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DEPLETED URANIUM AMMUNITION USE IN MODERN WARFARE – A CONCERN FOR ENVIRONMENT POLLUTION?

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Abstract

This literature mini-review explores the environmental and health impacts of depleted uranium (DU) ammunition. DU, a byproduct of uranium enrichment, is used in armor-piercing munitions due to its high density and pyrophoric properties. Upon impact, DU munitions release fine particles and fragments that contaminate soil, air, and water. These contaminants persist in the environment and may undergo complex chemical transformations. Human exposure occurs primarily through inhalation, ingestion, and embedded fragments, leading to the accumulation of uranium in organs like the kidneys, bones, and liver. Health concerns include nephrotoxicity, potential carcinogenicity, and neurological and reproductive effects, though evidence from human studies remains mixed. Studies of Gulf War veterans with DU exposure report ongoing excretion of uranium but limited clinically significant health effects. The review also addresses the environmental risks of depleted uranium use of ongoing Russo-Ukrainian war.

Key words: *depleted uranium, pollution, heavy metals, soil contamination, uranium rounds, Russo-Ukrainian war.*

Depleted uranium (DU) is a byproduct of the uranium enrichment process [1]. This process is primarily used to produce enriched uranium for nuclear reactors and weapons. During enrichment, the concentration of the uranium-235 isotope is increased, leaving behind a residual material that is depleted in this isotope. Consequently, DU primarily consists of uranium-238, with a significantly reduced concentration of the uranium-235 isotope compared to natural uranium [2]. Militarily, DU is primarily used in armor-piercing ammunition and tank armor, also used in ongoing Russo-Ukrainian war [3]. The high density and self-sharpening properties of DU make it exceptionally effective at penetrating armored targets. [4]. When DU munitions strike hard targets, they generate fine particles of DU dust that can disperse into the environment, contaminating soil, water, and air. The long-term behavior of these particles, including their rate of corrosion, transport mechanisms, and potential for bioaccumulation, is not fully understood. There are also concerns about potential health problems in exposed populations, including veterans and civilians [4], [5]. Exposure to DU can occur through inhalation, ingestion, or wound contamination. The potential health effects of DU exposure include kidney damage, respiratory problems, neurological effects, and an increased risk of cancer. The combination of environmental contamination and potential health risks has made DU a controversial topic in military and public health discussions.

The size of these particles can range from a few nanometers to several micrometers, making them easily dispersible by wind and other environmental factors. DU can also be released as large fragments and chemically unchanged oxides [6]. In some cases, DU munitions may not fully fragment upon impact, resulting in the release of large DU fragments into the environment. These fragments can corrode over time, releasing uranium oxides and other chemical compounds into the surrounding soil and water. The combination of DU dust, fragments, and oxides contributes to a complex pattern of environmental contamination in areas where DU munitions have been used.

Inhalation of DU dust is a major route of exposure, particularly in areas where DU munitions have been used [4], [7], [8]. The fine particles of DU dust generated during the impact of DU munitions can become suspended in the air and inhaled by individuals in the vicinity. The risk of inhalation exposure is particularly high in the immediate aftermath of DU munition use, when dust concentrations are at their peak. Resuspension of DU-containing particles can occur if the particle size is sufficiently small [4]. DU particles that have settled on the ground can be resuspended into the air by wind, vehicle traffic, or human activities. This resuspension can lead to prolonged inhalation exposure, even long after the initial DU release. Inhaled DU dust may lead to protracted exposure of the lungs and other organs. Once inhaled, DU particles can deposit in the respiratory tract, where they may persist for extended periods. The slow clearance of DU particles from the lungs can result in chronic exposure of the lung tissue and other organs to both the chemical and radiological toxicity of uranium. The potential health effects of inhalation exposure include respiratory irritation, lung damage, and an increased risk of lung cancer [4].

Ingestion of DU particles is another potential route of exposure, especially for individuals living in contaminated areas [7]. DU particles can be ingested through various pathways, including contaminated food, water, and soil. Hand-to-mouth activity can contribute to ingestion, particularly for children who may inadvertently ingest DU-contaminated soil or dust [6]. Children are more vulnerable to ingestion exposure due to their tendency to put their hands and other objects in their mouths. Transfer of DU to drinking water or locally produced food has limited potential to lead to significant exposure [4]. While DU can contaminate water and soil, the low solubility of DU and the natural processes of dilution and filtration tend to limit the extent of contamination in drinking water and food. However, in areas with high levels of DU contamination, the potential for ingestion exposure should not be disregarded. The potential health effects of ingestion exposure include gastrointestinal irritation, kidney damage, and other systemic effects, although the risks are very low.

The Baltimore Veterans Affairs (VA) DU Follow-Up Program, initiated in 1993, carefully monitors health effects stemming from DU exposure in Gulf War veterans [9]. This program is one of the most comprehensive efforts to assess the long-term health consequences of DU exposure in humans. Biennial surveillance visits provide detailed health assessments. These assessments include physical examinations, laboratory tests, and neurocognitive evaluations, allowing researchers to track the health status of DU-exposed veterans over time. The data collected through the Baltimore VA DU Follow-Up Program have provided valuable insights into the potential health effects of DU exposure.

Soldiers with embedded DU fragments continue to excrete elevated concentrations of uranium in their urine [9]. This indicates that the DU fragments are slowly corroding and releasing uranium into the body, leading to chronic exposure. With the exception of elevated urine U excretion, no clinically significant expected U-related health effects have been identified to date. This suggests that the levels of DU exposure in Gulf War veterans may not be high enough to cause significant health problems.

Cost-effective remediation approaches are critical for addressing widespread contamination. Recent concerns over potential human exposure to DU primarily have resulted in research into numerous innovative remediation technologies. Developing methods and processes for estimating the life cycle costs of implementing these various techniques is important in identifying cost-effective solutions [10].

Physical removal involves the excavation and disposal of DU-contaminated soil. This method is most suitable when uranium is concentrated in well-defined areas, such as firing ranges, weapons testing sites, or battle impact zones. By physically extracting the contaminated material, immediate risk reduction can be achieved. Soil washing is a chemical and physical process designed to leach uranium from soil particles using water or specialized chemical solutions. After excavation, the soil is processed through washing units that separate contaminants. The cleaned soil can often be returned to the site, while the wash water undergoes further treatment [10].

Chemical stabilization (immobilization) involves adding chemical agents to contaminated soils to bind uranium into stable, insoluble forms. The objective is not to remove uranium, but to reduce its mobility and bioavailability, thereby minimizing environmental and health risks. Common stabilizing agents include hydroxyapatites and clay minerals. Another prospective method could be phytoremediation, which uses plants to extract or stabilize uranium in the soil [11].

Nevertheless, it is crucial to maintain monitoring in potentially contaminated sites, including gamma ray emission surveys, soil sampling and uranium speciation.

Conclusions

The use of depleted uranium ammunition presents significant concerns for both environmental contamination and potential human health impacts. While DU offers clear tactical advantages in modern warfare due to its density and armor-piercing capabilities, its deployment leaves behind persistent environmental residues - ranging from fine aerosols to solid fragments that can contaminate air, soil, and water. Human exposure primarily occurs through inhalation, ingestion, or embedded fragments, each carrying distinct risks.

Although long-term studies, such as the Baltimore VA DU Follow-Up Program, have not conclusively linked DU exposure to major health effects in veterans, the chronic excretion of uranium and its bioaccumulation in organs call for continued vigilance. Moreover, the full environmental consequences of DU contamination remain incompletely understood, particularly in active conflict zones such as Ukraine.

Remediation efforts, including physical removal, chemical stabilization, and phytoremediation, offer promising strategies to mitigate DU's environmental footprint. However, these solutions require careful implementation, cost analysis, and long-term monitoring. Given the dual threats of chemical toxicity and radiological exposure, future use of DU munitions should be guided by precautionary principles, robust environmental assessments, and international discourse on the ethics and safety of such materials in warfare.

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ВИКОРИСТАННЯ БОЄПРИПАСІВ ІЗ ЗБІДНЕНИМ УРАНОМ У СУЧАСНИХ ВІЙНАХ — ЗАГРОЗА ДЛЯ ДОВКІЛЛЯ?

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Анотація

Цей короткий огляд літератури присвячений вивченню впливу збідненого урану (ЗУ) на довкілля та здоров’я людини. ЗУ, побічний продукт збагачення урану, використовується у бронебійних боєприпасах завдяки своїй високій щільності та пірофорним властивостям. Під час удару такі боєприпаси утворюють дрібнодисперсні частинки й уламки, які забруднюють ґрунт, повітря та воду. Ці забруднювачі можуть тривалий час зберігатися в навколишньому середовищі й зазнавати складних хімічних перетворень. Людина зазнає впливу ЗУ переважно через вдихання, заковтування чи внаслідок влучення уламків у тіло, що призводить до накопичення урану в органах, зокрема в нирках, кістках та печінці. Серед потенційних ризиків для здоров’я – нефротоксичність, можливий канцерогенний вплив, а також неврологічні та репродуктивні порушення, хоча дані досліджень на людях є суперечливими. У дослідженнях серед ветеранів війни в Перській затоці, які зазнали впливу ЗУ, фіксується тривале виведення урану з організму, але відсутні суттєві клінічно значущі наслідки для здоров’я. Огляд також розглядає екологічні ризики, пов’язані з використанням збідненого урану в умовах триваючої російсько-української війни.

Ключові слова: збіднений уран, забруднення, важкі метали, забруднення ґрунту, уранові, боєприпаси, російсько-українська війна.