples from sheep and other grazing animals were collected. Analysis of blood samples using Lyo-luminescence and Track Detectors proved the existing of very small concentrations of radioisotopes in a

few sheep that fed from and around the destroyed artillery and tanks within the studied areas. It is believed the polluted dust on the leaves was the source of radioisotopes in the tested blood samples.

2002: Al-Sadi, H.I. and Sawad, A.[42] from the Veterinary College of the University of Basrah also presented a study about the pathological conditions of the animals in Basrah. The study reported the existing of three types of animal neoplasm; seminoma in rams, mesotheliomas in buffalo, and ovarian cystademonas in bitches. These types of neoplasms have never been reported in these regions before the Nineties. Also some types of congenital defects in farm animals have been described.

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5. Conclusions

It is important to gather data and researches in the field of DU and of the effects of the "new wars" on man and environment. It is necessary to show that modern new weapons, instead of being "surgical", produce unacceptable damages to health and to environment.

Effects of the DU on man and environment must be shown without reticence: all evidences show that those effects exist, they are relevant, they should not be denied or neglected. The urgent ban of depleted uranium weapons seems mandatory .

The latest piece of intelligence is that, after the outcomes of the 1st Latin-American Conference on Depleted Uranium, held in San José (Costa Rica) in march 2009, the Costa Rica Parliament has proposed a law that prohibits the use, the storage, the transit and the trade of Depleted Uranium in the state's territory. Costa Rica – if the law will be enforced – will follow Belgium in this ban, and it will hopefully be followed by many other states in the world, in view of the International Ban that is under discussion at the United Nations.

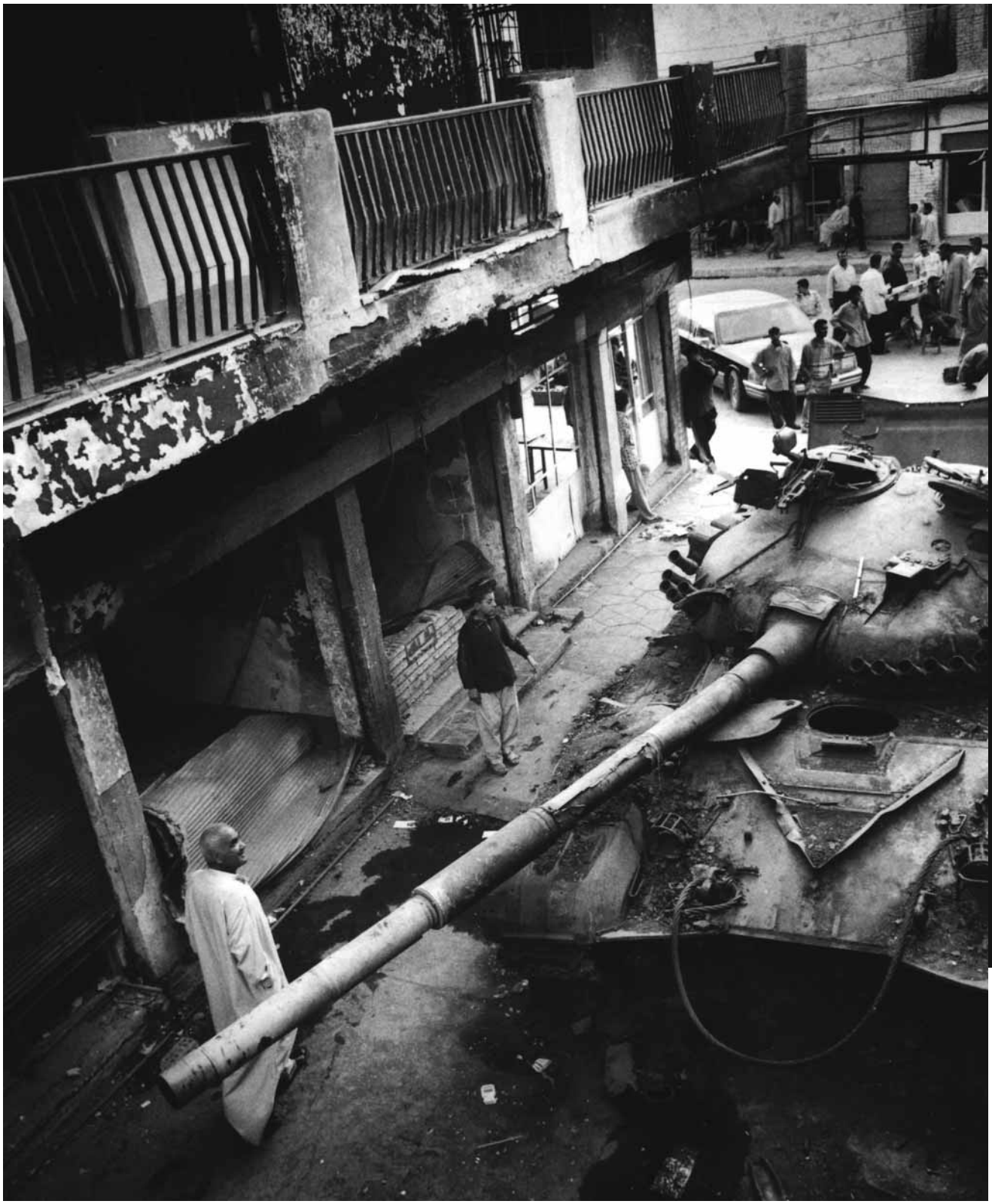
Coming to a conclusion the author thought a lot before adding this final part to this book, however he decided to do that for the sake of the truth about the effects of DU on human health.

Dr. Jawad Al-Ali, director of the Oncology Centre in Basrah, Iraq, has shown at many occasions what he has seen with his own eyes about the effects of DU on Iraqi civilians. Data and photos have been presented at many international conferences, like for instance at the World Uranium Weapons Conference, held on Oct 16-19, 2003 at the University of Hamburg, Germany, (see website: http://www.grassrootspeace.org/depleted_uranium_hamburg03.html).

Some of those pictures, among the thousands available on the net and from Iraqi doctors files, are shown in the following (see presentation: http://www.grassrootspeace.org/jawad_al-ali_iraq.pdf). Pictures are very unpleasant, the author warns young and emotive readers.

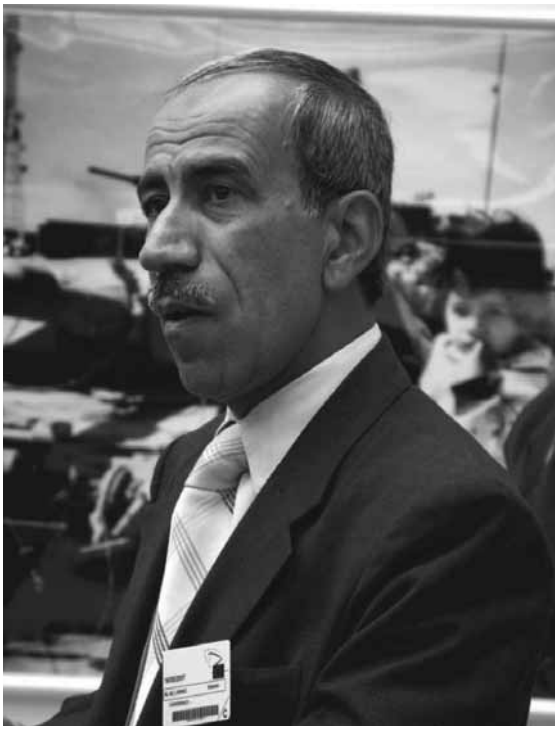
The children's graveyard in Basrah, Iraq (December 2002)

A gigantic bomb, dropped on a telephone station, destroyed a private house next to it (March 2003, Baghdad, Iraq)



A tank demolished and contaminated by DU shells in the residential area of Mahamdiya (April 2003, Iraq)

A child the day after an airstrike on the market in which 60 people were killed (March 2003, Baghdad)



Dr. Jawad Al-Ali, Director of the Oncology Center in Basrah, Iraq

All black and white photos were made by Naomi Toyoda from Japan, well-known for his pictures of DU victims

The coloured pictures were presented at The World Uranium Weapon Conference, in Hamburg, by Dr. Jawad Al-Ali, Director of the Oncology Center in Basrah