

Army Anagnostopoulos Exh. # 1-E

[Originally Attached As EXHIBIT HWA # 6 to Witness Anagnostopoulos' pre-filed testimony]

U.S. NUCLEAR REGULATORY COMMISSION

In the Matter of US ARMY (JEFFERSON PROVING GROUND)

Docket No. 40-8838-MLA Exhibit No. ARMY EXH. # 1-E

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*Health and Environmental Consequences of Depleted Uranium Use in the U.S. Army: Technical Report, U.S. Army Environmental Policy Institute, June 1995.
(Section 7.1.1)*

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**HEALTH AND ENVIRONMENTAL
CONSEQUENCES OF DEPLETED URANIUM
USE IN THE U.S. ARMY: TECHNICAL REPORT**

AEPI

U.S. Army Environmental Policy Institute

7 ENVIRONMENTAL RISKS ASSOCIATED WITH U.S. ARMY USE OF DU AND WAYS TO REDUCE THEIR LONG-TERM EFFECTS

The risks associated with DU releases to the environment through U.S. Army activities will be specific to each application of DU and to each site where it is used. Chapter 7 provides a discussion of the mobility, fate and effect of DU in the environment. Laws, regulations, criteria and standards are constantly revised to better manage the discharge contaminants into the environment. However, the basic physical phenomena do not change when the regulatory approach changes. A risk-based management system is the only approach that provides the Army sufficient flexibility to manage DU efficiently in a fluid regulatory environment. It asserts that to develop a formal risk assessment, one must understand the transport and fate of DU and its effects on plants and animals, including man. This chapter also describes how the Army has developed a considerable understanding of DU's behavior in the environment through studies at the three firing sites used for most DU weapons development and testing.

In addition, Chapter 7 discusses remediating sites contaminated with DU and available remediation technologies. Finally, this chapter offers a number of actions the Army can take to cost-effectively protect the environment from the long-term consequences of the use of DU.

7.1 *Environmental Transport and Fate*

Water is the dominant mechanism of environmental transport of all metals. Metals may move in groundwater or in surface water such as rivers. For metals widely dispersed across the land, the principal concern is groundwater contamination. Runoff also can transport contamination to surface streams and ponds (Ebinger et al., 1990). In an arid environment, wind erosion can transport dust containing DU (Price, 1991). In addition to aqueous transport and airborne transport, biological transport through the food chain can move a contaminant through the environment.

As discussed in Section 2.1.3, although the radiological properties of uranium isotopes differ considerably, their chemical behavior is essentially identical. Thus, in this discussion of the physical and chemical properties of DU in the environment, DU and U are used interchangeably. In the past 50 years, a large body of knowledge regarding the transport, transformation, fate and recovery of uranium has been developed, mostly as a result of uranium mining and milling. Much of this information applies to the environmental problems associated with the use of DU in weapons. Magness (1985) provides a brief summary of the environmental transport and fate of DU. Information that DOE compiled for the Uranium Mill Tailings Remedial Action (UMTRA) Project is particularly valuable. DOE conducted this project in response to the Uranium Mill Tailings Radiation Control Act of 1978. Portillo (1992) describes the UMTRA project, giving particular attention to its history and the technology developed to mitigate impacts of uranium milling operations.

7.1.1 *Airborne Transport*

Airborne transport of uranium involves particles. Vaporization is not a significant transport route because

uranium metal has a boiling point of 3818 °C. Powdered uranium metal may burn spontaneously in air, but larger pieces of metal, such as penetrators, require a heat source ranging from 700 °C to 1000 °C to produce ignition. A DU projectile creates very fine particles of uranium oxides (typically 75 percent U_3O_8 and 25 percent UO_2) upon impact or burning. These particles settle according to Stokes' Law. The larger particles [> 5 micron (μm)] settle rapidly and travel only short distances through air because they are so dense (specific gravities of 8.3 and 10.96, respectively).

A number of researchers have studied the dispersal of aerosol particles of uranium after a DU penetrator hits a hard target (Mishima, 1990; Jette et al., 1990; Glissmeyer and Mishima, 1979; Fliszar et al., 1989). In addition, Pacific Battelle Northwest Laboratory published studies on this topic in 1979 and 1990. Its 1979 report (Glissmeyer and Mishima) identified several experimental problems that were subsequently resolved, so the second study (Jette et al., 1990) is believed to be more technically defensible. Jette et al. found that approximately 18 percent of a penetrator round dispersed into airborne particles when it hit a hard target. Of the aerosol particles produced by the impact, 61 percent to 91 percent were less than 10 μm in diameter, depending on the type of round. Furthermore, they found a strong propensity for DU particles to resuspend when multiple rounds were fired, but they also found that the resuspended aerosol particles were larger on average than those from the first round fired. Lung-solubility analysis of the particles less than 10 μm in diameter found that 24 percent to 43 percent were class "D," representing a 50 percent dissolution time in simulated lung fluids of less than 10 days. The rest of the particles were class "Y" materials, with a 50 percent dissolution time longer than 100 days.

Fliszar et al. (1989) reported results of firing various penetrator munitions at tanks containing DU shielding under intensively instrumented conditions in open air at the DOE

Nevada Test Site. When the DU penetrator rounds hit a tank, more than 90 percent of the airborne DU remained within 50 m of the tank. During one test, a fire began inside a tank; it was allowed to burn more than 12 hours. Dense smoke from the fire plugged sampling systems disrupting measurements. However, as with the impact tests, airborne transport appeared to be minimal beyond about 50 meters (m).

7.1.2 Aqueous Transport

As previously discussed in Chapter 2, DU fragments exposed to the atmosphere will oxidize from DU metal to U(IV) and eventually to U(VI). Uranium is thermodynamically stable only as U(IV) or U(VI). The oxidation rate of DU fragments depends on several factors, including fragment size, pH, humidity, soil moisture content, soil chemistry and oxygen content. Previous studies of the role of aqueous systems on the transport and fate of DU have been conducted by Hanson and Miera (1976, 1978), Ebinger et al. (1990), and Erikson et al. (1990a, 1993).

Figure 7-1 is a pe-pH (electron activity-relative alkalinity of a fluid) diagram for uranium U(IV) and U(VI) species in the environment. It summarizes the acid-base and oxidation-reduction chemistry (commonly abbreviated as redox chemistry) of uranium. The vertical scale (pe) defines the potential for oxidation-reduction reactions, while the horizontal scale (pH) defines acidic or basic conditions.

Low pH values describe acidic conditions, while high pH values represent basic conditions. A neutral solution corresponds to a pH value of 7.0. The diagonal dashed lines on the figure represent the stability limits for water—the limits for equilibrium in environmental systems. Above the top line, water is oxidized to oxygen gas (O_2). Below the bottom line, water is reduced to hydrogen gas (H_2). Brookins (1988) presents a formal discussion of pe-pH diagrams.