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

APR 15 2003

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: Guidance -- Potential for Radiation Contamination Associated With Mineral and Resource Extraction Industries

FROM: Frank Marcinowski, Director
Radiation Protection Division

TO: Regional Radiation Contacts
Regional Superfund Staff (See Addressees)
National Hard Rock Mining Staff (See Addressees)
On-Scene Coordinators (See Addressees)

Summary: This guidance informs Environmental Protection Agency (EPA) personnel of the potential for radioactive contamination associated with a list of specific minerals and certain resource extraction, processing, or manufacturing industries. Some radioactivity may be associated with almost all minerals, rocks, ores, and water. However, the industries which extract or handle the minerals listed in the guidance, or industries which utilize large quantities of water containing naturally occurring radionuclides, have an increased likelihood of radioactive concentration at their facilities, within their wastes, or even in their products. Increased radiation may be found and could present a potential health and environmental hazard at sites where the listed minerals or materials occur, or are processed and stored. This advisory includes ores and materials that may be obtained nationally, or are imported, and sites which are operating, on standby, or have been closed, or abandoned. The identification of listed minerals and materials at an inspection or investigation site under the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), the Clean Water Act (CWA), the Safe Drinking Water Act (SDWA), the Clean Air Act(CAA), or the Toxic Substances Control Act (TSCA) authority should serve as cause for EPA personnel to contact EPA regional radiation staff to help implement radiation safety measures, and conduct radiation surveys as appropriate.

Purpose

This guidance provides information to inspectors, geological, engineering, or environmental specialists in EPA to determine which extraction, processing, and or manufacturing operations have radionuclides in wastes, ores, or products. The presence at a site of a mineral or material named in the lists in this document (See Appendices 3 and 4) does not imply that a site is radioactively contaminated, but instead should be considered as an advisory that radiation may be present, and should be considered as a potential environmental hazard similar to the occurrence of heavy metals or acid mine drainage. Documents identified in the Reference section can provide basic information on related radiation topics.

Potential Elevated TENORM Concentrations

Radioactive contaminants at mines or mineral processing/manufacturing facilities are often overlooked in site assessments, inspections, site investigations, environmental impact statements, or site cleanups. Such omissions may occur because the radioactivity is unexpected or because the principal mineral(s) being mined or processed were not suspected to be radioactive. However, the geological emplacement or geothermal phenomena which formed other valuable minerals may have also concentrated radioactive minerals as well, or the process of mining, beneficiation, and milling may have resulted in a concentration of the radioactive minerals in the waste. In some instances, the mineral(s) being mined may have radioactive elements included in their molecular structure which imparts radioactivity to the ore or even the finished product.

Appendix 3 of this document provides a listing of specific minerals and certain resource extraction, processing, or manufacturing industries with the potential for radioactive contamination. Appendix 4 provides an alphabetized check list of the minerals and ores, only, which are known to be radioactive, or have the potential for radioactive contamination.

Material containing radionuclides that are present naturally in soil, rocks, water and minerals and whose radioactivity has been concentrated and/or exposed to the accessible environment as a result of human activities is referred to as Technologically Enhanced Naturally Occurring Radioactive Materials, or TENORM.

In many cases, the radioactive elements may be mobilized, or leached, from the waste or ore by normal environmental processes. Uranium is particularly soluble in acidic waters that would typically be associated with acid mine drainage, but it can also be mobilized in basic

solutions. While radium is generally not soluble except in the presence of certain ionic solutions (e.g., barium), it can be swept along in water or wind to deposit in locations far from its source. Radioactive lead, a long-lived natural decay product of uranium, radium, and thorium, can be found in water and soils and has a low maximum contaminant limit for its presence in drinking water.

Process operations (e.g., acid or solvent extraction, electro winning circuit unit operations, and furnace heating) first leach, then concentrate the radioactive materials in the product and waste streams. Industrial facilities which utilize large quantities of water may also inadvertently concentrate the naturally occurring radionuclides present in all water sources.

Radioactive mineral scales may accumulate in piping or filters at processing and manufacturing plants, or radionuclides may accumulate in process waste waters, sludges or ash, or be emitted in smokestack gases. Manufacturing facilities which utilize certain of these minerals to make finished products may accumulate radioactive wastes in liquid or solid forms.

Oil and gas production, as an example, also results in the production of underground water which may contain radium. Not all oil and gas fields have TENORM accumulations however. The radium (if present in produced water) which is a result of changes in pressure, temperature, and chemistry at surface conditions may form a mineral scale on production piping, tanks, and separators at the field site. It may also be found in sludges and evaporite deposits in tanks, waste water and mud pits on the site. Small amounts of radium and radon may continue to be found in the produced oil and gas. TENORM contamination in refineries has also been reported. Radium bearing scales in production pipes, metal tanks and separators may not have been completely removed before the metal is sold as scrap, resulting in possible contamination at scrap metal recycling facilities; radium contaminated pipes have been used as structural members in houses and other buildings. Pipe yards where mineral scale has been removed may have radium contamination of soils at the site.

Underground mines of all kinds have the potential to accumulate and vent radon gas, whether they are active or inactive, placing EPA staff at risk. Active mines may have large fans that pump underground gases laden with radon to the surface, whereas closed or abandoned mines can accumulate the gas in underground chambers, or vent the gas through old openings, or fractures overlying collapsed excavations. Mines with listed minerals may have an increased risk of higher levels of radon. Raw or processed mineral ores with known TENORM associations that have been placed or stored either underground, or in warehouses or other buildings, create the greatest potential for radon concentrations.

Some of the minerals included in this guidance are gem stones, or may occasionally be used in jewelry or other ornamental or decorative objects, or be included in mineral collections. Small stones or samples should not constitute a hazard, but prolonged exposure and handling of the principal uranium and thorium minerals should be minimized. Larger concentrations or quantities could present a risk.

TENORM sands, gravels and rock, dusts, sludges and other liquids, ash, and scales may contaminate workplaces, wastes, piping and metal or other tanks and containers, storage drums and piles, vent stacks, and disposal sites. Concentrated raw or finished mineral products, including materials in barrels or piles, and metal/ceramic molds (coated with radioactive materials) are also sources of exposure. Reclaimed and graded lands, including old mine or petroleum or other industrial locations, may not have been decontaminated and can be exposure sources emitting radiation and radon gas.

Exposures of EPA employees to radioactivity at a site may come from inhalation (dusts and gases), ingestion (dusts, soils, water, vegetation or meat), and direct radiation (invisible alpha, beta, and gamma radiation from a radioactive source, plus radioactive dusts or soil or liquids contaminating clothing, hair and skin). The radioactivity is readily detectable with survey instruments.

Background Radiation Levels

Radionuclides are found in all soil, rock and materials. In general, the levels of radiation in the ground tend to be slightly higher on average in the western U.S. than the east. Some geographic areas can have much higher background levels (granites and phosphatic limestones for example may contain a number of radioactive minerals in their rock matrix). These levels may even be as high or higher than EPA source criteria, making determinations of background extremely important. As radiation program personnel identify sites with suspected contamination, they should design surveys that follow procedures, referenced below, to determine statistically appropriate reference levels of natural soil background in areas uncontaminated by human activity. This information must be collected in order to establish the extent of any additive man-made contamination, determining site related impacts, and assessing cleanup goals or requirements at or above background radiation levels (U.S. EPA et al., 2000; Eisenbud and Gesell, 1997; NCRP, 1987).

Protective Actions To Be Taken

If a site is suspected to have radioactive contamination above background levels resulting from human activities, it is recommended that EPA regional radiation personnel be contacted to determine next steps for site surveys, field sampling, and monitoring. Key

radiation program personnel may be located in the EPA regional Air and Toxics Program, Ecosystems program, Multimedia program, or Superfund program depending on regional organization and available staff.

Those individuals are listed in Appendix 1 of this document. However, as assignments may change over time, updated lists will be provided on the EPA web site: http://www.epa.gov/radiation/tenorm/keyradcontacts.htm

If TENORM is suspected to be present, care should be taken to avoid worker exposure until radiation surveys can be conducted to characterize contamination at the site, and protective measures devised if necessary. Personnel inspecting industrial sites suspected of having possible radiation contamination should include radiation safety measures in the health and safety plan for their site visits. In addition, cleanup, waste management, and post-closure decisions must take into account radioactive contamination. A sampling and monitoring plan developed with regional radiation personnel to determine the presence and concentrations of radon gas is prudent whenever underground mines or ore storage areas (above or below ground) will be inspected. In general, the radiation threshold for establishing occupational radiation protection measures is higher than for exposure limits for members of the public. Long term exposure to certain low levels of radiation below occupational limits may exceed EPA's guidance for CERCLA radioactively contaminated site cleanup. It should be noted that the types of instrumentation necessary for health and safety screening are different than those used for risk based site investigations.

In a few cases, a state radiation authority, or other federal or state agency may have licensed or permitted a mine or other processing facility for production of uranium or thorium, even though it had been originally permitted to produce another type of mineral (gold, copper, silver, or phosphate for example). Assuming a mine or processing facility produced only non-radioactive minerals is not appropriate; mine records may provide useful data. If the operation is closed or abandoned, EPA staff should be prepared to consult with appropriate federal or state agencies with jurisdictional responsibility to obtain information on that particular site.

Site Surveys

Site investigation or monitoring procedures that regional radiation staff may use are outlined in documents such as the Multi-Agency Radiation Site Survey Investigation Manual (MARSSIM), Revision 1 (EPA et al., 2000). MARSSIM was prepared specifically for site surveys involving radiological contaminants, contains useful information on sampling procedures, field measurement methods and instrumentation, quality assurance and quality control procedures and interpretation of results. The information was developed as a consensus site

closure approach by four federal agencies (EPA, DOE, NRC and DOD) to determine whether dose or risk-based release criteria for soils have been met. The MARSSIM document and related informational tools can be obtained from the EPA's Radiation Protection Division website (http://www.epa.gov/radiation/marssim/).

Another useful guide, for surveying a site early in the remediation process is the "Soil Screening Guidance for Radionuclides" and is available at http://www.epa.gov/superfund/resources/radiation/radssg.htm. The guidance is intended to be used to screen out areas of sites, exposure pathways, or radionuclides of concern from further consideration, assuming certain conditions are present, or to determine that further study is warranted at a site. Its use may significantly reduce the time it takes to complete soil investigations and cleanup actions at some sites, as well as improve the consistency of these actions across the nation.

Design and interpretation of site surveys and laboratory radiological analyses of soil, sediment and water should be the responsibility of regional radiation personnel.

Radiation Site Cleanup Guidances

There are several EPA guidance documents that generally address the cleanup under CERCLA of sites with radium, thorium, and/or uranium contamination. Appendix 2 provides some detailed information on guidances that pertain to cleanup of TENORM and radiation contaminated sites. More detailed information may also be found on the EPA Superfund Radiation websites at: http://www.epa.gov/superfund/resources/radiation/ index.htm#radiation/ and http://www.epa.gov/superfund/ resources/ radiation/whatsnew.htm

Radiation protection guidances and waste disposal requirements for TENORM have been established in a number of states. While predominantly for control of oil and gas TENORM, some states may have published regulations for other sources of TENORM, or radiation in general. Such guides should be consulted for their suitability in establishing ARARs for particular TENORM contaminated sites.

Internet Information Sources

Other information on radiation basics, TENORM, and radiation site clean up can be found at:
http://www.epa.gov/radiation
http://www.epa.gov/radiation/tenorm and
http://www.epa.gov/radiation/cleanup/

Contact

Questions regarding this document and its contents should be addressed to Loren Setlow, Office of Radiation and Indoor Air (6608J), U.S. EPA, Washington, DC 20460. Phone 202-564-9445, e-mail: Setlow.loren@epa.gov.

References:

Eisenbud, M., and Gesell, T., 1997, "Environmental Radioactivity–From Natural, Industrial, and Military Sources, Fourth Edition". Academic Press, New York.

Finch, R. And Ewing, R., 1990, "The Corrosion of Uraninite Under Oxidizing Conditions". Journal of Nuclear Materials. V. 190, p. 133-156.

Frondel, J., 1958, "Systematic Mineralogy of Uranium and Thorium". U.S. Geological Survey Bulletin 1064. Washington DC.

Frondel, J., Fleischer, M., and Jones, R., 1967, "Glossary of Uranium and Thorium-Bearing Minerals, Fourth Edition". U.S. Geological Survey Bulletin 1250. Washington DC.

Krauss, E., Hunt, W., and Ramsdell, L., 1959, "Mineralogy, An Introduction to the Study of Minerals and Crystals". McGraw -Hill Book Company, New York.

Langmuir, D., 1997, *Aqueous Environmental Geochemistry*. Prentice Hall, Upper Saddle River, NJ.

National Academy of Sciences, 1999, "Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials". Committee on Evaluation of EPA Guidelines for Exposure to Naturally Occurring Radioactive Materials, National Research Council. National Academy Press, Washington, DC.

National Council on Radiation Protection and Measurements, 1993, "Radiation Protection in the Mineral Extraction Industry". NCRP Report No. 118. Bethesda, MD.

1987, "Exposures of the Population in the United States and Canada from Natural Background Radiation". NCRP Report No. 94. Bethesda, MD.

Smith, D., 1984, "Uranium Mineralogy" in *Uranium Geochemistry, Mineralogy, Geology, Exploration and Resources* (eds., DeVivo, B., Ippolito, F., Capaldi, G., and Simpson P.). The Institution of Mining and Metallurgy, London, p.43-88.

U.S. Environmental Protection Agency (EPA), U.S. Nuclear Regulatory Commission (NRC), U.S. Department of Energy, and U.S. Department of Defense, 2000, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), Revision 1*. EPA 402-R-97-016, revision 1; NUREG-1575, revision 1; DOE-EH-0624, revision 1, August 2000.

U.S. Environmental Protection Agency, 2000, "Remediation Goals for Radioactively Contaminated CERCLA Sites Using the Benchmark Dose Cleanup Criteria in 10 CFR Part 40 Appendix A, I, Criterion 6(6)", OSWER Directive 9200.4-35P, April 11, 2000.

U.S. Environmental Protection Agency, 1998, “Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA Sites,” OSWER Directive 9200.4-25, February 12, 1998.

U.S. Environmental Protection Agency, 1997, “Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination”, OSWER Directive 9200.4-18, August 22, 1997.

U.S. Geological Survey (USGS), 1973, “United States Mineral Resources”, Professional Paper 820, Donald Brobst and Walden Pratt (Eds.). Washington, DC.

U.S. Nuclear Regulatory Commission, 2001, “Systematic Radiological Assessment of Exemptions for Source and Byproduct Materials”

APPENDIX 1 April 2003

KEY RADIATION PROGRAM PERSONNEL

Region 1 Boston, Massachusetts

Bonnie Wyvill
ORIA Regional Liaison
Radiation Protection Division
Ph: 202-564-9393

Region 2 New York, New York

Paul Giardina
Division of Environmental Planning and Protection
Ph: 212-637-4010

Jeanette Eng
Division of Environmental Planning and Protection
Ph: 212-637-4007

Eric Simpson
Division of Environmental Planning and Protection
Ph: 212-637-4024

Region 3 Philadelphia, Pennsylvania

Robert Kramer
Energy, Radiation and Indoor Environments Branch
Ph: 215-814-2704

Darice Ellis
Air Protection Division
Ph: 215-814-2024

Sheri Minnick
Air Protection Division
Ph: 215-814-2089

Region 4 Atlanta, Georgia

Van Shrieves
Monitoring and Technical Support Section
Ph: 404-562-9089

Rick Button

Air, Pesticides, and Toxic Management Division
Ph: 404-562-9135

Lloyd Genrette
Air, Pesticides, and Toxic Management Division
404-562-9138

Jon Richards
Waste Management Division
404-562-8648

Region 5 Chicago, Illinois
Sheila Batka
Radiation and Indoor Air Section
Ph: 312-886-6053

Larry Jensen
Superfund Division
312-886-5026

Jim Mitchell
Superfund Division
312-353-9537

Jack Barnette
Air and Radiation Division
Ph: 312-886-6175

Michael Murphy
Air and Radiation Division
Ph: 312-353-6686

Region 6 Dallas, Texas
Monica Smith
Multimedia Planning and Permitting Division
Ph: 214-665-6780

George Brozowski
Multimedia Planning and Permitting Division
Ph: 214-665-8541

Region 7 Kansas City, Kansas
Robert Dye
Air, RCRA, and Toxics Division
Ph: 913-551-7605

Stephen Chambers
Air, RCRA, and Toxics Division
Ph: 913-551-7260

Garianne Howard
Air, RCRA, and Toxics Division
913- 551- 7624

Region 8 Denver, Colorado
Richard V. Graham
Office of Partnerships and Regulatory Assistance
Ph: 303-312-7080

Robert Duraski
Office of Partnerships and Regulatory Assistance
Ph: 303-312-6728

Region 9 San Francisco, California
Mike Bandrowski
Air Division
Ph: 415-947-4194

Richard Lessler
Air Division
Ph: 415-947-4197

Charnjit Bhullar
Air Division
Ph: 415-972-3960

Steve Dean
Superfund Division
415-972-3071

Region 10 Seattle, Washington
Rick Poeton

Office of Environmental Cleanup
206-553-8633

Jeff Kenknight
Office of Air Quality
Ph: 206-553-6641

Jerrold Leitch
Office of Air Quality
Ph: 206-553-7660

APPENDIX 2
CERCLA GUIDANCES FOR RADIATION SITE CLEANUP

- OSWER Directive 9200.4-25, "Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA Sites," (February 12, 1998) provides general guidance regarding the potential status of the subsurface soil cleanup criteria in 40 CFR Part 192 as an applicable or relevant and appropriate requirement (ARAR) for radium or thorium in developing a response action under CERCLA.

- OSWER Directive 9200.4-35P, "Remediation Goals for Radioactively Contaminated CERCLA Sites Using the Benchmark Dose Cleanup Criteria in 10 CFR Part 40 Appendix A, I, Criterion 6(6)" (April 11, 2000). This memorandum provides guidance regarding the potential status of the "benchmark dose" criteria in Criterion 6(6) as ARARs in developing a response action under CERCLA for sites with radium-226, radium-228, thorium-230, thorium-232, and uranium-234, and/or uranium-238 as contaminants of concern. Because of the interrelationship between the standards under 40 CFR Part 192 and those under Criterion 6(6), this memorandum should be used in conjunction with the OSWER Directive 9200.4-25 discussed above.

- "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination" dated August 22, 1997 (OSWER Directive 9200.4-18), provides clarifying guidance for establishing protective cleanup levels for radioactive contamination at CERCLA sites. In particular, this memo discusses use of the risk range (generally 10^{-4} to 10^{-6}) for all carcinogens as established in the NCP for cleanup of radioactive contamination at CERCLA sites when ARARs are not available or are not sufficiently protective.

- On November 6, 2001, OSWER Directive no. 9283.1-14 was issued providing guidance on "Use of Uranium Drinking Water Standards under 40 CFR 141 and 40 CFR192 as Remediation Goals for Groundwater at CERCLA sites", thus clarifying EPA's cleanup standards for uranium contaminated ground waters at CERCLA sites that are current or potential sources of drinking water.

- EPA's risk assessment approach for establishing Preliminary Remediation Goals (PRGs) under CERCLA at the 1×10^{-6} cancer risk level is in the "Radionuclide Preliminary Remediation Goals (PRGs) for Superfund" electronic calculator which is available at: http://epa-prgs.ornl.gov/radionuclides/.

APPENDIX 3
MINERALS AND INDUSTRIES KNOWN OR SUSPECTED TO HAVE RADIOACTIVE CONTAMINATION POTENTIAL

The following lists of minerals and materials with known radioactive associations is by no means exhaustive, and, in some cases, the generic name for a mineral is provided rather than the individual species. EPA staff undertaking inspections or investigations for RCRA, CERCLA, CWA, SDWA, CAA, or TSCA programs for mining, or mineral, or industrial processing/manufacturing sites should: conduct literature searches, review mining and assay reports, and substantiate mineral and trace mineral assemblages. The occurrence of radioactive minerals, or those known to occasionally include radioactive elements in their crystal lattice as intergrowths or impurities, raises the possibility that the site under investigation or inspection has TENORM occurrence.

International research is very incomplete on the occurrence of TENORM radioactivity in many industries, and what happens to the radioactivity as a raw ore or material is processed into finished products. This Appendix provides information on additional industries which use specific minerals associated with radioactivity listed in this guidance, however, information on whether radioactivity may be present or not in these industries is incomplete or unknown. Appendix 4 is a combined alphabetical list of only the minerals and ores listed in this guidance.

Minerals Extracted for their Radionuclide Content

Uranium minerals (principal or major minerals): Uraninite, carnotite, pitchblende, coffinite, davidite, autunite, pyrochlore, samarskite, torbenite, uranophane, and many other species

Thorium minerals (principal or major minerals): Thorite, monazite, thorianite, thorogummite

Mineral Ores Known to Have TENORM Associated Wastes

Aluminum (bauxite)
Coal (and coal ash)
Copper
Fluorospar (Fluorite)
Gypsum
Molybdenum
Niobium
Phosphate (Phosphorous)
Potassium (Potash)
Precious Metals (gold, silver)
Rare Earths: yttrium, lanthanum, monazite, bastanite, ...

Tin
Titanium: Leucoxene, ilmenite, rutile
Tungsten
Vanadium
Zircon

Other Minerals with Radioactive Elements in Their Matrix
Allanite
Alunite
Apatite
Barite
Cerite
Cordylite
Doverite
Epidote
Karnasurtite
Loparite
Lead
Mosandrite
Roscoelite
Spencite
Sphene
Stillwellite
Vanadinite
Wulfenite
Xenotime
Yttrotantalite
Yttrotungstite
Zirconium, including baddeleyite

Some Minerals Known to Contain Uranium and Thorium as Intergrowths or Impurities
Adamite
Allophane
Chrysocolla
Columbite
Cryotomelane
Evansite
Fluorite
Limonite
Opal

Pyromorphite
Scapolite
Tantalite

Other Mineral Extraction Sites with TENORM Associated Wastes
Oil and gas
Geothermal energy

Other Processing/Manufacturing Facilities with Known TENORM Associated Wastes
The following are known to have TENORM contamination potential:

Water Treatment Facilities (radium scale and sludge contamination in wastes and filters)
Paper and Pulp Facilities (radium scale and sludge contamination)
Ceramics Manufacturing (zircon, uranium in wastes and molds)
Paint and Pigment Manufacturing (thorium, uranium, radium in wastes from titanium ores)
Metal Foundry Facilities (zircon contamination in molds for metal parts/machinery, thorium in welding rods)
Optical Glass (thorium incorporated in glass)
Fertilizer Plants (uranium, thorium, radium, radioactive potassium associated with fertilizer production, concentrations in wastes, filters, products, metal piping scales)
Aircraft Manufacture (depleted uranium counterweights; in older facilities, radium dials, nickel-thorium alloys used in engine manufacture)
Munitions and Armament Manufacture (depleted uranium in ammunition and armor)
Scrap Metal Recycling (TENORM contaminated piping and metal)

The following list of minerals are known to either be radioactive, or are known to have the potential for radioactive contamination by inclusion of radionuclides in their molecular structure, or association with other radioactive minerals in their original ore body. A list of industries which use these minerals are included for information purposes (USGS, 1973; Kraus et al., 1959). The inclusion of an industry in this listing does not necessarily mean that radioactivity may be present at any or all such sites.

Copper	Manufacture of copper wire, nails, and copper sheeting, brass, bronze, electrical and electronic equipment, war munitions, chemical reagents.
Fluorospar (Fluorite)	A flux in the manufacture of steel, enamelware, opalescent glass, hydrofluoric acid, refining of antimony and lead. Also used in manufacture of, vases, paper weights, dishes.
Gypsum	A flux in glass and porcelain manufacture, retarder in cement, filler in fertilizers. Alabaster used for statues vases, lamps, pedestals.

Molybdenum	Used in manufacture of steel and iron castings, and in high speed tools.
Niobium	Manufacture of stainless steel, high temperature alloys, jet engines and gas turbines.
Phosphate (Phosphorous)	Fertilizer manufacture, phosphoric acid for industrial and food manufacturing uses, water softeners, manufacture of glass and ceramics.
Potassium (Phosphorous)	Manufacture of glass, optical glass, incandescent light bulbs, black and gun powders, dyeing and tanning, (cyanide) solvent in gold extraction and photography.
Precious Metals (gold, silver)	Coinage and jewelry uses, scientific and electronics instrument manufacture, photography, gold plating, lettering, dentistry.
Rare Earths: (yttrium, lanthanum, monazite, bastanite, ...)	Thorium uses–electrodes, optical glass, refractory manufacture, textile industry.
Tin	Manufacture of tin plate or sheet tin, solder, bronze, tin amalgam, gun metal, type metal, speculum metal, pewter, also as a polishing powder.
Titanium: (Leucoxene, ilmenite, rutile)	Steel additive, metal for airplanes and ships, welding rod coatings, use in carbide cutting tools, white pigment for paint manufacture, lacquer enamels and rayon, glass, highly opaque light weight paper.
Tungsten	Used in manufacture of x-ray tubes, filaments in incandescent lights, automobile engines.
Vanadium	Used in manufacture of special steels and bronzes, high speed tools, ceramics, inks, silk dyeing.
Zircon	Used in strengthening steel, brass, copper. Widely used in ceramics as a glaze, coating for ceramic and metal molds, refractory bricks, polishing powder, pyrotechnics, sandblasting powder. Used in manufacturing aircraft engines and parts, cutting tools, nuclear reactors, surgical tools, electric arc lamps, tanning and manufacture of textiles.

APPENDIX 4,
ALPHABETIZED CHECK LIST OF MINERALS AND ORES
WITH RADIOACTIVE CONTAMINATION POTENTIAL

Refer to the lists in Appendix 3 of this guidance to determine whether a mineral or ore listed below is naturally radioactive, or is known to be found in association with radioactive minerals. Common names and mineral names are included in the list below.

Adamite
Allanite
Allophane
Aluminum
Alunite
Apatite
Autunite
Baddeleyite
Barite
Bastanite
Bauxite
Carnotite
Cerite
Coal (and Coal Ash)
Coffinite
Copper
Cordylite
Chrysocolla
Columbite
Cryotomelane
Davidite
Doverite
Epidote
Evansite
Fluorite
Fluorospar
Gold
Gypsum
Ilmenite
Karnasurtite
Lanthanum
Lead
Leucoxene
Limonite
Loparite
Molybdenum
Monazite
Mosandrite
Niobium
Opal
Phosphate
Phosphorous
Potassium
Potash
Pitchblende
Pyrochlore
Pyromorphite
Rare Earths
Roscoelite
Rutile
Samarskite
Scapolite
Silver
Spencite
Sphene
Stillwellite
Tantalite
Thorite
Thorianite
Thorogummite
Tin
Titanium
Torbenite
Tungsten
Uraninite
Uranophane
Vanadinite
Vanadium
Yttrium
Wulfenite
Xenotime
Yttrotantalite
Yttrotungstite
Zircon
Zirconium