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Mr. Gary Comfort
US Nuclear Regulatory Commission
Mail Stop T-8D16
Washington, D.C. 20555

April 20, 1995

RE: Revised Document "Radiological Impacts from the use of CANAL © - A Slag Fluidizer in Steel Production"

Dear Mr. Comfort:

Enclosed herewith please find, per your request, four copies of the above referenced document for your use and to be forwarded to the appropriate individuals within the NRC. If you have any questions or require additional information, please let me know.

Sincerely,

C. Scott

C. Scott Eves

CSE;dmg

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RADIOLOGICAL IMPACTS FROM THE USE OF CANAL© - A SLAG FLUIDIZER IN STEEL PRODUCTION

Submitted to:

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INTRODUCTION

Shieldalloy Metallurgical Corporation (SMC) operates a facility located in Newfield, New Jersey. This facility manufactures or has manufactured specialty steel and super alloy additives, primary aluminum master alloys, metal carbides, powdered metals, and optical surfacing products. Raw materials currently used at the facility include beneficiated ores which contain oxides of columbium (niobium), vanadium, aluminum metal, titanium metal, strontium metal, zirconium metal, and fluoride (titanium and boron) salts. During the manufacturing process, the facility generates a variety of by-products that have commercial application.

One by-product that has had a successful commercial market over the last several years is a ferrovandium slag, known by the trade name of V-40©. Because of its aluminum and calcium content, this material serves as an additive to the steel making process for reducing impurities in the final product.

Another by-product contains similar constituents but has improved applicability for steel manufacturing. This product, known commercially as CANAL©, is produced from ferrocolumbium slag rather than ferrovanadium slag. One of the differences between V-40© and CANAL© is that the latter contains a greater percentage of aluminum oxide, which makes it more effective as a slag fluidizer. CANAL© also contains a higher concentration of uranium and thorium than V-40©, although these elements have no effect on the performance of the product. However, because higher concentrations of these elements are present, the market for CANAL© in the United States, which requires the purchaser/recipient to be licensed by the U. S. Nuclear Regulatory Commission, is virtually non-existent.[1] However, a number of foreign countries do not require specific licensing of these low concentrations of radioactive materials, and different companies within these countries have expressed an interest in purchasing CANAL© to enhance

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[1] Pursuant to Title 10, Code of Federal Regulations, Part 40, materials containing greater than 0.05% of uranium and thorium by weight require specific licensing as "source material". This regulation was promulgated for reasons of non-proliferation rather than for reasons of public health and safety.

their own steel production.[2] While no specific licensing or special permits are necessary for these countries to import CANAL©, a question has been raised as to the potential health and safety impacts associated with its use.

This report was written to address potential radiological impacts associated with the sale of CANAL© for steel production, with emphasis on potential radiation doses to steel workers and members of the general public in the importing country. It contains a description of CANAL© and how it is produced, an assessment of its radiological constituents at various stages in the process, a description of likely exposure scenarios and hypothetical radiation doses from the use of CANAL© from initial receipt to end product usage, and a comparison of those hypothetical doses to those incurred by people from normal background radiation exposure. The findings in this report demonstrate that the use of CANAL© in steel manufacturing poses negligible radiological health and safety risks for workers or the public in the importing countries.

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[2] The International Atomic Energy Agency proposed recommendation for naturally-occurring radioactivity apply to solids with a total specific activity of less than 14,000 pCi/g. Lesser activities are considered to be "below concern".

DESCRIPTION OF CANAL© AND ITS USE IN STEEL PRODUCTION

Naturally-occurring Radioactivity in Ores, Product, By-Product and Wastes

Because radioactive material occurs naturally throughout the earth's crust, any mineral extraction operation or process, not just those commonly perceived to be processing radioactive materials, is a candidate for technologically-enhanced radiation exposures of workers and members of the general public. The naturally-occurring radioactivity of interest in the mineral extraction industry is associated, primarily, with the ^{238}U (uranium) and ^{232}Th (thorium) radioactive decay series. Table 1 contains a listing of naturally-occurring radioactivity related to mineral resources.

The abundance of uranium and thorium varies widely over geographic areas. Igneous and sedimentary rocks on average contain concentrations on the order of 0.5 to 5 mg per kg (conventionally) of ^{238}U and two to 20 mg per kg of ^{232}Th. These correspond to radionuclide concentrations of about 0.2 to 1.6 pCi/gram of ^{238}U and 0.2 to 2.2 pCi/g of ^{232}Th. In the absence of chemical or physical separation processes, an equilibrium is reached in which the number of atoms of each radionuclide in the series that decays during a specific time interval nearly equals the number of decays of the parent radionuclide. Therefore, the activity of each member of the series should be equal to the activity of its parent.

However, chemical and physical separation of parents and daughters are common due to mechanical influences and the effects of water movement through the rock. These processes typically lead to the relative depletion of some radionuclides in the series from certain rocks and soils, and the relative concentration of others. While these concentration and depletion processes create the potential for economical extraction of some minerals, they also result in widely varying radionuclide concentrations over ore types and locations.

In the mining, milling, and extraction process, a mineral of interest, which is found to be in relatively high concentration in a particular ore body, is extracted (e.g., aluminum is extracted from certain types of bauxitic limestone). This process can further alter the distribution of naturally-occurring radioactivity from that found in the original ore.

Radioactive Materials in Ferrocolumbium Slag

SMC currently holds U. S. Nuclear Regulatory Commission (USNRC) License No. SMB-743 which permits possession, use, and storage of source material in the form of pyrochlore ore for the production of ferrocolumbium and its by-products. Ferrocolumbium is produced by a modified electric arc and aluminothermic reduction of the pyrochlore ores and contains calcium, aluminum, uranium, thorium, and other trace constituents. The uranium and thorium, which are approximately 0.5% by weight of both the feed material and the slag, are naturally-occurring radioactive elements. Consequently, a USNRC license pursuant to 10 CFR 40 is required. The average radionuclide concentrations in ferrocolumbium slag are approximately 300 pCi/g each of thorium and of uranium.[3] However, in order to interject a measure of conservatism into the findings of this report, concentrations of 500 pCi/g of thorium and 400 pCi/g of uranium are assumed.

Radioactive Materials in CANAL©

SMC produces CANAL© by crushing, sizing and packaging ferrocolumbium slag in 1,500 pound bags, called "supersacks". This process does not modify the type and quantity of radiological constituents in the product. However, when CANAL© is used as a slag fluidizer or conditioner in steel production, the radionuclide concentrations in the slag produced at the back end of the steel manufacturing process are reduced to less than one-third of the original concentration (150 pCi/g of thorium and 100 pCi/g of uranium).[4]

Because of its local commercial value, the newly-produced slag is not likely to be stored on-site at the steel plant. Instead, it likely to be crushed, and sold, with approximately 80% used as aggregate for construction purposes (road beds, jettys).[5] It is anticipated that up to four percent of all slag produced by the steel plant will be from production runs using CANAL©. However,

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[3] EcoTek Laboratory Services Incorporated, Certificates of Analyses and data package from a slag sampling and analysis program, September 22, 1994, demonstrates a mean radionuclide concentration from ten samples of ferrocolumbium slag of 381 pCi/g of ^{232}Th, 367 pCi/g of ^{238}U, and 16 pCi/g of ^{235}U.

[4] None of the radioactive constituents remain in the steel.

[5] The remaining 20% is diluted further and used as an additive to the cement manufacturing process.

none of the slag types are segregated. Therefore, it can be assumed that aggregate sold by the steel plant will contain a mixture of CANAL© and other newly-produced slag, with an average radioactivity concentration of 6 pCi/g of thorium and 4 pCi/g of uranium.

HYPOTHETICAL EXPOSURE ISSUES

Characteristics Related to Radiation Dose

The potential radiation dose that workers or the general public may incur from exposure to radioactive materials is influenced by a number of factors. These include the amount of radioactivity involved, the types of radiation emitted by the material, the chemical and physical form of the material, the solubility of the material, the particle size distribution, the duration of the exposure, the inhalation pathways (including both airborne material and resuspended material), the ingestion pathways involving contaminated water, food stuffs and animal feeds, and the demographic and physiological characteristics of the population exposed.

With respect to CANAL©, workers at the steel plant may be exposed to low-levels of ambient gamma radiation during handling of the material upon delivery and with usage. In addition, a worker may be exposed to airborne radioactivity in the event that a container (supersack) of CANAL© is dropped and breaks open from the force of the fall.

Exposure of the general public may occur from end-use slag that is sold as aggregate. Possible exposure pathways under these circumstances are ingestion of slag by children, external exposure of individuals in the immediate vicinity of the aggregate when used as a gravel road or as bedding for a paved road, and the exposure pathways typically associated with the "agricultural farm family" scenario from homes constructed over soils in which slag may have been used as fill.

The hypothetical radiation doses to both workers and members of the general public from these exposure scenarios were determined. The intent of this effort was to establish a conservative exposure scenario (i.e., well above the average case) that is still within the range of possibility. Whenever possible, assumptions to complete the dose assessment were selected conservatively such that the maximum reasonable dose would result. The following is a description of the approach and the assumptions used.

Exposure of Mill Workers That Handle CANAL© in Supersacks During Steel Production

Evaluation of the ambient radiation exposure of workers who may be in the vicinity of CANAL© (forklift operators) requires knowledge of the exposure rate in the location of interest, along with the likely duration of the exposure. The following is the calculation methodology used:

$$DE = E_R \times t$$

where DE = the dose equivalent (rem) incurred by workers, E_R = the exposure rate (rem per hour), and t = the exposure duration (hours). The following are the assumptions used for this analysis:

- The CANAL© is contained in supersacks with dimensions of 2.5 ft x 2.5 ft x 2.5 ft.
- Supersacks are transported by forklift, with an operator located three (3) feet from the supersack, and no shielding exists between the operator and the supersack.
- One supersack is added to each heat, and the operator participates in four heats per shift, for a total of 1,000 heats per operator.
- The worker spends eight hours per day, one day per month unloading delivered CANAL© supersacks. In addition, the same worker spends 10 minutes staging a supersack for each production run. Consequently, the exposure duration (t) for this worker is 263 hours per year.
- The radionuclide concentrations in CANAL© are 500 pCi/g of thorium-232 and 400 pCi/g of uranium-238.
- The exposure rate is 200 microR per hour at a distance of one meter from the surface of the supersacks.[6]

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[6] The measured exposure rate one meter from two supersacks of CANAL© is approximately 200 microR per hour (Personal communication from C. R. Rieman, Safety and Ecology Consultants, Inc. to C. D. Berger, Integrated Environmental Management, Inc., April 12, 1995). The exposure rate one meter from the surface of a single supersack is estimated to be 123 microR per hour using the Microshield 4.10 code (Grove Engineering, Inc. Microshield 4.10, dated October, 1993.) To ensure an element of conservatism in the analysis, the measured value of 200 microR per hour was used.

From this exposure scenario, the maximum possible dose to a single hypothetical steel worker who performs all tasks is 53 millirem per year. If the functions are spread out among a number of workers, individual doses will be much lower.

Exposure of Mill Workers from Re-suspended Airborne Radioactivity from a Ruptured Supersack

To estimate the exposure that may be incurred by workers from radioactivity that becomes re-suspended from the CANAL© requires knowledge of the amount of material that may be re-suspended, the radionuclide concentration of the re-suspended material, the breathing rate of the worker while in the vicinity of the slag pile, and the duration of the worker's exposure. These doses are determined by first estimating the magnitude of intake of material by:

$$I_S = E \times V_m \times C_S$$

where I_S = the number of grams of re-suspended material inhaled, E = the Exposure Duration, V_m = the minute volume of air breathed, and C_S = the airborne concentration of soil. For this analysis, the following parameters are assumed:

- A continuous airborne concentration (C_s) of 200 micrograms of soil per cubic meter of air is representative of the conditions on the surface of the CANAL© pile for any action being performed. This value is the maximum dust loading noted for dusty occupations.[7]
- The workers' respiratory rate (V_m) is equal to that of an adult male performing light work for a minute volume of 20 liters per minute, or 1.2 m^3 per hour.[8]
- The worker moving CANAL© by forklift is exposed to airborne dust from a dropped supersack for five (5) minutes. The worker is also exposed to airborne dust for 55 minutes during clean-up operations. Therefore, the exposure duration, (E), is a total of one (1) hour.

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[7] National Council on Radiation Protection and Measurements, Report No. 91, "Recommendations on Limits for Exposure to Ionizing Radiation", June 1, 1987.

[8] International Commission on Radiological Protection, Report No. 23, "Reference Man", 1974.

- The radionuclide concentrations in CANAL© are 500 pCi/g of thorium-232 and 400 pCi/g of uranium-238.

From the estimated intake of re-suspended material, the reasonable maximum intake of radioactive materials is estimated by the following:

$$I_R = I_S \times C_R$$

where I_R = the intake of ^{238}U (and daughters) or ^{232}Th (and daughters), I_s = the number of grams of material inhaled, and C_R = the concentration of radioactivity in the re-suspended slag. For this analysis, C_R is assumed to be equal to radionuclide concentrations in CANAL©, shown above.

The U. S. Environmental Protection Agency (USEPA)[9] provides a series of factors to convert annual intake of radioactive materials into committed effective radiation dose equivalent (CEDE). These factors are based upon contemporary metabolic modeling and dosimetric methods. Using the USEPA methodology, the maximum committed radiation dose equivalent which may be incurred by workers as a result of inhalation of suspended CANAL© is estimated by:

$$CEDE = I_R \times DCF$$

where CEDE = the committed effective dose equivalent[10] incurred by the workers, and DCF = the dose conversion factor for inhalation of the various radionuclides. The maximum possible dose to steel workers by this pathway is 0.02 millirem per event.

Exposure of Members of the General Public from Homes Built on Slag as Fill

The dose rate for members of the public that could be exposed to radioactivity from slag used as fill under the foundation under their homes is estimated in the following manner:

- The slag produced from steel-making operations makes up 25% of the soil mass at the base of the home.

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[9] U. S. Environmental Protection Agency, "Federal Guidance Report Number 11", 1988.

[10] The CEDE is the dose equivalent weighted over all body organs for an irradiation period of 50 years.

- The home has a 0.15 m thick, above-grade foundation.
- The average radionuclide concentrations in the slag are 6 pCi/g of thorium-232 and 4 pCi/g of uranium-238.
- The average radionuclide concentrations in the soil are 1.5 pCi/g of thorium-232 and daughters (in equilibrium) and 0.6 pCi/g of uranium-238 and daughters (in equilibrium).
- The slag layer is 0.3 meters thick, with a density of 2.4 g/cm^3.
- The exposure pathways are direct (ambient) exposure and radon inhalation.
- The radon emanation coefficient from the soil is 0.25 for radon-222 and 0.15 for radon-220.
- An individual spends 50% of their 70-year lifetime in the home.

The dose rate to this hypothetical individual was calculated using the RESRAD computer code (Version 5.01).[11] The maximum possible dose from this exposure scenario is eight (8) millirem per year.

Exposure of a Child that Ingests Slag Used as a Soil Amendment or Conditioner

The dose rate from ingestion of slag mixed in soil is determined by multiplying the estimated rate of intake of the material by an appropriate Dose Conversion Factor (DCF). For this assessment, the following assumptions were used:

- Slag makes up 25% of the soil's mass, since it is assumed to be used as a soil conditioner.
- The radionuclide concentrations in the soil are 1.5 pCi/g of thorium-232 and 0.6 pCi/g of uranium-238.

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[11] Argonne National Laboratory Technical Report, Gilbert, T. L., et al, "A Manual for Implementing Residual Radioactive Material Guidelines", ANL/ES-160, June, 1989

- The soil ingestion rate is assumed to be 200 milligrams per day for a child under six and 100 milligrams per day for older children and adults.[12]

- For the DCFs, the Environmental Protection Agency, in Federal Guidance Report No. 11,[13] provides a series of factors to convert intake of radioactive materials into radiation dose.[14]

The maximum possible dose from this exposure scenario is one (1) millirem per year.

Exposure of a Member of the General Public Standing on a Paved Road

In this scenario, a police department official or a parking lot attendant stands on a road constructed with slag as the road bed. The slag would contain less uranium and thorium than the CANAL© slag due to successive dilutions. For the purposes of this report, the following is assumed:

- The individual spends eight hours per day (a total of 2,000 hours per year) standing on a road where slag is used as a sub-base.

- The sub-base is covered with one foot of concrete paving.

- The radionuclide concentrations in the sub-base is 6 pCi/g of thorium-232 and 4 pCi/g of uranium-238.

- The exposure rate on the road at a height of one meter above the paved road is 0.4 microR per hour, which was calculated using the Microshield code, Version 4.10.

The maximum possible dose from this scenario is one (1) millirem per year.

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[12] Defined in EPA's Supplemental Guidance on Standard Default Exposure Factors for infant, child/teen, and adult populations, 1991.

[13] U. S. Environmental Protection Agency, "Federal Guidance Report Number 11", 1988.

[14] These factors are based upon contemporary metabolic modeling and dosimetric methods.

Exposure of a Member of the General Public Standing on a Gravel Road

If the end-use slag is used to make gravel roads (without pavement), there are two possible exposure scenarios. The first is to road crews laying out a road. The second is to members of the general public who walk on the road. The following are the assumptions for these dose assessments:

- The road crew spends a total of 40 hours per week, one week per month, 12 months per year standing on the road.
- A member of the general public (pedestrian) walks on the road two hours per day, seven days per week, 52 weeks per year.
- The road bed is made up of six inches of gravel.
- The radionuclide concentrations in the road are 6 pCi/g of thorium-232 and daughters (in equilibrium) and 4 pCi/g of uranium-238 and daughters (in equilibrium).
- The exposure rate on the road at a height of one meter above the road is 14 microR per hour, which was calculated using the Microshield code, Version 4.10.

The maximum possible dose to the pedestrian and the road crew is 10 millirem and seven (7) millirem per year, respectively.

COMPARISON WITH BACKGROUND RADIATION DOSES

From the previous section, the maximally-exposed individual has the potential to incur up to 32 millirem per year as a result of loading and unloading supersacks of CANAL© for steel-making operations. All other exposure scenarios resulted in lower potential exposures.

To put this value into perspective, it is important to note that everyone in the world is exposed to radiation at all times from natural radiation sources. This is called "natural background radiation". The sources of background radiation include "cosmic" radiation, which is radiation from the solar system and outer space; "terrestrial" radiation, which is radiation from the radioactive elements found in soil; "airborne" radiation primarily from household radon; "internal" radiation from natural sources of radiation found in foodstuffs and the human body itself; and radiation from consumer products, such as emissions from coal-fired plants, smoke detectors, television sets, tobacco products, and a wide variety of other items. In addition to natural background, humans are also exposed to radiation from medical and dental x-rays and nuclear medicine studies.

The National Council on Radiation Protection and Measurements gives some examples of common radiation exposures.[15] [16] [17] Members of the general population receive, on average the following radiation exposures:

1300 millirem per year for the average cigarette smoker
650 millirem per nuclear medicine examination of the brain
110 millirem per computerized tomography of the head and body
7.5 millirem per year to spouses of recipients of certain cardiac pacemakers

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[15] National Council on Radiation Protection and Measurements, Report No. 93, "Ionizing Radiation Exposure of the Population of the Untied States", 1987.

[16] National Council on Radiation Protection and Measurements, Report No. 95, "Radiation Exposure of the U. S. Population from Consumer Products and Miscellaneous Sources", 1987.

[17] National Council on Radiation Protection and Measurements, Report No. 100, "Exposure of the U. S. Population from Occupational Radiation", 1989.

18 millirem per year from the potassium in our bodies
6 millirem per dental x-ray
6 millirem per year from the use of phosphogypsum in houses
5 millirem per year from foods grown on lands in which phosphate fertilizers are used.
4 millirem per year from highway and road construction materials
1.5 millirem from each 3,000 miles flown in an airplane
1 to 6 millirem per year from domestic water supplies
1 millirem per year from television receivers
0.8 millirem per year from the use of coal for home heating
0.5 millirem from eating one-half pound of Brazil nuts

Background radiation is unavoidable and its magnitude varies from one location on earth to another, depending on elevation, soil conditions, and other factors. For instance, the average person living in Dallas, Texas receives a dose of 80 millirem per year due to "cosmic" and "terrestrial" radiation only, while the average person living in Denver, Colorado receives 180 millirem per year from the same two sources. The difference of 100 millirem between the two locations is primarily due to Denver's higher elevation. In certain areas of India and Brazil, the residents receive over 1,000 millirem per year from "terrestrial" radiation alone, however these residents show no abnormal increase in cancer rates, birth defects, or genetic problems.

When all of the general sources of background radiation are considered, the average human being typically receives between 150 and 600 millirem per year, exclusive of medical exposures.[18] The highest maximum reasonable dose calculated for any of the individuals addressed herein (32 millirem per year for the steel worker staging supersacks of CANAL©) is over 10 times less than the dose associated with typical background radiation exposures received by average members of the general population.

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[18] United Nations Scientific Committee on the Effects of Atomic Radiation, "Sources, Effects and Risks of Ionizing Radiation", 1988 Report to the General Assembly, 1988.

SUMMARY AND CONCLUSIONS

Shieldalloy Metallurgical Corporation (SMC) has purchase orders for sale of CANAL© to steel manufacturing firms in various countries for use as an additive (fluidizer) in steel-making. Because CANAL© contains low concentrations of uranium and thorium, a pathways analysis and dose assessment was performed to assure that the radiological impact on workers at the steel plant and on members of the general population will be negligible. The following are the results of these analyses:

Exposure Scenarios	**Maximum Individual Dose (mrem/year)**
Direct Exposure of a Steel Worker	53
Inhalation Exposure of a Steel Worker per Dropped Supersack	0.02
Exposure of a Member of the General Public from Homes Built on Slag	8
Exposure of a Child that Ingests Slag	1
Exposure of a Member of the General Public Standing on Paved Roads Over Slag	1
Exposure of a Road Crew Member Constructing Slag Road	7
Exposure of a Member of the General Public Walking on Roads Constructed of Slag	10
Recommended Dose Limit (above background) to Individual Members of the General Public by the International Commission on Radiological Protection	100
Exposure of a Member of the General Public from Normal Background Radiation (Excluding Medical Exposures)	240

This table shows that, indeed, the maximum possible radiation dose to workers or end users is inconsequential when compared to the radiation doses incurred by these individuals every day by virtue of being alive. It is important to note, however, that these estimates reflect the maximum exposure *potential* for the groups of interest. There is no evidence that any radiation dose in excess of background will occur as a result of their proximity to CANAL© or its end use product. Furthermore, even after application of generous assumptions, the radiological conditions that may result from the use of CANAL© in steel manufacturing will not result in demonstrable adverse health effects.

TABLES

Table 1 - Naturally Occurring Radioactivity Related to Mineral Resources[19]

Mineral	Mineral or Waste Radioactivity
Aluminum	7 pCi U/gram of ore 3-11 pCi Ra per gram (bauxitic limestone, soil) 1-4 pCi Th per gram (bauxitic limestone, soil) 1-27 pCi Ra per gram (tailings)
Copper	1 - 2700 pCi U per gram ore 0.5 - 3 pCi Th per gram ore
Fluorspar	110 pCi Ra per gram (tailings
Monazite	160-540 pCi U per gram sands Thorium series (4% by weight)
Natural gas	55 - 460,000 pCi Rn/m^3 (gas, average) 10 - 1,460,000 pCi Rn/m^3 (gas, individual 3 - 1,400 pCi ^{210}Pb, ^{210}Po per gram (scale, residue in pumps, vessels and residual gas pipelines)
Oil	Ranging from 1 - 3,000 pCi per liter (brines or produced water) Ranging up to 2,000 pCi per gram (sludges) Ranging up to 100,000 pCi per gram (scales)
Phosphate	3 - 110 pCi U natural per gram ore 0.4 - 4 pCi Th natural per gram ore 15 - 80 pCi Ra per gram ore
Tin	30 - 55 pCi Ra per gram (ore and slag)
Titanium	1 - 20 pCi U per gram ore 1 - 20 pCi Th per gram ore
Uranium	400 pCi Ra per gram (ore) 2700 pCi Ra per gram (slimes) 270-540 pCi Ra per gram (tailings)
Zirconium	110 pCi U per gram sands 16 pCi Th per gram sands 100 - 200 pCi Ra per gram sands

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[19] National Council on Radiation Protection and Measurements, NCRP Report No. 118, "Radiation Protection in the Mineral Extraction Industry", November 30, 1993.

This report was prepared under the direction of
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