# Health Consultation

## Health Implications of Potential Exposure to Depleted Uranium at the Red River Aluminum, Incorporated, Site

## Stamps, Lafayette County, Arkansas

EPA Facility Identification Number: AR0000605322


**Prepared by:**
**Arkansas Department of Health**
Under a Cooperative Agreement With the
Agency for Toxic Substances and Disease Registry
U.S. Department of Health and Human Services

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## Summary and Statement of Issues

This health consultation has been prepared in response to a request made by the Arkansas Department of Environmental Quality (ADEQ) for assistance in determining the potential health risks associated with exposure to radioactive material at the Red River Aluminum, Inc. (RRA) site (see Appendix A, Figure 1). Specifically, this document reviews the radiation data that were collected on site to evaluate the potential exposures of trespassers and former site workers to depleted uranium (DU) located at the facility. The Arkansas Department of Health (ADH) prepared this health consultation under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

In November 2003, radiological data were collected at the RRA site. Exposure doses of absorbed radiation were estimated using the radiological data collected. The estimated exposure doses were then compared to ATSDR's minimal risk levels (MRLs) for uranium to determine whether there are health risks associated with exposure to DU found at the RRA site. On March 4, 2004, a Radiation Safety Officer for the Red River Army Depot removed and properly disposed of the DU.

To properly assess the public health implications posed by contamination at a site, it is necessary to evaluate site data and information on the site's history, the types and levels of contamination at the site, site-specific exposure pathways, community health concerns, and available toxicological implications of the contaminants at the site.

Based upon the review of recent radiological data for the RRA site, ADH categorized the levels of DU to represent *No Public Health Hazard*. The environmental sampling data do not indicate that humans are being or have been exposed to levels of DU expected to cause adverse health effects.

## Background

### Site Description and History

RRA occupies about 120 acres from which it operated a secondary aluminum recycling facility beginning in the mid-1980s (see Appendix A, Figure 1). The company brought reprocessed dross (impure aluminum surface scum from electrolytic cells of various primary aluminum smelters) on the site and fluxed it with sodium chloride, potassium chloride, and a small amount of calcium fluoride and remelted it in gas-fired furnaces to recover additional aluminum. The company ceased operations in November 1997 and subsequently filed for bankruptcy in December 1998 [1].

Citizens of Stamps, Arkansas, initially contacted ADH on July 5, 2000, to request that an inspection of the abandoned Red River Aluminum facility be performed to determine whether exposure to contaminants at the site could cause adverse health effects. Staff members from ADH and ADEQ conducted the initial site assessment on July 17, 2000. ADH and ATSDR have produced three other health consultations related to the site; in which they evaluated the potential health effects for residents in the vicinity of the RRA site concerning contaminated soil, potable water quality, and indoor air [2–5]. This health consultation reviews newly acquired radiological data to determine possible exposure risks to DU.

ADEQ and the U.S. Environmental Protection Agency (EPA) Region 6 have overseen clean-up activities at the site. Major clean-up activities include (1) capping approximately 200,000 cubic yards of saltcake waste product mounds with soil, and (2) creating a buffer zone of berms placed around the saltcake to divert runoff into holding ponds. Several dilapidated buildings remain on the site. Currently, the RRA site property is enclosed with chain link fencing and a locked bar gate to deter entry. However, there have been both eyewitness accounts and on-site evidence of trespassing. Children and teens are of particular concern for trespassing, since they live adjacent to the site and could easily access the site near the bar gate entry.

On October 20, 2003, it was reported to ADEQ that a local scrap dealer had rejected a load of scrap steel from RRA because of radiation. At the request of ADEQ, ADH's Radiation Control and Emergency Management team conducted a radiological site assessment (i.e., search for sources of radiation) of RRA to investigate a report that a potential source of radiation may still be located at the facility. Personnel from ADH—along with an ADEQ staff engineer—completed the on-site assessment on November 13, 2003. A wooden box, approximately 0.2 cubic meters ($\approx 0.2\ m^3$) in size, containing two pieces of DU was located on the second floor of Building 3 (see Appendix A, Figures 1–3). The length of time the DU was on site is unknown.

### Demographics

ADH estimated that during the time RRA was in operation, approximately 50 on-site workers were potentially exposed to the DU. Based on the 2000 U.S. Census information, ADH estimated that 29 people live within 1,107 feet of the location where the DU was stored in Building 3. ADH also used data from the 2000 U.S. Census to estimate that 8,559 people live in Lafayette County.

### Exposure Pathway Analysis

Exposure pathways to contaminants at the RRA site were evaluated to determine whether people could be exposed to potentially unsafe contaminants from the site. Exposure occurs only when a chemical comes into contact with a person and enters the body. Exposure pathways are various environmental routes by which contamination can be transported and available for possible contact with a person. Exposure pathways are classified as either completed, potential, or eliminated. For a chemical to pose a human health risk, a completed exposure pathway must exist. A completed exposure pathway consists of five elements 1) a source and mechanism of chemical release to the environment; 2) a contaminated environmental medium (e.g., air, soil, water); 3) a point (known as the exposure point) at which contact can be made with the contaminated medium; 4) an exposure route (e.g., inhalation, dermal absorption, or ingestion); and 5) one or more persons who have been exposed to the medium. In completed exposure pathways, all five elements exist. Potential exposure pathways are either 1) not currently complete, but could become complete in the future; or 2) are indeterminate due to lack of information. An eliminated pathway is one removed from further assessment because one or more of the five elements is missing and is never likely to exist.

Concerning the DU found at the RRA site, the five elements of the completed exposure pathway were present. The source of contamination was the DU. The environmental media was the air, which carried the radiation. Former workers of RRA and trespassers (particularly children and teens) to the site were the receptor population potentially exposed to the contaminant via absorption of radiation.

## Discussion

ADH reviewed recent radiological data collected at the RRA site, to evaluate the potential exposures of former site workers and trespassing children and/or teens to DU. DU is derived from natural uranium. Uranium is composed of three radioactive isotopes ($U^{238}$, $U^{235}$, and $U^{234}$), which ultimately decay to stable non-radioactive isotopes of lead. Uranium isotopes emit alpha (α) particles during decay. Alpha particles possess high energy, but are poorly penetrating. Thus in close proximity, uranium poses primarily an internal radiation hazard to tissue [6, 7].

Owing to uranium isotopes' relatively long half-lives ($10^5$–$10^9$ years), uranium is not very radioactive. In contrast, radon (a decay product of uranium) possesses a half-life of 3.8 days and a radiological activity 10,000 times greater. DU possesses only 60% of the radioactivity of natural uranium. This is because it has been "depleted" of much of its most highly radioactive $U^{234}$ and $U^{235}$ isotopes [6, 7].

Several factors influence the toxicity of DU, including the route of exposure, ability to dissolve in another substance, contact time, and the rate at which the body is able to eliminate the substance. Some of the chemical properties—high density and tensile strength—made DU an attractive material for use as counterbalances in ships and aircraft. It is also used as radiation shielding and in non-nuclear civil applications requiring high-density material [6, 7].

DU has been used in wide-body aircraft on rudders, wing assembly, and as counterweights. These counterweights come in a variety of weights and shapes ranging in weight from 0.23 kilograms (kg) to 77 kilograms [8]. It is believed that the DU located on the RRA site in Stamps, Arkansas, was used as an aircraft counterweight.

Radiological readings of the on-site material were taken using radiation probes. Results of the readings are shown in Table 1.

**Table 1. Radiation Readings of Depleted Uranium Located on the Red River Aluminum, Inc. Site; November 13, 2003**

| Location of Readings Taken | Readings (mrem/hr *) |
|---|---|
| Direct contact with depleted uranium | 3 |
| Contact with side of box | 0.35 |
| Contact with front of box | 0.275 |

* Radiation readings in millirem per hour
Note: Readings were taken using the following instruments: Ludlum Model 3, Serial 13220, calibrated 2-18-03, with 44-2, NaI(TI) probe; Ludlum Model 3, Serial 16252, calibrated 6-11-03, with 44-2, NaI(TI) probe; Ludlum Model 19, Serial 72163, calibrated 2-18-03, with Internal NaI(TI) probe.
NaI(TI) = sodium iodide activated with thallium

The values given in Table 1 represent the exposed dose if one were to be in direct contact with the DU. A MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without risk of adverse health effects over a specified duration of exposure (see Table 2). ADH used the MRLs to determine exposure risks associated with the on-site DU. ADH considered several conservative exposure assumptions to estimate external radiation dosage in Table 3 for both the former on-site 'adult' worker and a trespassing 'child'.

### Radiation Exposure Limits

In 1987, the Nuclear Regulatory Commission (NRC) implemented the "Radiation Protection Guidance to Federal Agencies for Occupational Exposure" establishing current occupational radiation exposure limits for federal agencies. These exposure limits also applied to all licensed uses of radioactive material, including DU, under the NRC's jurisdiction. As a matter of policy and directive, other federal agencies—including the Department of Defense—also observe this guidance [9,10].

The current established protection standards are:

- 5 rem[*] in a year for workers (to protect against delayed effects such as cancer);
- 50 rem in a year to any organ for workers (to protect against acute effects, such as changes in blood counts);
- 50 rem in a year to the skin or any extremity for workers (to protect against acute effects such as hair loss or radiation burns);
- 15 rem in a year to the lens of the eye for workers (to protect against cataracts); and
- 0.1 rem in a year (during a 70-year lifetime) for members of the public (to protect against delayed effects, such as cancer) [9,11].

These limits are in addition to the doses a person normally receives from natural background radiation, medical testing and treatment, and other sources [9,12].

These safety standards provide regulatory guidelines primarily for designing radiation protection programs and facilities. Their intent is to provide a working environment that is as safe as that of the so-called "safe industries," such as transportation, construction, and agriculture [9,13]. Limits for the public serve the same purpose, but generally include additional margins of safety to account for a wider range of ages (childhood to senior citizen), more diverse health conditions, and individual sensitivities.

Radiation exposure limits assist risk managers, health and safety personnel, and designers in designing facilities and developing procedures so potential exposures produce acceptable risks. Once an overexposure (above the limits) occurs, however, regulators may use the limits as a basis for imposing sanctions or penalties on violators. For the overexposed persons, the primary concern, of course, is the impact on health, as determined by the best available scientific and medical assessment. For radiation, this usually means thoroughly evaluating the dose combined

∗ A rem is a unit of measurement of an absorbed dose of radiation in man (or mammal) multiplied by a qualifying factor.

with what is known about the effects of radiation at that dosage. Even when doses are not high enough to produce so-called "acute" effects, science and medicine can estimate the total lifetime risk to an individual.

Scientists have never detected harmful radiation effects from low levels of natural uranium, although some may be possible. However, scientists have seen chemical effects. A few people have developed signs of kidney disease after intake of large amounts of uranium. Animals have also developed kidney disease after they have been treated with large amounts of uranium, so it is possible that the intake of a large amount of uranium might damage the kidneys. There is also a chance of getting cancer from any radioactive material like uranium, although natural and DU are only weakly radioactive and are not likely to cause you to get cancer from their radiation. In fact, no human cancer of any type has ever been seen as a result of exposure to either natural or DU [14].

## Minimal Risk Levels

A minimal risk level (MRL) is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. ADH and ATSDR health assessors use these substance-specific estimates as screening levels, which are not expected to cause adverse health effects. It is important to note that MRLs are not intended to define clean-up or action levels. MRLs are intended only to serve as screening tools to help public health professionals decide which substances need to be looked at more closely [14, 15].

To derive an MRL, ATSDR generally selects the most sensitive end point which is judged to represent the most sensitive human health effect for a given exposure route and duration. ATSDR cannot make this judgment or derive an MRL unless information (quantitative or qualitative) is available for all potential systemic, neurological, and developmental effects. If this information and reliable quantitative data on the chosen end point are available, ATSDR derives an MRL using the most sensitive species (when information from multiple species is available) with the highest no-observed-adverse-effect level (NOAEL). NOAEL is the highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

When a NOAEL is not available, a lowest-observed-adverse-effect level (LOAEL) can be used to derive an MRL. A LOAEL is the lowest concentration of a hazardous substance at which there is a statistically or biologically significant increase in the frequency or severity of an adverse effect between an exposed population and a control group. When using a LOAEL, an uncertainty factor (UF) of 10 must be employed. Additionally, UFs of 10 must be used both for human variability to protect sensitive subpopulations (people who are most susceptible to the health effects caused by the substance) and for interspecies variability (extrapolation from animals to humans). In deriving an MRL, these individual UFs are multiplied together. The product is then divided into the inhalation concentration or oral dosage selected from the study [14].

MRLs are generally based on the most sensitive end point considered to be of relevance to humans. Serious health effects (such as birth defects or irreparable damage to the liver or kidneys) are not used as a basis for establishing MRLs. Estimated doses that are less than these values are not considered to be of health concern. However, exposure to levels above the MRL does not automatically mean that adverse health effects will occur. To maximize human health protection, MRLs have built-in uncertainty or safety factors, making these values considerably lower than levels at which health effects have been observed. The result is that even if a dose is higher than the MRL, it does not necessarily mean that harmful health effects will occur. Rather, it is an indication that ATSDR should further examine the harmful effect levels reported in the scientific literature and more fully review exposure potential [14]. Table 2 shows the MRLs developed for uranium.

**Table 2. ATSDR's Minimal Risk Levels (MRLs) for Uranium [14 & 15]**

| Route | Duration | Form | MRL Value | Dose Endpoint |
|---|---|---|---|---|
| Inhalation | Intermediate | Soluble | 0.0004 $mg/m^3$ | LOAEL; Minimal microscopic lesions in the renal tubules in half the dogs examined were observed at doses of 0.15 $mg/m^3$. |
| Inhalation | Intermediate | Insoluble | 0.008 $mg/m^3$ | NOAEL; No adverse health effects were observed in dogs exposed to doses of 1.1 $mg/m^3$. |
| Inhalation | Chronic | Soluble | 0.0003 $mg/m^3$ | NOAEL; No adverse health effects were observed in dogs exposed to doses of 0.05 $mg/m^3$. |
| Oral | Intermediate | | 0.002 mg/kg/day | LOAEL; Renal toxicity was observed in rabbits exposed to doses of 0.05 mg/kg/day. |
| External Radiation | Acute | Ionizing Radiation | 400 mrem | NOAEL; The difference of 0.3 of an IQ point in intelligence test scores between separated and unseparated identical twins is considered the NOAEL. |
| External Radiation | Chronic | Ionizing Radiation | 100 mrem/year | NOAEL; The annual dose of 360 mrem/year has not been associated with adverse health effects in humans or animals. |

Acute = less than or equal to 14 days; Intermediate = 15 to 364 days; Chronic = exceeding 365 days.
The rabbit is the mammalian species most sensitive to uranium toxicity and is likely to be even more sensitive than humans.
LOAEL = Lowest-observed-adverse-effect level; NOAEL = No-observed-adverse-effect level
$mg/m^3$: milligram per cubic meter; mg/kg/day: milligram per kilogram per day; mrem/year: millirem per year; mrem: millirem (one thousandth of a rem)

## Estimated External Radiation Dose

When estimating exposure doses, health assessors evaluate chemical concentrations to which people could have been exposed, together with the length of time and the frequency of exposure. Collectively, these factors influence an individual's physiological response to chemical exposure and potential outcomes. Where possible, ADH used site-specific information regarding the frequency and duration of exposures. When site-specific information was not available, ADH employed several conservative exposure assumptions to estimate exposures. Although site access is somewhat restricted, the site is still accessible near the entry gate; therefore, ADH considered the exposed population to consist of former on-site 'adult' workers and 'children' trespassers.

The "External Radiation Dose Calculator," developed by WISE Uranium Project, was used to obtain the estimated external radiation dose [16]. Exposure doses of absorbed radiation are expressed in a millirem (mrem). To calculate the estimated external radiation dose at the RRA site, the typical range of 0.23 kg to 77 kg for the weight of the counterweight containing DU was used, along with an estimated 2,000 hours of exposure for 20 years. This resulted in an estimated external radiation dose of 0.18 mrem and 8.54 mrem at a distance of ½ (0.5) meter from the source for children, and 0.04 mrem and 1.95 mrem at 1 meter from the source for adults, respectively (see Table 3, Estimated External Radiation Dose). The distance variable used in the calculation of estimated external radiation dose for a child provided an added factor of approximately 4.5 times that of an adult. This measure was used because children are shorter than are adults thus closer to the DU than would be an adult. These values fall significantly below the ATSDR MRLs (see Table 2) for both acute and chronic external exposure routes. Therefore, no adverse health effects are anticipated for either the former on-site adult worker or a child trespasser.

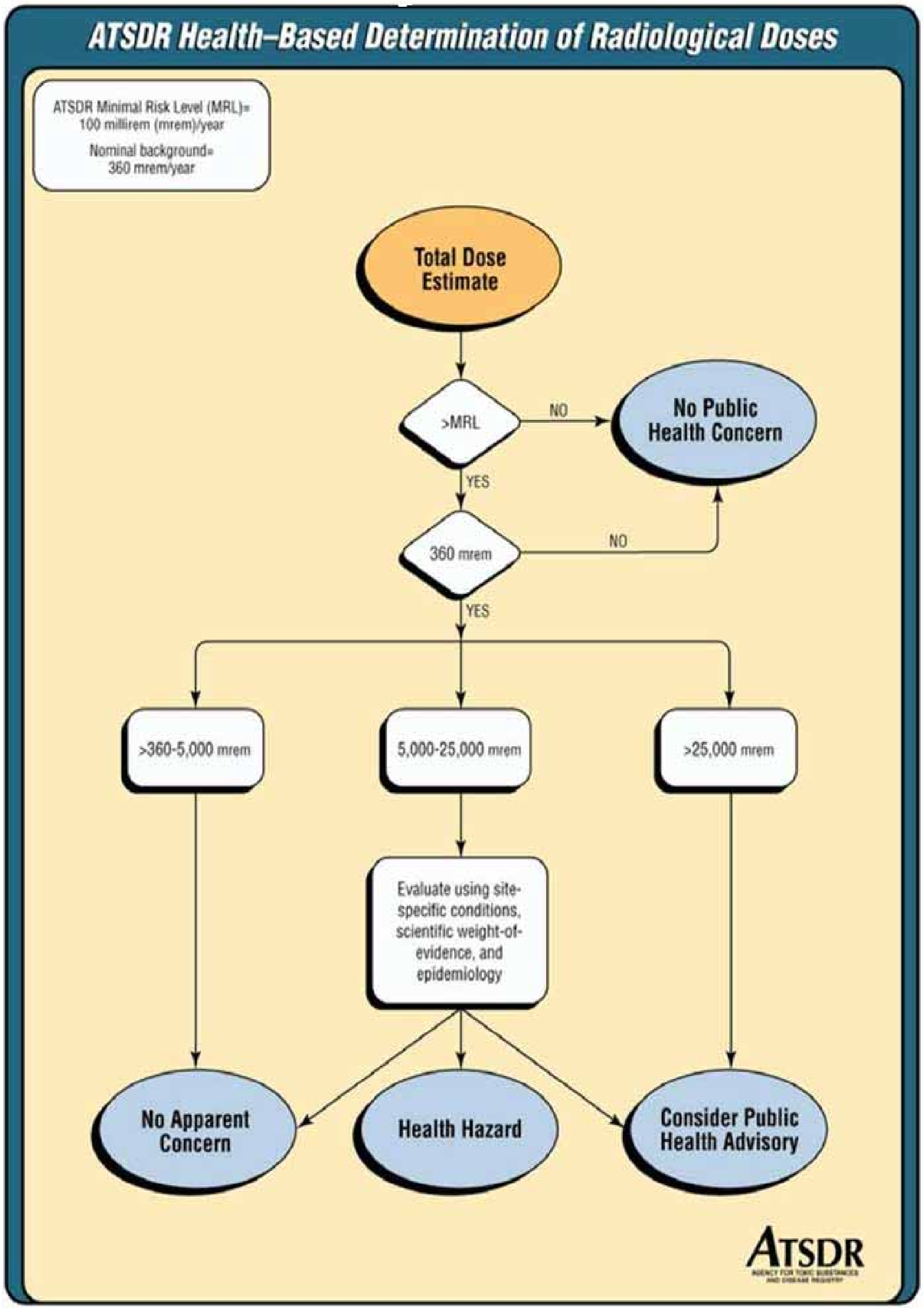
**Table 3. Estimated External Radiation Dose**

| | ADULT | | CHILD | |
|---|---|---|---|---|
| **Parameters** | **Values** | **Values** | **Values** | **Values** |
| Counterweight containing Depleted Uranium (DU)* | 0.23 kg | 77.0 kg | 0.23 kg | 77.0 kg |
| Source density | 18.95 g/cm$^3$ | 18.95 g/cm$^3$ | 18.95 g/cm$^3$ | 18.95 g/cm$^3$ |
| Uranium-238 | 12.42 × 10$^3$ Bq/g | 12.42 × 10$^3$ Bq/g | 12.42 × 10$^3$ Bq/g | 12.42 × 10$^3$ Bq/g |
| Uranium-234 | 2.076 × 10$^3$ Bq/g | 2.076 × 10$^3$ Bq/g | 2.076 × 10$^3$ Bq/g | 2.076 × 10$^3$ Bq/g |
| Uranium-235 | 160.0 × 10$^3$ Bq/g | 160.0 × 10$^3$ Bq/g | 160.0 × 10$^3$ Bq/g | 160.0 × 10$^3$ Bq/g |
| Shield density (Air, Dry-Near Sea Level) | 0.001205 g/cm$^3$ | 0.001205 g/cm$^3$ | 0.001205 g/cm$^3$ | 0.001205 g/cm$^3$ |
| Exposure for annual dose rates | 2,000 hours/year | 2,000 hours/ year | 2,000 hours/ year | 2,000 hours/ year |
| Length of time DU was potentially on the site† | 20 years | 20 years | 20 years | 20 years |
| Distance of receptor from source | 1 meter | 1 meter | 0.5 meter | 0.5 meter |
| **Estimated Exposure** | **0.04 mrem** | **1.95 mrem** | **0.18 mrem** | **8.54 mrem** |

* Counterweight containing Depleted Uranium (DU)= a weight that balances another, such as for an aircraft; typically weighing between 0.23 and 77 kilograms [8].
† RRA operated from the mid-1980s to November 1997, about12 years (Used a conservative figure of 20 years)
kg = kilogram;
g/cm$^3$ = gram per cubic centimeter;
Bq/g = Becquerel per gram

Furthermore, Figure 4 ('ATSDR Health-Based Determination of Radiological Doses') below outlines ADH's and ATSDR's process of determining radiological doses. Using the highest estimated external radiation dose of 8.54 mrem, we see that it falls significantly below the 360 mrem per year radiological dose and therefore is considered to represent *No Public Health Concern*.

***Figure 4.***



ATSDR Health–Based Determination of Radiological Doses
ATSDR Minimal Risk Level (MRL)= 100 millirem (mrem)/year
Nominal background= 360 mrem/year
Total Dose Estimate
>MRL
NO
No Public Health Concern
YES
360 mrem
NO
YES
>360-5,000 mrem
5,000-25,000 mrem
>25,000 mrem
Evaluate using site-specific conditions, scientific weight-of-evidence, and epidemiology
No Apparent Concern
Health Hazard
Consider Public Health Advisory
ATSDR

## Community Health Concerns

Citizens of Stamps, Arkansas, complained of generalized health effects resulting from potential contaminants left on the site after the closing of RRA. The residents expressed no specific health effects or concerns related to DU.

## Child Health Considerations

Both ADH and ATSDR recognize that the unique vulnerabilities of infants and children demand special emphasis in communities faced with air, water, soil, or food contamination. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus, adults need as much information as possible to make informed decisions regarding their children's health.

There have been both eyewitness accounts and on-site evidence of trespassing. Children and teens are of particular concern for trespassing, since they live adjacent to the site and could easily access the site near the entry gate. ADH considered the possible exposure pathway for children that may gain access to the site; although on-site exposure would likely be limited, due to the low frequency and short amount of time that a child might be on site. Estimated external radiation doses were calculated at ½ (0.5) meter from the floor to better estimate the proximity of an exposed child (see Table 3). Current epidemiological and toxicological information indicate that the estimated dose of an exposed child to DU is not expected to result in adverse health effects.

## Site Update

On March 4, 2004, ADH personnel met with the Radiation Safety Officer for the Red River Army Depot. The purpose of the meeting was to direct the Radiation Safety Officer to the DU for removal and proper disposal. The DU was successfully removed.

The Depot Radiation Safety Officer is assigned to the Red River Army Depot located 18 miles west of the joint city of Texarkana, Arkansas, and Texarkana, Texas. The Red River Army Depot is permitted by EPA—under the Resource Conservation and Recovery Act (RCRA) hazardous waste permitting program—to safely treat, store, and dispose of hazardous wastes, including DU [17].

## Conclusions

Based on the review of the radiological data and the conditions that were present at the time radiological readings were recorded, ADH categorized the DU found on the RRA site as *No*

*Public Health Hazard*. The review of environmental data indicated DU concentrations were below levels that would be expected to cause adverse health effects.

## Recommendations

No recommendations are indicated at this time.

## Public Health Action Plan

The purpose of the public health action plan is to ensure that health consultations or health assessments not only identify any current or potential exposure pathways or related health hazards, but also provide a plan of action to mitigate and prevent adverse human health effects resulting from exposures to hazardous substances in the environment. The first section of the plan contains a description of completed actions to mitigate exposures to environmental contamination. In the second section, there is a list of future public health actions that will be implemented as deemed necessary.

*Completed Actions*

- ADH's Radiation Control and Emergency Management team – along with ADEQ personnel – performed a radiological assessment on November 13, 2003.
- On March 4, 2004, the Radiation Safety Officer for Red River Army Depot took possession of the DU from ADH personnel for proper removal and disposal.

*Future Activities*

- No further actions are warranted at this time.

## Authors, Technical Advisors

### *Health Assessor*

Dan Seaton
Arkansas Department of Health

### *Designated Reviewer*

Lori Simmons
Arkansas Department of Health

### *ATSDR Regional Representative*

George Pettigrew
ATSDR Region 6

### *ATSDR Technical Project Officer*

Tammie McRae, M.S.
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

## Certification

This health consultation for the Red River Aluminum Site (Health Implications of Potential Exposure to Depleted Uranium) was prepared by the Arkansas Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was initiated.

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Tammie McRae, M.S.
Technical Project Officer
Division of Health Assessment and Consultation (DHAC)

The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation and concurs with its findings.

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Roberta Erlwein
Cooperative Agreement Team Leader, DHAC, ATSDR

## References


1. Arkansas Department of Health. Data package for Red River Aluminum Site. Little Rock, Arkansas: November 2000.

2. Agency for Toxic Substances and Disease Registry. Red River Aluminum Site, Stamps, Lafayette County, Arkansas, health consultation. Atlanta: U.S. Department of Health and Human Services; March 19, 2001.

3. Agency for Toxic Substances and Disease Registry. Health implications of exposure to contaminated soil in residential yards adjacent to the Red River Aluminum Site health consultation. Atlanta: U.S. Department of Health and Human Services; July 9, 2002.

4. Agency for Toxic Substances and Disease Registry. Assessment of potable water quality in residences located in the vicinity of the Red River Aluminum Site in Stamps, Arkansas, health consultation. Atlanta: U.S. Department of Health and Human Services; April 30, 2003.

5. Agency for Toxic Substances and Disease Registry. Assessment of indoor air in residences adjacent to the Red River Aluminum Site in Stamps, Arkansas, health consultation. Atlanta: U.S. Department of Health and Human Services; July 17, 2003.

6. McDiarmid MA. Depleted uranium and public health. BMJ 2001;322:123–4.

7. Geneva International Centre for Humanitarian Demining. Clearance of depleted uranium (DU) hazards. Technical Note 09.30 / 02 (V2). Retrieved March 18, 2004, from http://www.gichd.ch/standards/technical_notes.htm.

8. Radiation exposure from depleted uranium counterweights. Retrieved May 7, 2004, from http://www.antenna.nl/wise/uranium/ruxcw.html.

9. U.S. Department of Defense. Environmental exposure report - depleted uranium in the Gulf (II). Retrieved May 4, 2004, from http://www.gulflink.osd.mil/du_ii/index.htm.

10. U.S. Department of Defense. Instruction 6055.8, Occupational Radiation Protection Program. Revised May 6, 1996.

11. Code of Federal Regulations. 10 CFR 20, Standards for Protection Against Radiation, Subpart C, 20.1201, occupational dose limits for adults.

12. Code of Federal Regulations. 10 CFR 20, Standards for Protection Against Radiation. Subpart A, 20.1002, scope.

13. National Council of Radiation Protection and Measurements. Limitation of exposure to ionizing radiation, report No. 116, Bethesda, Maryland; 1993.

14. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Uranium. Atlanta: U.S. Public Health Service, U.S. Department of Health and Human Services; 1999.

15. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Ionizing Radiation. Washington, DC: US Public Health Service, 1999.

16. World Information Service on Energy. External radiation dose calculator. Retrieved May 18, 2004, from http://www.antenna.nl/wise/uranium/index.html.

17. U.S. Department of Defense, Joint Group on Depot Maintenance. Depot profiles—Army maintenance and repair facilities. Retrieved March 5, 2004, from http://www.jdmag.wpafb.af.mil/profiles44.htm#(RRAD).

# Appendix A

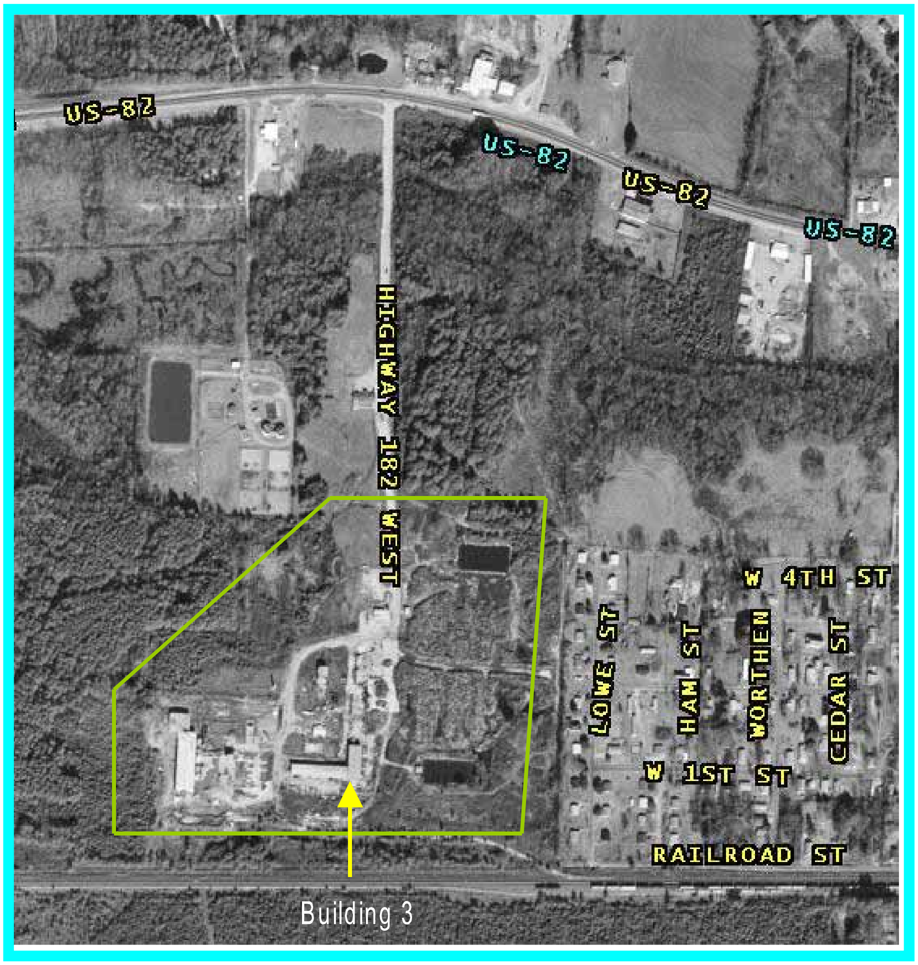


**Figure 1**. Aerial Photo of the Red River Aluminum Site. Outlined area indicates site boundaries. Arrow points to Building 3 where the depleted uranium was located.

**Figure 2**. Box Containing Two Pieces of Depleted Uranium Located at Red River Aluminum Site in Stamps, Arkansas.

**Figure 3**. Box Containing Depleted Uranium Properly Labeled for Pickup by Red River Army Depot.