BASELINE RISK ASSESSMENT OF THE MAXEY FLATS DISPOSAL SITE

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ABSTRACT

The Maxey Flats Disposal Site (MFDS), located in Morehead, Kentucky, operated as a low level radioactive waste disposal site from 1963 to 1977, at which time operations ceased due to the determination that leachate was migrating through the subsurface geology. In 1986, the site was listed on the National Priorities List to be addressed under the Superfund program.

On April 1, 1991, the Maxey Flats Steering Committee filed with EPA Region IV the Maxey Flats Disposal Site (MFDS) Feasibility Study (FS) Report in accordance with the Administrative Order by Consent (USEPA Docket No. 87-08-C) entered into by the Agency and consenting members of the Steering Committee. During the preparation of the FS Report, a number of technical and regulatory issues were raised and resolved with regard to the Applicable or Relevant and Appropriate Requirements (ARARs) for the site and the performance of a Baseline Risk Assessment. Accordingly, the MFDS docket establishes EPA precedence that may be applicable to other Superfund sites contaminated with radioactive materials.

The purpose of this paper is to (1) describe EPA requirements regarding Applicable or Relevant and Appropriate Requirements (ARARs) pertaining to the remediation of the MFDS, and (2) summarize the radiation exposure scenarios and assumptions used by the EPA to evaluate the baseline risks associated with the MFDS. It is intended that the regulatory interpretations and experience gained in preparing the MFDS RI/FS Reports will help to facilitate the remedial process at other Superfund sites containing radioactive materials.

ARARS

Section 121(d)(2)(A) of CERCLA requires that Superfund remedial actions meet any Federal standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate requirements (ARARs). In addition, State ARARs must also be met if they are more stringent than Federal requirements. Detailed EPA guidance on ARARs is provided in "CERCLA Compliance with Other Laws Manual," EPA/540/G-89/006, August 1988.

During the RI/FS review process for the MFDS, it became clear that there was considerable uncertainty regarding the ARARs for the site. A comprehensive review of the potential ARARs for the MFDS is presented in Appendix A of the FS Report. In general, the MFDS ARARs include:

- The Kentucky Administrative Regulations and the NRC regulations set forth in 10 CFR 20, which establish criteria that limit whole body exposures to members of the general public to 500 mrem/yr. These limits will be revised to 100 mrem/yr with the issuance of revised 10 CFR 20.
- Maximum Contaminant Levels (MCLs) in drinking water established by Kentucky Administrative Regulations and EPA regulations set forth in 40 CFR 141.
- The National Emissions Standards for Hazardous Air Pollutants (NESHAPS) set forth in 40 CFR 61 (EPA), which establish a 10 mrem/yr effective dose equivalent for airborne emissions.
- Kentucky (902 KAR 100) and Federal (10 CFR 61, NRC) licensing requirements for land disposal of radioactive waste which limit offsite whole body doses to 25 mrem/yr.
- The uranium mill tailings standards set forth in 40 CFR 192 (EPA), which limit the concentration of radium in the top 15 cm of soils to 5 pCi/g. The 15 pCi/g limit for contamination below 15 cm does not apply.

During the review process of the RI/FS draft reports, a great deal of discussion was held between EPA Region IV and the Steering Committee, which represents the Potentially Responsible Parties, regarding the degree to which these regulations are either applicable or relevant and appropriate for the site. For example, depending on which regulations are designated as ARARs for the site, the exposure limits could be as high as 500 mrem/yr (under 10 CFR 20) to as low as 4 mrem/yr (under 40 CFR 141). Questions were raised whether the Commonwealth or Federal drinking water standards are ARARs for the MFDS since groundwater in the immediate vicinity of the site is not currently used as a source of drinking water and is unlikely to be a source of community drinking water in the near future. In addition, questions were raised regarding the applicability to the MFDS of the licensing requirements for land disposal of radioactive waste (i.e., 10 CFR 61), since the current regulations apply to facilities that have been sited, designed, and constructed in accordance with the current regulations.

In response to these issues, EPA Region IV has taken the following position regarding ARARs for the MFDS:

- *The National Emission Standards for Hazardous Air Pollutants (NESHAPS) in 40 CFR 61.92 shall be treated as a contaminant-specific, relevant and appropriate requirement for setting emissions levels for radionuclides remaining on-site at Maxey Flats as residual contaminants. The NESHAPS for radionuclides in 40 CFR 61.92 states that emissions of radionuclides to ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/year. A key purpose of the NESHAP for radionuclides at DOE sites is to set standards based on "acceptable risk" to the public (54 Fed. Reg. 51664, Dec. 15, 1989). This is the same purpose for setting remediation goals at Superfund sites. Thus, based on the factors in the 1990 NCP in 300.400 (g) (2), EPA concludes that 40 CFR 61.92 is relevant and appropriate for setting emissions levels at Maxey Flats;*
- *The radiation protection standard of 25 mrem/year dose to the whole body, established in 10 CFR Part 61, Section 41, and 902 KAR 100:022, Section 18, shall be treated as a contaminant-specific ARAR and, as such, be used as the preliminary remediation goal for overall exposure to radionuclides after site cleanup.*

  As EPA noted in its 1989 ARARs Compliance With Other Laws Manual, although the standards of 10 CFR Part 61 are not applicable to previously closed low-level waste disposal sites, the standards "may be relevant and appropriate to existing CERCLA sites containing low-level radioactive waste if the waste will be left on-site." (CERCLA Compliance With Other Laws Manual, Part II, OSWER Directive 9234.1-02, August 1989, at p.5-15). Consistent with that stated policy, EPA believes that the 25 mrem/yr dose limit set by the NRC in 10 CFR Part 61 is a contaminant-specific requirement that is relevant and appropriate to remedial activities at the Maxey Flats Disposal site.
- *The MCLs, NESHAPs and Kentucky Water Quality Standards shall be the remediation goals for their specific media. The remediation goal for soil exposure shall be the difference between the overall 25 mrem/year cap and the combined exposures predicted by the risk assessment for the ground water, surface water and air pathways.*
- *The UMTRCA standards found in 40 CFR 192, which limit radium-226 concentrations in soil to 5 pCi/g in the top 15 cm, shall be considered contaminant-specific ARARs for soils at the Maxey Flats site.*

In addition to establishing ARARs for the site, the EPA has also taken the following position regarding the performance of the Baseline Risk Assessment at the MFDS:

- The potential risk from the site should be determined in the absence of any remedial or "closure" activity;
- No credit can be taken for institutional controls in determining the possible exposures to persons living in the vicinity of the site;
- No credit can be taken for institutional controls in determining the possible exposure to persons who may inadvertently intrude onto the site.

BASELINE RISK ASSESSMENT

As part of the EPA's review of the RI/FS, an independent Baseline Risk Assessment was performed of the MFDS. In accordance with EPA requirements, the Baseline Risk Assessment did not take credit for institutional controls, thereby resulting in exposure scenarios that assumed (1) the degradation of the existing soil cap and the subsequent leaching and transport of radionuclides offsite, and (2) individuals trespassing and establishing residence at the site.

In order to evaluate the offsite exposures, it was assumed that about 10% of rainwater penetrates deep into the trenches and leaches radionuclides from the waste. The contaminated rainwater is assumed to percolate down into the strata underlying the trenches and migrate laterally beneath the trenches to the sides of the hill on which the MFDS is located. From here, the contaminated water is assumed to partially evaporate and partially be transported down the hillside to the valley below. As a result of evapotranspiration, tritiated water becomes airborne and is transported offsite to receptor locations. The contaminated water that reaches the alluvial valley causes exposures by the cow milk and beef ingestion pathways because milk cows and cattle ingest pasture growing on the contaminated alluvial plain and drink water in the local creeks contaminated by the runoff. It was also assumed that a child ingests contaminated soil and that contaminated runoff recharges the local aquifer, which is used as a source of drinking water for humans. In addition, a hunter is assumed to ingest deer meat contaminated as a result of deer grazing at the hillside.

The risk assessment addressed a large number of radionuclides. However, the results revealed that tritium is the critical radionuclide due to its mobility and relative abundance at the site. The following presents the results of the independent dose assessment for tritium.

PATHWAY	H-3 DOSE EQUIVALENT (MREM/YR)
Milk	1.0
Beef	1.0
Deer	< < 1.0
Sediment	< < 1.0
Well Water	51
Evapotranspiration	< < 1.0

The results reveal that well water is by far the dominant pathway of exposure. This finding was a matter of considerable discussion between the EPA and the Steering Committee because of the current availability of public water supplies (which all the present residents at the MFDS are using) and the relatively poor quality of the alluvial aquifer water. However, the EPA determined that the alluvial well water pathway is an appropriate exposure scenario for the following reasons:

1. It cannot be assumed that the public water supply will be available to all areas of potential use in perpetuity.

2. Costs of connection to public supply may be an incentive to construct a private well.
3. Some people may feel a greater sense of independence by having their own well under their control, rather than depending on a public water supply over which they have no control.
4. It cannot be reasonably assumed that the current residents will continue as the only residents in the area over periods of decades to centuries. In the future, it is likely that additional residents seeking rural living will purchase land and build homes. It is not unlikely that some of those residents will construct and use a shallow well in the alluvium.
5. Residents in the area have used shallow wells in the alluvium previously, and residents of similar environments in the region continue to rely on these types of private wells.
6. Although the quality of water in the alluvial aquifers may not be ideal, it is probably suitable for domestic use.

Because no credit is taken for institutional controls, it was assumed that a trespasser may occasionally gain access to the site. Such a person would be exposed to direct external radiation and perhaps the inhalation of radioactive particulates that may become airborne through suspension processes. In addition, it is likely that the trespasser would also be exposed to airborne tritiated water vapor due to the evaporation of leachate.

The direct external radiation dose rate to a person standing on the trenches depends on whether the soil overlying the trenches is intact and uncontaminated. If it is, the clean soil overlying the waste in the trenches will serve as a shield from the radiation emitted by the underlying waste. However, if the overlying soil becomes contaminated as a result of the bathtub effect, the shielding effectiveness of the overlying soil is markedly reduced. As a result, two analyses were performed; one assuming 1 meter of intact clean soil overlies the waste, and the other assuming the overlying soil is contaminated as a result of the bathtub effect.

Columns 1 and 2 of Table I present the calculated external dose rate for the two cases. As can be seen by column 1, assuming the overlying soil is intact and clean, the direct radiation dose rates are extremely small. Such dose rates would be indistinguishable from external natural background radiation, which is typically about 1.0E-02 mrem/hr. As can be seen by column 2, however, if the overlying soil becomes contaminated as a result of the bathtub effect, the dose rates can increase by several orders of magnitude, to approximately 1.4 mrem/hr.

If the overlying soil is intact and clean, there is very little likelihood that radionuclide particulates could become airborne. However, if the overlying soil is contaminated as a result of the bathtub effect, wind and mechanical erosion processes could cause contaminated soil particles to become airborne. Once airborne, they could cause internal exposures due to inhalation and also external exposures from immersion in the airborne particulates. Columns 2 and 3 present the dose rates to a trespasser from suspended radioactive particulates. As can be seen by column 3, the inhalation doses are limiting. In addition, column 4 indicates that the external doses due to immersion in the airborne particulates are negligible.

Individuals standing in the vicinity of the trenches will likely be exposed to airborne tritiated water vapor. If the trench cap degrades and/or the trench leachate overflows, evaporation processes will result in airborne tritiated water vapor. Under worst case conditions, the tritium concentration in the water vapor will be the same as that in the trench leachate. Using a medium tritium concentration in leachate of 0.0532 Ci/m^3, and an airborne water vapor concentration of 8.4 g/m^3, the dose to a trespasser from airborne tritiated water vapor is about 0.026 mrem/hr, but could range up to about 5.7 mrem/hr depending on the tritium concentration in any one trench.

EPA's risk assessment also included an evaluation of the onsite exposures associated with the inadvertent intruder

TABLE I

Effective Dose Equivalents (mrem/hr) for Transient Intruder

	1	2	3	4
	Direct Gamma		Resuspension	
Years Decay	Waste	Soil	Inhalation[1]	Immersion[2]
0	4.5E-04	1.4E+00	1.4E-01	4.9E-08
10	1.7E-04	1.3E+00	1.3E-01	4.5E-08
20	9.7E-05	1.3E+00	1.3E-01	4.4E-08
30	7.8E-05	1.3E+00	1.3E-01	4.4E-08
40	7.3E-05	1.3E+00	1.3E-01	4.4E-08
50	7.1E-05	1.3E+00	1.3E-01	4.4E-08
75	6.8E-05	1.2E+00	1.3E-01	4.3E-08
100	6.7E-05	1.2E+00	1.3E-01	4.3E-08
200	6.4E-05	1.2E+00	1.2E-01	4.3E-08
300	6.1E-05	1.2E+00	1.2E-01	4.3E-08
400	5.9E-05	1.2E+00	1.2E-01	4.3E-08
500	5.6E-05	1.2E+00	1.2E-01	4.2E-08

1 Major contributors are Th-232 and Pu-238

2 Major contributor is Th-232.

construction and agriculture scenarios. Unlike the trespasser, these scenarios assume an intruder gains access to the site and is exposed for a prolonged period of time. A broad range of *onsite* exposure scenarios were evaluated in order to gain insight into the full range of possible exposures at the site and how they may change with time. The intruder scenarios were based on the assumption that an individual builds a home and lives on the waste site beginning today. It was also assumed that the intruder obtains his food locally and sinks a well into the aquifer underlying the site to obtain drinking water.

It is certainly unrealistic to assume that such scenarios could occur in the near future. However, these scenarios were included in the risk assessment to characterize fully the range of exposures that could conceivably be associated with the site. In addition, performing the intruder scenario calculations as a function of time, starting with time zero, lends insight into how the intruder exposures change with time and the importance of institutional controls that prevent individuals from gaining access to the site.

In the construction scenario, the builder is assumed to be exposed from the following pathways:

- Direct Gamma - Direct radiation from standing in the excavated hole.
- Suspension of Particulates from Construction - Inhalation of particles suspended during construction, external exposure from suspended particulates, and exposure to an area source consisting of particles deposited on the soil following suspension during construction.
- Airborne Tritium - Inhalation and skin absorption of airborne tritiated water vapor.

The results revealed that if a home were constructed at the site today, the dose to the construction worker over the 500 hours required for construction was estimated to be 3.2 rems and the lifetime risk of fatal cancer is about 1.2E-3. Most of this dose and risk is due to direct radiation, primarily from Co-60.

After a 100-year period of institutional control, the dose and risk decrease by about an order of magnitude, to 320 mrem. The decrease is due primarily to the decay of Co-60. However, direct radiation is still the major contributor to dose, though the dominant radionuclide is now Ra-226.

After a 500-year period of institutional control, the dose and risk to the construction worker decrease further, but by less than a factor of about 2, to 210 mrem. Direct radiation is still the major contributor to dose, and Ra-226 is still the dominant radionuclide.

In the agriculture scenario, the intruder is assumed to live in the house, plant a garden in soil excavated from the waste disposal site during construction, use water from an onsite well, and raise cattle and milk cows on the contaminated soil at the site. In addition, a child in the family is assumed to ingest contaminated soil, and radon daughters are assumed to build up indoors due to the radium contamination in the waste.

The results revealed that if a person were to live in a home constructed directly over the waste trenches today, the total dose to an adult from all pathways, not including radon, is about 20.4 rems/yr. A little over half the dose (i.e., 11.3 rems) is due to the ingestion of well water obtained from an aquifer directly beneath the trenches, where the radionuclide concentrations were assumed to be the same as in the trench leachate.

The major contributors to the dose are tritium, Co-60, Sr-90, Cs-137, Ra-226, Th-232, and Pu-238. If drinking water is obtained from an uncontaminated source, the dose is reduced to about 9.1 rem/year. Of this, about 8.7 rem is due to direct radiation, primarily Cs-137 and Co-60. The remainder of the dose, about 500 mrem, is due to the ingestion and evapotranspiration pathways.

The lifetime risk of fatal cancer at time zero associated with continual exposure is about 0.12. This risk is based on the assumption that a person is continually exposed to a declining source term for a 70-year period, but the figures do not include the risk associated with exposure *to elevated levels* of indoor radon progeny. The exposure to radon progeny was conservatively estimated to be 50 WLM (Working Level Month) per year, which corresponds to a lifetime risk of fatal lung cancer of close to 1.0. The calculated exposure to radon progeny was based on the assumption that the radium in the trenches is uniformly mixed in the soil and uses the empirical relationship of 1 pCi/L of radon indoors per pCi/g of Ra-226 in soil, which generally applies to natural radium in the environment. This may be a highly conservative assumption for the Maxey Flats site since the Ra-226 in the waste may be in a form that does not readily release radon or may be in localized "hot spots" at some distance from the building foundation.

If a 100-year period of institutional control is assumed, the dose decreases by a factor of about 3, to 7.2 rem/yr. The drinking water pathway remains dominant, but the critical radionuclides are the very long-lived radionuclides Ra-226 and Th-232 and the relatively long-lived Pu-238. Tritium and Sr-90 no longer contribute to the dose because they have decayed away. The direct radiation exposures have declined by about a factor of 10, to 780 mrem/yr, primarily due to the decay of Co-60. Ra-226 is now the dominant source of external exposure, with Cs-137 also an important contributor.

At 100 years, the lifetime risk of fatal cancer (not including radon progeny) due to continual exposure decreases from 0.12 to about 0.045. The exposures and risks associated with elevated levels of radon progeny indoors decrease only slightly, as expected, given the long half-life of Ra-226.

If a 500-year period of institutional control is assumed, the dose decreases to 5.1 rem/yr, and the risk (not including radon progeny) is about 0.031. The reason for the small decrease is that the dose from drinking water is dominated by very long-lived radionuclides. If uncontaminated sources of drinking water are used, the dose is about 600 mrem/yr. This dose is due primarily to direct radiation, which is dominated by Ra-226. The food ingestion pathways contribute less than 100 mrem/yr.

The analysis also revealed that the doses to the child are similar to the doses to the adult. The assumption that the child ingests soil does not affect the results because soil ingestion is not a dominant pathway of exposure. In addition, the differences in the ingestion rates and dose conversion factors for the child, as compared to the adult, are not sufficient to have a significant effect on the child doses.

An analysis was also performed of the erosion exposure scenarios. These pathways are based on the assumption that, without erosion controls, surface and hillside soil will be transported to the alluvial valley, and, if the eroded soil contains radionuclide contaminants, individuals living in the valley can be exposed to the contaminants. The analysis was based on the assumption that no steps are taken to prevent the bathtub effect or to protect the overlying soil from erosion. As a result of the bathtub effect, leachate is assumed to rise up periodically, saturate the overlying soil, and overflow the trenches. The overlying soil thereby becomes contaminated and, when eroded down to the alluvial valley, becomes a source of exposure to individuals living in the valley. The exposure pathways include (1) direct radiation from living on contaminated alluvium, (2) the ingestion of surface water, (3) the ingestion of vegetables grown in contaminated alluvium, and (4) the ingestion of beef and milk obtained from cattle and milk cows raised on water obtained from the creek and fodder from the contaminated alluvial plain.

The drinking water pathway is based on the assumption that an individual obtains all his drinking water from the local creek. At the MFDS, this is a highly conservative assumption, but was included as a "what if" scenario. Doses from the ingestion of vegetables are based on the assumption that all vegetables are obtained from gardens located on the contaminated alluvium. Similarly, milk and beef doses are based on the assumption that the cattle and cows obtain all their drinking water from the creek and fodder from grass growing in the contaminated alluvium. The doses also include direct radiation from continual exposure from living on contaminated alluvium. These doses were based on the assumption that the contamination is an effective infinite plane, with no credit taken for shielding. These assumptions establish a conservative upper bound on the doses from the erosion pathways.

The exposures associated with the erosion pathways were performed for a range of time periods that reflect a decaying source term and a changing erosion rate. The results of the analyses for the worst case are as follows:

PATHWAY	DOSE (MREM/YR)
External Exposure	160
Drinking Water	440
Vegetables	11
Milk	1.4
Meat	1.9

In summary, the regulatory interpretations and experience regarding ARARs and the Baseline Risk Assessment gained in the preparation and review of the MFDS RI/FS Reports should facilitate the remedial process at other Superfund sites containing radioactive materials.