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Depleted uranium

Sources, Exposure and Health Effects

Department of Protection of the Human Environment
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Preface

Depleted uranium (DU) has been used in medical and industrial applications for decades but only since its use in military conflicts in the Gulf and the Balkans has public concern been raised about potential health consequences from exposure to it. Concerns have been particularly for peacekeeping forces, humanitarian workers and local populations living and working in areas contaminated by DU following conflict.

There has been a large amount of research on the health consequences to workers in the mining and milling of uranium, and on its use in nuclear power, that enables a reasonable assessment of its impact on human health[1]. Since DU acts chemically in the same way as uranium, and the radiological toxicity is somewhat less than uranium, this research can be used to evaluate health risks from ingestion, inhalation and contact with DU.

In late 1999, the WHO Department on the Protection of the Human Environment (PHE) recognized the need for an independent review of the scientific literature from which health risks could be assessed from various DU exposure situations. Professor Barry Smith from the British Geological Survey, UK, was contracted to prepare the draft from the literature that would be subject to rigorous scientific review. The format of the review was to be modelled on monographs in the WHO environmental health criteria series.

An ad hoc review and oversight group of WHO staff members was formed and coordinated by Dr Michael Repacholi. Participants and contributors to the review included: Drs Antero Aitio, Jamie Bartram, Keith Baverstock, Elisabeth Cardis, Carlos Corvalan, Marilyn Fingerhut, Yoshikazu Hayashi, Richard Helmer, Jenny Pronczuk, Colin Roy, Dieter Schwela, Gennadi Souchkevich and Maged Younes.

The National Radiological Protection Board (NRPB) in the United Kingdom, a WHO Collaborating Centre on ionizing and non-ionizing radiation, provided many contributions relating to the radiological toxicity of DU. These contributions were provided by Dr Neil Stradling and other staff identified below.

The National Institute of Occupational Safety and Health (NIOSH) of the Center for Disease Control (CDC) in the USA, a WHO Collaborating Centre on occupational health, provided contributions mainly related to DU occupational health and safety requirements, protective measures and health monitoring. These contributions were provided by Dr Jim Neton and other staff identified below. The Centre for Health Promotion and Preventative Medicine (CHPPM) in the USA, provided contributions relating mainly to DU applications, radiological toxicity and medical care of people exposed to DU. These contributions were provided by Dr Mark Melanson and other staff identified below.

The International Atomic Energy Agency (IAEA) provided contributions on the effects of ionizing radiation and internationally recognized standards. These contributions were provided by Dr Carol Robinson and Dr Tiberio Cabianca.

Included in these reviewers and contributors are members of the International Commission on Radiological Protection (ICRP) an NGO in formal relations with WHO.

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[1] The Government of Iraq has reported increases in cancers, congenital abnormalities and other diseases following the Gulf war in 1991, but there are no published results for review. WHO is working with the Government of Iraq to prepare studies to investigate this situation.

There have been a large number of contributors to this monograph, and it has been reviewed widely. In addition to the internal WHO review group, contributors and reviewers are listed below in alphabetical order:

- AC-Laboratorium Spiez, Switzerland: Dr Ernst Schmid
- ATSDR, USA: Dr Sam Keith
- Battelle Pacific Northwest Laboratoies, USA: Dr Tom Tenforde
- CHPPM, USA: Drs Dave Alberth, Marianne Cloeren, Richard Kramp, Gordon Lodde, Mark Melanson, Laurie Roszell, Colleen Weese
- Electric Power Research Institute, USA: Dr Leeka Kheifets
- Hopital Cantonal Universitaire, Division de médecine nucléaire, Geneva: Dr Alfred Donath
- IAEA: Drs Tiberio Cabianca, Carol Robinson
- Karolinska Institute, Sweden: Dr Lennart Dock
- NIOSH, USA: Drs Heinz Ahlers, Bonnie Malit, Jim Neton, Michael Ottlinger, Paul Schulte, Rosemary Sokas
- NRPB, UK: Drs Mike Bailey, George Etherington, Alan Hodgson, Colin Muirhead, Alan Phipps, Ed Rance, Jennifer Smith, Neil Stradling
- SCK·CEN Studiecentrum voor Kernenergie Centre d'étude de l'Energie Nucléaire, Belgian Nuclear Research Centre : Dr Christian Hurtgen
- Swedish Radiation Protection Institute, Stockholm: Drs Gustav Akerblom, Jan Olof Snihs
- UNEP, Balkans Unit: Mr Henrik Slotte

The monograph was technically edited by Professor Barry Smith and language edited by Audrey Jackson, both from the British Geological Survey, UK. WHO acknowledges, with sincere gratitude, the contributions of all the authors and reviewers of this important monograph. In addition, WHO also acknowledges with thanks the photographs related to DU provided by IAEA, NIOSH and ATSDR.

WHO has and will continue to work with the United Nations Environment Programme (UNEP), the International Atomic Energy Agency (IAEA) and other UN agencies, Collaborating Centres and NGOs to advance our knowledge about exposure to DU and other environmental risk factors that could have consequences for health. Such programmes are aimed at providing essential information to member states and assisting national health services to deal with chemical, physical and biological risk factors in their environment.

Executive Summary

This scientific review on depleted uranium is part of the World Health Organization's (WHO's) ongoing process of assessment of possible health effects of exposure to chemical, physical and biological agents. Concerns about possible health consequences to populations residing in conflict areas where depleted uranium munitions were used have raised many important environmental health questions that are addressed in this monograph.

Purpose and scope

The main purpose of the monograph is to examine health risks that could arise from exposure to depleted uranium. The monograph is intended to be a desk reference providing useful information and recommendations to WHO Member States so that they may deal appropriately with the issue of depleted uranium and human health.

Information is given on sources of depleted uranium exposure, the likely routes of acute and chronic intake, the potential health risks from both the radiological and chemical toxicity standpoints and future research needs. Several ways of uptake of compounds with widely different solubility characteristics are also considered.

Information about uranium is used extensively because it behaves in the body the same way as depleted uranium.

Uranium and depleted uranium

Uranium is a naturally occurring, ubiquitous, heavy metal found in various chemical forms in all soils, rocks, seas and oceans. It is also present in drinking water and food. On average, approximately 90 µg (micrograms) of uranium exist in the human body from normal intakes of water, food and air; approximately 66% is found in the skeleton, 16% in the liver, 8% in the kidneys and 10% in other tissues.

Natural uranium consists of a mixture of three radioactive isotopes which are identified by the mass numbers ^{238}U(99.27% by mass), ^{235}U(0.72%) and ^{234}U(0.0054%).

Uranium is used primarily in nuclear power plants; most reactors require uranium in which the ^{235}U content is enriched from 0.72% to about 3%. The uranium remaining after removal of the enriched fraction is referred to as depleted uranium. Depleted uranium typically contains about 99.8% ^{238}U, 0.2% ^{235}U and 0.0006% ^{234}U by mass.

For the same mass, depleted uranium has about 60% of the radioactivity of uranium.

Depleted uranium may also result from the reprocessing of spent nuclear reactor fuel. Under these conditions another uranium isotope, ^{236}U may be present together with very small amounts of the transuranic elements plutonium, americium and neptunium and the fission product technetium-99. The increase in the radiation dose from the trace amounts of these additional elements is less than 1%. This is insignificant with respect to both chemical and radiological toxicity.

Uses of depleted uranium

Depleted uranium has a number of peaceful applications: counterweights or ballast in aircraft, radiation shields in medical equipment used for radiation therapy and containers for the transport of radioactive materials.

Due to its high density, which is about twice that of lead, and other physical properties, depleted uranium is used in munitions designed to penetrate armour plate. It also reinforces military vehicles, such as tanks.

Exposure and exposure pathways

Individuals can be exposed to depleted uranium in the same way they are routinely exposed to natural uranium, i.e. by inhalation, ingestion and dermal contact (including injury by embedded fragments).

Inhalation is the most likely route of intake during or following the use of depleted uranium munitions in conflict or when depleted uranium in the environment is re-suspended in the atmosphere by wind or other forms of disturbance. Accidental inhalation may also occur as a consequence of a fire in a depleted uranium storage facility, an aircraft crash or the decontamination of vehicles from within or near conflict areas.

Ingestion could occur in large sections of the population if their drinking water or food became contaminated with depleted uranium. In addition, the ingestion of soil by children is also considered a potentially important pathway.

Dermal contact is considered a relatively unimportant type of exposure since little of the depleted uranium will pass across the skin into the blood. However, depleted uranium could enter the systemic circulation through open wounds or from embedded depleted uranium fragments.

Body retention

Most (>95%) uranium entering the body is not absorbed, but is eliminated via the faeces. Of the uranium that is absorbed into the blood, approximately 67% will be filtered by the kidney and excreted in the urine in 24 hours.

Typically between 0.2 and 2% of the uranium in food and water is absorbed by the gastrointestinal tract. Soluble uranium compounds are more readily absorbed than those which are insoluble.

Health effects

Potentially depleted uranium has both chemical and radiological toxicity with the two important target organs being the kidneys and the lungs. Health consequences are determined by the physical and chemical nature of the depleted uranium to which an individual is exposed, and to the level and duration of exposure.

Long-term studies of workers exposed to uranium have reported some impairment of kidney function depending on the level of exposure. However, there is also some evidence that this impairment may be transient and that kidney function returns to normal once the source of excessive uranium exposure has been removed.

Insoluble inhaled uranium particles, 1-10 µm in size, tend to be retained in the lung and may lead to irradiation damage of the lung and even lung cancer if a high enough radiation dose results over a prolonged period.

Direct contact of depleted uranium metal with the skin, even for several weeks, is unlikely to produce radiation-induced erythema (superficial inflammation of the skin) or other short term effects. Follow-up studies of veterans with embedded fragments in the tissue have shown detectable levels of depleted uranium in the urine, but without apparent health consequences. The radiation dose to military personnel within an armoured vehicle is very unlikely to exceed the average annual external dose from natural background radiation from all sources.

Guidance on chemical toxicity and radiological dose

The monograph gives for the different types of exposure the tolerable intake, an estimate of the intake of a substance that can occur over a lifetime without appreciable health risk. These tolerable intakes are applicable to long term exposure. Single and short term exposures to higher levels may be tolerated without adverse effects but quantitative information is not available to assess how much the long term tolerable intake values may be temporarily exceeded without risk.

The general public’s ingestion of soluble uranium compounds should not exceed the tolerable intake of 0.5 µg per kg of body weight per day. Insoluble uranium compounds are markedly less toxic to the kidneys, and a tolerable intake of 5 µg per kg of body weight per day is applicable.

Inhalation of soluble or insoluble depleted uranium compounds by the public should not exceed 1 µg/m^3 in the respirable fraction. This limit is derived from renal toxicity for soluble uranium compounds, and from radiation exposure for insoluble uranium compounds.

Excessive worker exposure to depleted uranium via ingestion is unlikely in workplaces where occupational health measures are in place.

Occupational exposure to soluble and insoluble uranium compounds, as an 8-hour time weighted average should not exceed 0.05 mg/m^3. This limit is also based both on chemical effects and radiation exposure.

Radiation dose limits

Radiation dose limits are prescribed for exposures above natural background levels.

For occupational exposure, the effective dose should not exceed 20 millisieverts (mSv) per year averaged over five consecutive years, or an effective dose of 50 mSv in any single year. The equivalent dose to the extremities (hands and feet) or the skin should not exceed 500 mSv in a year.

For exposure of the general public the effective dose should not exceed 1 mSv in a year; in special circumstances, the effective dose can be limited to 5 mSv in a single year provided that the average dose over five consecutive years does not exceed 1 mSv per year. The equivalent dose to the skin should not exceed 50 mSv in a year.

Assessment of intake and treatment

For the general population it is unlikely that the exposure to depleted uranium will significantly exceed the normal background uranium levels. When there is a good reason to believe that an exceptional exposure has taken place, the best way to verify this is to measure uranium in the urine.

The intake of depleted uranium can be determined from the amounts excreted daily in urine. depleted uranium levels are determined using sensitive mass spectrometric techniques; in such circumstances it should be possible to assess doses at the mSv level.

Faecal monitoring can give useful information on intake if samples are collected soon after exposure.

External radiation monitoring of the chest is of limited application because it requires the use of specialist facilities, and measurements need to be made soon after exposure for the purpose of dose assessment. Even under optimal conditions the minimum doses that can be assessed are in the tens of mSv.

There is no suitable treatment for highly exposed individuals that can be used to appreciably reduce the systemic content of depleted uranium when the time between exposure and treatment exceeds a few hours. Patients should be treated based on the symptoms observed.

Conclusions: Environment

Only military use of depleted uranium is likely to have any significant impact on environmental levels. Measurements of depleted uranium at sites where depleted uranium munitions were used indicate only localized (within a few tens of metres of the impact site) contamination at the ground surface. However, in some instances the levels of contamination in food and ground water could rise after some years and should be monitored and appropriate measures taken where there is a reasonable possibility of significant quantities of depleted uranium entering the food chain. The WHO guidelines for drinking-water quality, 2 µg of uranium per litre, would apply to depleted uranium.

Where possible clean-up operations in conflict impact zones should be undertaken where there are substantial numbers of radioactive particles remaining and depleted uranium contamination levels are deemed unacceptable by qualified experts. Areas with very high concentrations of depleted uranium may need to be cordoned off until they are cleaned up

Since depleted uranium is a mildly radioactive metal, restrictions are needed on the disposal of depleted uranium. There is the possibility that depleted uranium scrap metal could be added to other scrap metals for use in refabricated products. Disposal should conform to appropriate recommendations for use of radioactive materials.

Conclusions: Exposed populations

Limitation on human intake of soluble depleted uranium compounds should be based on a tolerable intake value of 0.5 µg per kg of body weight per day, and that the intake of insoluble depleted uranium compounds should be based on both chemical effects and the radiation dose limits prescribed in the International Basic Safety Standards (BSS) on radiation protection. Exposure to depleted uranium should be controlled to the levels recommended for protection against radiological and chemical toxicity outlined in the monograph for both soluble and insoluble depleted uranium compounds.

General screening or monitoring for possible depleted uranium-related health effects in populations living in conflict areas where depleted uranium has been used is not necessary. Individuals who believe they have been exposed to excessive amounts of depleted uranium should consult their medical practitioner for examination, appropriate treatment of any symptoms and follow-up.

Young children could receive greater depleted uranium exposure when playing within a conflict zone because of hand-to-mouth activity that could result in high depleted uranium ingestion from contaminated soil. This type of exposure needs to be monitored and necessary preventative measures taken.

Conclusions: Research

Gaps in knowledge exist and further research is recommended in key areas that would allow better health risk assessments to be made. In particular, studies are needed to clarify our understanding of the extent, reversibility and possible existence of thresholds for kidney damage in people exposed to depleted uranium. Important information could come from studies of populations exposed to naturally elevated concentrations of uranium in drinking water.

Depleted uranium:

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