UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, Ca. 94105-3901

N00217.002878
HUNTERS POINT
SSIC NO.5090.3

September 8, 1993

Raymond E. Ramos
Base Closure Team
Western Division
Naval Facilities Engineering Command
900 Commodore Dr.
San Bruno, CA 94066-2402

Dear Mr. Ramos:

Enclosed are comments regarding radiation issues at PA-18 (in Parcel B), prepared by Steve Dean of our Office of Radiation and Indoor Air. Among other things, in this memorandum Mr. Dean is recommending that a petrographic analysis of the soil at PA-18 be done to assess whether the radium levels are from natural or human enhanced sources. We are currently looking into whether our National Air and Radiation Environmental Laboratory (NAREL) could perform this work; but if not, we believe the Navy should proceed to do so. Mr. Dean is working with your office and the State agencies to discuss these issues. Please call him directly at 744-2385 if you have any questions.

Sincerely,

Roberta Blank
Roberta Blank
Remedial Project Manager

Attachments (5):
(1) Steve Dean Memorandum, 8/27/93
(2) ORIA Memorandum, 6/10/93
(3) OSWER Fact Sheet, 5/92
(4) Petrographic Methods paper, undated
(5) Risk Assessment, S. Dean, 8/27/93

cc: Jim Sullivan, NSTI
Mike McClelland, WestDiv
Bill ~~McAvoy, WestDiv~~
Cyrus Shabahari, DTSC
Barbara Smith, RWQCB
Amy Brownell, SFPHD
Gary Welshans, PRC

Attachment (1)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, Ca. 94105-3901

MEMORANDUM

DATE: August 27, 1993

FROM: Steve M. Dean
Environmental Scientist, ORIA (A-1-1)

TO: Roberta Blank
Remedial Project Manager, FFEB (H-9-2)

SUBJECT: Radium Cleanup Levels for PA-18

On August 5, 1993, I attended a Radium Cleanup Conference hosted by Region 5 in Chicago to discuss possible cleanup levels for a variety of radium contaminated sites. Several issues presented there have direct relevance to the radium issues at Hunters Point Annex and particularly PA-18.

First, the most frequently used standard for radium cleanup levels is the Uranium Mill Tailings Reclamation Conservation Act (UMTRCA) 40 CFR 192. The EPA issued this guidance for dealing with radium contamination at DOE mill tailing sites and it is used commonly, though not universally, as an ARAR at other radium or uranium contaminated sites as well. For instance, EPA Region 8 with 7,000 uranium mines considers it an ARAR. Region 5 Superfund Program considers it guidance but not an ARAR for its thorium contaminated sites.

Radium 226 is a naturally occurring daughter of uranium 238, thus is found wherever uranium is present. Typical background levels of radium in U.S. soils range between 0.5 and 1.5 picoCurie per gram (pCi/g) with average being 0.8 pCi/g. Radium also decays in to radioactive daughters which are more toxic than radium itself, such as radioisotopes of bismuth, lead, and polonium.

UMTRCA states that the site must achieve a concentration of less than 5.0 pCi/g of combined Ra^{226} and Ra^{228} above the typical background level for the top 15 centimeters of soil. Below 15 cm, however, the maximum Ra^{226} concentration can be up to 15 pCi/g. One other consideration in UMTRCA is the radon flux levels emanating from the mill tailing piles. However, for most Superfund sites radon will not be an issue, this is particularly true of the Bayside Landfill at Hunters Point.

In my opinion, the Navy and PRC have been trying to apply 40 CFR

192 as an ARAR at Hunters Point but much of this guidance is not appropriate as a cleanup standard for Ra^{226} at this site.

Margo Ogre, Director of HQ ORIA, has issued a position memo on the application of 40 CFR 192 as an ARAR. The key points are:

- The 5.0 pCi/g limit is for combined Ra^{226} and Ra^{228}.

- The 5.0 pCi/g limit does **not** include background.

- The 5.0 pCi/g is for any depth of contamination, not just the first 15 centimeters.

- The 15 pCi/g below the first 15 cm is only for DOE Mill Tailing Sites, because 15 pCi/g is the lowest concentration that field down hole gamma logging can detect.

- The 5.0 pCi/g is a health based number, the 15 pCi/g is a technical limitation based number.

- Radon flux has little or no bearing on the 5.0 pCi/g clean up level.

While this has helped to clarify some issues many of Regional ORIA and Superfund staff do not feel that 5.0 pCi/g plus background is protective enough when considering the risk assessment for radium and its daughters. I personally feel that this level is too liberal when considering residential use and that a level of 3.5 pCi/g plus background is more appropriate. I have attached several risk assessments for Ra^{226}, as well as, Ra^{226} and its daughters (Ra^{226}d) using both commercial and residential scenarios to illustrate my point. However, the final clean up standard has not been determined yet.

The following chart summarizes the risk versus radium concentration in soils:

RADIUM 226 TOTAL RISK COMPARISONS

CONCEN-TRATION	COMMERCIAL		RESIDENTIAL	
pCi/gram	Ra^{226}	Ra^{226} +DAUGHTERS	Ra^{226}	Ra^{226} +DAUGHTERS
0.8	9.2×10^{-8}	3.2×10^{-5}	3.5×10^{-7}	1.4×10^{-4}
1.5	1.8×10^{-7}	6.0×10^{-5}	6.6×10^{-7}	2.2×10^{-4}
5.0	5.9×10^{-7}	2.0×10^{-4}	2.2×10^{-6}	7.2×10^{-4}

There are several points to mention about this risk table: The assessments were done using the RAGS HHEM Part B and the '92

HEAST Tables. Both the commercial and residential scenarios were run with the standard default values. The dominant risk pathway in every case was External Exposure. Radium decays into daughters that are more carcinogenic than radium itself which means that whenever radium is present most of its daughters will be also.

The table also shows that 5.0 pCi/g of radium 226 contamination in a residential scenario generates a risk of 7.2 cancer deaths in a population of 10,000. Add in the risk from the average soil background level of 0.8 pCi/gram the risk climbs to 8.6 in 10,000.

As for PA-18, the SCRS reported surface anomalies near the surface that had a high of 5.4 pCi/gram of Ra^{226}. Figure 15 which is a map of the PA-18 area actually details the "location of radioactive point sources" according to the map's legend.

When I first reviewed this I assumed these were indeed point sources similar to the ones in IR-2. However, in the Radiation Subgroup meeting held on July 7, 1993, Dave Martinez informed us that the radium anomalies are not discreet point sources and may be naturally occurring radium deposits in the soil around the restaurant. I would recommend that NAREL do a petrographic analysis of this soil using a technique developed by Dr. James Neiheisal of HQ ORIA which will determine whether or not the radium levels at PA-18 are from natural or human enhanced sources. I have attached a copy of the petrographic procedure with this memo for your review. If you agree that this analysis should be done I will coordinate the arrangements with NAREL and PRC.

Please feel free to contact me at 4-1045 regarding these comments or any issues regarding this radium or Hunters Point Annex.

CC: MICHAEL BANDROWSKI, Director ORIA (A-1-1)

A Hachment (2)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 10 1993

MEMORANDUM

OFFICE OF
AIR AND RADIATION

SUBJECT: Basis for the Soil Cleanup Criteria in 40 CFR Part 192

FROM: Margo Oge, Director Margo T. Oge
Office of Radiation and Indoor Air

TO: George Pavlou, Acting Director
Emergency and Remedial Response Division, Region II

You have asked for clarification of the basis and application of the criteria for radium in soil that are found in EPA's regulations for disposal and cleanup of uranium and thorium mill tailings (40 CFR Part 192). More specifically, you asked for "...confirmation that 15 pCi/g is inappropriate for use as an Applicable or Relevant and Appropriate Requirement for cleanup of contaminated soil at the Maywood Chemical Company Superfund Site, Maywood, New Jersey." The following outlines our Office's position, based on the rulemaking record, on the basis for and applicability of the soil criteria contained in 40 CFR 192. We are prepared to support this position, as outlined below, during the dispute resolution process.

It is useful to distinguish, first, which subparts of the regulation apply to cleanup and which to disposal and, second, the nature of the two soil criteria, that is, whether they were health-based or were derived using technical considerations that may or may not be relevant and appropriate to situations other than those to which they legally apply.

The Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) contains two relevant Titles. Title I authorized standards for disposal (Subpart A of 40 CFR Part 192) *and* cleanup (Subpart B) of uranium mill tailings at sites designated under Section 102(a)(1) of the Act. Those sites are a closed set chosen in 1979 and cannot be added to. They include the so-called "vicinity" sites at which cleanup of specified off-site properties for unrestricted use is authorized. (See Sections 101, 102, 108, and 206 of UMTRCA.)

Title II authorized standards for disposal of uranium (Subpart D) and thorium (Subpart E) tailings at sites licensed by the NRC. These standards address the management of disposal sites and were not developed as cleanup standards for release of land for unrestricted use. (Sections 202, 205, and 206 of UMTRCA.)

These standards are directly applicable only to situations that fall into one of the above categories. If they are to be taken from the legal context of UMTRCA and applied to other situations, care must be taken to assure that the circumstances in the new situation are comparable to those for which the standards were developed. For example, the Act specifies that sites regulated under Subparts A, D, and E shall be maintained in perpetuity under Federal or State custody (Sections 104 and 202). In contrast, the site at Maywood is to be cleaned up for unrestricted use. The only standards that were developed for applications involving unrestricted use are those found in Subpart B.

Subpart B contains two quite different soil standards, each developed for a different purpose. The concentration criterion for surface soil (5 pCi/g of radium-226) is a health-based standard. The relevant source of health risk for surface soil is exposure to gamma radiation, which is the basis for this standard. (This basis is noted in the preamble to the final regulation at 48 FR 600 and is discussed in greater detail in the accompanying Final Environmental Impact Statement (FEIS) at pp. 57, 111-112, and 134-137). Region II would have to determine whether the risk scenarios at the Maywood site are sufficiently similar to those in UMTRCA to warrant use of this health-based standard. This standard for a single radioisotope (radium-226) was developed to control the hazard from gamma radiation. Since the gamma radiation hazard at the Maywood site arises from the combined effect of two radiologically similar materials (radium-226 and radium-228), if this standard is considered for use at the Maywood site you may wish to consider applying it to their combined concentrations.

On the other hand, the concentration criterion for sub-surface soil in Subpart B (15 pCi/g of radium-226) is not a health-based standard. Thus, it should not be applied to situations in which a health-based standard is appropriate, or to situations that differ substantively from those for which it was derived. The basis for this criterion is documented in the materials accompanying the promulgation of Subpart B (see the preamble to the final rule at 48 FR 600, the FEIS at pp. 134-137 and D-51 to D-52, and *Findings of an Ad Hoc Technical Group on Cleanup of Open Land Contaminated with Uranium Mill Tailings, EPA, 1981, Docket A-79-25*), as summarized below.

The criterion for subsurface soil was derived as a practical measurement tool for use in locating discrete caches of high activity tailings (typically 300-1000 pCi/g) that were deposited in subsurface locations at mill sites or at vicinity properties. The criterion for subsurface soil in Subpart B was originally proposed as 5 pCi/g (46 FR 2562). The final regulation was changed, not because the health basis was relaxed, but rather in order to reduce the cost to DOE of locating buried tailings,

5 pCi/gm?
DRY WT?
RA 226+228?
OVER 1 BKG 2

under the assumption that this would result in essentially the same degree of cleanup at the Title I sites as originally proposed under the 5 pCi/g criterion (48 FR 600 and FEIS p. D-51). The use of a 15 pCi/g subsurface criterion allowed the DOE to use field measurements rather than laboratory analyses to determine when buried tailings had been detected. Thus, it was not developed for situations where significant quantities of moderate or low activity materials are involved. It is only appropriate for use, as a cost effective tool to locate radioactive waste, when contaminating subsurface materials are of high activity and are not expected to be significantly admixed with clean soil.

It is our understanding that there are significant quantities of moderate to low activity materials at the Maywood site, and that under some of the proposed remedial alternatives large additional quantities of such materials would be created and left on the site. The 15 pCi/g criterion was not developed for application to such situations, and its use under such circumstances would not satisfy the risk objectives achieved under Subpart B for uranium mill tailings.

You should be aware that all of the standards discussed above were developed over a decade ago, and that this Office is currently developing comprehensive cleanup standards for all radionuclides that will apply to all Federal agencies, including DOE. I hope this information is helpful to you. If you have any additional questions about this matter, please contact Allan Richardson of this Office at (202) 233-9213.

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United States Environmental Protection Agency
Office of Solid Waste and Emergency Response
Publication 9380.1-10FS
May 1992

EPA

Characterization Protocol for Radioactive Contaminated Soils

Office of Emergency and Remedial Response
Office of Radiation Programs, ANR-458
Quick Reference Fact Sheet

The Superfund Amendments and Reauthorization Act of 1986 (SARA) mandates that remediation at Superfund sites must utilize a permanent solution and alternative treatment technologies or resource recovery options to the maximum extent practicable. Treatment technologies that permanently and significantly reduce the mobility, toxicity, or volume of hazardous substances are preferred in this requirement. However, in most remedial actions conducted to date at radioactive sites, the radioactive soil has been excavated and stored in temporary above-ground containment facilities. To alleviate this storage situation the Office of Radiation Programs has developed an innovative soil characterization process applicable in the RI/FS stages of the Superfund process to support the development of technologies for on-site volume reduction of radioactive soils by physical separation[1,2] technologies.

BACKGROUND

The volume reduction methods employed are based on physical/mechanical technologies that are common to the coal and ore processing industries. These common technologies have been adapted, modified, and directed toward the task of soil restoration. This soil characterization protocol is designed to demonstrate the suitabilitiy (or lack thereof) of various radioactivity contaminated soils for physical or chemical separation processes. These could potentially remove the radioactive fraction from the soil, thus producing a smaller volume requiring disposal. The protocol combines radiochemical and petrographic analysis of soil fractions, focusing on the contaminant waste and its particle size distribution in the host media. Soil remediation by volume reduction takes advantage of the fact that radionuclide contaminants concentrate generally in the smaller soil size fractions, and tend to selectively associate with materials that possess unique physical and/or chemical properties. The data obtained by following this protocol are used as the first phase of remediation assessment to determine if volume reduction is feasible.

CHARACTERIZATION DESCRIPTION

This soil charácterization protocol examines the various size fractions of a representative sample of radioactive soil from a Superfund site, to provide the following information:

- Grain size distribution curve which relates weight percent versus particle size.
- Relationship of radioactivity to particle size.
- Identification of the mineral/material composition and physical properties of the radioactive contaminants for the various size fractions.
- Identification of the mineral composition and physical properties of the host material for the various size fractions.
- Addtional information on contaminant and host material mineralogical and physical properties in support of feasible volume reduction techniques, e.g., magnetic properties.

These data are used to conceptualize a site-specific volume reduction process based on one or more of the following technologies:

- screening,
- classification,
- gravity separation,
- magnetic separation,
- flotation,
- chemical extraction,
- washing,
- scrubbing,
- surface de-bonding, and
- attrition.

The two-tiered soil characterization protocol, as shown in Figure 1, consists of feasibility analyses (Tier I), and optimization analyses (Tier II), as necessary, to cost-effectively maximize the volume reduction.

Pre-Tier I

Prior to Tier I laboratory tests, the representative contaminated soil samples obtained in compliance with EPA and DOE directives from a site[3,4,5] are radiologically screened to assure that the activity levels are within laboratory license requirements and that proper safety practices will be applied. Additional chemical analyses should be performed on a portion of each soil sample for the presence of organic and heavy-metal constituents if that information has not been previously collected. This information not only identifies hazardous constitutents (e.g., cyanide, heavy metals, chlorinated hydrocarbons), but also contributes to the mineralogical determination of the soil.

The remaining portions of each soil sample are oven dried at 60°C prior to weighing. The upper limit of 60°C is specified in order to maintain the mineral integrity of the soil by preventing the loss of water of hydration associated with the mineral structures which occur in some clays and other minerals at low temperatures.

Tier I

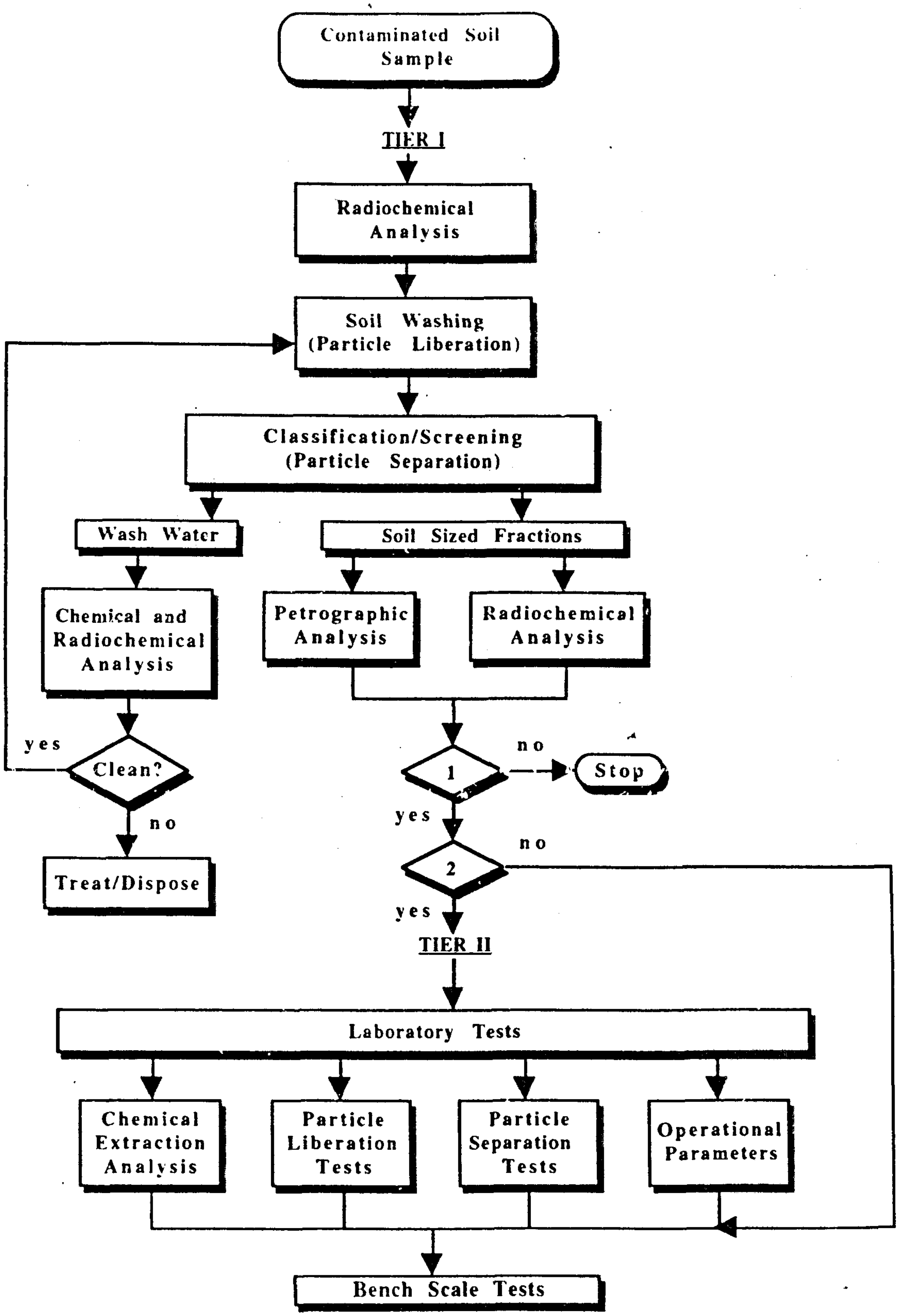
Tier I begins with radioanalysis of the dry soil samples by high-resolution gamma spectroscopy, and if necessary, alpha and beta spectroscopy analysis (using standard leaching/digestion and chemical methods[6]) to determine the level and type of activity present in each sample.

Physical separation of the soil particles is accomplished by mixing at least 250 grams of each soil sample with water to produce a liquid-to-solid (L/S) ratio of 5/1, agitating the mixture with a vigorous motion for 30 minutes at ambient temperature, and wet screening[7] through a set of nested sieves. In some site specific cases it may be advantageous to perform a less vigorous wash because of the nature of the constituents. The standard sieves include at least mesh sizes 4 (4.75 mm), 50 (0.30 mm), 100 (0.15 mm), and 200 (0.075 mm). Each soil fraction is dried at 60°C, weighed, and analyzed for radionuclide activity. From this procedure the weight and radionuclide distribution by particle size is determined. A similar separation is also performed using hydroclassification methods. The results of these tests indicate the compatability of the soil to remediation by particle-size hydroseparation techniques.

[NOTE: All water used must be collected and analyzed since it may contain transferred radioactive contaminants, Target Analyte List metals, volatile organic solvents, and/or pesticides. The analytical results will determine if the water can be recycled, safely disposed down a drain, or if it must be treated as a hazardous waste.]

Petrographic analysis is conducted on each of the size fractions to identify the mineral/material composition and physical properties of the radioactive contaminants and host materials. Petrographic procedures[8,9,10] include the use of binocular and petrographic microscopes to provide a statistical point count of all materials larger than silt-size to 0.038 mm (400 mesh size), and x-ray diffraction analysis of fines less than 0.038 mm size. Density separations are made on sand and silt size fractions (0.30 to 0.045 mm) to concentrate heavy particles greater than 3.0 specific gravity using sodium polytungstate as the separating liquid. The heavy fractions, in many cases, provide focus on radioactive particles which tend to concentrate in minerals or anthropogenic radioactive materials of the heavy fractions. The degree of weathering, presence of coatings, particle shape, surface texture,

Figure 1: Soil Characterization Flow Chart



LEGEND

1 Volumetric reduction feasible?

hardness, magnetism, and degree of aggregation or homogeneous nature are also physical properties examined for interpretations that relate to adsorption, waste form, and potential physical separation methods.

Tier I Report

Tier I tests results are gained from the petrographic and radiochemical analysis of the size fractions, as depicted in Figure I, to assess the feasibility of using volume reduction as a remediation technology. The test results include a grain size distribution curve of weight percent versus particle size, graphic data on activity level versus particle size, and tables and graphs on complete physical and mineralogic descriptions. This data is instrumental to the interpretation of the radioactive contaminants concentration in specific size ranges and the physical similarity and difference of the contaminants in relation to host materials.

It is assumed that the petrography and radiochemistry will be performed by personnel who are qualified by education and experience to employ the methodology specified and that recommendations for additional tests to validate key parameters for future tests will be incorporated in the report, e.g., recommend analysis of diagnostic elements that constitute chemical signatures to radioactive compounds. Radiochemical data should also be correlated with mineralogic data for interpretations, e.g., secular equilibrium of radionuclides to validate natural radioactive mineral assemblages reported or in the event of non-secular equilibrium of radionuclides, to reflect on anthropogenically enhanced radioactive waste forms in the radioactive soil. Any historic data on the ore minerals used and chemical processes used to convert the radionuclides to anthropogenic compounds should also be reported for the forensic data it might provide to support the list of radioactive compounds reported in the Tier I testing.

The Tier I report will provide an assessment of the technical feasibility of using one or more of the volume reduction technologies. Based on the feasibility of the most promising alternative, the Tier I report will also provide recommendations on further testing (Tier II) focusing on the validation of key factors that affect volume reduction. On the other hand, an evaluation of the test data could lead to the preliminary conclusion that volume reduction is not technically feasible.

Tier II

If the Tier I test data indicates the soil is satisfactory for remediation consideration Tier II testing is conducted. Tier II tests are designed to collect additional data for further characterization of contaminated soils. For example, additional soil fractions may be tested to focus on the mineral phase of opaque constituents, particle coatings, or special materials requiring more precise instrumentation for validation of particles than was made available for Tier I tests. Additional tests may also be necessary to provide optimum soil separation sizes. These tests can be performed with small soil volumes. The results are to be used to plan bench-scale tests that are designed to take advantage of unique physical and chemical characteristics of radioactive contaminants and host soil constituents. Tier II tests to be considered are in support of one of the following general categories of treatment technologies:

- Particle separation,
- Particle liberation, and
- Chemical extraction.

Particle separation is the separation of a mixture of various particles into two or more portions. For example, magnetic separation separates a mixture of soil particles based on the difference in magnetic susceptibilities.

Particle liberation is the physical de-bonding of contaminated particles or coatings from clean particles. For example, attrition removes friable coatings from soil particles.

When performing chemical extraction, the soil is immersed in a solvent that has been carefully chosen to preferentially extract the contaminant.

Selected chemical extraction tests may be performed in Tier II (as shown in Figure 1) to determine the potential for remediation by simple chemical extraction. Chemical extraction tests are designed to remove contaminants from selected particle-size fractions or from whole soil if it proves to be unsuitable for remediation by physical separation techniques. For example, the latter possibility exists for soils with uniform radionuclide distribution among the various particle sizes.

The chemical extraction tests are conducted on 100 gram samples of selected soil fractions or whole soil. On a sample in which the nature of the contaminant is poorly known, extractions are performed at 90°C with water and each of four extracting reagents known to be effective in removing various radionuclides from contaminated soils. These reagents include dilute solutions of hydrochloric acid, nitric acid, sodium chloride with hydrochloric acid, and sodium hexametaphosphate. With foreknowledge of the presence of a contaminant in a particular mineral form, one or two other select extracting reagents specific for the mineral are also included in these preliminary tests. The results of these tests provide information about the potential of chemical extraction as a complement or alternative to remediation.

Along with Tier I results, data from the Tier II tests can be used to select bench-scale test equipment for conducting remediation tests of contaminated soils. The initiation of bench-scale testing is based on the preliminary information provided by soil characterization which assesses the differences in physical properties between the waste form and host materials. For example, for physical volume reduction the applicable information relating to the differences in the waste form from the host material may be classified as follows:

- Relationship of radioactivity to particle sizes.
- Relationship of radioactivity to particle densities.
- Relationship of radioactivity to particle wettabilities.
- Relationship of radioactivity to particle shapes.
- Relationship of radioactivity to particle magnetic properties.
- Relationship of radioactivity to friability of particles or of particle coatings.
- Solubility of contaminants.

The most important information is the relationship of radioactivity to particle sizes. The information on the other physical properties such as density is obtained by identifying the waste form and host matrix using petrographic techniques. It is important to develop this petrographic information for various ranges of particle size. And, based on a careful analysis of this information, a preliminary bench-scale test can be designed using batch applications of physical methods if a difference in the physical properties stated exists between the radioactive contamination and the host materials.

Tier II Report

The Tier II report consists of the test data generated in the categories depicted in Figure I. In most cases, except for the chemical extraction tests, the Tier I recommendations provided focus on amplification of specific objectives that appear in tables and graphs in the report. Tier II tests results, just like Tier I tests results, are evaluated to assess the feasibility of using volume reduction, and if so, to what degree. The evaluation has focus on the physical differences previously cited between the waste form and host materials for design of bench-scale tests that will provide more realistic quantification of degree of separation possible by volume reduction equipment. The nature of the site specific soil drives the testing performed so that, while no standard format is presented, it is assumed that the test objectives will be governed by qualified personnel skilled in the state of the art of quality benefication testing. The report data can thus generate preliminary cost and time assessments that relate to the feasibility of volume reduction for the particular site.

SUMMARY

The characterization protocol described above for radioactive contaminated soils depends mainly upon the physical, chemical, and mineralogical characteristics of the soil and radioactive particles with respect to grain size. The intent is to return the "clean" soil fractions, which can be a major portion of the soil (by volume), to the ground, preferrably on-site.

Supplemental information concerning this protocol may be obtained from James Neiheisel or Mike Eagle at (202) 233 9386, 6603, Environmental Protection Agency, 401 M Street SW, Washington, D.C. 20460.

REFERENCES

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10. Neiheisel, James, *Characterization of Contaminated Soil from the Montclair/Glen Ridge, New Jersey Superfund Sites,* U.S. EPA Office of Radiation Programs, EPA/500/1-89-012, 1989.

Attachment (4)

Petrographic Methods in Characterization of Radioactive and Mixed Waste

James Neiheisel. Ph.D.
Office of Radiation Programs
U.S. EPA
Washington, D.C.

ABSTRACT

The Office of Radiation Programs has developed a soil characterization protocol for radioactive sites on the NPL that uses petrographic techniques in concert with radiochemical analysis to assess potential remediation technologies. The petrographic method is essentially a laboratory procedure that examines representative soil fractions separated by wet sieving and sedimentation techniques. This procedure uses the petrographic and stereographic microscopes and X-ray diffraction (XRD) techniques to determine the physical properties and mineral composition of the contaminants and the host medium. This focus, on precise physical and compositional differences between radioactive contaminants and individual components of the host materials of various size fractions, provides diagnostic information applicable to the assessment of soil washing as a feasible remediation measure.

The basic petrographic procedure (Tier I) consists of a statistical particle count (150 to 300 particles) of sieve fractions (sand size and larger) by petrographic and stereoscopic microscopes. X-ray diffraction is conducted on the fines passing the smallest sieve. Additional examination of heavy minerals on medium to fine sand-size fractions provides focus on these materials of higher density that frequently contain higher concentrations of radioactive contaminants. In more advanced testing (Tier II), use of the scanning electron microscope, equipped with an energy dispersive analyzer, provides diagnostic data on contaminant materials.

The application of petrographic and radiochemical techniques to assess the feasibility of soil washing as a remediation measure is based upon case studies of radium contaminated soil of the Montclair and Glen Ridge, New Jersey, NPL sites and thorium contaminated soil at the Wayne and Maywood, New Jersey, sites. The potential application of the petrographic and chemical testing is suggested for mixed waste sites with heavy metals and other hazardous toxic materials.

INTRODUCTION

The petrographic examination of earth materials has been employed in research by universities for nearly a century and as a standard operating procedure for several decades by the mining industry and government agencies. Petrography deals with the description and systematic classification of rocks and materials by means of microscopic examination of their optic and physical properties. Petrographic examination, for example, has been a cost-effective means used by the U.S. Corps of Engineers for rapidly assessing with certainty the presence or absence of small quantities of deleterious materials in concrete aggregate that could cause failures in major concrete engineering structures. The radioactive constituents in radioactive/mixed waste site soils, in like manner, usually occur in such minute amounts that it is difficult to gain an accurate assessment of the size range, physical properties, or waste form composition if the soil characterization is limited to bulk sample analysis. Therefore, the separation of the radioactive soil into several size fractions for petrographic and radiochemical analysis is an essential first step to quantify the composition and physical properties of the soil and focus on radioactive or hazardous contaminants that might otherwise be masked in the background of bulk samples.

Prior to SARA's passage in 1986, radioactive soil characterization was generally limited to bulk samples analysis during the RI/FS process at Superfund sites. The radioactivity readout on bulk samples by high resolution gamma spectroscopy provided precise activity levels and the radionuclides present; these are parameters used for assessing public health. However, the soil characterization, limited to these parameters, did not provide the parameters necessary for assessing the feasibility of soil washing or other technologies that Section 104 of SARA prescribed for cleanup of Superfund sites.

The purpose of this paper is to describe a petrographic procedure which identifies the composition and physical properties of contaminants and host materials. This procedure, combined with radiochemical analysis of several size fractions separated by sieving and sedimentation techniques, is the basis of the innovative soil characterization protocol developed by the Office of Radiation Programs to determine the feasibility of radioactive soil for washing.[1] The procedure was developed from radium- and thorium-contaminated soils on the NPL and the application of the protocol has been suggested, based on these investigations, to provide data quality objectives in site characterization and risk assessment as well as feasibility studies for volume reduction by soil washing.[2] The application of the protocol is also suggested for feasibility consideration of cleanup of toxic heavy metals at Superfund sites.

CHARACTERIZATION OF RADIOACTIVE SOILS

The soil characterization protocol described in the U.S. EPA's OSWER 9380.1-10FS[1] combines radiochemical/chemical and petrographic analyses of soil fractions in a tiered framework to demonstrate the feasibility of separating the contaminants from host materials. The methodology provides: (1) a grain size distribution curve that relates weight percent of size fraction to particle size, (2) a relationship of specific radionuclide activity levels versus particle size, (3) an identification of the mineral material composition of the radioactive contaminant waste forms and their physical properties, and (4) a mineral/material identification of the host medium and its specific physical properties.

ROLE OF PETROGRAPHY IN RADIOACTIVE SOIL ANALYSIS

The petrographic examination includes identification of observed physical properties visually or microscopically as well as the mineral/material identification of particles by optical properties observed in grain mounts in index oils under the petrographic microscope.[3] In the examination of radioactive soils, the petrographer also uses the radiochemical/chemical data to correlate and interpret the waste form. Historic data, relating special manufacturing processes, used for the production of the anthropogenic radioactive or other toxic compounds, are also used as a forensic tool for focus on the radioactive or heavy metal contaminants and associated precipitates and coprecipitates from the manufacturing process.

The physical differences found between the contaminants and the host materials provide the parameters for assessing the potential for separation of contaminants and host media. Some of the physical properties are inferred from the identification of minerals by optic means or by x-ray diffraction (e.g., zircon identified by these means has a listed grain density of 4.6 to 4.7 and quartz has a grain density of 2.6). Hardness, general shapes, chemical composition, magnetic susceptibility, and other properties may also be inferred from positive identification of certain materials by referral to published lists; however, the bulk of the physical properties are described from the visual procedures used in the petrographic examination.[3]

TIER I: PETROGRAPHIC APPARATUS AND METHODS

In Tier I testing, petrographic analysis is conducted on each size fraction to identify the mineral/material composition and physical properties of the radioactive contaminants and host materials.

Prior to testing the soil fractions, the sample received is prepared in a prescribed manner.[1] The soil sample as received is air dried at room temperature or oven dried at 60 °C. Approximately 250 grams of representative sample are riffled or quartered from the bulk sample in accordance with the ASTM methods.[4] A sample for a grain size distribution curve, to facilitate weight percent calculations for any size fraction consideration, is set aside for testing in accordance with the ASTM procedure for particle-size analysis of soils.[5]

The soil fractions for the Tier I radiochemical/chemical and petrographic analysis are soaked overnight in 5 parts by volume of deionized water to 1 part solids. The slurry is stirred and then passed through a set of U.S. Standard Sieves, with the sieve size determined by the size range of the particles. Usually this sieving process will include mesh sizes 4 (4.75 mm), 30 (0.59 mm), 100 (0.149 mm), and 200 (0.075 mm). Additional size fractions will be made of the fines by sedimentation and centrifugation techniques that are governed by Stokes Law.[6] The fine size fractions might include, but are not limited to, the following: 53 microns, 44 microns, 20 microns, 10 microns, 5 microns, 2 microns, and 0.5 μm sizes.

The petrographic and stereoscopic microscopes and the x-ray diffractometer are the essential apparatus for the Tier I petrographic testing. The microscopic examination is preferred for all material within the optically visible range. A statistical point count (150 or more grains) on each size fraction provides quantitative data on the physical forms and condition of particles as well as the mineral composition identification of transparent soil particles.[7] X-ray diffraction used to examine of fines beyond the optical range is severely limited in identification of small quantities of material that may be masked if more than a few varieties of mineral compounds occur in the fines or if amorphous materials (glass, etc.) are present.

In general, the apparatus and supplies that are required to support the use of the optical petrographic microscope, binocular (stereoscopic) microscope and x-ray diffraction equipment are described in detail by Hutchison[7] and in ASTM C-295.[3] The application of this apparatus to objective goals will be described in the description of the petrographic tests.

TIER II: PETROGRAPHIC APPARATUS AND METHODS

The Tier II examination generally consists of the examination of more size fractions selectively based on the data provided from the Tier I study. If the fine fractions contain radioactive materials, linear density gradient separations of the fine fractions supported by analysis with XRD, Scanning Electron Microscopy (SEM) with energy dispersive x-ray spectrum, and gamma spectroscopy can be instrumental in delineating of the radioactive compounds.[8]

PETROGRAPHIC EXAMINATION OF COARSE FRACTIONS

The petrographic examination normally begins with the examination of the largest size fractions. The coarse fraction will generally consist of a gravel-size and coarse sand-size material. The gravel-size material is that portion of the radioactive soil sample retained on the number 4 sieve (4.74 mm). On the average, the material tested will rarely exceed 76 mm in diameter. The coarse sand-size fraction is that material between number 4 sieve-size and number 30 sieve-size (0.60 mm). Soil materials in the gravel and coarse sand fractions generally consist of aggregated rock particles, quartz, feldspar, and a variety of anthropogenic materials, including concrete, glass, slag, coal ash/clinkers, and other materials. Case studies of several NPL sites have shown that the amount of radioactive material in the coarse fraction is nearer background levels, and the tendency is for the finer fractions to concentrate the bulk of the radioactivity.[2]

In the examination of the coarse fraction, the petrographer must select the categories of materials that will be reported. In grouping rock types into categories, it is preferred to group the metamorphic and igneous rocks into granitic types in one category and basalt and other mafic rock types in another category. Major sedimentary rock classes may be categorized individually or together depending on the percent representation; if there is less than 10% representation, it is generally advisable to group them together. In a similar manner, the anthropogenic materials should be restricted to as few categories as possible, especially if the radioactivity levels are near background in the size fraction being tested. The radioactivity may exist in discrete minerals, anthropogenic compounds, or as adsorbate on specific particle surfaces; therefore, each variety of contaminant should be reported.

The physical condition and properties of each category of ma[illegible] should be noted on each size fraction. Physical properties reported in the protocol petrographic examination should, as a minimum include particle shape, hardness, degree of weathering, density presence of coatings, number of dense versus porous or friable particles, magnetic versus nonmagnetic particles, and other physical properties that might be applicable to volume reduction considerations. The physical data collected should be formatted into tables such a[illegible] described in ASTM, C-295-85.[3] Only significant data applicable t[illegible] soil washing need be tabulated; however, all physical data collecte[illegible] should be briefly summarized in the test report. If the visu[illegible] examination leaves some materials in question regarding mineral com[illegible] position or identity, a representation portion should be set aside f[illegible] reduction in size by a mortar and pestle or appropriate vessels f[illegible] identification with the polarizing petrographic microscope or by mea[illegible] of x-ray diffraction techniques.

PETROGRAPHIC EXAMINATION OF SAND AND SILT SIZE FRACTIONS

The radioactive soil fractions less than 30 sieve-size (0.60 m[illegible] but coarser than 0.038 mm will generally comprise two or three fra[illegible] tions and should be tested with the optical petrographic microsco[illegible] in conjunction with the stereoscopic microscope. Photomicrograp[illegible] should be taken of significant mineralogical or physical features th[illegible] are applicable to volume reduction considerations.

The materials identified in the sand and silt size will undoubte[illegible] include some of the same materials found in the coarser fractio[illegible] however, most of the material will be disaggregated homogene[illegible] particles or particles unique to that size range. The categories w[illegible] include those of the coarser material and the materials unique to t[illegible] size range. One of the categories will be heavy minerals obtai[illegible] the sink-float method using sodium polytungstate (2.98 speci[illegible] gravity) as the heavy liquid.[1] The heavy mineral category [illegible] important since many of the natural radioactive minerals as well anthropogenic radioactive materials have a density higher than 2.95 and are often found in this fraction. A statistical point count of 150 to 300 particles should be conducted on each fraction tested.

Many physical properties of sand and silt-size fractions are determined by examination with the stereoscopic microscope. It is convenient to move and probe the particles with a steel needle or forceps to check for various properties described in the coarse fraction of the preceding section. Color, particle shape, degree of weathering, presence of coatings, and other properties (e.g., magnetic, as determined by a hand magnet) should be based on a statistical particle count.[7] A summary paragraph in the petrographic report should describe the physical properties and their potential application to volume reduction methods.

The optical petrographic microscope is used to identify all transparent mineral grains by employing optical crystallographic techniques. Examination of mineral grains immersed in index oils under plane polarized light provides refractive indices of mineral grains along their crystallographic axes. In the early exploratory phase, the petrographer will utilize refractive indices measurements and all the techniques that are well documented by Bloss[9] and Kerr.[10] Once this initial investigation phase has been accomplished, the diagnostic optical properties are used for the point count to determine the percentage of each mineral present. In the petrographic examination, photomicrographs should be made at various magnifications to obtain graphic features applicable to physical separation techniques.

After the mineral composition has been documented for the sand and silt-size fractions, correlation should be made with the radiochemical data. If the radioactive contaminants are confined to natural radioactive minerals, the radionuclides should be in secular equilibrium. Secular equilibrium in ore minerals has been cited for thorium contaminated sites, and examples of nonsecular equilibrium have been cited at radium contaminated sites.[2] Any marked deviation from secular equilibrium could indicate anthropogenically enhanced radioactive waste forms in the radioactive soil.

PETROGRAPHIC EXAMINATION OF FINE SILT AND CLAY

X-Ray Diffraction (XRD)

The fine silt (0.002 to 0.038 mm) and clay-size (less than 0.002 mm) material are examined by x-ray diffraction techniques for mineral composition. Unlike the visual or microscopic methods of analysis used for coarser materials, the x-ray diffraction method cannot determine mineral morphology or physical properties. In addition, minor amounts (a few percent) could be easily obscured in the background scatter of the diffractogram. However, with the radionuclide data from coarser size fractions, the radioactive contaminants will be known and a reasonable estimate can likely be made. It is also essential to determine the composition of all materials in the fines since some are likely candidates as adsorbates for radionuclides deposited from solution. The increased surface area of the fines as well as the physico-chemical nature of the various clay minerals are correlative with the degree of adsorption of the various radionuclides. If the radionuclides and the mineral species are known, the degree of adsorption may be predicted from published lists of distribution coefficients.[11]

The fine silt and clay-size fractions are dried onto a glass slide from a well mixed slurry at 60 °C and x-rayed as a randomly oriented powder. The randomly oriented mounts are x-rayed between the angles of 2 to 60 degrees two theta on the diffractometer using copper radiation and a scanning rate of 2 degrees two theta per minute.

The principles of x-ray diffraction are well established and in common use in many laboratories.[12] The areas and intensities of mineral peaks on x-ray diffractograms may vary significantly, especially in the silt-size range, because of variations that occur in sample orientation and thickness, machine conditions, and the influence of peak intensities by other mineral phases. One method for estimating the percentages of silt-size materials is comparison of known mineral assemblages in various proportions.[?] For the clay-size fraction, usually comprised largely of plate-shaped phyllosilicates (layer silicates), the method adapted from Biscaye[?] generally is used. The method calculates weighted peak area percentages for montmorillonite, kaolinite, chlorite, and illite. The peaks and weighing factors used are, (1) the area of the 17 Angstrom (Å) glycolated peak for montmorillonite, (2) four times the 10-Å peak area for illite, and (3) twice the area of the 7-Å peak for the combined total of kaolinite and chlorite. Individual kaolinite and chlorite percents are assigned according to the ratio of the 3.58-Å peak of kaolinite and 3.54-Å peak of chlorite. The weighing factor for montmorillonite, adjusted for the amount of illite layers or chlorite layers present in the crystal structure, is used to calculate the estimates for these mixed-layer montmorillonites. All peak areas are generally computed from the glycolated patterns.

Scanning Electron Microscopy (SEM) and X-Ray Dispersive Spectroscopy (EDX)

Where more quantitative data are required for radioactive materials in the fines, using a scanning electron microscope (SEM) and x-ray dispersive spectroscopy (EDX) on linear density gradient fractions from heavy liquid separations in conjunction with XRD and gamma spectroscopy is effective. Such extensive, time-consuming, and expensive measures are generally warranted only in a Tier II type investigation. This type of investigation has been reported on radium contaminated soils from Montclair and Glen Ridge, New Jersey.[5]

APPLICATION OF PETROGRAPHY TO MIXED WASTES

The petrographic procedure described for radioactive contaminated soil is also applicable to other toxic hazardous wastes, such as heavy metals. Chemical analysis for specific toxic substances of each sieve fraction should be made available to the petrographer and correlated with the petrographic data. The nature of the waste form, such as opaque heavy metal compounds, would require more extensive use of x-ray diffraction on all size fractions to support the microscopic analysis. The use of reflected light microscopy on mineral grains would also be helpful in the identification of opaque minerals. In other respects, the nature of the petrographic examination would be similar in relating physical differences between the toxic contaminant and the host media.

CONCLUSION

The petrographic analysis of soil fractions of radioactive or toxic hazardous waste is important for assessing the feasibility of volume reduction by soil washing or chemical extractions as a remediation technology. The test results of the soil characterization protocol include a grain size distribution curve of weight percent versus particle size, graphic data on activity level versus particle size, and tables and graphs on complete physical and mineralogic descriptions. The petrographic analysis uses all these data in the interpretation of physical differences that lends itself to separation of the radioactive or toxic chemical contaminants from the host materials.

Radiochemical data should be compared with mineralogic data for interpretations, e.g., secular equilibrium of radionuclides to reflect on anthropogenically enhanced radioactive waste forms in the radioactive soil. Any historic data about the ore minerals processed and the chemical processes used to convert the radionuclides or the toxic chemicals to anthropogenic compounds also should be reported. The information may provide forensic data to support the list of radioactive or toxic chemical compounds reported in the Tier I testing.

The Tier I procedure is designed to perform a limited number of tests on several size fractions. The testing is designed for lower cost and a relatively rapid turnaround time of 4 to 6 weeks for completing the tests and reporting the results relating to potentially feasible remedial measures. The Tier II testing is for optimization analysis if the Tier I tests indicate that volume reduction is potentially feasible.

ACKNOWLEDGEMENTS

Appreciation is extended to Dr. Florie Caporuscio, U.S. EPA, Office of Radiation Programs Criteria and Standards Division, Washington, D.C.; Darryl Keith, U.S. EPA, Environmental Research

Laboratory, Narragansett, Rhode Island, Clinton Cox, U.S. EPA National Air and Radiation Environmental Laboratory (NAREL), Montgomery, Alabama; and Dr. William Richardson, Sanford Cohen and Associates, Inc. for critical review of this manuscript.

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AHCCHWKW(5)

COMMERCIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 15:08:12

SAMPLE ID: Typical radium 226 background concentration

SITE NAME & COMMENTS: Typical U.S. soils

RADIONUCLIDE OF CONCERN: Ra226

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	1.2E-08 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: .8 pCi/Gram

COMMERCIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	3.0E-08
VOLATILE RISK =	3.0E-22
PARTICULATES RISK =	6.5E-11
EXTERNAL EXPOSURE RISK =	6.4E-08
TOTAL RISK =	9.4E-08

Risk-based PRELIMINARY REMEDIATION GOAL is 8.6E+00 pCi/Gram

COMMERCIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	250	250
Exposure Duration (yrs)	25	25
Daily Air Inhalation Rate (m^3/day)	20	20
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	.333	.333
*Soil Volatilization Factor (m^3/kg)	9.9E+20	9.9E+20

(* nuclide specific)

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

COMMERCIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 15:11:15

SAMPLE ID: Typical upper limit of Ra226

SITE NAME & COMMENTS: In U.S. soils

RADIONUCLIDE OF CONCERN: Ra226

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	1.2E-08 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: 1.5 pCi/Gram

COMMERCIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	5.6E-08
VOLATILE RISK =	5.7E-22
PARTICULATES RISK =	1.2E-10
EXTERNAL EXPOSURE RISK =	1.2E-07
TOTAL RISK =	1.8E-07

Risk-based PRELIMINARY REMEDIATION GOAL is 8.6E+00 pCi/Gram

COMMERCIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	250	250
Exposure Duration (yrs)	25	25
Daily Air Inhalation Rate (m^3/day)	20	20
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	.333	.333
*Soil Volatilization Factor (m^3/kg)	9.9E+20	9.9E+20

(* nuclide specific)

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

Attachment 5

COMMERCIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 15:12:48

SAMPLE ID: UMTRCA Allowable Limit

SITE NAME & COMMENTS: DOE Mill Tailing Sites

RADIONUCLIDE OF CONCERN: Ra226

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	1.2E-08 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: 5 pCi/Gram

COMMERCIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	1.9E-07
VOLATILE RISK =	1.9E-21
PARTICULATES RISK =	4.0E-10
EXTERNAL EXPOSURE RISK =	4.0E-07
TOTAL RISK =	5.9E-07

Risk-based PRELIMINARY REMEDIATION GOAL is 8.6E+00 pCi/Gram

COMMERCIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	250	250
Exposure Duration (yrs)	25	25
Daily Air Inhalation Rate (m^3/day)	20	20
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	.333	.333
*Soil Volatilization Factor (m^3/kg)	9.9E+20	9.9E+20

(* nuclide specific)

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

COMMERCIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 15:08:49

SAMPLE ID: Typical radium 226 background concentration

SITE NAME & COMMENTS: Typical U.S. soils

RADIONUCLIDE OF CONCERN: Ra226D

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	6.0E-06 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: .8 pCi/Gram

COMMERCIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	3.0E-08
VOLATILE RISK =	3.0E-22
PARTICULATES RISK =	6.5E-11
EXTERNAL EXPOSURE RISK =	3.2E-05
TOTAL RISK =	3.2E-05

Risk-based PRELIMINARY REMEDIATION GOAL is 2.5E-02 pCi/Gram

COMMERCIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	250	250
Exposure Duration (yrs)	25	25
Daily Air Inhalation Rate (m^3/day)	20	20
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	.333	.333
*Soil Volatilization Factor (m^3/kg)	9.9E+20	9.9E+20

(* nuclide specific)

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

COMMERCIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 15:11:45

SAMPLE ID: Typical upper limit of Ra226

SITE NAME & COMMENTS: In U.S. soils

RADIONUCLIDE OF CONCERN: Ra226D

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	6.0E-06 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: 1.5 pCi/Gram

COMMERCIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	5.6E-08
VOLATILE RISK =	5.7E-22
PARTICULATES RISK =	1.2E-10
EXTERNAL EXPOSURE RISK =	6.0E-05
TOTAL RISK =	6.0E-05

Risk-based PRELIMINARY REMEDIATION GOAL is 2.5E-02 pCi/Gram

COMMERCIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	250	250
Exposure Duration (yrs)	25	25
Daily Air Inhalation Rate (m^3/day)	20	20
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	.333	.333
*Soil Volatilization Factor (m^3/kg)	9.9E+20	9.9E+20

(* nuclide specific)

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

COMMERCIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 15:13:15

SAMPLE ID: UMTRCA Allowable Limit

SITE NAME & COMMENTS: DOE Mill Tailing Sites

RADIONUCLIDE OF CONCERN: Ra226D

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	6.0E-06 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: 5 pCi/Gram

COMMERCIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	1.9E-07
VOLATILE RISK =	1.9E-21
PARTICULATES RISK =	4.0E-10
EXTERNAL EXPOSURE RISK =	2.0E-04
TOTAL RISK =	2.0E-04

Risk-based PRELIMINARY REMEDIATION GOAL is 2.5E-02 pCi/Gram

COMMERCIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	250	250
Exposure Duration (yrs)	25	25
Daily Air Inhalation Rate (m^3/day)	20	20
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	.333	.333
*Soil Volatilization Factor (m^3/kg)	9.9E+20	9.9E+20

(* nuclide specific)

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

RESIDENTIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 15:15:29

SAMPLE ID: Typical radium concentration

SITE NAME & COMMENTS: In US soils

RADIONUCLIDE OF CONCERN: Ra226

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	1.2E-08 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: .8 pCi/Gram

RESIDENTIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	1.2E-07
VOLATILE RISK =	3.8E-22
PARTICULATES RISK =	8.2E-11
EXTERNAL EXPOSURE RISK =	2.3E-07
TOTAL RISK =	3.5E-07

Risk-based PRELIMINARY REMEDIATION GOAL is 2.3E+00 pCi/Gram

RESIDENTIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	350	350
Exposure Duration (yrs)	30	30
Daily Air Inhalation Rate (m^3/day)	15	15
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	1.0	1
Soil Volatilization Factor (m^3/kg) (nuclide specific)	9.9E+20	9.9E+20
Age-Adjusted Soil Ingestion Factor (mg-yr/day)	3600	3600

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

RESIDENTIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 18:07:43

SAMPLE ID: Typical upper limit of Ra226

SITE NAME & COMMENTS: In U.S. soil

RADIONUCLIDE OF CONCERN: Ra226

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	1.2E-08 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: 1.5 pCi/Gram

RESIDENTIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	2.3E-07
VOLATILE RISK =	7.2E-22
PARTICULATES RISK =	1.5E-10
EXTERNAL EXPOSURE RISK =	4.3E-07
TOTAL RISK =	6.6E-07

Risk-based PRELIMINARY REMEDIATION GOAL is 2.3E+00 pCi/Gram

RESIDENTIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	350	350
Exposure Duration (yrs)	30	30
Daily Air Inhalation Rate (m^3/day)	15	15
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	1.0	1
Soil Volatilization Factor (m^3/kg) (nuclide specific)	9.9E+20	9.9E+20
Age-Adjusted Soil Ingestion Factor (mg-yr/day)	3600	3600

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

RESIDENTIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 17:59:41

SAMPLE ID: UMTRCA Allowable Upper Limit

SITE NAME & COMMENTS: DOE Mill Tailing Sites

RADIONUCLIDE OF CONCERN: Ra226

INGESTION SLOPE FACTOR = 1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR = 3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR = 1.2E-08 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: 5 pCi/Gram

RESIDENTIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK = 7.6E-07
VOLATILE RISK = 2.4E-21
PARTICULATES RISK = 5.1E-10
EXTERNAL EXPOSURE RISK = 1.4E-06

TOTAL RISK = 2.2E-06

Risk-based PRELIMINARY REMEDIATION GOAL is 2.3E+00 pCi/Gram

RESIDENTIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	350	350
Exposure Duration (yrs)	30	30
Daily Air Inhalation Rate (m^3/day)	15	15
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	1.0	1
Soil Volatilization Factor (m^3/kg) (nuclide specific)	9.9E+20	9.9E+20
Age-Adjusted Soil Ingestion Factor (mg-yr/day)	3600	3600

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

RESIDENTIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 15:15:45

SAMPLE ID: Typical radium concentration

SITE NAME & COMMENTS: In US soils

RADIONUCLIDE OF CONCERN: Ra226D

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	6.0E-06 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: .8 pCi/Gram

RESIDENTIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	1.2E-07
VOLATILE RISK =	3.8E-22
PARTICULATES RISK =	8.2E-11
EXTERNAL EXPOSURE RISK =	1.2E-04
TOTAL RISK =	1.2E-04

Risk-based PRELIMINARY REMEDIATION GOAL is 6.9E-03 pCi/Gram

RESIDENTIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	350	350
Exposure Duration (yrs)	30	30
Daily Air Inhalation Rate (m^3/day)	15	15
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	1.0	1
Soil Volatilization Factor (m^3/kg) (nuclide specific)	9.9E+20	9.9E+20
Age-Adjusted Soil Ingestion Factor (mg-yr/day)	3600	3600

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

RESIDENTIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 18:08:04

SAMPLE ID: Typical upper limit of Ra226

SITE NAME & COMMENTS: In U.S. soil

RADIONUCLIDE OF CONCERN: Ra226D

INGESTION SLOPE FACTOR	=	1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR	=	3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR	=	6.0E-06 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: 1.5 pCi/Gram

RESIDENTIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK =	2.3E-07
VOLATILE RISK =	7.2E-22
PARTICULATES RISK =	1.5E-10
EXTERNAL EXPOSURE RISK =	2.2E-04
TOTAL RISK =	2.2E-04

Risk-based PRELIMINARY REMEDIATION GOAL is 6.9E-03 pCi/Gram

RESIDENTIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	350	350
Exposure Duration (yrs)	30	30
Daily Air Inhalation Rate (m^3/day)	15	15
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	1.0	1
Soil Volatilization Factor (m^3/kg) (nuclide specific)	9.9E+20	9.9E+20
Age-Adjusted Soil Ingestion Factor (mg-yr/day)	3600	3600

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.

RESIDENTIAL SOIL
RADIONUCLIDE RISK ASSESSMENT
Performed by Steve M. Dean

08-27-1993 18:00:04

SAMPLE ID: UMTRCA Allowable Upper Limit

SITE NAME & COMMENTS: DOE Mill Tailing Sites

RADIONUCLIDE OF CONCERN: Ra226D

INGESTION SLOPE FACTOR = 1.2E-10 Risk/pCi
INHALATION SLOPE FACTOR = 3.0E-09 Risk/pCi
EXTERNAL EXPOSURE SLOPE FACTOR = 6.0E-06 Risk/yr per pCi/Gram

RADIONUCLIDE CONCENTRATION: 5 pCi/Gram

RESIDENTIAL SOIL Risk Assessment with DEFAULT SCENARIO FACTORS

INGESTION RISK = 7.6E-07
VOLATILE RISK = 2.4E-21
PARTICULATES RISK = 5.1E-10
EXTERNAL EXPOSURE RISK = 7.2E-04

TOTAL RISK = 7.2E-04

Risk-based PRELIMINARY REMEDIATION GOAL is 6.9E-03 pCi/Gram

RESIDENTIAL SOIL SCENARIO FACTORS	DEFAULT	SELECTED
Exposure Frequency (days/year)	350	350
Exposure Duration (yrs)	30	30
Daily Air Inhalation Rate (m^3/day)	15	15
Daily Soil Ingestion Rate (mg/day)	50	50
Particulate Emmission Factor (m^3/kg)	4.63E09	4.63E+09
Gamma Shielding Factor (unitless)	0.2	.2
Gamma Exposure Time Factor (unitless)	1.0	1
Soil Volatilization Factor (m^3/kg) (nuclide specific)	9.9E+20	9.9E+20
Age-Adjusted Soil Ingestion Factor (mg-yr/day)	3600	3600

This program calculates risk assessment based on 'Risk Assessment Guidance For Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Remediation Goals)': Interim Final, OERR Washington DC, EPA/540/R-92/003, December 1991.

Slope factors used for the pathway risk calculations are taken from Health Effects Assessment Summary Tables (HEAST): Annual Update, FY 1992, OERR 9200.6-303 (92-1), March 1992.