EXHIBIT K

VDH URANIUM STUDY:

INTERIM REPORT #1

Uranium Study:
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Commonwealth of Virginia
Department of Health

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LIST OF ACRONYMS

µg/dL	micrograms of lead per deciliter
ACGIH	American Conference of Governmental Industrial Hygienists
AEA	Atomic Energy Act
AHR	Airway Hyperresponsiveness
ALARA	As Low As is Reasonably Achievable
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
APPLETREE	ATSDR’s Partnership to Promote Localized Efforts to Reduce Environmental Exposures
ARPANSA	Australian Radiation Protection and Nuclear
ATSDR	Agency for Toxic Substances and Disease Registry
BP	Blood Pressure
BRFSS	Behavioral Risk Factor Surveillance System
CAP's	Criteria Air Pollutants
CBC	Complete
CCD	Counter Current Decantation
CDC	Centers for Disease Control and Prevention
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
CHF	Congestive Heart Failure
CNSC	Canadian Nuclear Safety Commission
COPD	Chronic Obstructive Pulmonary Disease
CSMs	Conceptual Site Models
CT	Computerized Tomography
CVD	Cardiovascular Disease
DAC	Derived Air Concentration
dBA	Decibels
DE	Diesel Exhaust
DEQ	Department of Environmental Quality
DMME	Department of Mines, Minerals and Energy
DOE	Department of Energy
DOL	Department of Labor
DOLI	Department of Labor and Industry
DPM	diesel particulate matter
EC	Elemental Carbon
ED	Emergency Department
EFRC	Energy Fuels Resources Corporation
EGU's	Electricity Generating Units

EL's	Effluent Limits
EPA	Environmental Protection Agency
FRC	Federal Radiation Council
GAO	General Accounting Office
GF-AAS	Graphite Furnace – Atomic Absorption Spectrometry
HAT	Health Assessment and Toxicology
HCP	Hearing Conservation Program
HDL	High-Density-Lipoprotein
HEW	Department of Health, Education, and Welfare
HIPAA	Health Insurance Portability and Accountability Act
HPS	Health Physics Society
HRV	Heart Rate Variability
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
ICC	International Cadmium Conference
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectrometry
ICP-MS	Inductively Coupled Plasma – Mass Spectrometry
ICRP	International Commission on Radiological Protection
IDLH	Immediately Dangerous to Life or Health
IHD	Ischemic Heart Disease
ISL	Iin Situ Leaching
ISR	In Situ Recovery
IT	Intratracheal
IX	Ion Exchange
J-h/m^3	millijoule-hours per cubic meter
LNT	Linear-no-threshold
MCEF	Mixed Cellulose Ester Filter
MCLs	Maximum Contaminant Levels
mg/l	milligrams per liter
mg/m^3	milligrams per square meters
MILDOS	the standard computer code for calculating dose from uranium mills
mR	milliroentgen
mrem	millirem
MSDS's	Material Safety Data Sheets
MSHA	Mine Safety and Health Administration
mSv	millisievert
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NATS	National Adult Tobacco Survey
NCAC	North Carolina Administrative Code

NCRP	National Council on Radiation Protection
NIOSH	National Institute for Occupation Safety and Health
NMEPHT	New Mexico Environmental Public Health Tracking
NO_X	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
OEEB	Environmental Epidemiology Branch
OEHHA	Office of Environmental Health Hazard Assessment
OMSHR	Office of Mine Safety and Health Research
OSHA	Occupational Safety and Health Administration
OSL	Optically Stimulated Luminescent
PEL	Permissible Exposure Limits
PHA	Public Health Assessment
PM	Particulate Matter
PMP	Probable Maximum Precipitation
PRAMS	Pregnancy Risk Monitoring System
QA/QC	Quality Assurance/Quality Control
RADS	Reactive Airways Dysfunction Syndrome
REL	Recommended Exposure Limit
RSL's	Regional Screening Levels
SAG	Semi-Autogenous Grinding
SC&A	S. Cohen & Associates
SCBA	Self-Contained Breathing Apparatus
SES	Socioeconomic Status
SI	international units
Sv	Sievert
SX	Solvent Extraction
TC	Total Carbon
TCEQ	Texas Commission on Environmental Quality
TDHR	Texas Department of Health Resources
TEDE	Total Effective Dose Equivalent
TLD	Thermoluminescent dosimeters
TLVs	Threshold Limit Values
TMDL's	Total Maximum Daily Loads
TNORM	The Naturally Occurring Radioactive Materials
tpd	tons per day
TSDH	Texas State Department of Health
TWA	Time Weighted Average
UFP's	Ultrafine Particles
UMETCO	UMETCO Minerals Corporation

UNSCEAR	United National Scientific Committee on the Effects of Atomic Radiation
VDACS	Virginia Department of Agriculture and Consumer Services
VDH	Virginia Department of Health
VHI	Virginia Health Information
WES	Wright Environmental Services, Inc.
WHI	Women’s Health Initiative
WL	Working Level
WLM	Working Level months
yr	year
U.S.	United States

1.0 INTRODUCTION

Mining of uranium does not now occur in Virginia because of a legislative moratorium on that activity. If the General Assembly were to lift the moratorium, an entity could propose a uranium mine of some type or a mine and mill complex to extract and process the uranium. Once that proposed action occurs then Virginia would need to choose whether to amend its Agreement State status with the Nuclear Regulatory Commission (NRC) for the purposes of regulating the uranium milling complex. Whether or not the Agreement is amended, Virginia would need to have certain regulations and practices in place. If an Agreement State, Virginia would be bound to have regulations in place that are compatible with NRC regulations. Appendix I details the NRC compatibility with Virginia regulations.

A proposed action by a potential licensee would trigger a submission of a detailed application that describes the location of the facility; its design and operating parameters; sociologic, environmental, and radiologic analyses; emergency response plans and other pertinent data. If the Agreement were to be amended, Virginia would review, assess and potentially, approve the license application. If Virginia does not amend the Agreement, those tasks would fall to the NRC.

This report includes a set of recommendations to the Virginia Department of Health (VDH) concerning statutes, regulations and requirements that are necessary and relevant for effective life-cycle regulation of uranium mining and milling in Virginia. The report also provides our recommendations for optimizing Virginia's overall regulatory policy associated with potential uranium mining and milling in the Commonwealth, including the development of an internally consistent and uniform set of policies.

In order to provide a basic understanding of the impacts associated with mining and milling of uranium, detail is provided in Appendices II-IV on Virginia water resources, background radiation, and the toxicity of constituents potentially associated with uranium recovery, respectively.

2.0 MINING AND MILLING OF URANIUM

Uranium occurs in a wide variety of geological settings. Typical mining processes include open pit, underground mine and in situ recovery. Both underground and open pit mines are used for a variety of minerals, besides uranium. In situ recovery involves installation of a series of injection and recovery wells in a specified pattern to recover uranium from the underground uranium-bearing formation. The choice of the mining process depends largely on the geologic setting, including the depth to the deposit, the grade of the ore, and the potential solubility of the ore body. For ore mined by underground or open pit methods, the specific characteristics of the ore will influence the subsequent ore processing methods.

2.1 In Situ Recovery

Some ore is found in porous unconsolidated material (such as gravel or sand) and may be accessed simply by dissolving the uranium and pumping it out. This is known as in situ recovery (ISR). ISR can be applied where the ore body is confined vertically, and ideally, horizontally. Such facilities are not licensed where potable water supplies may be threatened. Where appropriate, ISR is likely the mining method with least environmental impact and will be employed. ISR mining means that removal of the uranium minerals is accomplished without major ground disturbance. Weakly acidified or alkali water fortified with oxygen is circulated through uranium ore body. In either the acid or alkali recovery method the fortified water is pumped into the ore body via a series of injection wells where it slowly migrates through the formation, dissolving the uranium. The solution is collected at strategically placed extraction wells where the liquid is pumped to the surface for processing. The solution bearing the uranium is then pumped via above ground pipes to a central processing facility where the uranium is extracted, precipitated, dried and packaged.

2.2 Open Pit and Underground Mining

If the ore body is near the surface, it may be accessed by open cut mining, involving a large pit and the removal of much overburden (overlying rock) as well as substantial waste rock. Deeper ore bodies require underground construction of access shafts and tunnels, but with less waste rock removed and less environmental impact. This process is identical to that used for other metal and non-metal mines.

In the event of either open pit or underground mining, the ore must be processed to remove the uranium. This process is called milling and is described in the following section. Figure 2-1 is a schematic of a generic co-located open pit mine, underground mine and milling facility.

2.3 Milling of Uranium

The Piñon Ridge mill in Montrose County, Colorado proposed by Energy Fuels Resources Corporation (EFRC) is the most recent conventional mill to apply for a radioactive materials license. Since it is the newest conventional mill designed in the country, it is a reasonable model for a mill that could be built in Virginia. The Piñon Ridge Facility Operating Plan may be found at http://www.colorado.gov/cdphe/cse-google-static/?q=pinon+ridge&cof=FORIDA10&ie=UTF-8&sa=Search. The Piñon Ridge mill is expected to process ore mined from EFRC mines, and ore purchased from other mines, at the rate of 1,000 tons per day (tpd).

Most historic mills in the United States (U.S.) have been located some distance from the uranium mine. The Piñon Ridge mill is designed to process from mines that are "located within a reasonable truck-haul distance." Given the size of the Coles Hill uranium deposit, it is reasonable to assume that the mine and the milling facility may be co-located on the same property. The mine permit boundary would encompass both the mine and the mill as shown on the previously mentioned Figure 2-1. Ore from the mine would be stockpiled near the pit or the mine adit. Waste rock would be stored on the spoils piles for later disposal. Ore to be processed would be stockpiled and hauled to the dumping station at the milling facility. Protore, i.e. ore that cannot be processed cost-effectively, may be stored and used later as market conditions allow.

The milling facility would be wholly enclosed in the mine permit boundary. The NRC or Virginia-licensed areas would encompass all the milling operations, as well as warehouses, and the administration building. The actual milling operations would be enclosed in a Restricted Area, which controls access to radiation workers or escorted visitors and requires monitoring and personnel scanning upon egress.

Most conventional mills include the following processes:

- Ore storage;
- Crushing and grinding of ore;
- Pre-stripping and thickening;
- Stripping;
- Separation and purification;
- Uranium precipitation; and
- Drying and packaging.

Processes applicable to a uranium mill in Virginia as described in the EFRC license application are summarized below. Figure 2-2 is a schematic of a generic uranium processing mill (Seidel, 1981). Also, Appendix IV is a compilation of constituents that could be present in the process of mining and milling uranium.

2.3.1 Ore Storage

In the co-located facility, ore would be delivered to the mill facility by truck. A dumping station would be created to allow the ore to be deposited into the mill restricted area without actually entering that area, thereby eliminating the need to survey the truck for contamination as would be required if the vehicle entered the restricted area. Once the ore is deposited into the licensed mill area, it is regulated under the license.

Historic mills typically did not have lined ore storage areas, but simply stored ore on the ground. Modern mill designs, such as Piñon Ridge, have concrete ore storage pads as well as geosynthetic clay liners with a protective layer of compacted native soils and roadbase materials.

2.3.2 Grinding

Ore from the storage pile is loaded into a feed hopper and delivered by belt conveyor to a crusher then to a semi-autogenous grinding (SAG) mill, often located in the mill building. Ore is combined with water in the SAG mill and tumbled with steel balls. This process grinds the ore into a fine powder, exposing the uranium mineral surfaces from the host rock.

2.3.3 Pre-recovery and Thickening

Slurry from the SAG mill, consisting of small particles (less than a millimeter in diameter) and water is distributed to large, steel, pulp storage tanks. The slurry is pumped from the storage tanks to rubber lined, steel pre-leach tanks where the pulp reacts with sulfuric acid that reduces its density to approximately 25% solids. The pulp is then pumped to a rubber-lined, steel thickener tank. The overflow from the thickener is clarified, filtered and sent to a feed tank for uranium recovery. Partially dewatered underflow from the thickener is pumped to the recovery circuit.

2.3.4 Recovery

Recovery may be either acid or alkaline depending on the characteristics of the ore. The operator would test the ore prior to the license application to determine whether acid or alkaline recovery was preferable.

Alkaline recovery is used most often for limestone-based ores. However, alkaline recovery is less effective than acid leaching and is usually only used in cases of high carbonate ore (Connelly, 2008). Alkaline recovery of uranium ores is possible because, under oxidizing conditions, soluble anionic uranium carbonate complexes can form.

The most common alkaline stripping solutions are mixtures of sodium carbonate and sodium bicarbonate. To achieve reasonable recovery rates, high temperatures are required, and pressurized leaching systems are used in nearly all alkaline leaching plants so that recovery temperatures greater than 100 degrees Celcius (°C) can be achieved (Seidel, 1981).

The Piñon Ridge mill is designed to use a sulfuric acid recovery. The recovery circuit consists of eight rubber-lined steel tanks with agitators. The pulp pumped from the pre-recovery thickener tank is heated with steam and then leached with sulfuric acid to dissolve the uranium and vanadium minerals. Sodium chlorate is added as an oxidant as necessary. In the recovery circuit, pulp pumped from the pre-recovery thickener tank is heated to 185°C using steam, and permeated with sulfuric acid to dissolve the uranium minerals. Sodium chlorate may be added as an oxidant.

2.3.5 Liquid/Solid Separation and Purification

For an alkaline recovery, sodium hydroxide is added to raise the pH and recover the uranium. The high pH destroys the anionic complex and allows the uranium to precipitate as a sodium diuranate.

In the Piñon Ridge design, the recovered pulp is pumped to a series of 40-foot diameter counter current decantation (CCD) thickener tanks, where liquids and solids are separated. The uranium-bearing solution is separated from the remaining solids, the mill tailings, which consist of a variety of other minerals that were present in the ore. Tailings include the decay products of natural uranium, including Th-230, Ra-226 and a variety of shorter-lived radionuclides. The uranium solution is pumped to the uranium recovery feed tank and the tailings are pumped to the tailings disposal cell.

2.3.6 Uranium Recovery

Depending on the characteristics of the ore, a solvent extraction (SX) or an ion exchange (IX) process may be used to concentrate and recover the uranium from the uranium solution. During the SX process, the solution is filtered and the uranium separated and purified using a kerosene-based solvent, often a diluted organic amine salt that can selectively extract the uranium ions into an organic complex that is insoluble in water. The result is a uranium solution, which is washed with sulfuric acid and water to remove impurities. Following washing, the uranium is stripped from the solvent using a sodium carbonate solution.

2.3.7 Drying and Packaging

Hydrogen peroxide is added to precipitate the uranium. The precipitate is known as yellowcake. The yellowcake powder is then partially dewatered, washed, filtered and dried. Modern mills use a vacuum dryer, which release no particulates. This is a significant improvement over historic mills at which a dryer stack was a source of release from the mill resulting in a potential public dose from inhalation of particulate radionuclides.

Finally, the dried yellowcake is packaged, weighed, and sealed in 55-gallon, steel drums for shipment. Each packed drum will weigh approximately 900 pounds. Workers in the packaging area are required to wear respirators as a precaution against inhalation of radionuclide particulates.

3.0 POTENTIAL RELEASES AND PATHWAYS TO THE PUBLIC

Radiation is a natural part of the earth's environment. The U-228 is a naturally occurring, primordial radionuclide that decays through a series of other radionuclides (termed decay products) to stable lead. Appendix III includes a brief discussion of the uranium decay series and background radiation.

Uranium mining and milling have the potential to release naturally occurring radioactive materials and other hazardous constituents into the environment through air and water. Such releases are controlled through various mitigation strategies and regulated by federal (e.g., U.S. Environmental Protection Agency [EPA] and NRC) or Agreement State radiation control regulations, as well as specific license conditions that may be imposed on any facility and may be stricter than the regulations require. If the Commonwealth amends its Agreement with the NRC with respect to uranium recovery, it can control the licensing process and the imposition of license conditions on milling facilities. Regulations and license conditions limit the radiation dose to humans and the environment. Operating facilities are required to report effluent monitoring and environmental surveillance data semi-annually to the licensing agency. The operator is also required to report estimated potential doses to members of the public annually. These reports are public information. Copies may be routinely sent to stakeholders such as local communities or tribal entities.

Conceptual Site Models (CSMs) describe, in general, the pathways for exposure to human and ecological receptors. Pathway descriptions are contained in specific facility license applications and cannot be fully represented by generic CSMs.

3.1 Generic Conceptual Site Models for Uranium Mining and Milling

CSMs are designed to show graphically the potential sources, release mechanisms, and pathways of exposure to members of the public for constituents derived from uranium mining and milling processes. The CSMs are based on experience with existing uranium mines and mills. The CSMs in this section are generic, developed without site-specific data. Site-specific CSMs are based on site-specific topographic, demographic, meteorological, hydrological, and cultural information as well as facility operating parameters.

Generic open pit and underground mines, as well as uranium mills, are modeled separately, as the sources and pathways differ (Figures 3-1 through 3-3). The potential release mechanisms and pathways shown in the CSMs include those for which releases are contained under normal operating conditions. The containment features of uranium mines and mills are shown in Figure 2-1, mentioned previously. CSMs represent hypothetical conditions and do not necessarily indicate that the releases will occur or that exposure pathways would be complete.

Table 3-1 augments the CSM with a brief description of the potential health effects attributable to exposures. Appendix IV includes more information concerning the toxicity of constituents of concern, and provides references to more detailed toxicity data and evaluations beyond the scope of this report. Table 3-2 provides further discussions of pathways and the rationale for designating them as likely or unlikely to be complete, or to produce a radiation dose greater than 1 millirem per year (mrem/yr) (less than 0.2 percent of the natural background dose to Virginia residents).

Direct gamma radiation is a potential exposure pathway for site visitors. Due to the expected distance of the nearest residence from an ore stockpile or a waste rock pile (>0.5 miles), it was not included in the CSM for the general population. The potential external radiation doses from an ore pile was calculated using the WISE Uranium External Radiation Dose Calculator (WISE) (2012) for a large ore pile, 5 meters tall by 140 meters wide, with a uranium ore grade of 1.2 percent. The calculated annual direct gamma dose at a distance of 0.4 miles (600 meters) from the toe of the pile was calculated to be 1 mrem/yr. The calculator does not take into account shielding by topographic features or vegetation.

It should be noted that MILDOS (Argonne National Laboratory [ANL], 2012), the standard computer code for calculating dose from uranium mills, does not include direct gamma radiation from mill features as a pathway but does include direct gamma radiation from windblown contamination. In most cases, this pathway is a very minor contributor to the total dose even for facilities with a long history of airborne particulate emissions. A National Academy of Sciences report "The Scientific Basis for Risk Assessment and Management of Uranium Mill Tailings" (National Academy of Sciences [NAS], 1986) states that "gamma radiation emitted from tailings does not appear to pose a significant biological risk." Direct gamma radiation doses are required to be measured at the facility perimeter as discussed in Interim Report #2 (Wright Environmental Services, Inc. [WES], 2012b) and are included in the total dose calculated annually for members of the public.

Because direct gamma radiation is an exposure pathway for site workers and visitors, it must be considered in the analysis of worker and visitor potential health impacts.

The primary environmental media potentially impacted by emissions from the mine or mill are ambient air, groundwater, surface water and soil. The secondary media include plants and animals, if they are a part of a food chain for humans (i.e., ingestion of vegetation, uptake by beef cattle, dairy cows or wild game). Impact to vegetation may occur by dry deposition of re-suspended windblown materials or irrigation with affected ground and surface water supplies. Uptake by animals occurs though ingestion of impacted forage or water supplies. The transfer coefficients for beef, milk, and vegetation are shown in Table 3-3 (National Council on Radiation Protection (NCRP), 1996). The transfer coefficient is the ratio of the concentration or intake of a particular element in environmental media to the concentration in food. However, it is impossible to predict the potential impact and dose from ingestion of meat, milk, and vegetation without specifying the concentrations in these foodstuffs or concentrations in environmental media. As with other required monitoring, described in Interim Report #2, concentrations of radionuclides in food, fish, water and vegetation are measured annually to determine the impact of facility emissions on the food supply. The MILDOS Code calculates potential dose to members of the public from airborne emissions. All pathways, including ingestion of locally grown food, are included in the MILDOS calculation of public dose. Each facility must demonstrate compliance with the annual dose limit, 25 mrem/yr to any organ excluding radon decay products. The estimated lifetime risk associated with a total effective dose equivalent (TEDE) of 25 mrem/yr for 30 years would be 4 in 10,000. The limiting factor in uranium mill dose compliance is generally the dose to specific organs such as the bone and lung. The estimated risk from 25 mrem per year to the bone is a factor of 100 less than the TEDE risk; the risk to the lung is a factor of 8 less than the TEDE risk, based on International Commission on Radiological Protection (ICRP) 103 weighting factors (ICRP, 2007).

3.2 Specific Constituents of Concern

Due to space constraints, the constituents of concern are provided in generic terms in the CSMs. The specific constituents are listed in Table 3-2, along with the principal organ affected and a brief description of the adverse health impact associated with the constituent.

3.3 Potentially Complete Pathways

The pathways shown on the CSMs are potentially complete pathways. Some of the pathways are designated as potentially complete but unlikely or with potential doses less than 1 mrem/yr. The pathways shown in the CSMs are designated as such because either the release mechanism is not likely or the exposure would result in a radiation dose of less than 1 mrem/yr under normal operational conditions. For example, most of the constituents of concern for uranium mining and milling are poorly absorbed through the skin; therefore, dermal exposure is not considered a likely pathway.

The CSMs are designed to depict normal operating conditions. Accidental or abnormal conditions or releases are considered in Interim Report #2 (WES, 2012b). Under such situations, pathways that are not normally important may contribute significantly to dose to members of the public. For example, a failure of a pollution control device on the crusher stack, or loss of containment in the yellowcake dryer, could release significant quantities of airborne contaminants. Catastrophic floods could release tailings or stored ore into adjacent water bodies. A National Academy of Sciences report states that the risk posed by release of tailings under such circumstances “is small and inconsequential compared with other impacts of such catastrophic events” (NAS, 1986); however, such impacts and the probability of occurrence are site-specific and must be considered in any facility license or permit application. Interim Report #2 describes, in detail, the impact of the Church Rock tailings dam failure in New Mexico and other accidental releases. The pathways, by source, are shown in Table 3-2. Pathways determined to not be significant are those that are unlikely to be complete or would result in a radiation dose less than 1 mrem/yr.

3.4 Conceptual Site Model Summary

The CSMs provide a description of the potential pathways of exposure to members of the public from normal operation of a uranium mine and mill. They do not show site-specific pathways. Dust control measures, pollution prevention devices on stacks, ore storage pad and tailings impoundment liners, and water diversion channels will minimize off-site impacts from mine and mill operation (Figures 3-1 through 3-3).

In general, the CSMs demonstrate that radon decay product inhalation is the most significant potential health risk for members of the public from operation of conventional mines and mills. To the extent feasible, measures will be employed to reduce radon emissions. Extensive and comprehensive site-specific environmental monitoring programs must be designed and implemented to enable regulatory agencies, the public and the operator to assess the hazard from radon, as well as other constituents of concern.

Radon is ubiquitous in the environment, outdoors and particularly indoors. The National Academy of Sciences study (NAS, 1986) found that average radon concentrations around some uncovered tailings piles fall to background within a kilometer, and that the concentrations around all measured piles fell to background within a few kilometers. As with other radionuclides, airborne concentrations at site boundaries must be routinely monitored. Monitoring programs are described in detail in Interim Report #2.

Radiation dose estimates for operating facilities are based on measured releases and concentrations at boundary locations. The estimates of total effective radiation doses from airborne particulate and radon releases at the boundary of Colorado’s proposed Piñon Ridge mill are less than 10 mrem/yr based on the MILDOS dose assessment (Two Lines, 2009). The estimated annual effective doses to the nearest resident from the Cotter uranium mill in Cañon City, Colorado are less than 10 mrem/yr (Cotter, 2012). It is not possible to estimate the potential dose from a uranium recovery facility without specifying the configuration of the facility and the distance to site boundaries. The Annual Environmental Monitoring Reports, required for each operating facility, generally include public dose estimates based on monitoring. The EPA The Naturally Occurring Radioactive Materials (TNORM) Technical Report (EPA, 2007) provides some estimates of doses to individual members of the public at a distance of 2,000 meters from a typical mill. The estimated effective dose including radon decay products is less than 10 mrem/yr. This estimate was based on 1980 mill operating conditions. Current doses are expected to be lower due to regulatory limitations on the size of tailings impoundments, and the use of zero-particulate-emission vacuum dryers. Current tailings impoundments are limited to 10 or 40 acres, depending on the disposal method, and must be lined and below grade, compared to previous above grade tailings unlined impoundments that ranged in area up to 130 acres or more (SC&A, 2008).

4.0 COMPARISON OF RECOMMENDATIONS TO EXISTING REGULATIONS

4.1 Radiation Protection Regulations (12 VAC5-481)

Existing VDH Radiation Protection Regulations were compared for compatibility with NRC regulations for source material. This comparison is tabulated in Appendix I.

In analyzing existing VDH regulations in order to suggest recommended changes to them, two scenarios were considered. The first scenario assumes that the Commonwealth decides not to become an Agreement State for uranium milling. The second scenario is based upon the situation in which the Commonwealth decides to become an Agreement State for uranium milling.

4.2 Commonwealth Not An Agreement State for Uranium Milling

Analysis of the existing VDH Radiation Protection Regulations shows them to be compatible with NRC regulations in 10 Code of Federal Regulations (CFR) Part 40 with regard to the regulation of source material, if uranium/thorium milling is not included. Therefore, no amendments to the existing regulation are necessary to maintain the status quo.

However, there is ambiguity in the existing VDH Radiation Protection Regulations with regard to the licensure status of undisturbed ore bodies containing uranium and or thorium. This ambiguity does not apply to the NRC regulations because the Atomic Energy Act (AEA) gives regulatory authority to the NRC only when such ores are removed from their "*place of deposition in nature*".

It is recommended that VDH add the following language to its regulations as 12 VAC5-481-390.B to clear up this ambiguity:

"Any person is exempt from 12 VAC5-481-380 if that person receives, possesses, uses, or transfers unrefined and unprocessed ore containing source material; provided that, except as authorized in a specific license, such person shall not refine or process such ore."

In order for VDH to have the authority in its regulations to regulate the releases of radioactive materials to air and water from ores and mining wastes, and require personnel dosimetry for workers in uranium mines, the regulation should be modified to read:

"Any person is exempt from 12 VAC5-481-380 if that person receives, possesses, uses, or transfers unrefined and unprocessed ore containing source material; provided that, except as authorized in a specific license, such person shall not refine or process such ore. This exemption does not apply to the mining of ore containing source material."

If VDH adopts the above regulation, the regulatory status of uranium mining needs to be stated in regulations. That is, will uranium mining be subject to regulation via a general or specific license?

If such a regulation is adopted by VDH, it is recommended that uranium mining be regulated as a generally licensed activity. The establishment of uranium mining as a generally licensed activity could be added to the VDH regulations at 12 VAC5-481-420.D by adding the following or similar wording:

"Uranium Mining - A general license is issued to mine, transport, and transfer ores containing source material without regard to quantity. Persons who mine, transport, and transfer ores containing source material shall comply with the provisions of Part IV Standards for Protection Against Radiation."

4.3 Commonwealth as an Agreement State for Uranium Milling

The recommended changes above should also be considered for adoption by VDH if the Commonwealth becomes an Agreement State for uranium milling.

A comparison of the existing VDH Radiation Protection Regulations with NRC regulations in 10 CFR Part 40 with regard to the regulation of uranium/thorium milling identifies changes that would have to be made to the VDH regulations to make them compatible with those of the NRC. Table I.2 in Appendix I summarizes the sections of the NRC regulations that are not included in the existing VDH regulations. These would need to be added for the Commonwealth to become an Agreement State for uranium milling.

VDH should consider adding a separate part to its regulations to address uranium milling, as it has done for other types of licenses such as industrial radiograph, low-level radioactive waste, etc.

The following paragraphs discuss the provisions of NRC regulations that would need to be added to VDH regulations.

1. 10 CFR Part 40.2a Coverage of Inactive Tailings Sites – Although the requirements in this section are assigned a Level of Compatibility "A" by the NRC for states seeking an Amended Agreement for uranium milling, it does not appear that these provisions of the NRC regulations apply to the Commonwealth since there are no existing uranium mill tailings sites located within Virginia. Therefore, it does not appear that VDH regulations would need to be amended to include these provisions.
2. 10 CFR Part 40.3 License Requirements –VDH will need to add this section to its regulations (12 VAC5-481-380) in order to have regulatory authority for uranium milling operations and associated tailings disposal.

3. 10 CFR Part 40. 4 Definitions – The following definitions would need to be modified or added for VDH regulations (12 VAC5-481-10) to be compatible.
    - Commencement of Construction – modified to agree with 10 CFR Part 40.4.
    - Uranium Milling – definition added.
4. 10 CFR Part 40.13 Unimportant Quantities of Source Materials – These provisions are adopted by reference in 12VAC5-390; however, it is recommended that the wording mentioned above as an addition to 12 VAC5-390 be added at 12 VAC5-390.B.
5. 10 CFR Part 40.22 Small Quantities of Source Material - These provisions are adopted by reference in 12 VAC5-420.A; however, it is recommended that the wording mentioned above as an addition to 12 VAC5-420 be added at 12VAC5-420.D.
6. 10 CFR Part 40.26 General License for Possession and Storage of Byproduct Material as Defined in This Part - Although the requirements in this section are assigned a Level of Compatibility “C” by the NRC for states seeking an Amended Agreement for uranium milling, it does not appear that these provisions of the NRC regulations apply to the Commonwealth since there are no existing uranium mill tailings sites located within Virginia. Therefore, it does not appear that VDH regulations would need to be amended to include these provisions.
7. 10 CFR Part 40.31 Application for Specific Licenses – VDH will need to add provisions to it regulations to incorporate the provisions of 10 CFR Part 40.31(f) through (m).
8. 10 CFR Part 40.65 Effluent Monitoring Reporting Requirements - VDH will need to add provisions to it regulations to incorporate the provisions of 10 CFR Part 40.65.
9. 10 CFR Part 40, Appendix A, Criteria Relating to the Operation of Uranium Mills and the Deposition of Tailings or Waste Produced – This Appendix to 10 CFR Part 40 contains specific requirements related to the design, construction, operations, and closure of a uranium mill. VDH will have to add these or more stringent requirements to its regulations. It should be noted that the NRC has made recent changes to this Appendix (FSME-12-064) and is currently reviewing these requirements with the intent of strengthening them. VDH should closely follow the NRC review of proposed changes to this Appendix.
10. The Criteria are essentially performance-based rather than prescriptive. In its review of these Criteria VDH may want to consider the advisability of modifying some of these Criteria to be more prescriptive or adding additional prescriptive based criteria.

Each of the Criteria has been reviewed and those with recommended changes are identified in the following paragraphs.

1. References to NRC regulations and reporting to the NRC should be replaced with references to specific citations in VDH regulations and VDH reporting requirements, references to the

“Commission” should be replaced with references to VDH, and references to pre-existing byproduct material, milling, and tailings sites should be deleted since these do not exist in Virginia.

2. 10 CFR Part 40, Appendix A, Introduction - Since there are presently no existing uranium milling or tailings disposal sites in Virginia, the definition for “Existing portion” need not be included in VDH regulations.
3. Consideration should be given to modifying the definition of “Uppermost aquifer” to read:

   “Uppermost aquifer means the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility's property or within five (5) miles of its boundary.”

4. 10 CFR Part 40, Appendix A, Criterion 3 – It is recommended that the first sentence in this Criterion be replaced with the following to de-emphasize the option of deposing of tailings in the mine:

   “The ‘prime option’ for disposal of tailings is placement below grade such that the need for any specially constructed retention structure is minimized. However, if placement of the tailings in the mine is proposed, the applicant should demonstrate to the written satisfaction of VDH that this practice will not result in degradation of groundwater quality.”

5. 10 CFR Part 40, Appendix A, Criterion 4 – Considering the environmental conditions, including rainfall, in Virginia, the following changes to this Criterion are recommended:
   - Subparagraph (a) – Modify to read:

     “Upstream rainfall catchment areas must be minimized to decrease erosion potential and the size of the floods which could erode or wash out sections of the tailings disposal area. Storm water diversion systems shall be designed, constructed, maintained, and operated around the mine and mill sites to safely accommodate the probable maximum precipitation (PMP) event in the upstream rainfall catchment areas.”

   - Subparagraph (c) – Modify to read:

     “Embankment and cover slopes must be relatively flat during operations and after final stabilization to minimize erosion potential and to provide conservative factors of safety assuring long-term stability. The broad objective should be to contour final slopes to grades which are as close as possible to those which would be provided if tailings were disposed of below grade; for example, slopes of 10 horizontal to 1 vertical (10h:1v) or less steep. Where steeper slopes are proposed, reasons why a slope less steep than 10h:1v would be impracticable should be provided, and

compensating factors and conditions which make such slopes acceptable should be identified."

- Subparagraph (d) - Modify to read (added language is shown in italics):

  *"A full self-*sustaining vegetative cover must be established and maintained *during operations and following closure* to reduce wind and water erosion to negligible levels."

  "Furthermore, all impoundment surfaces must be contoured to avoid areas of concentrated surface runoff or abrupt or sharp changes in slope gradient. In addition to vegetative cover on slopes, areas toward which surface runoff might be directed must be well protected with substantial rock cover (rip rap). In addition to providing for stability of the impoundment system itself, overall stability, erosion potential, and geomorphology of surrounding terrain must be evaluated to assure that there are not ongoing or potential processes, such as gully erosion, which would lead to impoundment instability."

4.4 Additional Criteria for Consideration by VDH

Due to Virginia's environment and the concerns of citizens and local organizations (both private and governmental) expressed repeatedly in public meetings and in previous reports relating to the potential adverse effects that uranium mining and milling could present, the following additional criteria are provided for consideration by VDH. These additional criteria would demonstrate the resolve of VDH to conduct a regulatory program that goes beyond the current recommendations of the NRC.

The term "licensed area" as used in these criteria includes the surface area around both the mine and the mill, if the mill were to be located at the mouth of the mine. In reality, all activities involving the ore that are conducted once the ore leaves the mine are part of the processing of the ore and therefore should be licensed activities.

4.4.1 License Area

The license area shall be contoured and provided with detainment structures or areas to ensure that no runoff from the licensed area is released off-site until the liquids have been sampled, analyzed, and determined to meet as a minimum the stream standards of the receiving stream or drainage basin. The capacity of such holding features shall be designed, constructed, and operated to have a capacity of holding the runoff from the entire licensed area for the probable maximum precipitation (PMP) event over the licensed area. In the design of such features no credit for evaporation shall be assumed to occur.

4.4.2 Environmental Laboratory

The applicant/license shall have an analytical environmental laboratory, either on site or readily available, capable of detecting and measuring environmental levels of radionuclides and chemicals associated with uranium mining and processing. The laboratory shall be capable of making these determinations in all media including air, water (and other liquids including milk), and solids (including soil, vegetation, and animal tissue). The laboratory shall be capable of completing analyses within 24 hours of the time a sample is taken.

"All analyses shall be performed based on written procedures for sampling, sample processing, and analysis. The analysis shall be conducted under a quality assurance/quality control (QA/QC) program approved by VDH, which ensures the accuracy of the results."

The laboratory shall be licensed/certified by organizations and agencies acceptable to and/or approved by VDH.

All liquid wastes from the laboratory shall be handled in a separate, controlled disposal system, which is not interconnected with domestic waste or other waste handling systems. All solid wastes from the laboratory shall be controlled and assumed to be radioactively contaminated until surveyed/analyzed and determined not to be contaminated above release limits set by VDH.

4.4.3 Environmental Monitoring of Water Sources by Applicant/Licensee

The applicant/licensee shall sample and analyze on a monthly basis all surface waters including streams, ponds, and springs within 2 miles of the site boundaries during the one-year baseline sampling period used for the environment report which will accompany the license application. All sampling and analyses shall be conducted according to procedures and methods approved by VDH prior to commencement of sampling. The applicant/licensee shall continue the same sampling and analyses on a quarterly basis from the end of the one-year baseline sampling program until the radioactive materials license for the mill is either granted or denied by VDH. As used in this criterion, "quarterly" means at intervals not to exceed 3 months, and evenly spaced throughout the year. If the license is issued by VDH, the applicant/licensee shall continue the sampling of all surface waters as required by VDH per the applicable license. The applicant/licensee shall file a report of its findings twice each year no later than 45 days following the end of the second quarter of each sampling period.

The same methodology will be utilized for private water wells (within 2 miles) and public water supplies (within 5 miles).

4.4.4 Environmental Monitoring of Commercial Food Sources by Applicant/Licensee

The applicant/licensee shall conduct representative sampling and associated analyses of crops being commercially grown for human and/or livestock foodstuff (including pasture land grasses and tobacco) within 2 miles of the site boundaries during the one-year baseline sampling period used for the environment report which will accompany the license application. All sampling and analyses shall be conducted according to procedures and methods approved by VDH and the Virginia Department of Agriculture and Consumer Services (VDACS) prior to commencement of sampling. The applicant/licensee shall continue the same sampling and analyses from the end of the one-year baseline sampling program until the radioactive materials license for the mill is either granted or denied by VDH. If the license is issued by VDH, the applicant/licensee shall continue the sampling and analyses as required by VDH per the license. The applicant/licensee shall file a report of its findings annually by March 31 of the year following the sampling period.

4.4.5 Meteorological Station

In order to provide meteorological data necessary to assess off-site radiation doses it is essential to have local data that can be used in dose calculations for the license application and during operations. Both the NRC and the EPA have produced guidance documents concerning the collection of meteorological data. This guidance and specifics regarding the establishment and operation of a meteorological station are provided in “Uranium Study: Air Quality Monitoring Report Commonwealth of Virginia Department of Environmental Quality (DEQ), Department of Mines, Minerals and Energy (DMME)”. This report was produced by WES under contract to DEQ/DMME. This project’s Interim Report 2 (WES, 2012b) provides detailed discussions of appropriate meteorological monitoring systems.

The following criterion is suggested for consideration by VDH:

- The applicant/licensee shall have an on-site meteorological station capable of continuously measuring and recording meteorological conditions including temperature, wind speed and direction, precipitation, evaporation, and barometric pressure. This station shall be available and operating throughout the baseline period until the radioactive materials license for the mill is either granted or denied by VDH. If the license is issued by VDH, the applicant/licensee shall continue the operation of the meteorological station as required by VDH per the license.

4.5 Water Works Regulations (12 VAC5-590 et seq.)

The regulations of VDH related to water works providing water to public water systems currently contain provisions addressing the radiological quality of those waters at 12 VAC5-590 et. seq. These standards are consistent with those of the EPA and are considered protective of public health. No changes to those regulations appear to be necessary.

One issue, which VDH may want to consider pursuant to the *Waterworks Regulations*, is as follows: After meeting radiological quality standards for a period of time, the sampling and analysis interval at a water works may be extended. Such a decision would be at the discretion of VDH.

It is suggested that if a site is identified for uranium mining and milling VDH should require waterworks to sample and have water samples analyzed for radiological quality on a more frequent schedule. At a minimum, these water samples should be evaluated at intervals not to exceed three months. This sampling and analysis could be coordinated with the environmental monitoring program of the applicant/licensee of the uranium facility.

4.6 Disease Reporting and Control Regulations

The Commonwealth of Virginia currently mandates statewide disease surveillance and reporting under Sections 32.1-35 and 32.1-39 of the *Code of Virginia* and 12 VAC 5-90-80 and 12 VAC 5-90-90 of the Board of Health *Regulations for Disease Reporting and Control* - http://www.vdh.virginia.gov/epidemiology/regulations.htm.

See Section 5.1.1 for a comparison of Virginia regulations with federal and other state requirements.

4.7 Private Water Well Regulations (12VAC5-630 et seq.)

The regulations of VDH related to private water wells are almost exclusively devoted to the permitting and construction of new wells, and re-works of existing wells. Other than stand-off distances from certain identified potential sources of pollution, there are few requirements regarding siting.

The only references to water quality are those related to testing for bacteriological contamination for certain new and re-worked private water wells and the remedial actions that must be taken if the well does not meet the standards in the regulations. There are no requirements within the regulations for routine, regularly conducted re-testing of private water wells.

To determine what other states have implemented as regulations for private water wells, the private water well requirements of the states of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, Delaware, Maryland, Pennsylvania, West Virginia, North Carolina, and Iowa were reviewed. The New England states and Iowa were included in the review because of problems that these states have experienced due to high levels of radionuclides (primarily uranium and radon) in groundwater and to determine what the regulatory responses have been in those states. The other states included in the review were included due to their proximity to Virginia.

All of the states reviewed have regulations similar to those of VDH requiring permitting of the construction of new private water wells and reworks of existing private water wells and testing for bacteriological contamination. Some states include springs and cisterns in their requirements.

In addition, some states require that the owner of the private water well perform testing prior to the transfer of ownership of land with a private water well to a new owner; in other states such testing may be required by lending companies and mortgage holders. The states have not (except as noted below) set water quality standards for potential chemical pollutants and radionuclides and do not require testing of private water wells for these.

Several of the states, notably those in the New England area, do have aggressive programs to encourage private well owners to have testing done, and in some cases provide the service by state laboratories (for a fee), or provide lists of commercial laboratories approved by the state to perform such tests. States also recommend that private water well owners not use wells that exceed the limits for public water supplies as sources of drinking water.

In 2008, the State of North Carolina adopted regulatory standards for private water wells equivalent to those for public water systems regarding potential chemical and radionuclide pollutants, and required that private water wells be tested. Included in the regulations were follow-up requirements to notify local health departments in the event a private water well sample exceeded regulatory limits.

*“**15A NCAC 18A .3805 DATA REVIEW***

(a) For all private well sampling data where chemical or biological contaminants are detected exceeding the Maximum Contaminant Levels (MCLs) for public drinking water, as defined in 15A NCAC 18C, the North Carolina Occupational and Environmental Epidemiology Branch (OEEB) shall provide the following to the local health department from which the sample was collected:

(1) information about the contaminant(s) exceeding public drinking water MCLs;

(2) recommendations for water use limitations or treatment options to reduce exposure to a level comparable to meeting public drinking water MCLs; and

(3) recommendations about the need for and the frequency of repeat sampling.

(b) The local health department shall provide information to the well owner or respective lease holder concerning chemical and biological contaminants exceeding public drinking water MCLs and the need for exposure limitation, remediation, or future sampling. History Note: Authority G.S. 87-97; Eff. July 1, 2008.”

The North Carolina testing and notification program is aimed at allowing the well owner to know if there are any issues regarding the water quality of a private water well. North Carolina cannot prohibit the use of a private water well unless that well is serving as conduit for contamination of an aquifer. If a well is found to exceed water quality standards, North Carolina recommends various treatment options and recommends that the well owner consult with a local water treatment specialist for treatment methods.

In order for VDH to regulate water quality in private water wells including chemical and radiological concentrations, it would be necessary for VDH to adopt regulations to impose such standards. This will require changes in Commonwealth laws related to private water wells and the role of VDH has in regulating such wells.

Appropriate regulations for the radiological quality of private wells could be similar to those presently in 12 VAC5-590-400 for public drinking water sources. Similar regulations for other potential chemical pollutants could be similar to those presently in 12 VAC5-590 et. seq. The regulations of the State of North Carolina might be considered if VDH decides to adopt regulations regarding the water quality of private water wells.

4.8 Regulations Concerning Recreational Use of Water

There are no regulations regarding the radiological quality of waters for recreational use. The EPA with the cooperation of the states does evaluate the water quality of surface waters throughout the United States. Surface waters are rated as GOOD –meaning, "*The waterbody fully supports its intended uses*" or IMPAIRED – meaning, "*The waterbody does not support one or more of its intended uses*".

Appendix II provides a tabulation of the waterbodies within Virginia that were determined to be impaired in 2010, the last year for which data is available, and the causes of the rating. A total of 1,586 impairments were noted with the largest number (691) being due to pathogens in the waterbody. None of the impairments was due to the presence of radionuclides in the waterbody. A listing of impaired waterbodies in Virginia is available from the EPA's website.

4.9 MSHA Regulations

As noted in Section 8.0, Mine Safety and Health Administration (MSHA) is responsible for worker radiation protection at mines. MSHA regulations cover all aspects of physical safety at mine and operating uranium mills. However, MSHA has no responsibility for public exposures from radiation.

5.0 DETERMINE AND CHARACTERIZE AVAILABLE HEALTH DATA

This section of the report determines and characterizes available data (including national and Virginia-specific data) on potential health outcomes related to exposures of concern.

5.1 Adequacy of Current Reporting Requirements and Laboratory Testing Capabilities for Chemical and Toxins

5.1.1 Reportable (Notifiable) Diseases and Conditions

"Reportable" or "Notifiable" diseases and conditions are generally mandated in state regulations, under the authority and oversight of the State Board of Health and State Health Department. Reporting of diseases may be further defined in state regulations to indicate the reporting agency (i.e., laboratories, physicians, other healthcare providers or facilities), and/or reporting timeline. Reportable conditions may vary by location within the state; (e.g., the State of Colorado limits required reporting of certain diseases to Denver Metropolitan Area Counties only.) Please note that different terminology is used by states to describe the same types of reportable conditions. Examples include terminology used to describe food-borne illnesses and outbreaks, illnesses caused by exposure to toxic chemicals, water-borne illnesses, and situations where larger numbers of individuals in a community become ill with the same condition. In most cases, a list of potential "toxic" substance exposures is not provided. These exposures and health outcomes are grouped into a single category of "exposure-related" illnesses.

Virginia’s regulations and mandates track closely with those of the Centers for Disease Control and Prevention (CDC) and those of other states (e.g., Colorado, New Mexico, Texas, and Wyoming) that have historic or current uranium mining and processing facilities. Specific diseases or conditions for which reporting to local, state, or national health authorities is mandatory differ somewhat, based on geographic location (presumably reflecting prevalence of certain infectious diseases or opportunities for exposure to infectious agents), and disease definitions. Reporting regulations generally group public health concerns related to population clusters of disease (“outbreaks”) or population exposures to toxic chemicals or agents in environmental or occupational settings into categories such as “Outbreaks” or “Toxin-Induced Illness”. The latter may be defined more specifically in state codes or regulations. For example, the Commonwealth of Virginia’s Board of Health *Regulations for Disease Reporting and Control, Part III REPORTING OF DISEASE, 12 VAC 5-90-80, Reportable Disease List, Section D. Toxic substance-related illnesses* states:

“All toxic substance-related illnesses, including pesticide and heavy metal poisoning or illness resulting from exposure to an occupational dust or fiber or radioactive substance, shall be reported.”

New Mexico's regulations are more specific regarding the types of occupational exposures or health conditions that must be reported (e.g., silicosis, occupational asthma, hypersensitivity pneumonia, etc.), although these are still limited in terms of the particular chemical or toxin exposures and potential disease outcomes. (Note: These and other occupational illnesses and exposures may also be reportable within the state to the Department of Labor, National Institute for Occupation Safety and Health [NIOSH] or MSHA, even if they are not reportable to the state's Health Department or CDC.)

The Colorado Department of Public Health and Environment (CDPHE), Disease Control and Environmental Epidemiology Division operates under a specific set of state regulations promulgated by the State Board of Health pertaining to "environmental and chronic disease", *6 CCR 1009-7 State Board of Health Rules and Regulations Pertaining to the Detection, Monitoring and Investigation of Environmental and Chronic Disease"* http://www.colorado.gov/cs/Satellite/CDPHE-Main/CBON/1251631269028. This set of regulations is specific to "environmental and chronic disease" reporting, separate from the regulations covering other reportable conditions in the state of Colorado. Colorado is also a member of the CDC's "Environmental Public Health Tracking" network. This is a relatively recent partnership, beginning with funding for planning that was received in August 2009 from the CDC. Colorado and New Mexico (see Section 6.2.1) are among 24 states and cities that are currently participating in the environmental public health tracking network. However, other than containing a very specific list of congenital and birth defects that must be reported to the Department of Health, these Colorado regulations are no more specific regarding chemical or environmental exposures than any of those discussed above.

In Virginia, 12 VAC 5-90-80 also speaks to the broad categories of conditions and exposures described above:

Section E. Outbreaks

"The occurrence of outbreaks or clusters of any illness which may represent a group expression of an illness which may be of public health concern shall be reported to the local health department by the most rapid means available."

Section F. Unusual or ill-defined diseases or emerging or reemerging pathogens

"Unusual or emerging conditions of public health concern shall be reported to the local health department by the most rapid means available. In addition, the commissioner or his designee may establish surveillance systems for diseases or conditions that are not on the list of reportable diseases. Such surveillance may be established to identify cases (delineate the magnitude of the situation) to identify the mode of transmission and risk factors for the disease, and to identify and implement appropriate action to protect public health. …"

Required reporting for cancer and congenital anomalies in Virginia are included in the following regulations and statute:

Cancer. Regulations for Disease Reporting and Control, Commonwealth of Virginia, State Board of Health, March 2011, Part VIII. CANCER REPORTING, Regulations 12 VAC 5-90-150, 12 VAC 5-90-160, 12 VAC 5-90-170, and 12 VAC 5-90-180.

Congenital Anomalies. *Code of Virginia Section 32.1-69.1 Virginia Congenital Anomalies Reporting and Education System.* Data from birth and death certificates and fetal death reports are filed with the State Registrar of Vital Records, along with data obtained from hospital medical records. The chief administrative officer of every hospital is required to make a report regarding any child less than two years of age diagnosed as having a "congenital anomaly".

Therefore, based on this analysis, it would seem that the Commonwealth of Virginia's current reporting requirements reflect the national standard, even in states that have uranium mining and processing operations and potential exposures. With respect to diseases and conditions (Table 5-1) that have the potential to be related to uranium mine/mill operations, cancer outcomes are already reported and are part of VDH's "Comprehensive Cancer Control Project", with statistics updated and reported annually. Similarly, VDH maintains a registry of "congenital anomalies" (see statute above). VDH's Chronic Disease Prevention, Health Promotion, and Oral Health service area is charged with implementing programs that address chronic diseases, including cancer and diabetes, both conditions of interest with respect to mining and milling exposures for workers and the public (cancer as a long-term health outcome, diabetes as a confounder or exacerbating condition). Statutory authority to "administer and provide a comprehensive program of preventive, curative, restorative and environmental health services,[…] and collect and preserve health statistics," comes from the *Code of Virginia* (Section 32.1-2), and Sections 32.1-70 and 32.1-71 of the *Code of Virginia* require VDH to maintain a population-based central cancer registry based on reports from hospitals, clinic, pathology laboratories, and physicians.

Asthma statistics (including statistics on work-related asthma) have been collected and reported by health district through the CDC-funded "Asthma Control Project" that resulted in a state Asthma Control Plan and a state Asthma Coalition. Funding for this collaborative effort ended in 2010, but basic prevalence data continues to be collected through the Behavioral Risk Factor Surveillance Study.

Concerning toxic substances surveillance, two separate databases are maintained within the Public Health Toxicology Program. The first contains information on children, age 15 years or younger, with an elevated blood lead level of greater than or equal to 10 micrograms of lead per deciliter of whole blood (micrograms of lead per deciliter [µg/dL]). The information is reported to VDH by physicians, laboratories, hospitals, and medical facilities. Statistical analysis is performed on the number of reported cases by race, sex, age, range of elevation, population rates, locality, and health district. The second database contains information on adults whose diagnostic test results implicate a possible exposure to a toxic substance. Examples of the reports include blood or urine test results for exposure to lead, cadmium, mercury or arsenic. Information is also provided on individuals diagnosed with asbestosis or pneumoconiosis. The data is collected from physicians, laboratories, hospitals and other state agencies.

The VDH also conducts seasonal surveillance of influenza cases through a network of physicians, laboratories, and hospitals and other medical facilities.

Baseline data and trends for smoking rates, diabetes and related conditions may be obtained through the CDC's annual Behavioral Risk Factor Surveillance System (BRFSS) and National Adult Tobacco Survey (NATS). This data is sampled at the health district level, and therefore, may not be statistically valid for county-level trends. Additional data on kidney disease could be obtained through a reporting network such as that used for the Public Health Toxicology Program.

5.1.2 Laboratory Reporting Protocols for Chemical/Toxin Exposures

The Commonwealth of Virginia appears to have the most specific instructions – among the states listed in Table 5.1 for reporting of laboratory testing of biosamples in cases of suspected chemical/toxin exposure or illnesses attributed to these types of exposures. Under Section 32.1-36 of the *Code of Virginia*, and 12 VAC 5-90-80 and 12 VAC 5-90-90 of the Board of Health *Regulations for Disease Reporting and Control*, laboratory directors are required to report the following for suspected "Toxic substance-related illness": *"Blood or urine laboratory findings above the normal range, including but not limited to heavy metals, pesticides, and industrial-type solvents and gases. Speciation of metals should be reported, if applicable and available, when blood or urine levels are elevated in order to differentiate the chemical species (elemental, organic, or inorganic)"*.

5.2 Baseline Rates of Lung Cancer, Silicosis and Radon-Associated Health Problems

This section discusses the adequacy of current tobacco use surveillance for establishing baseline rates of lung cancer, silicosis and radon-associated health problems using standard epidemiological analytic methods.

Information about population smoking rates, occupational or recreational exposures to silica dust, and radon levels in buildings within a geographic area, provide useful information for assessing the component of disease causation that may be attributable to new environmental exposures. An assessment of tobacco use within a health district or county is available through the annual BRFSS. It may be possible to infer rates of occupational exposure to silica from

Department of Labor statistics. Radon levels, designated as "radon zones" are available for each state through the EPA's "Map of Radon Zones", http://www.epa.gov/radon/zonemap.html. More specific information may be available through Commonwealth resources for Virginia counties and communities.

5.3 Other Available Data to Establish Baseline Rates for Conditions of Concern

The VDH's "congenital anomalies" database, mortality tracking, and the ability to obtain state-wide hospital discharge and emergency room/urgent care visit data thorough an existing contractual arrangement with Virginia Health Information (VHI) should provide sufficient data to determine baseline rates for conditions of concern including respiratory conditions (i.e. asthma, chronic obstructive pulmonary disease or [COPD]) and kidney disease. Hospitalization and emergency room or clinic visit baseline rates for respiratory conditions such as asthma and COPD are particularly important for identifying short- and long-term exacerbations of these conditions as a result of fugitive dust exposures from a mining or mill site. Baseline rates of diabetes-related kidney disease, in particular, are important for determining whether increased reports of kidney disease are related to heavy metal exposures or other conditions. Hospital admission/discharge data obtained by VHI can be used to establish baseline rates of disease and track any changes in disease patterns.

5.4 Need for Retrospective or Other Studies to Determine Baseline Rates

If baseline rates for the conditions described above have not been determined, it may be useful to attempt to establish these baselines for Pittsylvania County and any other potentially affected county. These baselines can be utilized to determine whether any conditions that are reported after the start-up of uranium mining or processing operations exceeded baseline rates and/or existed prior to the start of these operations.

5.5 Necessary Changes or Enhancements to Cancer, Congenital Malformation Reporting

Paracelsus is credited with first articulating that the 'poison is in the dose', which for radiation epidemiology translates as 'the lower the dose, the lower the risk' and, as an important corollary, the lower the dose, the greater the difficulty in detecting any increase in the number of cancers possibly attributable to radiation (Boice, 2012).

This principle is important in evaluating the adequacy of population-based registries of cancer and birth defects, when trying to detect long-term health outcomes from exposure to low levels of radiation or toxins, especially in small, rural populations. Poverty and low socio-economic status have been associated with somewhat higher cancer rates, in general (Kavachi and Lochner, 2000).

That said, VDH maintains state-wide registries for both cancer and birth defects that should provide appropriate baseline data for evaluating incidence rates in Pittsylvania County and identifying long-term trends and/or occurrences of disease clusters, rare cancers or unusual congenital malformations. In addition, VDH's Pregnancy Risk Monitoring System (PRAMS) collects state-wide data on pregnancy outcomes that will be available to supplement the information provided by the birth defects registry and to identify any unusual trends in health outcomes for vulnerable populations of fetuses and infants. It is worth noting, in this context, that Brugge and Buchner, in their 2011 review of research on uranium-related health effects did not find any *in vivo* research that supported uranium-related genotoxicity (Brugge and Buchner, 2011).

6.0 DEVELOP AND TEST CASE REPORT INVESTIGATION MATERIALS

6.1 Case Investigation Worksheets

The specified task was to develop and test case report investigation (web-based and paper form) worksheets and other documents for local health department, Central Office and laboratory and medical provider use in any necessary investigations for relevant health outcomes. Based on information supplied in Section 6.2 below, the existing system appears to be adequate for any potential health outcomes that might result from uranium mining and milling in the Commonwealth.

6.2 Existing Investigation Worksheets and Other Tools from Virginia and Other States

With respect to reporting authorities and lines of communication, reporting protocols again generally follow the same pattern among the example states. Like the Commonwealth of Virginia (as defined in the Administrative Code 12VAC5-90-90), each state's regulations specify the individuals (e.g., physicians, other healthcare providers) and agencies (e.g., hospitals, laboratories, childcare centers) that are required to report any of the specified diseases or conditions and the timeframe within which the reporting must occur. The latter varies depending on the nature of the condition, particularly with respect to the infectious nature or population threat of the disease or exposure.

These regulations also specify the means by which reporting may occur and the agency to which the report must be made (local health department, state Department of Health, etc.). In all of the examples provided, both paper forms and electronic reporting are possible. (The VDH reporting form is available at www.vdh.virginia.gov/Epidemiology/ documents/pdf/Epi1.pdf. Reports may also be made using a computer-generated printout, the CDC surveillance form or by secure electronic transmission.) Immediate reporting by phone is sometimes required. VDH requires immediate reporting of 33 of the conditions on the reportable disease list.

In the case of laboratory-verified diagnoses, states generally require that both the diagnosing physician and the verifying laboratory submit reports. Reporting forms generally request the following types of information:

- name of disease or condition;
- patient's name;
- patient's date of birth, gender, race and ethnicity;
- patient's home address and phone;

- physician's name, address and phone;
- laboratory information, including test name, collection date and specimen type;
- name, agency name, address, contact information for person submitting report; and
- space may be provided for other information regarding the illness (e.g., immunization status, occupational status or risk situation, treatment, signs/symptoms).

6.2.1 Changes to Improve Data Completeness, Accuracy and Information Flow

The states of New Mexico and Texas have established specific programs for monitoring, tracking and preventing adverse health outcomes of hazardous substance exposures. Both present interesting models, some aspects of which might be applicable to VDH.

The Health Assessment and Toxicology Program – Texas (www.dshs.state.tx.us/epitox/hat.shtm)

The Health Assessment and Toxicology Program (HAT) program is the principal state public health program involved with hazardous waste issues, and operates within the Department of State Health Services under the *Health and Safety Code, Title 6, Chapter 503.005: Health Risk Assessments* and *Title 2. Subtitle H, Chapter 161.0211. subchapter C: Epidemiology or Toxicology Investigations*. "The program is responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life." The HAT program works with agencies such as the Agency for Toxic Substances and Disease Registry (ATSDR), the EPA, the Texas Commission on Environmental Quality (TCEQ), local governments and health departments, etc. to conduct studies of communities where people may be exposed to hazardous substances in the environment. These studies involve public health and risk assessments.

The VDH's Division of Environmental Epidemiology has a program that is similar to the HAT program. The ATSDR's Partnership to Promote Localized Efforts to Reduce Environmental Exposures (APPLETREE) program is a cooperative agreement between the VDH and the ATSDR. The stated purpose of the partnership is "to examine issues that involve human exposure to hazardous substances in the environment". One of the things that this partnership can do is conduct a Public Health Assessment (PHA), the result of which is an ATSDR-certified document that examines hazardous substances, health outcomes, and community concerns at a particular hazardous waste site. A PHA helps to determine the possible health effects related to site contamination. A PHA also includes actions to protect public health.

The Texas Occupational Conditions Reporting Act (www.dshs.state.tx.us/ epitox/eeop.shtm)

In 1985, the Texas State Legislature passed the Texas Occupational Conditions Reporting Act. The act originally required reporting of four occupational conditions to the Department of State Health Services: adult elevated blood lead levels, acute occupational pesticide poisoning, silicosis, and asbestosis. (All of these conditions are reportable in Virginia.) The Texas Board of Health was also given the authority, under the act, to add other preventable occupational conditions to the list. Since 1987, NIOSH provides limited funding for occupational disease surveillance in Texas.

New Mexico Environmental Public Health Tracking System (http://nmhealth.org/ eheb/envtracking.shtml)

The New Mexico Environmental Public Health Tracking (NMEPHT) system is part of the CDC's National Environmental Public Health Tracking Network. The objective of the NMEPHT and the CDC Public Health Tracking Network is to identify links between environmental exposure and health effects. The network provides a mapping tool that helps to identify exposure and potentially related disease patterns "to enable quicker responses to environmental public health issues and focused action to prevent disease." The NMEPHT is currently being used to map and create datasets for the following:

- air quality (ambient air particulate matter and ozone);
- water quality (drinking water contaminants, including arsenic, uranium, lead, nitrate and drinking water products);
- biomonitoring (blood, urine, hair; monitored contaminants include arsenic, uranium, lead, mercury and other metals);
- respiratory effects (including asthma hospitalization age-adjusted rates);
- cardiovascular effects (including heart attack hospitalization age-adjusted rates);
- cancer (including age-adjusted incidence rates for various types of cancers);
- birth defects (including prevalence of infants with cleft lip with or without cleft palate);
- reproductive health; and
- population data (population migration, percentage poverty, etc.).

6.2.2 Ascertain Necessary Content of Worksheets and Other Appropriate Tools or Necessity for Developing a State-Wide Database

Based on the above comments, worksheets necessary to track conditions or diseases that might be related to uranium mining and recovery are already in place. The health tracking systems cited above in Section 6.2.1 could be considered by VDH, as mentioned.

6.2.3 Draft Report Investigation Worksheets

If broad, large population epidemiological studies of potential uranium recovery-related health outcomes were planned then a new set of report investigation worksheets might be needed. However, given that no mining or milling is on-going, no such study is forthcoming. Any data collection/survey forms that would be needed for a population-based epidemiological study of communities impacted by uranium operations should be developed in conjunction with the study design. Please note that this statement implies the need for studies beyond the surveillance that is recommended in this report. As noted in the epidemiological review of the Initial Report, epidemiological studies of communities near uranium mines and mills have shown no significant impact to the non-worker population. It should also be noted that such studies are not routinely conducted by other states with uranium recovery facilities. Nevertheless, doing such studies is certainly possible and could document that no health effects have occurred. If VDH ascertains that such studies are necessary to assure the public that the Commonwealth is adequately protecting public health, then worksheets specific to the epidemiological studies would need to be developed. Worksheets that are already in place for ongoing VDH surveillance programs are adequate for baseline data collection and/or incidence-related health data reporting.

7.0 DEVELOP LOCUS OF RESPONSIBILITY

7.1 Current Responsibility for Long-term Monitoring of Health Effects

The VDH's *"Regulations for Disease Reporting and Control, 12 VAC 5-90-40. Administration"* provide the following guidance for assigning responsibility for short- and long-term health outcomes monitoring and surveillance:

"A. The State Board of Health ("board") has the responsibility for promulgating regulations pertaining to the reporting and control of diseases of public health importance and to meet any emergency or to prevent a potential emergency caused by a disease dangerous to the public health including but not limited to specific procedures for responding to any disease listed pursuant to § 32.1-35 of the Code of Virginia that is determined to be caused by an agent or substance used as a weapon or any communicable disease of public health threat that is involved in an order of quarantine or an order of isolation pursuant to Article 3.02 (§ 32.1-48.05 et seq.) of the Code of Virginia.

B. The State Health Commissioner ("commissioner") is the executive officer for the State Board of Health with the authority of the board when it is not in session, subject to the rules and regulations of and review by the board. The commissioner has the authority to require quarantine, isolation, immunization, decontamination, or treatment of any individual or group of individuals when he determines any such measure to be necessary to control the spread of any disease of public health importance and has the authority to issue orders of isolation pursuant to Article 3.01 (§ 32.1-48.01 et seq.) of the Code of Virginia and orders of quarantine and orders of isolation under exceptional circumstances involving any communicable disease of public health threat pursuant to Article 3.02 (§ 32.1-48.05 et seq.) of the Code of Virginia.

C. The local health director is responsible for the surveillance and investigation of those diseases specified by this chapter which occur in his jurisdiction. He is further responsible for reporting all such surveillance and investigations to the Office of Epidemiology. In cooperation with the commissioner, he is responsible for instituting measures for disease control, which may include implementing the quarantine and isolation orders of the commissioner.

D. The Office of Epidemiology, an organizational part of the department, is responsible for the statewide surveillance of those diseases specified by this chapter, for defining and disseminating appropriate disease control protocols for an outbreak situation, for coordinating the investigation of those diseases with the local health director, and for providing direct assistance where necessary. The Director of the Office of Epidemiology acts as the commissioner's designee in reviewing reports and investigations of diseases and recommendations by local health directors for quarantine or isolation. However, authority to order quarantine or isolation resides solely with the commissioner.

E. All persons responsible for the administration of this chapter shall ensure that the anonymity of patients and practitioners is preserved, according to state and federal law including the provisions of §§ 32.1-38, 32.1-41, and 32.1-71 of the Code of Virginia."

7.1.1 12 VAC 5-90-50. Applicability

A. This chapter has general application throughout the Commonwealth.

The *Code of Virginia* provides the following guidance for assigning responsibility for short- and long-term health outcomes monitoring and surveillance.

7.1.2 § 32.1-39. Surveillance and Investigation

A. The Board shall provide for the surveillance of an investigation into all preventable diseases and epidemics in this Commonwealth and into the means for the prevention of such diseases and epidemics. Surveillance and investigation may include contact tracing in accordance with the regulations of the Board. When any outbreak or unusual occurrence of a preventable disease shall be identified through reports required pursuant to Article 1 (§ 32.1-35 et seq.) of this chapter, the Commissioner or his designee shall investigate the disease in cooperation with the local health director or directors in the area of the disease. If in the judgment of the Commissioner the resources of the locality are insufficient to provide for adequate investigation, he may assume direct responsibility and exclusive control of the investigation, applying such resources as he may have at his disposal. The Board may issue emergency regulations and orders to accomplish the investigation.

7.1.3 § 32.1-40. Authority of Commissioner to Examine Medical Records

Every practitioner of the healing arts and every person in charge of any medical care facility shall permit the Commissioner or his designee to examine and review any medical records which he has in his possession or to which he has access upon request of the Commissioner or his designee in the course of investigation, research or studies of diseases or deaths of public health importance. No such practitioner or person shall be liable in any action at law for permitting such examination and review.

7.2 Additional Monitoring or Changes in Loci of Responsibility for Monitoring

See the discussion in Section 6.2 regarding public health programs established by the states of New Mexico and Texas.

7.3 Monitoring Occupational Exposures and Adverse Health Effects

This section summarizes existing regulatory programs for monitoring occupational exposures to licensed and non-licensed materials and adverse health effects.

7.3.1 Effects

NRC-licensed facilities are required by 10 CFR 19.13 (*Notifications and reports to individuals*), annually to report to each radiation worker their radiation exposure. The reports must include radiation exposure data, the results of any measurements, analyses, and calculations of radioactive material deposited or retained in the body each notification and report must be in writing; include appropriate identifying data such as the name of the licensee, the name of the individual, the individual's social security number and include the individual's exposure information. This is typically accomplished using NRC Form 5.

Exposures below the limit of 5 rem annually to a worker are considered to be safe. Hence, to the best of our knowledge, no state monitors for health effects on radiation workers at licensed facilities. An overexposure of a worker or workers would trigger a reportable event to the licensing agency.

During regulatory inspections by the NRC or the Agreement State, worker dose records may be examined, but they are not typically reported by name to the NRC or the Agreement State. However, summaries of collective doses or publications of trends by the licensee are published in annual reports to the licensing agency. Even if a facility is licensed by the NRC and Virginia is not an Agreement State, VDH could request copies of the annual report from the licensed facility operator.

7.3.2 Non-Licensed Facilities

Under the auspices of Section 40.1-1 of the *Code of Virginia* the Virginia Department of Labor and Industry (DOLI) is responsible in the Commonwealth for administering and enforcing occupational safety and health activities as required by the federal Occupational Safety and Health Act. The DOLI administers a state plan consistent with the provisions of Section 18(e) of the federal act. Under the state plan, DOLI may conduct an inspection of a facility when a fatality or catastrophe is reported, a formal complaint is received, a life-threatening condition referral is received, when an unsafe condition is observed by an inspector, or according to a general schedule.

The DOLI maintains statistics and contributes to the federal Occupational Safety and Health Administration (OSHA) occupational injuries and illnesses database. Incidences of the number of recordable cases (accidents, etc.), days away from work, and cases with job transfers or restrictions are accounted for annually. Information is segregated depending on the industry and economic sector. Virginia DOLI does not maintain a database of long-term health impacts on individual workers.

Additionally, see the description of the Texas Occupational Conditions Reporting Act in Section 6.2.1.

7.4 Recommendations for Modifying Virginia's Regulatory Framework

This section provides recommendations regarding options for modifying Virginia's regulatory framework to provide long-term tracking of adverse health effects from occupational exposures

The existing Virginia regulatory structure is adequate to track potential health effects from exposures received at either a uranium mine or mill. However, no state which processes uranium does such tracking. If tracking were to be undertaken in Virginia, there would be several difficulties with doing so. First, is the transience of workers. A short-term, temporary or former worker would need to submit to the tracking agency their current address, and submit either to a medical exam or a medical questionnaire on a recurring basis. Long-term employees of the milling facility could be required by license condition to undergo an annual physical with information being supplied to VDH. The Health Insurance Portability and Accountability Act (HIPAA) might present difficulties with sharing of the information. Second, given the long lag time between potential exposures from either industrial chemicals or radioactive materials at a mine or a mill, these surveys would need to be conducted for 10 to 20 years.

Worker exposures to radioactive materials at a mine or a mill are described in Section 8.0, below. The operator tracks those exposures by a variety of methods that are described. With the exception of long-term exposure to radon in mines, in conjunction with tobacco smoking, there is very little evidence of long-term health risk to either miners or millers.

Respiratory damage might be detected by the facility operator in that each worker who must wear a respirator as part of their job performance must pass at least an initial medical evaluation.

The NIOSH conducts a variety of studies of worker health studies for a wide variety of exposure scenarios including uranium worker studies. These, however, are not real time studies, but retrospective analyses of worker health for such facilities. In addition to uranium miners and millers, studies of other radiation workers at U.S. Department of Energy sites and worker exposure to radon have also been conducted. Summaries of the various studies can be found at: http://www.cdc.gov/niosh/pgms/worknotify/.

8.0 MONITOR WORK SPACES

This Section focuses on worker protection in uranium recovery facilities, specifically addressing monitoring and record keeping. Environmental monitoring to assess exposures to the general public will be addressed in Interim Report II (WES, 2012b).

Worker monitoring requirements and exposure limits in existing federal regulations and guidance are different in some aspects for uranium mines and mills. Worker radiation protection at mines is the responsibility of MSHA. Workers at operating uranium mills are under the jurisdiction of MSHA for most safety and health aspects and the NRC or an Agreement State for radiation protection. The NRC has no jurisdiction over uranium mines. An interagency agreement between MSHA and OSHA, dated 3/29/79, specified the responsibilities of each of the agencies in relation to mineral mining and milling (DOL, 1979). Workers at operating uranium mills are required to hold MSHA training certificates. MSHA regulations cover all aspects of physical safety at mine and operating uranium mills.

Air quality monitoring requirements for surface and underground, metal and non-metal mines are contained in 30 CFR 56 and 30 CFR 57, respectively. Requirements for monitoring of radon and diesel fumes are specified in the MSHA regulations for underground mines. Details of other monitoring programs for mines are left to the operator to develop with the caveat that the programs must be capable of detecting health hazards and concentrations of airborne contaminants in excess of the 1973 Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH). DMME has adopted the more recent ACGIH TLVs. The Commonwealth of Virginia may also wish to enact regulations with more specific and detailed provisions for monitoring.

In contrast to mining requirements, acceptable monitoring schedules and procedures for worker monitoring at uranium mills are defined in NRC Regulatory Guide 8.30. The NRC Regulatory Guides are not mandatory but deviations from their provisions generally must be shown to be at least as protective.

8.1 Underground and Open Pit Mines

As noted above, mine safety, including radiation protection is regulated under MSHA and DMME. The MSHA regulations cited in this section relate to metal and non-metal mines. The regulations for underground mines are contained in 30 CFR 57; for surface mines, 30 CFR 56. MSHA expands on the regulations for metal and non-metal mines in its Program Policy Manual, (DOL, 2012).

8.1.1 Evaluate Work Spaces

Routine evaluation of work spaces is addressed in Subpart Q of 30 CFR 56/57 that requires a "competent person" to examine each work area at least once each shift for conditions that might adversely affect safety or health and that records of the inspection be kept. This is a non-specific requirement but best practices would dictate that a standard form be used to insure that all potential hazards would be noted and corrected.

8.1.2 Potential Exposures

Potential exposures to uranium miners include direct radiation, radon decay product inhalation, inhalation of dust, mist, and diesel fumes as well as noise and other physical and safety hazards. This section is focused on hazards specific to uranium mining as well as airborne hazards likely to be encountered in all mines. Safety hazards covered by MSHA regulations are extensive, common to all mining situations and most do not involve monitoring, per se. Therefore, they are not addressed in this section.

8.1.2.1 Direct Radiation Exposures

MSHA regulations require annual gamma radiation surveys in underground uranium mines. Gamma radiation exposures must be measured using personal dosimetry if the average gamma radiation measurement from the survey is greater than 2.0 milliroentgen (mR) per hour[1]. The maximum allowable gamma radiation dose to a miner is 5 rem per year. The NRC and Agreement States require personal monitoring and dose tracking at a potential annual dose of 500 mrem or approximately 0.2 mrem per hour.

8.1.2.2 Radon

Radon monitoring requirements for underground uranium mines are specified in 30 CFR 57.5037. The frequency of monitoring is dependent on the measured radon decay product concentrations. All mines are required to measure radon concentration in exhaust mine air. If concentrations greater than 0.1 working level (WL)[2] are found in the exhaust air from underground uranium mines, radon decay product concentration measurements representative of the worker's breathing zone are required every two weeks in all working areas. If concentrations greater than 0.3 WL are found, measurements must be taken every week. If the initial exhaust

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[1] A radiation exposure of 1.0 mR is essentially equivalent to a dose of 1.0 mrem.

[2] The working level (WL) is a measure of the potential alpha energy in air and is equal to 1.3 x 10^5 million electron volts (MeV) of alpha energy emitted by the short-lived decay products of radon-222 (polonium-218, lead-214, bismuth-214, and polonium-214). The WL is nominally equivalent to 100 picocuries per liter of radon in equilibrium with its short-lived decay products.

air concentration is less than 0.1 WL, exhaust air measurements are required monthly. The required monitoring frequencies for non-uranium mines are somewhat less stringent. The maximum allowable concentration for miners without adequate respiratory protection is 1.0 WL. If the level is greater than 10.0 WL, protection using a self-contained breathing apparatus is required (SCBA).

The maximum allowable annual radon decay product exposure to an underground miner under MSHA regulations is 4.0 working level months (WLM). The WLM is the concentration in WL multiplied by the number of hours of exposure and divided by 170 hours, the hours in a normal working month. NIOSH issued a recommendation that based on the results of epidemiologic studies of lung cancer in miners, the exposure limit should be set at 1.0 WLM per year (NIOSH, 1987). Mine operators are required to submit to MSHA annually a record of all miner exposures. MSHA regulations include a caveat that states that if the EPA recommends an exposure limit different from the 4.0 WLM per year and it is approved by the President, the MSHA limit will be changed.

The MSHA concentration limits for radionuclides in airborne particulate matter are based on the 1973 TLVs, which, in turn, were based on 1960s radiation dosimetry. These values are outdated. However, in practice, radon decay products and gamma radiation account for nearly the entire radiation dose to miners. The American National Standards Institute (ANSI) Standard N13.8 (ANSI, 1973), referenced in the MSHA regulations, is outdated and in the process of revision. The ANSI standard adopts the maximum permissible concentrations of radionuclides in air and water for occupational exposure in the National Council on Radiation Protection and Measurements (NCRP) Report No. 22, a 1959 document (NCRP, 1959).

Since radiation doses to miners from gamma radiation and radon decay products are accounted for separately in MSHA regulations, rather than summed as in the NRC regulations, a miner could receive a total dose two times the dose allowed to a worker in a facility licensed by the NRC or an Agreement State, i.e., uranium mill. A radon decay product exposure of 1.0 WLM is essentially equivalent to a dose of 1.0 rem (NCRP, 2009); therefore, a radon decay product exposure of 4 WLM would result in a dose of 4 rem. When that dose is added to the 5 rem per year gamma radiation dose limit, the total allowable dose would be 9 rem per year, without the addition of the dose from airborne particulates. Several attempts have been made at the federal level to harmonize the regulations but they have not been successful. However, there does not seem to be any legal barrier to states wishing to harmonize the mine standards to the NRC standards within their own jurisdictions.

There are no specific MSHA radiation protection regulations for surface mines.

8.1.2.3 Silica

The only specific requirement in 30 CFR 56/57 with regard to monitoring for airborne dusts is that "dust, gas, mist, and fume surveys shall be conducted as frequently as necessary to determine the adequacy of control measures." Otherwise, there are no regulatory standards for monitoring of silica in underground or surface mines. The MSHA Program Policy Manual (MSHA, 2012) does not add specific guidance except to note that MSHA will determine whether surveys are adequate to determine that controls are effective in reducing exposures to airborne contaminants. The types of surveys are not specified in either the regulation or the manual. However, the manual does note that the surveys *should* be conducted in accordance with established scientific principles. The silica standard applicable to mines under MSHA is the 1973 TLV, 0.1 mg/m^3. MSHA issued a notice of proposed rulemaking in April 2010. The proposed rule-making does not appear to include specific sampling requirements. NIOSH has recommended an exposure limit of 0.05 mg/m^3.

MSHA determines whether dust, mist, gas and fume surveys are conducted frequently enough to determine whether controls are effective in reducing exposures to airborne contaminants. Sampling frequency should be greater for results that approach the standard (TLV) and may be determined by changes in mining operation, work schedules, maintenance of controls, or other factors that would affect concentrations of constituents in air (DOL, 2012).

While MSHA does not specify frequency or methods for complying with the general requirement, best practices at some mines include personal dust monitoring using lapel or breathing zone samples. Samples are generally analyzed for radionuclides (gross alpha) but not necessarily for respirable dust or silica.

8.1.2.4 Diesel Fumes

The MSHA requirements for exposure to diesel particulate matter (DPM) are contained in 30 CFR 57.5060. DPM consists of solids, liquids, and vapors; burned and unburned hydrocarbons; oxides of sulfur, nitrogen; metal fragments, metal oxides and other substances. Diesel fumes are ultrafine particles that can cause irritation of eyes, nose, lungs, throat, lightheadedness and nausea. Diesel fumes have recently been formally classified as a carcinogen. Diesel fumes are difficult to measure. However, carbon components can accurately be measured at low concentrations. Therefore, the diesel standard is based on total carbon (0.16 mg total carbon per cubic meter).

As with the general requirements for air sampling, the mine operator must monitor as often as necessary to effectively determine whether the average personal full-shift airborne exposure to DPM exceeds 0.16 mg/m^3. There are no specific requirements for periodic measurements or particular types of measurements. Compliance is maintained by requirements on sulfur content of diesel fuel and limits on fuel additives as well as requirements for maintenance of diesel-powered equipment, including emission control devices.

8.1.2.5 Noise

Noise is a potential hazard in all mines. The Noise Standard, 30 CFR 62, applies to all mining activities including metal and non-metal mines as well as mills that are covered under MSHA. The standard requires that the mine operator evaluate each miner's noise exposure to determine compliance with the 8-hour Time Weighted Average (TWA_8) permissible exposure level of 90 dBA with an action level of 85 dBA TWA_8. Miners whose exposure exceeds the action level must be enrolled in a Hearing Conservation Program (HCP) and must have annual audiograms in addition to a baseline audiogram in accordance with procedures described in 30 CFR 62.

8.1.2.6 Biological Hazards

There are no requirements in MSHA regulations for monitoring potential biological hazards such as mold or pollens except as they are covered under the general requirement that monitoring be conducted as frequently as necessary to determine the adequacy of control measures.

8.1.3 Tracking Worker Cumulative Exposures

8.1.3.1 Radiation Exposures

Direct gamma radiation exposures are tracked for underground miners in areas where the average radiation exposure rate exceeds 2 mR/h and personal dosimetry is required. Otherwise, MSHA regulations contain no requirements for tracking gamma doses at lower exposure rates.

Radon decay product exposures are tracked for all underground uranium miners under MSHA (30 CFR 57.5040) but not for surface miners. Mine operators are required to report annually to MSHA individual exposures to radon decay products ("daughters") and keep records with respect to each individual's TWA_8 current and cumulative exposure.

8.1.3.2 Nuisance Dust, Silica and Other Airborne Chemical Constituents

There are no specific requirements for tracking individual worker exposures to nuisance dust or silica. In contrast to radiation exposures (gamma, radon, and radionuclides in airborne particulate matter), the allowable exposures are based on an 8-hour average concentration so no individual exposure tracking over time is necessary. Exposure to diesel fumes is not tracked on an individual miner basis.

Medical monitoring, in the form of chest x-rays, is required to be offered to miners exposed to silica; but while participation is encouraged, it is not required. Mine operators must report any cases of silicosis or other occupational lung disease to MSHA if a medical diagnosis is made or compensation awarded.

8.1.4 Bioassay for Mines

There are no specific bioassay requirements for uranium mines in MSHA regulation. However, it is best industry practice to periodically collect urine bioassay samples from miners and analyze them for uranium as a method of determining intake of uranium.

8.1.5 Noise Exposure

The results of audiometric testing must be reported to the miner and maintained by the mine operator and must be tracked on an individual miner basis.

8.2 Uranium Mills

The maximum allowable radiation dose to a uranium mill worker is 5 rem per year under the NRC and Agreement State regulations. The committed effective doses from inhalation of radon decay products and inhalation of radionuclides in airborne particulate matter, as well as the effective whole body dose from direct radiation are summed to obtain a TEDE. The radiation monitoring requirements are designed to demonstrate compliance with the dose limit and to provide assurance that doses are being kept as low as is reasonably achievable (ALARA). In practice, radiation doses to mill workers rarely exceed 1 rem per year.

Radiation monitoring requirements for uranium mill workers are described in detail in NRC Regulatory Guide 8.30. Since mills are under the jurisdiction of MSHA, the monitoring requirements described above for non-radiation related hazards in mines would also apply to mills and are not repeated in this section.

8.2.1 Radon

Radon decay product concentrations are measured monthly where the concentrations routinely exceed 0.03 WL (above background) and weekly in areas where radon daughter concentration are normally greater than 0.08 WL. Quarterly measurements are made in areas of the mill where radon decay products may be present at levels below 0.03 WL. Radon decay product measurements are commonly made using the Kusnetz method, a procedure by which a sample is taken in an area and then counted for gross alpha radiation at an interval between 40 and 90 minutes after collection. Standard correction factors are used to convert the count rate to the radon decay product concentration in WL. Alternatively, a working level meter that provides real time measurement can be used. Personal radon dosimeters can be used but do not replace timely area measurements.

8.2.2 Direct Gamma Radiation and Beta Radiation Surveys

Gamma radiation surveys are performed throughout the mill semi-annually to determine where radiation areas must be posted and to assess whether personal dosimetry is required. Radiation areas, i.e., areas where an individual might receive a radiation dose of 0.005 rem in one hour, are required to be surveyed quarterly.

Personal dosimetry is required for individuals who might receive a radiation dose in excess of 10% of the applicable limit in one year. Most uranium facilities use optically stimulated luminescent (OSL) dosimeters or thermoluminescent dosimeters (TLDs) to monitor workers. These dosimeters are generally worn for a month (for pregnant women) or a quarter then returned to the vendor for analysis. There are real time dosimeters available that are used in some facilities. These dosimeters can be connected to a computer to provide an instant reading of an individual's dose. However, few if any current uranium mining or milling facilities use the devices. Self-reading pocket dosimeters or electronic dosimeters are often issued to site visitors who will spend only a few days in the mill.

Beta dose rate surveys are required in areas where aged yellowcake may be stored for several weeks or more, allowing the shorter-lived beta emitting decay products of uranium-238 to build in from the decay of the parent uranium.

8.2.3 Radionuclides in Airborne Particulate Matter

Surveys for uranium ore dust are conducted in ore handling areas of a mill to demonstrate compliance with the occupational dose limits, meet the "airborne radioactivity area" posting requirements, determine what precautions are needed to meet the limits, and to determine whether airborne concentrations of radiation materials are being kept ALARA. Monthly grab samples of 30-minute duration are acceptable in areas where the airborne radioactivity concentration is below the Derived Air Concentration (DAC)[3]. Samples must be taken weekly in areas where the concentration exceeds the DAC. Air samples from outdoor areas are collected quarterly.

Yellowcake areas are surveyed by a combination of general air sampling and personal breathing zone sampling. General air samples are taken weekly in airborne radioactivity areas and monthly in other areas. Breathing zone samples are taken on workers performing specific tasks that may result in a worker being exposed to greater than 12 DAC-hours per week. One DAC-hour is the exposure that a worker would receive in being exposed to a concentration equal to the DAC for one hour. In practice, breathing zone samples are employed for any routine or non-routine task that could result in an exposure to a worker.

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[3] The DAC is the concentration of a radionuclide in air that will result in a dose of 5 rem in one year to an individual breathing the atmosphere for 2,000 hours per year.

8.2.4 Surface Contamination Surveys

Surface contamination surveys are conducted weekly in areas such as change rooms, break rooms, control rooms, lunch rooms and offices. The limits for surface contamination are specified in NRC Regulatory Guide 8.30. In addition, while there are no regulatory standards for surface contamination in restricted areas[4], contamination levels should be assessed to prevent contribution to airborne radioactive levels and contamination of personnel. Specific contamination levels for restricted area surfaces that are considered ALARA are suggested in Regulatory Guide 8.30.

All equipment that has been in the restricted area must be surveyed prior to release and must meet the contamination limits specified in NRC Regulatory Guide 8.30 and, in some cases, incorporated into facility licenses. Some Agreement States have adopted the release limits into their regulations even though the release limits are not defined in NRC regulations. Individuals must survey for contamination prior to leaving a controlled or restricted area to prevent the spread of contamination to unrestricted areas. The goal for skin contamination is background.

Other surveys, such as of packages prepared for shipment, ventilation systems, and respirators are described in the NRC Regulatory Guide 8.30.

8.2.5 Bioassay Measurements

Urine bioassay measurements are required for most uranium mill workers, with frequency based on the potential for exposure. For example, yellowcake workers are generally monitored weekly, with other workers less likely to be exposed monitored bi-weekly, monthly, or quarterly depending on the potential for intake of uranium. The laboratory reporting limit for bioassay measurements is 0.005 milligrams per liter (mg/l). It is rare for a mill worker to have a bioassay measurement exceeding that value. In most cases, a bioassay sample that exceeds 0.005 mg/L is the result of inadvertent contamination. Those issues are resolved by re-sampling the individual. The action limit is 0.015 mg/l; however many facilities investigate any bioassay sample greater than the laboratory reporting limit of 0.005 mg/l.

8.2.6 Tracking Worker Cumulative Dose

Tracking worker doses is required if the annual dose is likely to exceed 10% of the annual dose limit of 5 rem TEDE with all sources and pathways summed. A dose report (NRC Form 5 or equivalent) is provided to the worker and must be available for inspection by the NRC or Agreement State. There is no requirement to routinely report individual doses to the NRC or

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[4] Restricted areas and controlled areas are portions of the site to which access is controlled for the purposed of limiting radiation exposures.

Agreement State unless the annual dose exceeds 5 rem. Licensees are required to perform an ALARA Audit each year. The Audit Report generally includes the distribution of facility worker doses for the calendar year but no individual doses.

8.3 Worker Training to Prevent Exposures and Keep Exposures to Radiation and Other Hazards As Low As Reasonably Achievable

The NRC Regulatory Guide 8.31 specifies the content of radiation worker training for mills but not for mines (NRC, 2002) since it applies only to uranium recovery facilities. The suggested training includes the following basic topics:

- fundamentals of health protection : toxic and radiologic hazards of exposure to uranium and its decay products, routes of entry and why exposures should be kept ALARA;
- radiation safety: protective clothing, respiratory protection, work rules, decontamination;
- radiation protection systems: ventilation, housekeeping, radiation safety aspects of process equipment, standard operating procedures, security and access control, electronic data gathering and storage, automated processes;
- health protection measurements: air sampling, bioassay, contamination surveys, personal dosimetry;
- radiation protection regulations: regulatory authorities, worker rights (10 CFR 19), radiation protection requirements (10 CFR 20); and
- emergency procedures.

In practice, radiation worker training at most sites also covers some basic aspects of radiation physics and biology including:

- basic radiation: biological effects of radiation, radiation risks in perspective, background radiation levels;
- site specific work rules;
- site description and history; and
- radiation hazards associated with specific tasks.

Depending on the complexity of the site and the potential for exposure, initial radiation worker training can take anywhere from four hours to several days. At some sites OSHA Hazardous Waste Operations and Emergency Response training is also required. Annual refresher training is required for all workers. The refresher training is generally an abbreviated version of the initial training but may include discussion of situations that have occurred in the past year, and distribution of the radiation dose records to individual workers (NRC Form 5).

In addition to the basic radiation worker training, all women of child-bearing age must be trained in risks of pre-natal radiation exposure as per NRC Regulatory Guide 8.13 (NRC, 1999). NRC Regulatory Guide 8.29 (NRC, 1996) also provides information on risks or radiation exposure, however, it is outdated and facilities generally use more current information in discussing risks with workers.

Certification of MSHA miner training, either surface miner or underground as appropriate, is required for both mines and mills under 30 CFR 48. The regulation does not specify specific topics for the training, which may be provided by an independent contractor. The MSHA training focuses primarily on safety and health issues applicable to most mines, but the specific content appears to be the responsibility of the operator. Site-specific and task-specific training are required. In addition, MSHA requires hearing conservation training for miners enrolled in a HCP.

8.4 Comparison with International Standards for Radon and Radon Daughter Exposures

8.4.1 IAEA Radiation Protection Regulations

The International Atomic Energy Agency (IAEA) has published a Safety Guide for Occupational Radiation Protection in the Mining and Processing of Raw Materials (IAEA, 2004). The recommendations are not binding on member states unless they receive assistance from the IAEA. Most countries with uranium mining facilities have adopted the IAEA standards. The IAEA standards are essentially the same as the International Commission on Radiological Protection (ICRP) recommendations in Publication 103 (ICRP, 2007). The ICRP is in the process of developing recommendations for exposure to radon decay products. The U.S. has not adopted the recommendations of the ICRP, which are more stringent than current U.S. standards.

The IAEA standard for dose limitation is an effective dose of 100 mSv (10 rem) over a 5 year period with no more than 50 mSv (5 rem) in any one year from all sources of radiation (excluding background and medical uses) and routes of exposure. The IAEA expresses radon decay product exposure in international units (SI units) of millijoule-hours per cubic meter (J-h/m^3). One mJ-h/m^3 is equal to approximately 0.28 WLM. The IAEA Safety Standard equates a radon decay product exposure of 1.0 WLM to 5 mSv or 0.5 rem. The NCRP equates 1.0 WLM to 1.0 rem (NCRP, 2009).

The IAEA Safety Standard does not specify a particular monitoring program but states that comprehensive surveys of gamma exposure rates, airborne radioactive dust, radon decay products, and surface contamination levels should be conducted, noting that in open pit mines, stagnant atmospheric conditions may affect radiation exposure (presumably to radon decay products). The frequency of radon decay product measurements should take into account concentration levels and their variability over time.

The IAEA recommends personal dosimeters for monitoring exposure to external gamma radiation if the individual could receive a significant fraction of the dose limit, which is not defined. Personal monitors for airborne dust and radon decay products are deemed somewhat impractical under normal operating conditions but should be considered for dusty areas and for conditions when exposures could be unusually high. Urine bioassay is recommended for routine monitoring of intakes of uranium.

8.4.2 Australian and Canadian Radiation Protection Standards

The Canadian and Australian radiation protection standards for uranium mines and mills are consistent with the IAEA recommendations (Australian Radiation Protection and Nuclear [ARPANSA], 2005; Canadian Nuclear Safety Commission [CNSC], 2012a, CNSC 2012b). In contrast to U.S. regulations, the Canadian and Australian regulations do not distinguish between mines and mills. Both are under the jurisdiction of the Canadian Nuclear Safety Commission or the Australian Radiation Protection and Nuclear Safety Agency, respectively.

The Canadian radiation dose limit is 100 mSv (10 rem) effective dose over a five year period with no more than 50 mSv effective dose (5 rem) in any one year. The Canadian regulations assume that 1.0 WLM is equivalent to a dose of 5 mSv (0.5 rem) for a worker. The maximum allowable dose to an individual who is not a nuclear energy worker is 1 mSv (0.1 rem) per year, the same as in the NRC regulations. However, the Canadian regulations assume that 1 WLM is equivalent to a dose of 4 mSv (0.4 rem) for a member of the public. These are the values given by the ICRP in its Publication 65 (ICRP, 1993). The ICRP is in the process of revising those values. The Canadian regulations do not specify monitoring protocols.

The Australian Code of Practice, Radiation Protection Series No. 9, Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (ARPANSA, 2005) references the ICRP radiation safety standards and the Australian Recommendations for Limiting Occupational Exposure to Ionizing Radiation (ARPANSA, 2002). The radiation protection standards are the same as the IAEA and ICRP recommendations. There are no specific protocols for monitoring except that the employer is responsible for conducting a monitoring program that will protect the workers. There may be more specific guidance in Australia and in Canada as there is in the United States in the form of the NRC Regulatory Guides.

8.5 NIOSH Recommendations for Radon Decay Product Exposure

In 1987, NIOSH issued a recommended standard for exposure to radon decay products in mines of 1 WLM per year to replace the 4 WLM per year MSHA standard (NIOSH, 1987). The basis for the recommendation was the observed high risk of lung cancer in underground miners and the conclusion that existing technology was sufficient to achieve compliance with the reduced standard. The standard describes a complex statistically based radon decay products monitoring protocol. The protocol specifies two samples on randomly selected days during each two week period in each work area. The sampling protocol would be adjusted based on the measured radon decay products concentration. The standard requires exposure to radon decay products to be recorded daily for each miner. Medical surveillance including an initial medical examination and annual updates are required. The NIOSH standard has not been adopted by MSHA or the NRC.

8.6 Recommendations for Monitoring and Evaluation of Work Spaces in Mines and Mills to Augment Current Regulatory Requirements in Virginia

The VDH should consider instituting the following requirements for uranium mines or mills if the moratorium is lifted, to augment current regulations.

- Require safety training and written materials to be provided in a language understood by the workers.
- Require routine general dust measurements in uranium facilities as well as specifically silica dust and diesel fumes.
- Attempt to harmonize, through VDH radiation protection regulations, the worker dose limits for uranium mining and milling. Require that the sum of radiation doses to miners from inhalation of radon decay products, inhalation of radionuclides in airborne particulates, and direct radiation not exceed 5 rem per year. If the separate standards are maintained for a Virginia uranium recovery facility with the potential for a co-located mine and mill, the difference between the NRC and MSHA dose standards would make it difficult to regulate the facility, as workers could spend time at both facilities during a calendar year. Radiation protection standards should apply to surface mines as well as underground mines even though the potential for significantly elevated occupational exposures in surface mines is considerably lower.
- Specify in state regulations or provide technically based guidance, concerning appropriate monitoring frequencies and schedules for airborne constituents in mines. The monitoring frequency should be based on the initial measurements, variability in the measurements, and worker occupancy in areas where hazardous airborne constituents are present. Initial measurements should be made before work is performed in such areas. As a starting point, the guidance might recommend monthly measurements in areas where the constituent concentrations exceed 10% of the TLV and at least weekly where the measurements exceed 25% of the TLV. However, the

frequency of the measurements must be determined based on the potential for exposure.

- Incorporate by reference in regulations pertaining to uranium mines and mill, the most recent ACGIH TLVs for non-radionuclides, and 10 CFR 20, Appendix B, DACs, for radionuclides. Specify that the regulations be reviewed at least every five years.

9.0 MONITORING OF LONG-TERM HEALTH EFFECTS

The long-term health effect associated with uranium mining and milling is primarily a potential increased risk of cancer from exposure to radiation, either direct gamma radiation or through deposition of radionuclides in the body. The biological effects of radiation are well known, having been studied extensively for over more than half a century. The primary risk from low-level radiation is an increased risk of cancer. The risks associated with low-level radiation doses have been quantified by extrapolation from studies of individuals exposed at high levels, i.e., the atomic bomb survivors, individuals exposed to medical radiation, early radiation workers such as the radium dial painters, and miners exposed to high levels of radon. This data was discussed in the Initial Report. Population-based monitoring of potential health effects is covered in Sections 5.0 and 6.0 of this report (Interim Report #1). Monitoring for the precursors to potential health effects, i.e., environmental monitoring and surveillance, are described in detail in Sections 5.0 and 6.0 of Interim Report #2 (WES, 2012b).

Estimated risks for uranium recovery workers and members of the public in the vicinity of such facilities are based on radiation risks derived assuming a linear-no-threshold dose response. Because cancer is a very common disease and, in contrast to some other cancer-causing factors such as asbestos, radiation-induced cancers are not unique, it is not possible to determine whether a particular cancer is the result of radiation exposure. The only way of estimating whether a cancer is a likely result of radiation exposure is through direct measurement of dose (gamma radiation) or measurement of radionuclide concentrations in the environment.

Environmental radiation measurements are conducted within the facility boundaries to estimate doses to workers and to site visitors. Such measurements include direct gamma exposure rates both in the general area and for individual workers, radionuclide concentrations in airborne particulate matter, and radon gas and decay products concentrations. The same types of measurements are conducted at the site boundaries and often at other sensitive locations, i.e., nearest downwind residence. In addition, food and water are sampled and analyzed at off-site locations. Environmental samples are analyzed for natural uranium and its decay products, including U-238, U-234, Th-230, Ra-226, Pb-210, and Po-210. In addition, some samples may be analyzed for non-radioactive constituents that may be associated with the specific ore being mined or processed.

10.0 IMPACTS ON CISTERNS AND ONSITE SEWAGE SYSTEMS

The potential introduction of a uranium mine and uranium milling facility in Pittsylvania County, Virginia has given rise to concerns about potential impacts to private cisterns and sewage systems. This section discusses that potential and factors that might be important in determining impacts. In this context, the phrase "impacts to cisterns or private sewage systems" should be understood to mean not damage to the cistern or sewage system itself, but potential harm to the users of cisterns, sewage management systems or water released from sewage management systems.

10.1 Potential Pathways

As shown in the CSMs (Figures 3-1 through 3-3), potential off-site pathways include groundwater, surface water, and air. Theoretically, waterborne and airborne transport mechanisms could contact both cisterns and sewage systems.

Potentially contaminated groundwater that leaves the mine or the mill could contain dissolved or suspended uranium and uranium decay products. However, a mill will employ a network of monitoring wells designed to detect releases via groundwater. Criteria in 10 CFR 40 Appendix A, specifically Criteria 5A-5D and Criterion 13, incorporate the basic groundwater protection standards imposed by the EPA in 40 CFR Part 192, Subparts D and E (48 FR 45926; October 7, 1983) which apply during operations and during closure. Groundwater monitoring to comply with these standards is required by Appendix A.

As shown in the schematic diagram of a co-located mine and mill (Figure 2-1), potentially impacted surface run-off should be controlled via containment in a pond or tank, and then treated to meet National Pollutant Discharge Elimination System (NPDES) discharge limits. In extreme weather situations, runoff of storm water could occur, but appropriate planning and design should prevent such an occurrence. Mill tailings ponds should be designed to prevent failure, and with freeboard adequate to handle maximum precipitation events.

Airborne emissions of radioactive particulates and radon will occur from a number of different locations and processes at the mine or mill. These are detailed in the conceptual site models and narrative in Section 3.0.

10.2 Potential Impacts

10.2.1 Cisterns

A cistern is a method of collecting water from rainfall. Cisterns are commonly used in areas where groundwater is scarce, access is expensive, or where private wells are impractical.

Cisterns may be used to collect rainwater from a catchment area on a building roof or may be used to store potable water from a stream, well or spring.

Although usually located underground, cisterns also may be placed at ground level or on elevated stands either indoors or outdoors. Cisterns are watertight, generally have smooth interior surfaces and lids, and are large enough to provide adequate storage. They are generally fabricated from materials such as reinforced concrete, galvanized steel or plastic. Cisterns designed for non-potable use might be constructed of less hygienic materials.

Cisterns for the collection of rainwater depend on a catchment system, often a building roof. Water collected in this way is most likely non-potable, used to water plants, wash laundry or for bathing, as opposed to drinking.

10.2.1.1 Groundwater

Releases from the licensed mill would be limited to license-specified radionuclide concentrations that meet groundwater standards. Associated concentrations in wells, or in surface streams linked to groundwater flows, would not exceed those limits. Watertight cisterns near or above the ground surface should not communicate directly with groundwater.

10.2.1.2 Surface Water

Releases of radionuclides and other materials from the site to surface water must also meet license-specified applicable standards. Associated concentrations in cisterns using surface water sources should not exceed those standards. In the cases of an extreme rainfall event or other unplanned release situation, radionuclide concentrations greatly exceeding applicable surface water limits would be possible. Case-by-case evaluations of the potential for contamination of down-gradient cisterns during such an event would be required during facility licensing, and appropriate measures, including development of alternative water supplies where significant contamination potential exists, would be implemented in advance by the facility operator.

10.2.1.3 Airborne Emissions

As shown in the CSMs, airborne emissions will contain radon and radioactive particulates. Radon gas decays to Pb-210, Po-210 and other nuclides, which become attached to airborne particulate matter. Direct particulate emissions from mining and milling will contain uranium, Th-230, Ra-226, radon decay products and other nuclides from ore being extracted or processed and from dried tailings. Product uranium in the form of yellowcake should not be emitted to air routinely, given current drying and packaging technology, but significant quantities could be released in the event of an accident. Current mine/mill technology is designed to minimize the potential for routine or accidental releases, and to limit the amount of material likely to be released in an accident.

Routine emission rates of radionuclides will be limited by design to facility license-specified levels that would result in a maximum operations-related radiation dose of 100 mrem/yr to any off-site resident. The ALARA principles, incorporated in the facility license, focus on reducing this dose in practice to levels that are as low as reasonably achievable.

Airborne emissions could enter a cistern by being deposited on the catchment basin and collected. Because waters of this type are generally used for non-potable purposes, it is highly unlikely that a user would be impacted via drinking water. Potential for human intake via secondary pathways, primarily irrigation of gardens, would exist. The presence of cisterns in the vicinity of a planned facility would call for an evaluation of such exposure potential during the environmental assessment process, with mitigation measures to be performed in advance by the facility operator, if required to minimize potential dose. The potential for significant dose associated with routine operation of the facility would be very small, given license restrictions on releases and adequate modeling of radionuclide environmental transport. The potential for significant radionuclide concentrations in the environment in the event of an unplanned release does exist, and must be taken into account during facility design and operation, and via assessment, during licensing, of potential impacts and required mitigation measures.

10.2.2 Private Sewage Systems

Private sewage systems, often known as septic systems, may be present as gravity drain fields, pressure distribution drain fields, and sand filter systems and in other forms. All would include a septic tank that holds the sewage and allows it to be treated by anaerobic bacteria before discharge to the drain field. Water in the tank is slowly absorbed and filtered by the ground in a properly designed drain field. The size of the drain field is determined by how well the ground absorbs water. In places where the ground is hard clay that absorbs water very slowly, the drain field must be larger. Different types of drain fields are described below.

10.2.2.1 Gravity Drain Fields

Gravity drain fields work by letting gravity drain the effluent from the septic tank into a series of trenches. This means that a gravity drain field area must be below the draining level of the septic tank. Otherwise, a pump tank is necessary. In conventional gravity systems the drain field consists of a network of small perforated pipes, laid in gravel-filled trenches in natural, undisturbed soil. The bottom of the trench should be 18 inches above any restrictive layer such as hardpan, or the water table. The soil between the bottom of the trench and the hardpan or water table is essential to the final treatment of septic tank effluent.

Soil below the drain lines filters effluent as it passes through the pore spaces. Natural chemical and biological processes treat the effluent as it percolates down through the soil. The treatment process cleans the effluent before it reaches groundwater. This works best when the soil is somewhat dry, permeable, contains adequate amounts of oxygen and there is enough soil depth to complete the cleaning process.

The size of the drain field depends on the estimated daily wastewater flow and soil conditions. The required capacity and the soil type determine the total number of square feet of drain field area needed.

10.2.2.2 Pressure Distribution Drain Fields

Pressure distribution systems are usually installed when there is less than optimal soil depth available for complete treatment of the effluent by a gravity system. These are generally more expensive than a gravity drain field, and are used less frequently. Pressure distribution systems use a pump to release effluent in a controlled manner into the drain field. A series of pressurized lines from the pump tank to the drain field make sure the entire drain field receives effluent at the same time.

10.2.2.3 Sand Filter Systems

If there is minimal soil available for treatment, a sand filter system is sometimes used. This system will include a sand containment vessel between the pump tank and the pressurized drain field. The sand acts to treat the effluent before it enters the shallow soils on site, compensating for the lack of soil depth. The sand filter itself is a concrete or PVC-lined box filled with a specific sand content. A network of pressurized lines is placed in a gravel-filled bed on top of the sand. The septic tank effluent is pumped through the pipes in controlled doses to insure uniform distribution. As the effluent trickles down through the sand, it is treated. Gravel underneath the drain collects and moves the treated wastewater to either a second pump chamber for discharge into a pressurized drain field, or the filter may drain into a gravity flow drain field. The second pump chamber is commonly located within the sand filter.

10.2.2.4 Impacts via Groundwater

Releases from the mill would be limited to concentrations that meet groundwater standards, as noted. Associated concentrations in groundwater interacting with a septic system drain field or septic tank would not exceed those limits. Materials from groundwater that enter the drain field would be diluted by septic system effluent moving through the drain field.

10.2.2.5 Impacts via Surface Water

Releases of radionuclides and other materials from the facility would be controlled by the facility license conditions. In the event of an abnormal event, a septic system tank or drain field would be subject to increased contaminant concentrations associated with the event. Dilution of concentrations associated with abnormal events would occur within the drain field, reducing the significance of drain field contamination if it were to occur. Water contained within a septic system does not have potential for direct human consumption; water in the drain field would be somewhat diluted and of less significance, in terms of contamination and potential human exposure, than the impacting surface water itself.

10.2.2.6 Impact via Airborne Emissions

Routine emissions are controlled via the facility license specifications to limit dose to any offsite individual to specific limits, all pathways to humans considered. In the event of an accidental release to air, pathways to humans via septic systems would include dilution of radionuclide concentrations via the drain field system, reducing this pathway's significance compared to more direct human exposure routes.

10.3 Summary

Potential impacts to humans from routine facility release, via either water storage cisterns or private septic systems, are likely to be less or much less significant than impacts via other pathways including more direct exposures via air and water. Proper facility planning, design and impact assessment will result in low but not zero potential for cistern or septic system pathways to humans associated with accidental releases. Case-by-case evaluation of the potential for significant accidental release risk associated with specific cisterns will be required, with potential mitigation by the facility operator required prior to operations. No significant pathway to humans, in comparison to other exposure scenarios, is found for septic systems.

11.0 SUMMARY AND CONCLUSIONS

This report summarizes the uranium recovery process as well as potential releases from that process. Background radiation exposures to the general public are included to provide perspective regarding potential doses to the public from uranium mining and milling. In general, from natural sources, the average American receives 310 mrem/yr, most of which is from decay of radon gas. Doses to the general public from releases or external exposure from a mining and milling facility are limited by regulation to values which are much lower than what is naturally received from background exposures, 25 mrem/yr.

Pathways of release and potential constituents from a mine and mill are similar to those from other industrial facilities with the exception of radon and particulate radionuclides. Both particulates and radon releases would be required to be monitored by the facility operator for both the workers and the general public. Occupation doses would be tracked and reported on an annual basis.

Existing health data registries and processes within Virginia are comparable to those existing in other states and with federal requirements, and are adequate to monitor for potential health impacts that might result from releases from a uranium processing facility. The predominant health risk to the public would be an increase in cancer rates. Studies in other uranium mining areas have shown no significant increase in cancer rates among the general public. Other potential health risks from public exposures might include silicosis and asthma from long-term exposure to dust, potential kidney dysfunction from ingestion of large amounts of uranium in water. Registries for these diseases are already functioning in Virginia.

Virginia’s regulatory framework for tracking long-term health outcomes is adequate to do so and there is no need for additional regulations.

There is very little likelihood that private cisterns or sewage systems can be damaged by releases from a mining or milling complex. The small amounts of radioactive material released from a facility during normal operation would be non-detectable after transport downwind or downstream in most cases. Catastrophic releases, such as tailings dam failures could release large amounts of material. An event of that sort will be discussed in Interim Report #2 (WES 2012b).

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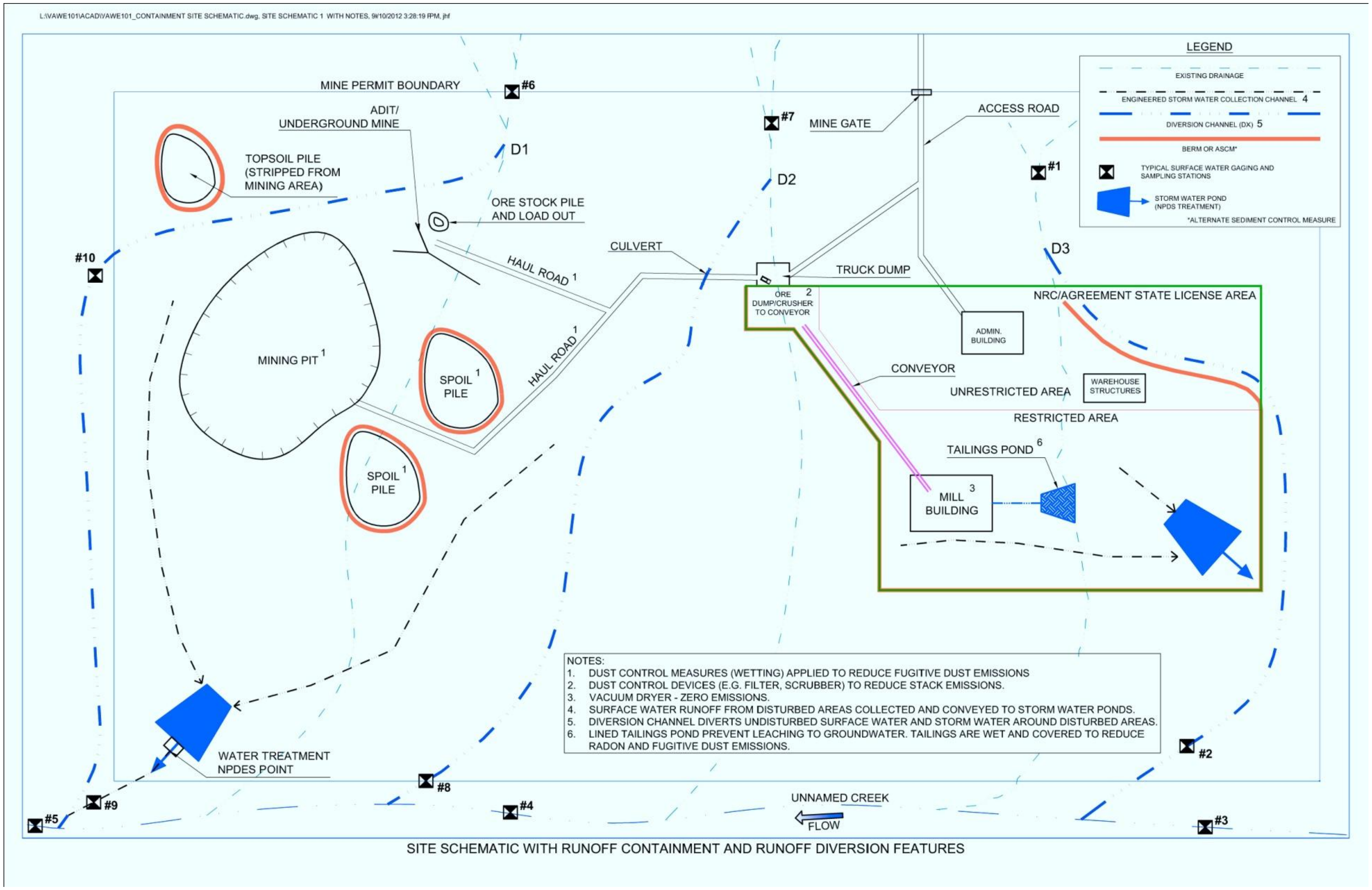
FIGURES

Figure 2-1 Co-Located Mine and Mill Site Schematic with Containment Features



NOTES:

1. DUST CONTROL MEASURES (WETTING) APPLIED TO REDUCE FUGITIVE DUST EMISSIONS
2. DUST CONTROL DEVICES (E.G. FILTER, SCRUBBER) TO REDUCE STACK EMISSIONS.
3. VACUUM DRYER - ZERO EMISSIONS.
4. SURFACE WATER RUNOFF FROM DISTURBED AREAS COLLECTED AND CONVEYED TO STORM WATER PONDS.
5. DIVERSION CHANNEL DIVERTS UNDISTURBED SURFACE WATER AND STORM WATER AROUND DISTURBED AREAS.
6. LINED TAILINGS POND PREVENT LEACHING TO GROUNDWATER. TAILINGS ARE WET AND COVERED TO REDUCE RADON AND FUGITIVE DUST EMISSIONS.

SITE SCHEMATIC WITH RUNOFF CONTAINMENT AND RUNOFF DIVERSION FEATURES

Figure 2-2 **Schematic Diagram of Uranium Milling Process (adapted from IAEA Bulletin 23, Seidel, 1981)**

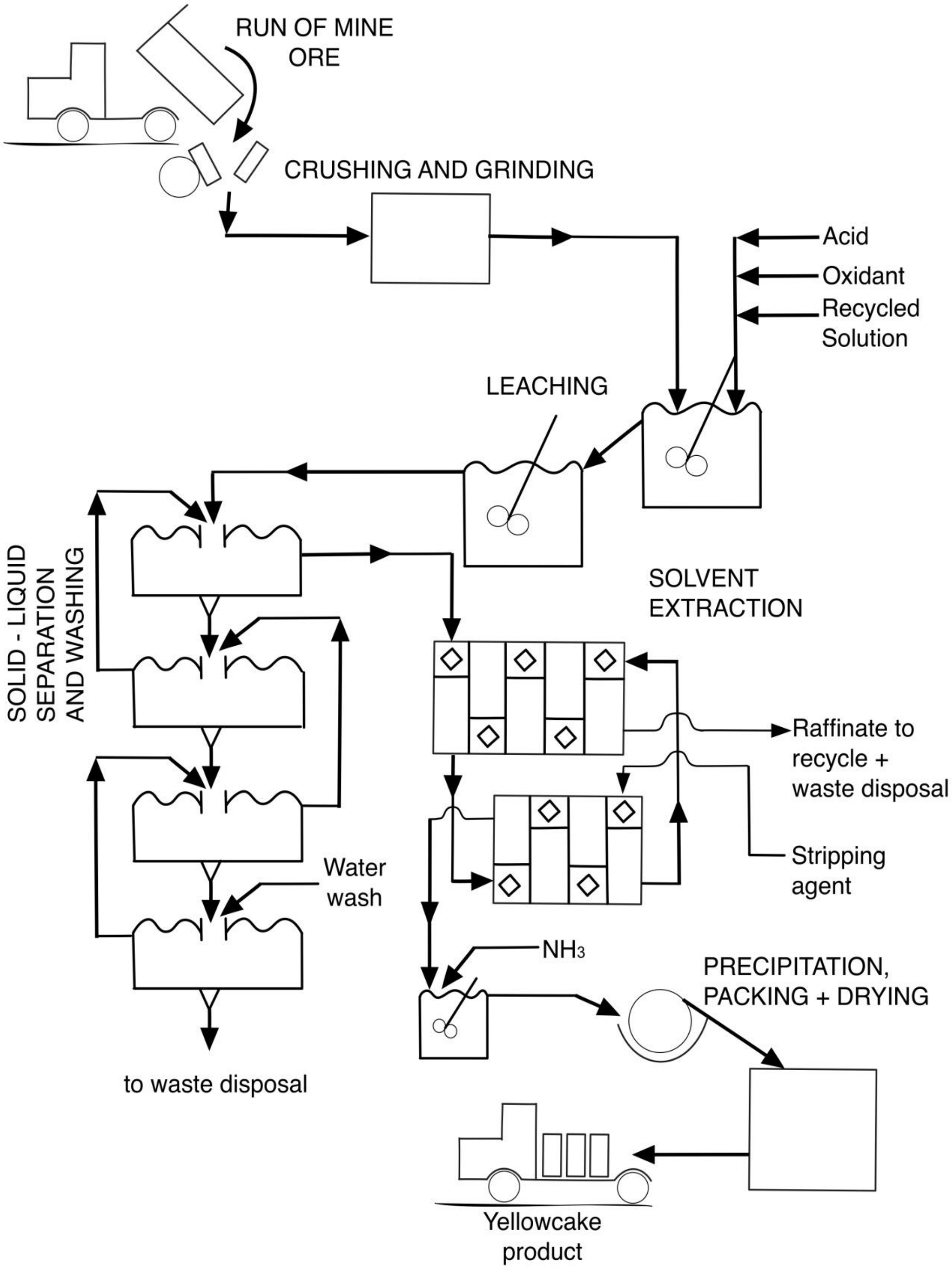


Figure 3-1 Conceptual Site Model Mill - Population Exposure

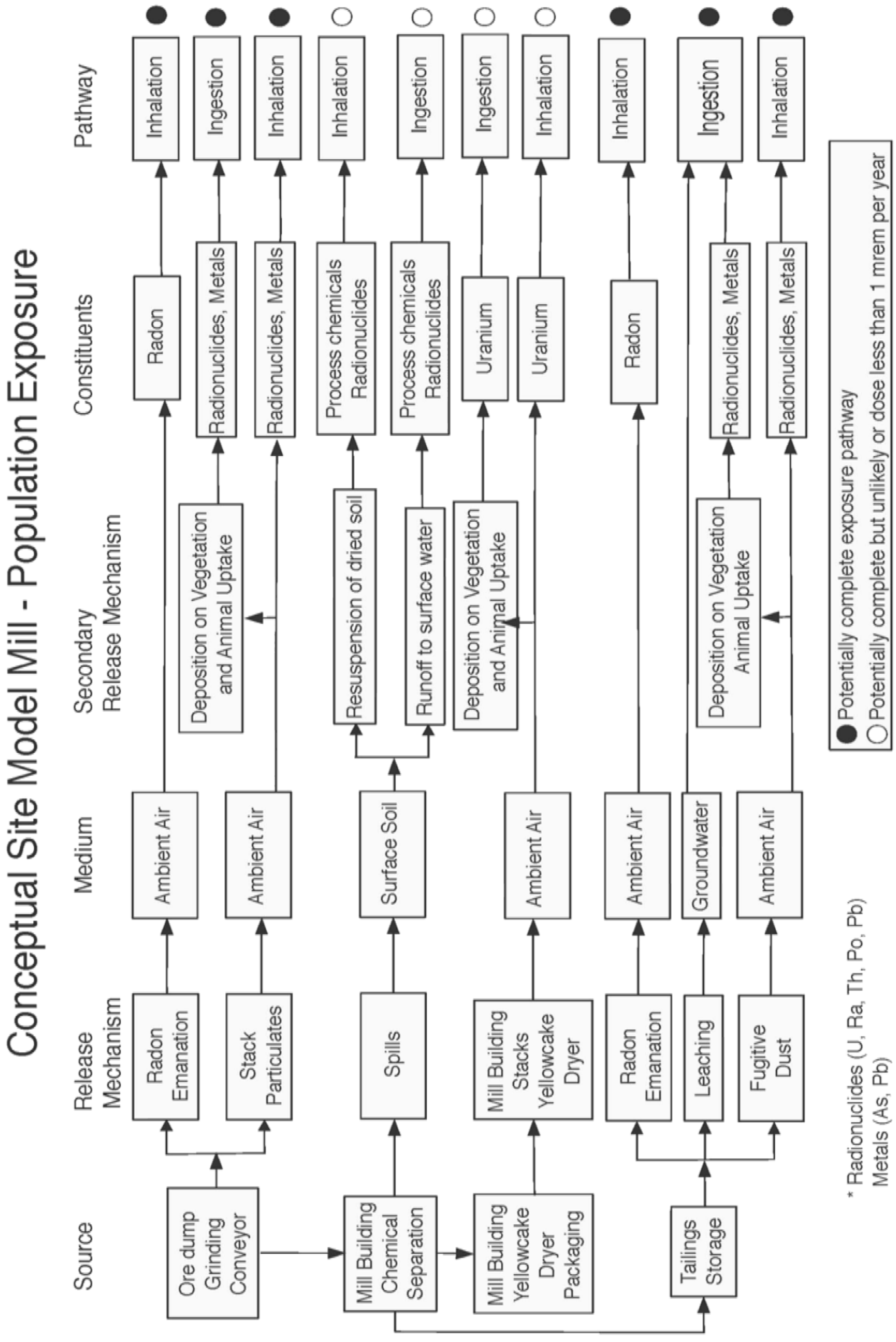


Figure 3-2 Conceptual Site Model Open Pit Mining – Population Exposure

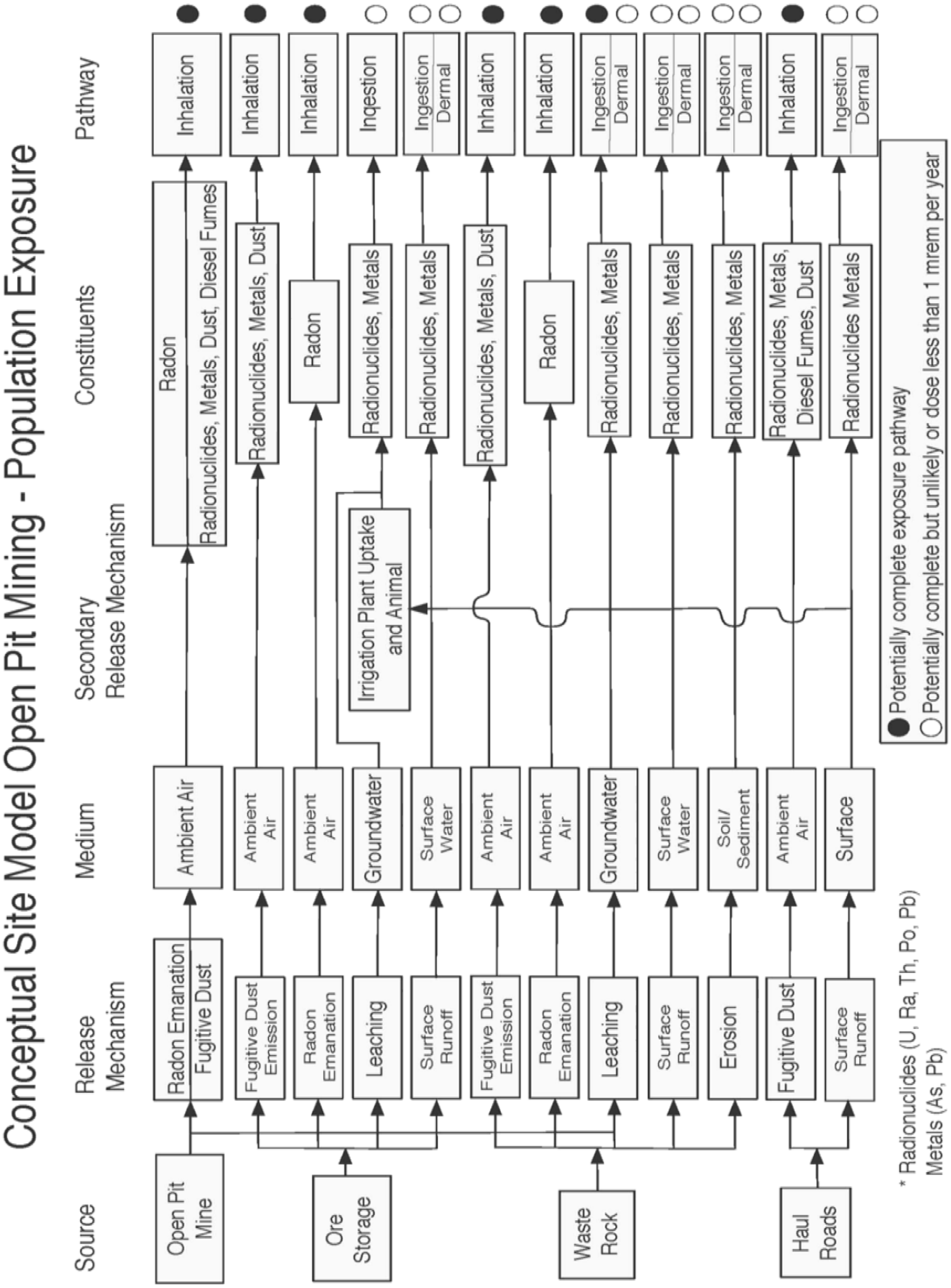
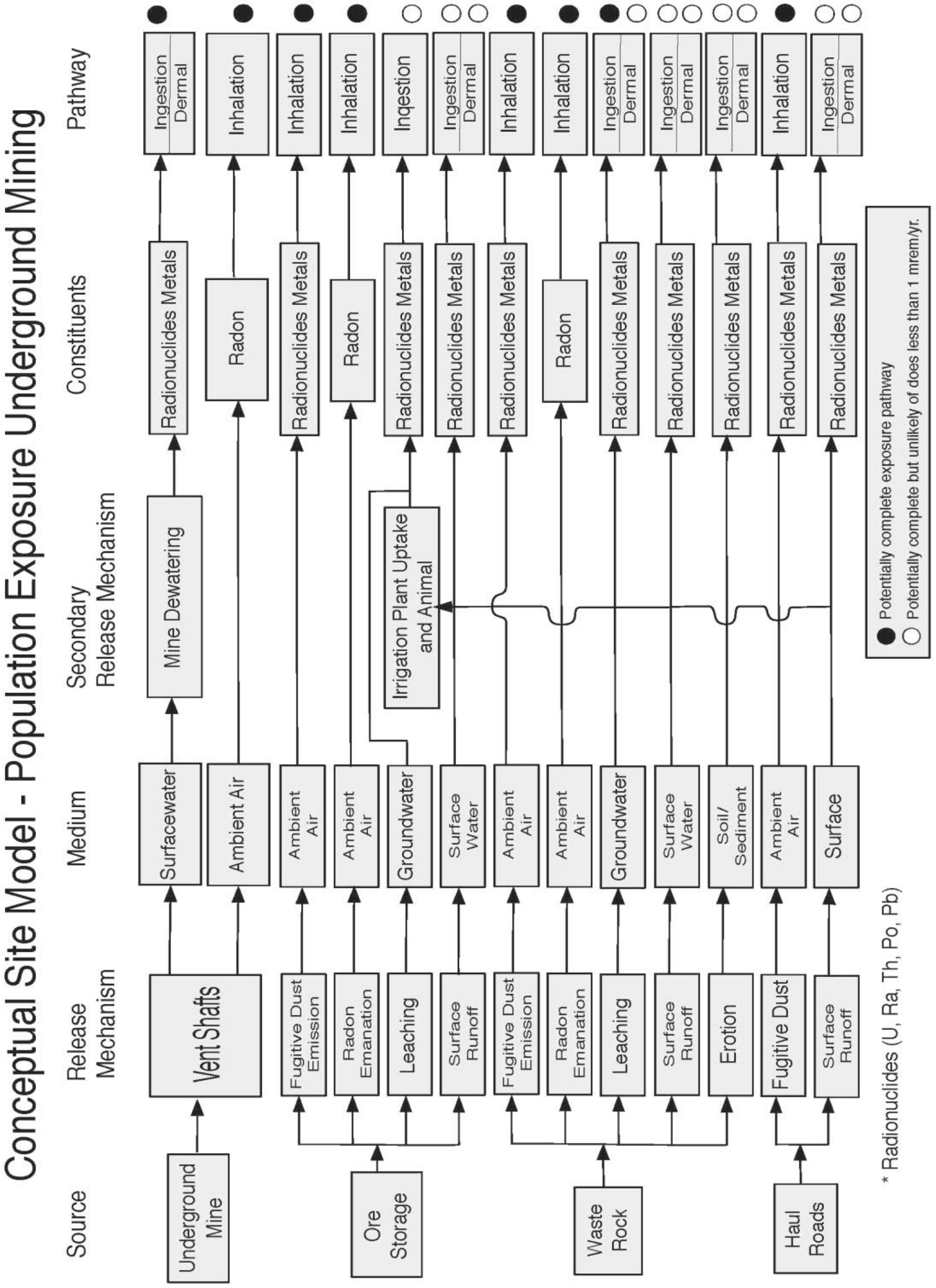


Figure 3-3 Conceptual Site Model - Underground Mining Population Exposure



TABLES

Table 3-1 Constituents of Concern, Pathway and Affected Organs (See Appendix IV for details)

Constituent	Route of Exposure	Principal Affected organ(s)	Potential adverse health effect
Radionuclides			
Natural uranium	Inhalation	Lung	Increased risk of lung cancer
Natural uranium	Ingestion	Kidney	Kidney damage; possible kidney cancer
Natural uranium	Dermal absorption	Kidney	Kidney damage
Th-230	Inhalation	Lung, bone	Increased risk of lung, bone cancer
Th-230	Ingestion	Bone and liver	Increased risk of bone, liver cancer
Ra-226	Inhalation	Bone	Increased risk of bone cancer
Ra-226	Ingestion	Bone	Increased risk of bone cancer
Rn decay products	Inhalation	Lung	Increased risk of bone cancer
Pb-210	Ingestion	Bone	Increased risk of bone cancer
Po-210	Ingestion	Bone	Increased risk of bone cancer
Metals (with over 0.01% in ore)			
Zinc	Inhalation, ingestion	Blood	Essential element; overexposure may cause decrease in erythrocyte copper
Lead	Inhalation, ingestion	Central nervous system	Forgetfulness, irritability, tiredness, headache, fatigue
Strontium	Inhalation, ingestion	Not applicable	No known harmful effects
Manganese	Inhalation, ingestion	Central nervous system	Essential element; but at high exposures central nervous system effects
Barium	Inhalation, ingestion	Kidney	Nephropathy
Copper	Inhalation, ingestion	Liver, kidney, blood forming organs	Liver and kidney damage, anemia, immunotoxicity, developmental toxicity; concentration is homeostatically controlled in the body.
Specific metals with 0.01% or less in ore (included because of potential toxicity)			
Arsenic (0.001%)	Inhalation	Lung	Increased risk of cancer
Arsenic (0.001%)	Ingestion	Skin	Hyperpigmentation; keratosis
Chromium (up to 0.004%)	Inhalation, ingestion	Respiratory tract	Irritation, asthma; carcinogenic – lung cancer, stomach cancer

Table 3-1 Constituents of Concern, Pathway and Affected Organs (See Appendix IV for details)

Constituent	Route of Exposure	Principal Affected organ(s)	Potential adverse health effect
Molybdenum (up to 0.01%	Inhalation, ingestion	Central Nervous system, liver, kidney, joints	Essential element, but overexposure can cause central nervous system effects, liver disease, gout-like disease
Vanadium (up to 0.01%)	Inhalation, ingestion	Respiratory tract, GI tract	Airway irritation, diarrhea, cramps, nausea
Equipment emissions			
Diesel fumes	Inhalation	Lung, mucous membranes	Increased risk of lung cancer; irritation of eyes, nose, throat and lungs; inflammation of the lungs aggravates chronic respiratory symptoms and asthma.
Dust			
Nuisance dust	Inhalation	Respiratory tract, skin	Irritation of eyes and nasal passages, injury to the skin or mucous membranes; possible exacerbation of asthma
Silica	Inhalation	Lungs, immune system	Silicosis, lung cancer, complicates pulmonary tuberculosis; potential autoimmune disease, renal disease
Process chemicals			
Organics (tertiary amines, decanol, acrylamide, kerosene, etc.)	Inhalation	Neurological systems, liver	Possible increased risk of cancer, liver damage, possible effects on the reproductive systems
Corrosives (acids and bases)	Inhalation (dermal exposure for workers only)	Skin, Lung	Irritation, lung damage

Table 3-2 Potential Pathways of Public Exposure by Source

Source	Constituent	Pathway	Potentially Complete	Comment
Underground Mine	Radon	Inhalation	Yes	Radon is vented from the underground mine workings
Underground Mine	Radionuclides, metals	Ingestion of groundwater or surface water	Yes	The probability of ingestion of groundwater is low depending on hydrologic parameters
Open Pit Mine	Radon	Inhalation	Yes	Radon emanates from exposed ore in the pits
Open Pit Mine	Radionuclides, metals	Fugitive Dust Inhalation	Yes	Dust resulting from excavation or blasting operations; will be mitigated by water spray as needed
Ore storage (Applies in all cases to Open Pit Mine, Mill, Underground Mine)	Radionuclides, metals	Fugitive Dust Inhalation	Yes	Dust is generally mitigated by water spray
Ore storage	Radon	Inhalation	Yes	Radon emanates from exposed stored ore
Ore storage	Radionuclides, metals	Ingestion of groundwater and impacted food from deposition of dust	No	The ore storage pad will be lined to prevent leaching to groundwater so the pathway for release is possible but unlikely; direct ingestion of impacted groundwater is unlikely; environmental monitoring will provide early warning.
Ore storage	Radionuclides, metals	Ingestion of surface water and impacted food from irrigation	No	Diversion channels prevent runoff from off-site to enter storage area; surface water runoff on-site is diverted to the stormwater pond. No exposure under normal operating conditions
Ore storage	Radionuclides, metals	Dermal exposure to impacted water	No	Same as above; naturally occurring radionuclides are not readily absorbed through skin
Waste Rock piles (Applies in all cases to open pit and underground mines)	Radionuclides, metals	Fugitive Dust Inhalation	Yes	Potential dusting off of waste rock piles mitigated using water spray; concentrations of radionuclides in waste rock are lower than for ore; therefore, air particulate constituent concentrations will be lower and may be in the range of background.
Waste rock piles	Radon	Inhalation	Yes	Radon emanates from waste rock with slightly elevated uranium concentration

Table 3-2 Potential Pathways of Public Exposure by Source

Source	Constituent	Pathway	Potentially Complete	Comment
Waste rock piles	Radionuclides, metals	Ingestion of groundwater and impacted food	Yes	Leaching of hazardous constituents from the waste rock
Waste rock piles	Radionuclides, metals	Dermal exposure to water	No	Naturally occurring radionuclides are not readily absorbed through the skin; therefore internal deposition is unlikely. Direct contact with skin through water is not a hazard for radionuclides.
Waste rock piles	Radionuclides, metals	Ingestion of surface water and impacted food	No	Surface runoff will be diverted to the stormwater pond; no exposure under normal operating conditions
Waste rock piles	Radionuclides, metals	Ingestion of soil from eroded piles	No	No public access to the waste rock piles
Waste rock piles	Radionuclides, metals	Dermal exposure to soil	No	No public access: naturally occurring radionuclides are not readily absorbed through the skin.
Mine Crusher/screen	Radon	Inhalation	Yes	Radon released during ore crushing.
Mine Crusher/screen	Radionuclides, metals	Fugitive dust inhalation	Yes	Fugitive dust will be controlled by water spraying as necessary
Haul roads	Radionuclides, metals, fugitive dust	Inhalation	Yes	Mitigated by use of dust control techniques
Haul roads	Radionuclides, metals	Ingestion of water from surface runoff	No	Runoff water will be diverted to the stormwater pond
Mill – ore dump, conveyor, crusher	Radionuclides, metals	Fugitive Dust Inhalation	Yes	Water sprays will mitigate fugitive dust; dust from crushing (grinding) will be mitigated by dust-collecting bag house if necessary
Mill – ore dump, crusher, conveyor, mill building exhaust	Radon	Inhalation	Yes	Radon released when ore is disturbed or crushed.
Mill – ore dump, conveyor, crusher	Radionuclides, radon	Ingestion food impacted by dust deposition	Yes	Stacks will have pollution control devices installed as necessary to mitigate dust release
Mill building – chemical separation	Process chemicals	Spill -Inhalation of suspended soils from dried spills	No	Spill will be cleaned up before it dries
Mill building – chemical separation	Process chemicals	Spill – ingestion of water from runoff	No	Runoff is diverted to the stormwater pond.

Table 3-2 Potential Pathways of Public Exposure by Source

Source	Constituent	Pathway	Potentially Complete	Comment
Mill Building – yellowcake dryer	Uranium	Inhalation of stack emissions	No	A modern system will use a vacuum dryer will with zero particulate emissions, as described by the NRC in NUREG 1910 (NRC, 2009); experience with vacuum dryers at ISR facilities demonstrates no emissions.
Mill building – yellowcake dryer	Uranium	Ingestion of food impacted by stack emissions	No	The dryer will be a modern vacuum dryer with zero stack emissions (NUREG 1910)
Tailings storage	Radon	Inhalation	Yes	Radon emissions are minimized by water cover and limiting the uncovered tailings area
Tailings storage	Radionuclides, metals	Inhalation	Yes	Wet tailings will not be resuspended
Tailings storage	Radionuclides, metals	Ingestion	Yes	Wet tailings will not be resuspended; no significant off-site deposition
Tailings storage	Radionuclides, metals – leaking from storage facility	Ingestion	No	Tailings disposal cells will be lined; limited area for tailings disposal; tailings covered to prevent infiltration after facility is at capacity

Table 3-3 Transfer Coefficients for Uranium and its Decay Products

Element	B_v	B_{vs}	F_{milk} (d/kg)	F_{beef} (d/kg)
U	0.002	0.1	0.0004	0.0008
Th	0.001	0.1	5E-6	0.0001
Ra	0.04	0.2	0.001	0.001
Po	0.001	0.1	0.0004	0.005
Pb	0.004	0.1	0.0003	0.0008
Bi	0.1	0.5	0.001	0.002

B_v = transfer from soil to vegetation (unitless)
B_{vs} = transfer from soil to vegetation assuming consumption of unwashed vegetables (unitless)
F_{milk} = transfer from intake (water, forage, soil, etc.) to milk (pCi/kg per pCi/d)
F_{beef} = transfer from intake (water, forage, soil, etc.) to beef (pCi/kg per pCi/d)

Table 5-1 Diseases/Conditions Potentially Related to Uranium Mine/Mill Operations

Exposure	**Disease/Condition**	**Acute/Long-Term**	**Baseline Data***
Heavy metals (lead, cadmium, arsenic, etc.)	Kidney disease (nephrotoxicity)	Acute and long-term	Diabetes, pre-existing kidney disease
Dust (PM10, PM2.5, diesel exhaust)	Asthma, pneumoconiosis, silicosis	Acute (asthma), Long-term (pneumoconiosis, silicosis)	Asthma** Chronic Obstructive Pulmonary Disease (COPD)** Smoking rates
Radon	Lung cancer	Long-term	Baseline radon Smoking rates
Other radionuclides	Cancer Birth defects	Long-term Mid-Long-term	Cancer & congenital defects data

* For establishing base rates of disease in community or “confounders” for new disease related to exposures

** Underlying disease may be exacerbated by dust exposure

APPENDIX I - NRC REGULATORY COMPATIBILITY CATEGORIES AND URANIUM REGULATIONS

Table I.1	NRC Categories of Compatibility and Explanation of Their Meanings (adapted from FSME, 2009)
Table I.2	USNRC Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10CFR Part 40 Compatibility Table, November 11, 2011)

Table I.1 U.S. Nuclear Regulatory Commission Categories of Compatibility and Explanation of Their Meanings (adapted from FSME, 2009)

COMPATIBILITY CATEGORY	EXPLANATION OF CATEGORY	COMMENTS
A	Basic radiation protection standard or related definitions, signs, labels or terms necessary for a common understanding of radiation protection principles. The State program element should be essentially identical to that of U.S. Nuclear Regulatory Commission (NRC).	
B	Program element with significant direct transboundary implications. The State program element should be essentially identical to that of NRC.	
C	Program element, the essential objectives of which should be adopted by the State to avoid conflicts, duplications or gaps. The manner in which the essential objectives are addressed need not be the same as NRC, provided the essential objectives are met.	
D	Not required for purposes of compatibility.	
NRC	These are NRC program elements that address areas of regulation that cannot be relinquished to Agreement States pursuant to the Atomic Energy Act or provisions of 10 Code of Federal Regulation (CFR). The State should not adopt these program elements.	
H&S	Program elements identified by H&S are not required for purposes of compatibility; however, they do have particular health and safety significance. The State should adopt the essential objectives of such program elements in order to maintain an adequate program.	The NRC reviews of proposed State regulations appear in many cases to consider the H&S category as one in which the regulations must be "identical" to those of the NRC with little latitude for deviation in the wording.

The compatibility level that the NRC has determined applies to each section within 10 CFR Part 40 is provided in Table 13. For a state to obtain an Amended Agreement for authority to regulate uranium recovery facilities within the state, the state must have regulations in place prior to the signing of the Amended Agreement that meet the compatibility levels shown in the table. The compatibility table can be found at: http://nrc-stp.ornl.gov/regulationtoolbox/10cfr40.pdf.

Table I.2 U.S. Nuclear Regulatory Commission Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10 CFR Part 40 Compatibility Table, November 11, 2011) continued

NRC Regulation Section	Title	Level Of Compatibility	Analysis	Comments
General Provisions				
Section				
40.1	Purpose	D		
40.2	Scope	D		
40.2a	Coverage of Inactive Tailings Sites	A – States with authority to regulate U mill activities D – States without authority	Not Applicable	There Are No Existing U Tailings Sites in Virginia
40.3	License Requirements	C	12 VAC5-481-380	Will Need to Add Reference Specific to U Mills
40.4	Definitions	A through D, H&S, NRC	12 VAC5-481-10	See Text of Report
40.5	Communications	D		
40.6	Interpretations	D		
40.7	Employee Protection	D		
40.8	Information collection requirements: OMB approval	D		
40.9	Completeness and accuracy of information	D		
40.10	Deliberate misconduct	C	12 VAC5-481-30	
Exemptions				
40.11	Persons using source material under certain Department of Energy and Nuclear Regulatory Commission contracts.	B	12 VAC5-481-90	
40.12	Carriers	B/NRC	12 VAC5-481-390	40.12(a) Adopted by Reference
40.13	Unimportant quantities of source material	B/NRC	12 VAC5-481-390	Adopted by Reference – See Text of Report

Table I.2 U.S. Nuclear Regulatory Commission Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10 CFR Part 40 Compatibility Table, November 11, 2011) continued

NRC Regulation Section	Title	Level Of Compatibility	Analysis	Comments
40.14	Specific Exemptions	D		
General Licenses				
40.20	Types of licenses	C/D	12 VAC5-481-410	Adopted by Reference
40.21	General license to receive title to source or byproduct material	C	12 VAC5-481-420	Adopted by Reference
40.22	Small quantities of source material	B	12 VAC5-481-420A	Adopted by Reference – See Text of Report
40.23	General license for carriers of transient shipments of natural uranium other than in the form of ore or ore residue	NRC		
40.24	[Reserved]	Not Applicable		
40.25	General license for use of certain industrial products or devices	C	12 VAC5-481-420C	Adopted by Reference
40.26	General license for possession and storage of byproduct material as defined in this part	C – States with authority to regulate U mill activities D – States without authority	Not Applicable	There Are No Existing U Tailings Sites in Virginia
40.27	General license for custody and long-term care of residual radioactive material disposal sites	NRC		
40.28	General license for custody and long-term care of uranium or thorium byproduct materials disposal sites	NRC		

Table I.2 U.S. Nuclear Regulatory Commission Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10 CFR Part 40 Compatibility Table, November 11, 2011) continued

NRC Regulation Section	Title	Level Of Compatibility	Analysis	Comments
License Applications				
40.31	Application for specific licenses	D, NRC, H&S	12 VAC5-481-440 But Does Not Include U Milling	Will Need to Add Equivalent of 40.31(f) through (m)
40.32	General requirements for issuance of specific licenses	D, H&S, NRC	12 VAC5-481-450 and 490	
40.33	Issuance of a license for a uranium enrichment facility	NRC		
40.34	Special requirements for issuance of specific licenses	B, D	12 VAC5-481-480 through 480 K	For DU Products
40.35	40.35 Conditions of specific licenses issued pursuant to § 40.34	B, C, D,	12 VAC5-481-500 & 480 through 480K	For DU Products
40.36	Financial assurance and recordkeeping for decommissioning	H&S, NRC	No Requirements Specific to U Mills in VDH Regulation	Will Need to Be Added
40.38	40.38 Ineligibility of certain applicants	NRC		
Licenses				
40.41	Terms and conditions of licenses	C, D, NRC, H&S	12 VAC5-481-500	
40.42	Expiration and termination of licenses and decommissioning of sites and separate buildings or outdoor areas	D, H&S	12 VAC5-481-510	
40.43	Renewal of licenses	D	12 VAC5-481-520	
40.44	Amendment of licenses at request of licensee	D	12 VAC5-481-530	

Table I.2 U.S. Nuclear Regulatory Commission Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10 CFR Part 40 Compatibility Table, November 11, 2011) continued

NRC Regulation Section	Title	Level Of Compatibility	Analysis	Comments
40.45	Commission action on applications to renew or amend	D	12 VAC5-481-540	
40.46	Inalienability of licenses	C	12 VAC5-481-500.B	
Transfer of Source Material				
40.51	Transfer of source or byproduct material	C, NRC	12 VAC5-481-570	
40.52	Restrictions on the use of Australian-obligated source material	NRC		
40.53	[Reserved]			
40.54	[Reserved]			
40.55	[Reserved]			
40.56	[Reserved]			
Records, Reports, and Inspections				
40.60	Reporting requirements	C, D	12 VAC5-481-1110	Adopted by Reference
40.61	Records	C, D, H&S	12 VAC5-481-571	
40.62	Inspections	D	12 VAC5-481-110	
40.63	Tests	D	12 VAC5-481-180	
40.64	Reports	NRC		
40.65	Effluent monitoring reporting requirements	C – States with authority to regulate U mill activities D –States without authority	Not in VDH Regulations	Will Need to Be Added
40.66	Requirements for advance notice of export shipments of natural uranium	NRC		

Table I.2 U.S. Nuclear Regulatory Commission Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10 CFR Part 40 Compatibility Table, November 11, 2011) continued

NRC Regulation Section	Title	Level Of Compatibility	Analysis	Comments
40.67	Requirement for advance notice for importation of natural uranium from countries that are not party to the Convention on the Physical Protection of Nuclear Material	NRC		
Modification and Revocation of Licenses				
40.71	Modification and revocation of licenses.	D		
Enforcement				
40.81	Violations.	D		
40.82	Criminal penalties.	D		
Appendix A	Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced	Definitions – A for States with authority to regulate U mill activities. Criterion 1	Not in VDH Regulations	Will Need to Be Added – See Text of Report
I. Technical Criteria		C		
Criterion 1		C	Not in VDH Regulations	Will Need to Be Added
Criterion 2		C	Not in VDH Regulations	Will Need to Be Added
Criterion 3		C	Not in VDH Regulations	Will Need to Be Added – See Text of Report
Criterion 4		C	Not in VDH Regulations	Will Need to Be Added –See Text of Report
Criterion 5		C	Not in VDH Regulations	Will Need to Be Added
Criterion 6		C	Not in VDH Regulations	Will Need to Be Added
Criterion 6A		C	Not in VDH Regulations	Will Need to Be Added

Table I.2 U.S. Nuclear Regulatory Commission Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10 CFR Part 40 Compatibility Table, November 11, 2011) continued

NRC Regulation Section	Title	Level Of Compatibility	Analysis	Comments
Criterion 7		C	Not in VDH Regulations	Will Need to Be Added
Criterion 8		C	Not in VDH Regulations	Will Need to Be Added
Criterion 8A		C	Not in VDH Regulations	Will Need to Be Added
II. Financial Criteria				
Criterion 9		C	Not in VDH Regulations	Will Need to Be Added
Criterion 10		C	Not in VDH Regulations	Will Need to Be Added
III. Site and Byproduct Material Ownership				
Criterion 11		NRC for 11A through F		
IV. Long-Term Site Surveillance				
Criterion 12		NRC		
V. Hazardous constituents				
Criterion 13		C	Not in VDH Regulations	Will Need to Be Added

APPENDIX II – IMPAIRED WATER BODIES OF VIRGINIA

Table II.1	Virginia 2010 Causes of Impairment for Listed Waters
Table II.2	Virginia Cumulative TMDL's by Pollutant

Virginia 2010 Causes of Impairment for 303(d) Listed Waters

Table II.1 Virginia 2010 Causes of Impairment for Listed Waters

Cause of Impairment Group Name	Number of Causes of Impairment Reported
Pathogens	691
Cause Unknown - Impaired Biota	282
Organic Enrichment/Oxygen Depletion	206
pH/Acidity/Caustic Conditions	162
Mercury	71
Temperature	55
Polychlorinated Biphenyls (PCBs)	49
Pesticides	19
Noxious Aquatic Plants	16
Algal Growth	8
Nutrients	8
Metals (other than Mercury)	6
Toxic Organics	5
Salinity/Total Dissolved Solids/Chlorides/Sulfates	2
Total Toxics	2
Ammonia	2
Dioxins	1

Total: 1,585 Causes of Impairment

Virginia Cumulative TMDLs by Pollutant

This chart includes TMDLs since October 1, 1995.

Table II.2 Virginia Cumulative TMDL's by Pollutant, continued

Pollutant	Number of TMDLs	Number of Causes of Impairment Addressed
Fecal Coliform	331	332
Escherichia Coli (E. Coli)	226	235
Ammonia	147	147
Pathogens	108	110
Sediment	89	89
Polychlorinated Biphenyls (PCBs)	77	77
Phosphorus, Total	43	43
Nitrogen, Total	42	42
Total Suspended Solids (TSS)	36	36
Enterococcus Bacteria	29	29
Mercury	26	26
Phosphorus	19	21
Total Dissolved Solids (TDS)	18	18
Dissolved Oxygen	16	16
Total Kjehldahl Nitrogen (TKN)	13	13
Carbonaceous Bod	10	10
Benthic	9	9
Copper	8	8
Tributyltin	8	8
Cyanide	6	6
Organic Enrichment	6	6
Polycyclic Aromatic Hydrocarbons (PAHs) (Aquatic Ecosystems)	6	6
Temperature	6	6

Table II.2 Virginia Cumulative TMDL's by Pollutant, continued

Pollutant	Number of TMDLs	Number of Causes of Impairment Addressed
Zinc	6	6
Biochemical Oxygen Demand (BOD)	4	4
Chlorine	4	4
Fecal	4	5
Pentachlorophenol (PCP)	4	4
Whole Effluent Toxicity (WET)	4	4
Chlorides	3	3
Nitrogen	3	3
PCBs in Sediment	3	3
Pollutants in Urban Stormwater	3	6
Total Residual Chlorine	3	3
pH	3	3
Benzene	2	2
Di-2-Ethylhexyl Phthalate	2	2
Lead	2	2
Nitrate	2	2
Shellfish Harvesting Advisory	2	2
Silver	2	2
Aldrin	1	1
Alkalinity	1	1
Aluminum	1	1
Arsenic	1	1
Bacterial Slimes	1	1
Cadmium	1	1
Chloride	1	1
Chlorine, Residual (Chlorine Demand)	1	1

Table II.2 Virginia Cumulative TMDL's by Pollutant, continued

Pollutant	Number of TMDLs	Number of Causes of Impairment Addressed
Chloroform	1	1
Chromium, Hexavalent	1	1
Chromium, Total	1	1
DDT	1	1
Dioxin	1	1
Eldrin	1	1
Endrin	1	1
Ethylbenzene	1	1
Manganese	1	1
Metals (other than Mercury)	1	1
Naphthalene	1	1
Nickel	1	1
Organic Enrichment/Low Dissolved Oxygen	1	1
Toluene	1	1
Xylene	1	1

Total: 1,358 TMDLs; 1,376 Causes of Impairment Addressed

APPENDIX III - BACKGROUND RADIATION

1.0 Background Radiation

Radiation is a natural part of the earth's environment that comes from outer space (cosmic), the earth's crust (terrestrial) and the human body itself (internal). Man has evolved in this radioactive environment for all of human history. Radiation levels vary across the earth's surface depending altitude, latitude and geologic composition of the surface materials. The average radiation dose from natural background in the United States (U.S.) is 310 millirems per year (mrem/yr) (NCRP, 2009).

1.1 Cosmic Radiation

Cosmic radiation comes from the solar system, from interstellar space, the galaxy outside the solar system, and from beyond the galaxy. It consists of charged particles, primarily protons that interact with the atmosphere to generate other particles including electrons, and electromagnetic radiation in the form of high-energy photons. Cosmic radiation levels depend on altitude and latitude; the higher the altitude and the greater the northern latitude, the higher the cosmic radiation dose. The average radiation dose from cosmic radiation in the U.S. is 34 mrem/yr. The cosmic radiation dose in Denver is approximately twice the sea level dose. The average cosmic radiation dose in Virginia would be approximately the same as for the U.S. The cosmic radiation levels in coastal areas of Virginia are approximately 32 mrem/yr ranging up to approximately 45 mrem/yr in the more mountainous regions of western Virginia (NCRP, 2009).

1.2 Terrestrial Radiation

The dose from terrestrial gamma radiation depends on the composition of the surface materials in the earth's crust. There are three primary "primordial"[5] radioactive elements in rock and soil: uranium, thorium, and a radioactive isotope of potassium (i.e., potassium-40). Natural uranium and thorium decay into a series of other radionuclides, termed decay products. The decay scheme for U-238 is shown in Table V.

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[5] Primordial radionuclides are nuclides that have been present in the earth's crust since its formation.

Table III.1 Uranium-238 Decay Series

Nuclide	Atomic Number	Mode of Decay	Energy (MeV) (percent) [emissions greater than 10% only]	Half-life	Decay Product
U-238	92	Alpha	4.15 (22.9) 4.20 (76.8)	4.47E9 y	Th-234
Th-234	90	Beta	0.189 (72.5) 0.096 (18.6)	24.1 d	Pa-234m
Pa-234m	91	Beta	2.28 (98.6)	1.17 m	U-234
U-234	92	Alpha	4.72 (27.4) 4.77 (72.3)	2.45E5 y	Th-230
Th-230	90	Alpha	4.62 (23.4) 4.69 (76.2)	7.7E4 y	Ra-226
Ra-226	88	Alpha	4.78 (94.4)	1.6E3 y	Rn-222
Rn-222	86	Alpha	5.49 (99.9)	3.82 d	Po-218
Po-218	84	Alpha	6.00 (100)	3.05 m	Pb-214
Pb-214	82	Beta Gamma	0.67 (48) 0.73 (42.5) 0.295 (19.2) 0.352 (37.1)	26.8 m	Bi-214
Bi-214	83	Beta Gamma	3.27 (17.7) 1.54 (17.9) 1.51 (17.6) 0.609 (46.1) 1.12 (15.0) 1.77 (15.9)	19.9 m	Po-214
Po-214	84	Alpha	7.69 (100)	0.164 ms	Pb-210
Pb-210	82	Beta	0.016 (80) 0.063 (20)	22.3 y	Bi-210
Bi-210	83	Beta	1.16 (100)	5.01 d	Po-210
Po-210	84	Alpha	5.305 (100)	138.4 d	Pb-206 Stable

The dose from direct gamma radiation outside the body varies depending on the composition of the surface materials. Annual doses across the U.S. range from about 7 mrem/yr in Florida coastal areas to over 70 mrem per year in some areas of Colorado and Wyoming. The average annual dose from terrestrial radiation in the U.S. is about 22 mrem/yr. The estimated average direct gamma radiation exposure rate from terrestrial radiation in Virginia is 7.4 microroentgens per your (μR/hr) based on an Oak Ridge National Laboratory report (Myrik, 1981) or an annual dose of approximately 20 mrem/yr, assuming 25% outdoor occupancy, 50% indoor occupancy, an indoor shielding factor of 0.4, and a conversion factor of 0.7 rem per roentgen for adults (UNSCEAR, 2000).

1.3 Internal Radiation

The human body is radioactive, in part because of the intake of naturally occurring radioactive materials in water, air, and food (uranium, thorium, and radium) and partly because of the potassium, which is an essential element in muscle tissue. As noted above, one isotope of potassium (potassium-40) is a primordial radionuclide. It is present in the human body in proportion to the amount of muscle mass. A normal body regulates the amount of potassium so that ingesting food rich in potassium, such as bananas, does not affect the amount retained by the body. On average, the annual dose to an individual from internal radiation is 28 mrem.

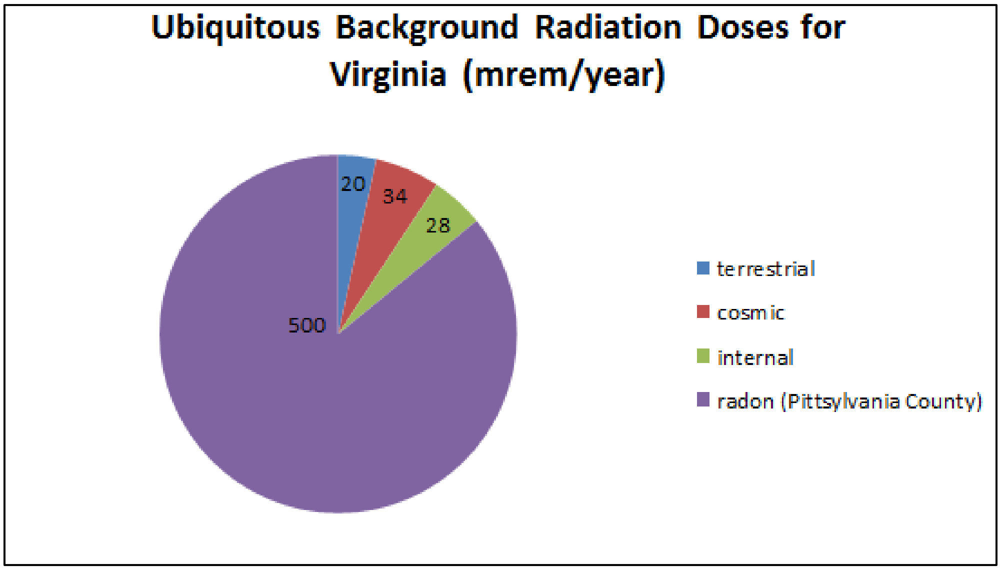
1.4 Indoor Radon

Radium in soil decays to an inert gas, radon. Radon itself is not hazardous because it is breathed in and breathed out without interacting significantly with body tissues. However, the immediate short-lived decay products of radon are particles and, when inhaled, stick in the lung. In general, the higher the radon concentration and the lower the ventilation rate, the greater the dose to an individual. Inhalation of radon decay products constitutes the largest component of background radiation dose to people. The type of construction and lifestyle of the occupants will affect the radiation dose from indoor radon. On average, in the U.S., the annual dose is approximately 220 mrem. The dose from radon decay products is highly variable within states and even within neighborhoods. Based on county-specific data for Virginia showing an average indoor radon concentration of 3.2 pCi/L for Pittsylvania County (VDH, 2012), the annual radiation dose from inhalation of radon decay products would be approximately 500 mrem/yr (assuming an equilibrium factor of 0.4 and 75% indoor occupancy). The estimated lifetime risk (30 year duration) from ubiquitous background would be 9.4 in 1,000 or nearly 1 in 100 assuming the validity of the Linear-no-threshold (LNT) theory. It should be noted that the measurements quoted in the Virginia Department of Health Radon website are screening measurements reported by a radon measurement vendor, AirChek, Inc., and may not accurately reflect average radon concentrations to which residents are exposed.

1.5 Summary of Annual Doses from Natural Background Radiation

The estimated annual radiation doses in Virginia from ubiquitous natural background, summarized in Figure III-1, include 500 mrem/yr from indoor radon, 28 mrem/yr from internally deposited radionuclides, 20 mrem/yr from terrestrial radiation and 34 mrem/yr from cosmic radiation, for a total of 572 mrem/yr. The US annual average radiation dose from natural background is 310 mrem/yr (NCRP, 2009). The average background radiation dose to a resident of Denver is about twice that amount due to the increased cosmic, terrestrial, and indoor radon doses. The average annual dose including medical radiation, described in Section 3.1.7, is approximately 600 mrem/yr. For comparison, the average annual allowable dose to a member of the public from a uranium mill is 25 mrem/yr (excluding radon) above background (40 CFR 190, 192). The maximum allowable dose to a member of the public from any licensed facility from all sources is 100 mrem/yr above background (10 CFR 20).

Figure III.1 Ubiquitous Background Radiation doses for Virginia



2.0 CONSUMER PRODUCTS

Consumer products, with the exception of tobacco, account for only a very small portion of the average radiation dose to a resident of the U.S.

2.1 Smoke Detectors

Ionization chamber smoke detectors generally use a very small radiation source to produce a current that is blocked by smoke. When the current drops, the smoke detector gives off a piercing alarm. The radioactive source in the smoke detector produces essentially no radiation dose outside the detector housing.

2.2 Ceramics, glassware, lantern mantles, luminous watches

Certain ceramics and glassware contain small amounts of uranium producing the classic yellow or orange color (e.g., orange Fiesta-ware, yellow Vaseline glass). People have been using these items for decades with no detectable effect or radiation exposure. The mantles used in lanterns popular with campers, may contain natural thorium. As with the ceramics, no detectable radiation effects have been noted in campers who have the mantles. Radium was used in luminous watch dials in the early part of the 20th century. These watches are no longer produced since less hazardous substitutes have been found.

2.3 Cigarette smoking

Cigarette smoking at a rate of a pack a day produces an effective radiation dose of about 40 mrem/yr to 70 mrem/yr (NCRP 2009). The dose to the small areas of lung itself is much higher than the effective dose and can range up to 16,000 mrem/yr (NCRP, 1995). Tobacco leaves contain uranium decay products, Po-210 and Pb-210. The amount of radioactive material depends on soil conditions and fertilizer use. These radionuclides attach to dust particles that are collected by the sticky tobacco leaves. The dust particles do not wash off the tobacco leaves because of a sticky substance on the surface of the leaf that is not water soluble. The radionuclides remain on the tobacco through the entire curing and cutting process and into the manufacture of the cigarettes (EPA, 2012). When the user smokes the cigarette, he or she inhales the radioactive particles. Phosphate fertilizer, commonly used in growing tobacco, contains naturally elevated concentrations of uranium and radium contributing to the radioactive material in the tobacco leaf.

Figure III.2 Tobacco Leaf

2.4 Commercial Air Travel

Cosmic radiation results in doses to aircraft crews and passengers. The radiation dose from air travel is approximately 0.5 mrem per hour in the air. It should be noted that the security screening devices used in airports result in about the same radiation dose to the passenger as two minutes in flight (Brent, 2012).

2.5 Medical Radiation

Radiation was used in medical practice within six months of the discovery of x-rays in 1895. It continues to be a life-saving technology with x-rays, nuclear medicine, and the recent development of computerized tomography (CT) scans. Until CT scans became commonly used the average dose to a member of the public in the United States from medical radiation (excluding therapy) was approximately 50 mrem/yr. Dental x-rays produce a radiation dose to the patient of approximately 2 mrem; chest x-rays, 8 mrem (NCRP, 2009). CT scans produce doses ranging from 200 mrem for a head scan to 2,000 mrem for a CT angiography of the heart. The average dose attributable to medical radiation (excluding therapy) is approximately 300 mrem/yr. However, the average is a misleading figure since less than 25% of the population actually receives a CT scan. The high dose per scan skews the average calculation.

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Appendix IV Potential Constituents of Concern

1.0 INTRODUCTION

This Appendix includes specific information regarding the chemical and radiological constituents that are potentially present in uranium recovery operations. Section 1.0 describes the hazards uniquely present in uranium mining; Section 2.0, hazards specific to uranium milling; and Section 3.0 hazards that may be present but are not specific to uranium recovery. Physical safety hazards and constituents common to mining or industrial processes in general are not included except where they might be exacerbated by uranium recovery activities or are of specific concern to the public. The constituents of concern are listed in Table IV.1.

Where they are available, current 29 Code of Federal Regulations (CFR) 1910 Permissible Exposure Limits (time-weighted average [PELs]) and Environmental Protection Agency (EPA) regional screening levels (RSLs) for non-radioactive constituents are included in the brief constituents descriptions. It should be noted that health and safety of workers at uranium mines and operating mills is the responsibility of the Mine Safety and Health Administration (MSHA), not the Occupational Safety and Health Administration (OSHA). MSHA regulations cite the 1973 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). The OSHA PELs are cited in this document because they are explicitly called out in 29 CFR 1910, 1925, and other OSHA regulations.

The RSLs are from the Regional Screening Level Summary Table dated April 2012 (accessed at www.epa.gov/region9/superfund/prg) (EPA, 2012). RSLs are risk-based values calculated using the most recent toxicity values, default exposure assumptions and chemical and physical properties. The RSLs may not reflect actual risks to members of the public. The EPA provides a calculator that allows the user to substitute site-specific parameter values for generally conservative default values.

Nuclear Regulatory Commission (NRC) 10 CFR 20 Appendix B Derived Air Concentrations (DACs) for occupational exposures along with effluent limits (ELs), are provided in Table 2. The occupational dose limits are intended to apply to adults, e.g., workers, and do not necessarily take into account the particular vulnerability of children. However, the 10 CFR 20 appendix B inhalation ELs for radioactive materials are calculated for a radiation dose of 50 mrem/yr rather than the dose limit of 100 mrem/yr to account for the variability in the population including age. The EPA RSLs are intended to determine whether potentially significant levels of contamination are present and warrant further investigation and do not necessarily mean the levels constitute a risk. The acceptable levels quoted in this document are for residential occupancy which implies that population age distributions are taken into account in calculating the values.

The Agency for Toxic Substances and Disease Registry (ATSDR) publishes toxicity profiles for most of the constituents of the ore and other toxic substances that might be released during uranium recovery. These documents were used in this assessment. The Toxicity Profiles can be accessed at: www.atsdr.cdc.gov/toxprofiles/index.asp.

Risks and potential exposures cannot be quantified without adequate information on uranium mine and mill location, demographics, process, site plan, meteorology, and other specific details regarding such a facility. Potential public radiation dose information is generally provided in the application documents for a specific facility and the semi-annual environmental reports (10 CFR 40.65 or equivalent reports). In general, no other exposures are considered in the assessment of impacts to members of the public.

Workplace monitoring may be required for particular constituents, e.g., radionuclides, total dust, and silica, however other monitoring requirements are dependent on specific workplace conditions and initial measurements. Workplace monitoring requirements are established by the MSHA for mines and for non-radiological constituents in uranium mills. In most cases, no environmental surveillance is projected for specific chemical constituents. Monitoring for radionuclides is described in detail in Section 7 of Interim Report #2 (WES, 2012b). Additional monitoring has been suggested for $PM_{2.5}$ and PM_{10} as well as total particulates.

A section on antidotes has been included in the constituent descriptions; however, antidotes are applicable to acute poisoning not environmental levels. Therefore, in some cases, no antidotes have been specified. For specific constituents, the Material Safety Data Sheets (MSDSs) must be consulted for appropriate actions in the event of an acute exposure to a worker.

Table IV.1 Potential Health Risks Associated With Uranium Mining and Milling (from VDH, 2012) (Note: This table will be expanded in the Final Report to provide information on potential risk to public and workers)

Toxic material	Mine or Mill[6, 7]	Potentially affected population W-workers; P-public	Potential pathways A-air; GW-groundwater SW = surface water; V-vegetation[8]; DR = direct radiation	Comments: probability of exposure depends on mill process and composition of ore; example: Coles Hill (CH) ore as noted in Section 2.0.	Toxic material
Acrylamide/Polymeric Flocculants	Mill	W	A	Depends on mill process	Acrylamide/Polymeric Flocculants
Amine	Mill	W		Depends on mill process	Amine
Arsenic	Mine/Mill	W, P	A, SW, GW, V	Low probability: Up to 0.001% in CH ore; soil background concentration	Arsenic
Barium	Mine/Mill	W, P	A, SW, GW, V	Up to 0.11% in CH ore	Barium
Beryllium	Mine/Mill	W, P	A, SW, GW, V	Low probability: <0.0002% in CH ore; soil background concentration	Beryllium
Cadmium	Mine/Mill	W, P	A, SW, GW, V	Low probability; Up to 0.0001% in CH ore; soil background concentration	Cadmium
Carbon Monoxide	Mine	W	A	Depends on type of equipment used in the mine	Carbon Monoxide

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[6] Mine designation includes haul roads

[7] Constituents of ore are assumed to be potentially present in the mine and the mill

[8] Any constituent in ground or surface water was assumed to be taken up by plants

Table IV.1 Potential Health Risks Associated With Uranium Mining and Milling (from VDH, 2012) (Note: This table will be expanded in the Final Report to provide information on potential risk to public and workers)

Toxic material	Mine or Mill[6, 7]	Potentially affected population W-workers; P-public	Potential pathways A-air; GW-groundwater SW = surface water; V-vegetation[8]; DR = direct radiation	Comments: probability of exposure depends on mill process and composition of ore; example: Coles Hill (CH) ore as noted in Section 2.0.	Toxic material
Chromium	Mine/Mill	W, P	A, SW, GW, V	Low probability; Up to 0.0039% in CH ore; soil background concentration	Chromium
Cobalt	Mine/Mill	W, P	A, SW, GW, V	Low probability; Up to 0.0015% in CH ore; soil background concentration	Cobalt
Decanol	Mill	W	A	Depends on mill process	Decanol
Diatomaceous Earth, silica with alumina and iron oxide	Mine	W	A		Diatomaceous Earth, silica with alumina and iron oxide
Diesel Emissions/Diesel Particulate Matter	Mine	W, P	A	Mine and haul road vehicle emissions	Diesel Emissions/Diesel Particulate Matter
Dust/Particulate NOS	Mine/Mill	W, P	A	Mine and haul road emissions	Dust/Particulate NOS
Flocculant Polymer	Mill	W	A	Depends on mill process	Flocculant Polymer
Iron	Mine/Mill	W, P	A, GW, SW, V	Content in ore not reported	Iron
Isodecanol	Mill	W	A	Depends on mill process	Isodecanol
Kerosene	Mill	W	A	Depends on mill process	Kerosene
Lead	Mine/Mill	W, P	A, GW, SW, V	Up to 0.025% in CH ore	Lead
Lindane	?		SW, V		Lindane
Manganese	Mine/Mill	W, P	A, GW, SW, V	Up to 0.0525% in CH ore	Manganese

Table IV.1 Potential Health Risks Associated With Uranium Mining and Milling (from VDH, 2012) (Note: This table will be expanded in the Final Report to provide information on potential risk to public and workers)

Toxic material	Mine or Mill[6, 7]	Potentially affected population W-workers; P-public	Potential pathways A-air; GW-groundwater SW = surface water; V-vegetation[8]; DR = direct radiation	Comments: probability of exposure depends on mill process and composition of ore; example: Coles Hill (CH) ore as noted in Section 2.0.	Toxic material
Mercury	Mine/Mill	W, P	A	Not reported in CH ore	Mercury
Molybdenum	Mine/Mill	W, P	A, GW, SW, V	Low probability; Up to 0.01% in CH ore	Molybdenum
Nickel	Mine/Mill	W, P	A, GW, SW, V	Low probability; up to 0.0008% in CH ore; soil background concentration	Nickel
Nitrates	Mill	W	A		Nitrates
Nitrogen Oxides/Explosive Gases	Mine/Mill	W	A		Nitrogen Oxides/Explosive Gases
Uranium-238, Thorium-232, Radium-226, Radium-228 and decay products	Mine/Mill	W, P	A, GW, SW, V, DR	Radiation effects only	Uranium-238, Thorium-232, Radium-226, Radium-228 and decay products
Radon and short-lived decay products	Mine/Mill	W, P	A	Ubiquitous in the environment but concentration increased due to mining/milling	Radon and short-lived decay products
Selenium	Mine/Mill	W, P	A, GW, SW, V	Not listed in CH ore constituents	Selenium
Silica	Mine/Mill	W, P	A	Concentration in CH ore not specified	Silica
Silver	Mine/Mill	W, P	A, GW, SW, V	Low probability; up to 0.0005% in ore	Silver

Table IV.1 Potential Health Risks Associated With Uranium Mining and Milling (from VDH, 2012) (Note: This table will be expanded in the Final Report to provide information on potential risk to public and workers)

Toxic material	Mine or Mill[6, 7]	Potentially affected population W-workers; P-public	Potential pathways A-air; GW-groundwater SW = surface water; V-vegetation[8]; DR = direct radiation	Comments: probability of exposure depends on mill process and composition of ore; example: Coles Hill (CH) ore as noted in Section 2.0.	Toxic material
Sodium Carbonate	Mill	W	A	Depends on mill process	Sodium Carbonate
Sodium Chlorate	Mill	W	A	Depends on mill process	Sodium Chlorate
Sodium Hydroxide/Hydrogen Peroxide/Ammonia/Ammonia Sulfate	Mill	W	A	Most likely present in mill process	Sodium Hydroxide/Hydrogen Peroxide/Ammonia/Ammonia Sulfate
Sulfate	Mill	W, P	GW, SW		Sulfate
Sulfur Dioxide	Mill	P	A	Emissions from mill	Sulfur Dioxide
Sulfuric Acid (and other corrosive acids)	Mill	W	A	Air and direct contact	Sulfuric Acid (and other corrosive acids)
Tertiary Amines	Mill	W	A	Depends on mill process	Tertiary Amines
Thorium	Mine/Mill	W, P	A, GW, SW, V, DR	Less than 0.005% in ore	Thorium
Thorium by-product material	na			Covered under thorium and decay products	Thorium by-product material
Uranium (chemical effects)	Mine/Mill	W, P	A, GW, SW, V, DR	0.025 – 0.5% in CH ore	Uranium (chemical effects)
Vanadium	Mine/Mill	W, P	A, GW, SW, V	Up to 0.01% in CH ore	Vanadium
Zinc	Mine/Mill	W, P	A, GW, SW, V	Up to 0.023% in ore	Zinc

1.1 Risks and Hazards Uniquely Present in Uranium Mining

The following sections describe the potential hazards attributable to constituents uniquely associated with uranium mining. Where the constituents, including uranium and other radionuclides, arsenic, and silica, are applicable to both mining and milling, the toxicity profile is not repeated in Section 2.0.

1.2 Uranium (radiological or chemical effects)

Natural uranium is a substance that is inherently present in the uranium mining/milling processes. It consists of three naturally occurring isotopes: U-238, U-235, and U-234. The percent abundance of each of the three isotopes in natural uranium is as follows: U-238, 99.3%; U-235, 0.72%; and U-234, <0.001%. Uranium is naturally occurring in rocks (ore), air, soil and water as minerals.

Uranium ore is processed in uranium mills to produce "yellowcake" or uranium oxide. Yellowcake may actually be yellow, black, green or various shades depending on how it is processed and dried and the specific chemical form. However, in all cases "yellowcake" is highly concentrated uranium with a concentration approximately equal to 85%. Yellowcake may be soluble or insoluble in body fluids depending on how it is dried. Yellowcake dried in modern vacuum dryers at relatively low temperatures tends to be soluble while yellowcake dried at high temperatures, tends to be less soluble.

Millworkers involved in the drying and packaging process particularly are at risk of inhalation, and in some cases, inadvertent ingestion of yellowcake. While the vacuum drying process is totally enclosed, packaging still may entail potential exposure during routine operations. When drums are not properly packaged and sealed, they can burst and release yellowcake locally resulting in significant worker exposure. Yellowcake operators are required to wear respiratory protection and are generally subject to at least bi-weekly urine bioassay.

Toxicity: The target organ for inhaled insoluble yellowcake is the lung. The target organs for soluble yellowcake are the bone and kidney. Uranium is excreted from the body through the kidneys and its chemical toxicity is generally considered to be of greater concern than its radiotoxicity. Intake of uranium, ingestion in particular, may result in kidney dysfunction, which is indicated by the presence of proteins, enzymes, or glucose in the urine. Kidney dysfunction may be temporary. Kidney toxicity has not been seen at low doses. Inhaled, insoluble uranium is retained in the lung and produces a radiation dose to the lung tissue. The International Agency for Research on Cancer (IARC) lists internally deposited alpha emitting radionuclides as Group 1 carcinogens but lists specific radionuclides only if there is "sufficient evidence" for human carcinogenicity. Uranium is not specifically listed implying that the evidence for human carcinogenicity for uranium specifically is insufficient to categorize it as carcinogenic to humans. However, due the fact that all three uranium isotopes emit alpha radiation, they are generally assumed to be carcinogenic, depending on the solubility. Insoluble, inhaled uranium the target organ is the lung. For soluble uranium, the target organ is the kidney.

A kidney concentration of 3 µg/g has been used as a guideline for chemical toxicity of uranium (DOE, 2009). A literature review summarized in the Department of Energy (DOE) guidance suggests that worker exposure resulting in kidney concentration of 2 µg/g to 6 µg/g kidney “might” be tolerated with no serious effect but noted that it is not necessarily the same as causing no detectable damage. Another report noted that a soluble intake of 10 mg or less is unlikely to cause detectable effects. An occupational airborne concentration limit of 0.2 mg/m^3 was derived based on the 3 µg/g kidney concentration guideline (DOE, 2009). A mass concentration of 0.2 mg/m^3 is equal to an activity concentration of 1.4E-10 µCi/mL natural uranium (U-nat). A concentration of 0.2 mg/m^3 for a 40 hour work week would result in an intake of 9.6 mg, assuming a breathing rate of 1.2 m^3/hr. This results in an equilibrium kidney burden of 900 µg or a concentration of approximately 3 µg/g.

The ATSDR has published a draft revision to the Uranium Toxicity Profile (ATSDR, 2011). The report states that no cardiovascular or gastrointestinal effects have been reported in humans from inhalation of uranium. The report notes that inhalation exposure to uranium has had no effect on hematological parameters but cites a study that showed mortality from lymphatic and hematopoietic tissue effects other than leukemia that may have been due to Th-230. While uranium is nephrotoxic, no increase in mortality due to renal disease was reported for uranium workers. Thun (1985) found that uranium mill workers showed a higher excretion of beta-2-microglobulin than a reference group of cement plant workers noting that the “renal effects of chronic occupational exposure to soluble uranium should not be ignored.”

The ATSDR review notes that none of the epidemiologic studies of uranium workers showed increased incidence of death due to diseases of the immune system. The review states that it is unlikely that inhalation of uranium “produces a significant effect on reproductive health and that no studies reported effects of uranium on development in humans or animals.”

Routes of Exposure: Inhalation of particulates, inadvertent ingestion of dust or soil, ingestion of impacted water

Acceptable Levels in Air and Water:

OSHA PEL: 0.05 mg/m^3 soluble U; 0.25 mg/m^3 insoluble uranium (DOE, 2009)

EPA RSL$_{air}$: no RSL RSL$_{water}$: 4.7E-2 mg/l (MCL: 3.0E1 mg/l)

NRC: Mass concentration for workers – 0.2 mg/m^3

NRC: Mass equivalent to the radiological effluent limit – 4.4 E-3 mg/m^3

(See Table 2 for radiological DAC and EL for uranium isotopes)

Estimated Risk: Without site-specific information, the risk to workers and members of the public from uranium operations cannot be estimated. However, the intake for uranium mill workers is limited to 10 mg per week. The reference dose for uranium is 3.0 E-3 mg/kg per day (EPA, 2012). Assuming a worker weighs 70 kg and works 5 days per week, the maximum intake would be 2.9 E-2 mg/kg-day. The DOE Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities (DOE, 2009) states that a concentration of the reference dose includes an uncertainty factor of 1,000. Therefore, while the maximum allowable weekly dose to a worker exceeds the reference dose, it is well below the dose that has been shown to cause adverse health effects. The maximum allowable effluent limit for soluble uranium from a uranium mill is 3 E-12 µCi/mL. Assuming an individual breathes at a rate of 1.7 E7 mL/day, the daily intake at the effluent limit would be 5.1E-5 µCi/day. The specific activity of natural uranium (i.e., uranium with its naturally occurring isotopes present at their natural abundance) is 6.8E-1 µCi/g. The daily intake would then be 7.5E-5 g/day. Assuming and average 70 kg body weight, the intake would be approximately 1E-6 g/day-kg or 1E-3 mg/d-kg, a factor of three less than the reference dose.

Bioassay: Urine bioassay for uranium is routinely used for workers in uranium recovery facilities with the frequency varying from weekly to quarterly depending on the potential for exposure, particularly to soluble yellowcake. In vivo lung counting to detect radionuclides such as uranium is occasionally used for miners and individuals exposed to airborne insoluble uranium. Routine bioassay for members of the public is not a practical option due to the difficulty of obtaining a valid sample and sample custody issues. However, both urine bioassay and in vivo lung counting could be employed in the event of a serious accident that has the potential to expose members of the public, long term, to uranium concentrations comparable to the occupational concentration limits.

Laboratory Tests for Environmental Concentrations: See Interim Report #2

Action Levels: See Acceptable Levels Above

Antidotes: None for levels that could be encountered in uranium milling. Antidotes for acute poisoning are not appropriate for environmental levels that would occur even under spill or airborne release conditions.

Surveillance Systems: See Interim Report #1 for medical surveillance systems; Interim Report #2 for Environmental Monitoring.

1.3 Radium, Thorium, and Their Decay Products (radiological effects) (See Table 2 for DAC and EL)

Uranium-238 decays through a series of radionuclides to stable lead as depicted in Appendix III. The decay products of uranium are assumed to be in equilibrium in the type of uranium ore present in Virginia; that is, the activity concentration of each decay product is equal to the activity concentration of U-238. Of the decay products of U-238 and U-235 only the parent nuclides, U-238 and U-235 are chemically toxic. The chemical toxicity of natural uranium is discussed in the section above. While U-235 constitutes only 0.72 percent of natural uranium, the decay products of U-235 may contribute to the risk due to their metabolic properties. Natural thorium (Th-232) is present at a very low concentration (NAS, 2011) so would have negligible incremental effect on the radiation risk. Therefore, Th-232 and its decay products are not considered in this analysis.

Uranium and its decay products are ubiquitous in the earth's crust, present at an average concentration of 1.8 parts per million (NCRP, 2009) or 0.6 pCi/g for each of the members of the series.

Toxicity: The specific radiological characteristics and target organs for each of the decay products are given in Table 2. The primary adverse health effect for these decay products at low levels associated with uranium recovery facilities is increased risk of cancer. The target organ depends on the metabolism of the particular element. The risk from internally deposited radionuclides is a function of the type of radiation (radiation weighting factor) and the sensitivity of the target organ (tissue weighting factor). Direct radiation dose attributed to Ra-226 is actually due to the short-lived decay products of Rn-222 discussed in the next section.

Table IV.2 Characteristics of long-lived U-238 and U-235 decay products

Nuclide	**Half-life**	**Decay chain**	**Type of emission**	**Target organ**	
				Ingestion	Inhalation
Th-234	24 d	U-238	Beta	Lower large intestine wall	Lung
Th-230	7.7 E4 y	U-238	Alpha	Bone surface	Bone surface
Pa-231	3.3E4 y	U-235	Alpha	Bone surface	Bone surface
Ac-227	21.8 y	U-235	Alpha	Bone surface	Bone surface
Ra-226	1.6E3 y	U-238	Alpha	Bone surface	Lung, bone surface
Pb-210	22 y	U-238	Beta	Bone surface	Bone surface
Po-210	138 d	U-238	Alpha	All organs	Lung

Because of their shorter half-lives, the specific activities[9] of Th-230 and Ra-226 are much higher than the specific activity of the uranium isotopes. Therefore, the mass concentrations are orders

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[9] Specific activity is the activity per unit mass of a nuclide and is roughly inversely proportional to the half-life.

of magnitude lower than the mass concentrations of U-235 and U-238. Chemical toxicity is not a factor for the decay products of U-238; the radiotoxicity is the over-riding concern.

Routes of Exposure: Air and direct radiation for workers; air and water for members of the public.

Acceptable Levels in Air and Water: The acceptable concentrations of the decay products of uranium are given in Table IV.3.

Table IV.3 Derived Air Concentrations and Effluent Limits for Radionuclides

Nuclide	Occupational Limits				Effluent Limits (Public Exposure)			
	Derived Air Concentration (µCi/mL)			Water ALI (µCi)	Air (µCi/mL)			Water (µCi/mL)
	F[10]	M[11]	S[12]		F	M	S	
U-238	6E-10	3E-10	2E-11	1E1	3E-12	1E-12	6E-14	3E-7 (300 pCi/L)
U-235	6E-10	3E-10	2E-11	1E1	3E-12	1E-12	6E-14	3E-7
U-234	5E-10	3E-10	2E-11	1E1	3E-12	1E-12	5E-14	3E-7
Th-234		8E-8	6E-8	3E+2		3E-10	2E-10	5E-6
Th-230		3E-12	6E-12	4E0		2E-14	3E-14	1E-7
Pa-231		6E-13	2E-12	2E-1		6E-15	8E-15	6E-9
Ac-227	2E-13	7E-13	2E-12	2E-1	1E-15	4E-15	6E-15	5E-9
Ra-226		3E-10		2E0		9E-13		6E-8
Pb-210	1E-10			6E-1	6E-13			1E-8
Po-210	3E-10	3E-10		3E0	9E-13	9E-13		4E-8

Estimated risk: Without site-specific information, the radiation risk to workers and members of the public from uranium facilities cannot be quantified. However, the upper limit of the potential risk to members of the public can be calculated assuming the maximum dose to any individual would be no greater than the regulatory dose limit of 100 mrem/yr including dose from radon decay products (10 CFR 20.1301). The estimated risk to a member of the public for thirty years of exposure, assuming a risk coefficient of 5.4 x 10-2 per Sievert (Sv) [5.4 x 10-7 per mrem] (ICRP, 2007) would be 1.6 x 10-3. As noted in previous reports, actual estimated doses from operating uranium facilities tend to be significantly lower than the regulatory dose limits. The

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[10] Fast lung clearance

[11] Moderate lung clearance

[12] Slow lung clearance

annual radiation doses to members of the public from the Denison White Mesa Mill are less than 10 mrem/yr (Denison, 2011, 2012). The average radiation doses to workers range from 200 to 500 mrem/yr above background. Assuming a 30-year working life-time, the estimated risk, assuming a risk coefficient for workers of 4.1 x 10-2 per Sv [4.1 x 10-7 per mrem] (ICRP, 2007) would be 2.5 x 10-3 to 6.2 x 10-3.

The EPA estimated the committed doses for workers and nearby individuals from uranium mills and determined that the committed effective annual dose to a nearby individual from one mill would be approximately 10 mrem; the average annual committed effective dose to a worker was estimated to be 450 mrem (EPA, 2007). These estimates were based on 1980s uranium recovery technology and would be likely to be lower using current technology, e.g., zero release vacuum dryers. The estimated maximum annual dose at the fenceline of the Pinon Ridge Mill in Colorado is 9 mrem/yr (Two Lines, 2009). The reported doses to the nearest resident to the White Mesa Mill, the only operating uranium mill in the U. S., for 2010 and 2011 were approximately 10 mrem (Denison, 2011; Denison, 2012). The nearest resident is approximately 0.4 miles from the White Mesa Mill. The average dose to the maximally exposed member of the public from the Cotter Mill in Canon City, Colorado for the years 2003 through 2011 was 10 mrem (Cotter, 2012). Therefore, a reasonable estimate of the maximum expected dose to a member of the public from a potential uranium recovery facility in Virginia would be10 mrem/yr.

Bioassay: Personal dosimetry used for workers; no bioassay for members of the public except for epidemiological survey applications.

Laboratory Tests for Environmental Concentrations: See Interim Report #2

Action Levels: See Acceptable Levels above

Antidotes: None

Surveillance Systems: See Interim Report #1 for medical surveillance systems; Interim Report #2 for Environmental Monitoring.

1.4 Radon

Radon is a naturally occurring radioactive gas, formed from the radioactive decay of uranium. Radon is an inert gas and is not by itself hazardous since it is inhaled and exhaled with little absorption or deposition in the body. Radon decays by alpha emission to a series of short-lived decay products, the characteristics of which are given in Table IV.4.

Table IV. 4 Short-lived Decay Products of Rn-222

Nuclide	Half-life	Type of emission
Rn-222	3.83 days	Alpha
Pb-218	3.0 minutes	Alpha
Pb-214	26.8 minutes	Beta, gamma
Bi-214	19.7 minutes	Beta, gamma
Po-214	1.6E-4 seconds	Alpha

The concentration of radon decay products in air depends on the age of the air. The decay products build in to equilibrium as a complex function of their half-lives. Full equilibrium is reached in less than 4 hours. The concentration of radon decay products is expressed as the potential alpha energy released when all of the short-lived decay products present decay to Pb-210. The common unit used in the United States is the Working Level (WL). One WL is the concentration of radon decay products present such that a total potential alpha energy of 1.3 E5 million electron volts (MeV) or 100 pCi/L of Rn-222 in equilibrium with its short-lived decay products. Exposure to radon decay products in air is expressed as a function of the concentration and the exposure time. One Working Level Month (WLM) is equal to exposure to 1.0 WL for a period of 170 hours (the estimated number of hours worked per month).

Radon can be released into the air from water but generally adds only a small increment to the indoor air concentration. The incremental concentration in air from radon in water is about 1E-4 pCi/l per pCi/L in water (NAS, 1999). Only very high radon concentrations in water contribute significantly to indoor radon.

The short-lived radon decay products (Pb-214 and Bi-214) account for nearly all of the direct gamma radiation dose from the U-238 decay series. The estimated dose rate from an infinitely thick, infinite plane of soil containing a concentration of 1 pCi/g of U-238 with all of its decay products in equilibrium is 1.3 µrem/hour.[13]

Toxicity: Radon decay products affect the respiratory system and are known to be human carcinogens. The risk of lung cancer in underground miners is well documented and was covered in the Initial Report dated July 20, 2012. As noted above, radon is an inert gas and is not by itself hazardous since it is inhaled and exhaled with little absorption of deposition in the body; however, the short-lived decay products of radon (Po-218, Pb-214, Bi-214, and Po-214) are solids and are deposited in the lung. Polonium-218 and Po-214 are alpha emitters and when

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[13] Calculated by summing the effective dose rates for all U-238 decay products and adjusting for soil density (EPA, 1993).

deposited in the lung tissue, irradiate the cell and increase the risk of lung cancer, an effect that is exacerbated by smoking with a risk that is up to 25 times higher than for non-smokers (HPS, 2009). Studies of indoor radon exposures indicate the increased risk with smoking. Miner studies show a similar increased risk for smokers. The miner data on which most of the previous lung cancer risk estimates were based came primarily from an era when radon concentrations were not as well controlled in underground mines as they are under modern mining conditions.

Table IV.5 Relative Risk of Lung Cancer by Smoking Status and Average Radon Concentration (HPS, 2009; adapted from Darby, 2006)

Smoking Status	Average Radon Concentration ($Bq\ m^{-3}$)		
	<25 $Bq\ m^{-3}$ (0.7 $pCi\ L^{-1}$)	100 $Bq\ m^{-3}$ (2.7 $pCi\ L^{-1}$)	400 $Bq\ m^{-3}$ (10.8 $pCi\ L^{-1}$)
Lifelong Nonsmoker	1.0	1.2	1.6
Continuing Smoker (15–24 cigarettes per day)	25.8	29.9	42.3

Radon in water can also pose a risk from inhalation due to emanation from water and ingestion. Inhalation accounts for about 87 percent of the risk from radon in water with ingestion accounting for 13 percent of the risk primarily due to stomach cancer (NAS, 1998).

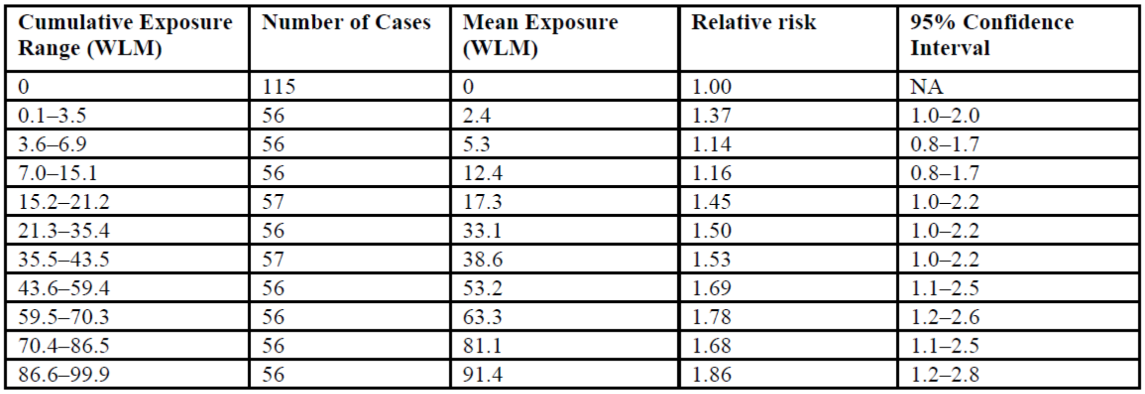
Acceptable Concentrations:

- DAC: 4E-6 µCi/mL with no decay products; 3E-8 with decay products in equilibrium or 4 WLM per year.

Effluent Limit: 1E-5 µCi/mL with no decay products; 1E-7 µCi/mL with decay products in equilibrium

Estimated Risk: The estimated risk from radon cannot be calculated without specific information regarding the particular facility; however, the risk at the maximum allowable exposure, 4 WLM/year, for 30 years would be approximately 6 percent assuming a risk coefficient of 5 E-4 per WLM (ICRP, 2011). The relative risks for miners with cumulative exposures more likely to be encountered in modern mines with adequate engineering controls, are given in Table IV.6. It should be noted that the excess relative risk per WLM decreases with increasing mean exposure. The excess relative risk to miners at the NIOSH recommended exposure limit of 1.0 WLM/y for 30 years would be approximately 0.5. The absolute risk of lung cancer would be approximately 1.5%. The absolute risk would depend on the smoking status of the worker.

Table IV.6 Summary of Miner Epidemiological Data at Low Cumulative Exposures (HPS, 2009; adapted from Lubin, 1997)



Cumulative Exposure Range (WLM)	Number of Cases	Mean Exposure (WLM)	Relative risk	95% Confidence Interval
0	115	0	1.00	NA
0.1–3.5	56	2.4	1.37	1.0–2.0
3.6–6.9	56	5.3	1.14	0.8–1.7
7.0–15.1	56	12.4	1.16	0.8–1.7
15.2–21.2	57	17.3	1.45	1.0–2.2
21.3–35.4	56	33.1	1.50	1.0–2.2
35.5–43.5	57	38.6	1.53	1.0–2.2
43.6–59.4	56	53.2	1.69	1.1–2.5
59.5–70.3	56	63.3	1.78	1.2–2.6
70.4–86.5	56	81.1	1.68	1.1–2.5
86.6–99.9	56	91.4	1.86	1.2–2.8

The estimated incremental lifetime risk to members of the public from radon decay products at the Effluent Limit assuming 30 years of residence and 75% occupancy would be as follows:

Risk = (0.1 pCi/L/100 pCi/L-WL)(30 y)(0.75)(8760 h/y/170 h/M)(5E-4/WLM = 6E-4

The estimated average US indoor radon concentration is 1.3 pCi/L (NCRP, 2009). The estimated risk using the same calculation and assuming an equilibrium factor of 0.4, is 3 E-3.

Bioassay: No routine bioassay for workers or members of the public. Sputum cytology in extreme cases for workers where lung cancer is suspected.

Laboratory Tests for Environmental Concentrations: See Interim Report #2

Action Levels: See Acceptable Levels Above

Antidotes: None

Surveillance Systems: See Interim Report #1 for medical surveillance systems; Interim Report #2 for Environmental Monitoring.

1.5 Arsenic

Arsenic occurs widely in the environment and is a very small component of uranium ores in Virginia comprising up to 0.001% (10 mg/kg). The 95 percentile of eastern soils background levels is approximately the same at 12 mg/kg (EPA, 2003). When arsenic is combined with oxygen, chlorine, and sulfur, inorganic arsenic compounds are formed. Arsenic in animals and plants combines with carbon and hydrogen to form organic arsenic compounds.

Toxicity: According to ATSDR (ATSDR, 2012) it affects the dermal, gastrointestinal, hepatic, neurological and respiratory systems. Effects on the skin include patches of darkened skin and "corns" or "warts" as well as the potential for skin cancer. Arsenic is a known human carcinogen. It has been reported to increase the risk of liver, bladder, and lung cancer.

Arsenic is extremely hard to convert to water-soluble or volatile products. Arsenic is not mobilized but if it is, it also spreads easily. Mining and smelting have been able to mobilize arsenic (Lenntech BV). Although unlikely, it could affect water, plants and animals under the right conditions, however concentrations are usually minimal and also usually from natural sources.

Exposure to arsenic in drinking water has been associated with reduced intellectual function in children. Children exposed to arsenic concentrations in water at levels greater than 50 µg/L have been shown to achieve significantly lower scores on performance tests than children exposed at levels less than 5.5 µg/L when results were adjusted for socioeconomic factors and other constituents of water (Wasserman, 2004).

Further information on arsenic may be found on the ATSDR website at: http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=22&tid=3

Acceptable Levels:

PEL: 10 µg/m^3

RSL$_{air}$: 5.7E-4 µg/m^3 RSL$_{water}$: 4.5E-2 µg/L (MCL = 0.01 ppm or 0.01 mg/l)

Estimated Risk:

Reference dose: 3E-4 mg/kg-day

Cancer Slope Factors: Oral: 1.5E0 (mg/kg-day)$^{-1}$; Inhalation: 4.3E-3 (µg/m^3)$^{-1}$

The risk due to inhalation or ingestion of arsenic from Virginia uranium deposits is essentially the same as background risk since the concentration of uranium is within the range of background concentrations (EPA, 2003; NAS, 2011). However if a mill located in Virginia were to accept ores from outside of the Commonwealth or other countries, arsenic could become a risk to workers and to members of the public. This risk should be addressed in permits or a license amendment for acceptance of such out-of-area ores. The risk would arise primarily from leaching into groundwater, runoff into surface water, and re-suspension of dust from ore processing or dried uranium milling residues. There is no way of estimating the risk from arsenic without site- and material-specific information.

The estimated cancer risk from ingestion of water at the MCL of 0.01 mg/l, assuming intake of 2 liters per day for a 70 kg person, would be 6E-4. The intake at the MCL would exceed the reference dose of 3E-4 mg/day for a person drinking 2 liters of the affected water per day.

Bioassay: No routine bioassay is required for workers given the low levels in proposed ore source. However, that would need to be re-visited in license and permit amendments if ores from other sources are processed. Urine bioassay can be used to detect arsenic in the event of a significant accident involving contamination of water supplies.

Laboratory Tests for Environmental Concentrations: No routine environmental measurements of arsenic are currently performed around uranium recovery facilities. Due to the background concentration in the Virginia ore, no measurements are necessary. However, if ore from other sources is accepting for milling in Virginia, the issue of monitoring for arsenic should be re-visited in the permit or license application.

Action Levels: See recommended levels above

Antidotes: While chelating agents may be used to treat acute arsenic poisoning, antidotes for chronic arsenic intake at levels that could be encountered in a uranium recovery operation, even in the event of an accident, are not applicable.

Surveillance Systems: See Interim Report #1 for medical surveillance systems and Interim Report #2 for a discussion of environmental monitoring. Arsenic is generally included in groundwater analyses around uranium mills.

1.6 Silica

Silica is the most common mineral in the earth's crust. It is abundant, and naturally occurring in many minerals, including uranium minerals found in Virginia. Silica exists in two forms: amorphous and crystalline. The most common form of silica is quartz (SiO_2). Silica is likely to be present in dusts generated in a mine or mill during drilling, blasting, excavation of waste rock and ore, crushing and grinding ore or as windblown dust from ore, waste rock, and dried tailings piles. In addition, sandblasting, road construction, and other infrastructure operations can result in generation of mineral dusts containing significant concentrations of silica.

Toxicity: Inhalation, the primary route of exposure to silica, can cause silicosis, a disabling and sometimes fatal lung disease. Kidney and immune system diseases have also been associated with silica exposure along with chronic obstructive pulmonary disease, bronchitis and emphysema. The IARC has classified silica as a known carcinogen.

The toxicity of crystalline silica is described in detail in Chapter 5 of the National Academy of Sciences Report on Uranium Mining in Virginia (NAS, 2011) and the Initial Report for the Uranium Working Group (WES, 2012a). The NAS report and the WES Initial Report describe several epidemiologic studies of uranium miners that indicated the adverse health effects of exposure to silica.

Particle size is a critical factor in the toxicity of crystalline silica. Smaller particles penetrate deeper into the lung. The particle surface characteristics affect the toxicity. Inhalation causes cellular inflammation, nodule formation, suppressed immune function, and alveolar proteinosis (Hethmon, 2005). The OSHA PEL is based on percent crystalline silica in the airborne material and the particle size.

Acceptable Levels:

OSHA PEL (mineral dust): respirable: 10 $mg/m^3/(\% SiO_2 + 2)$; total: 30 $mg/m^3/(\% SiO_2 + 2)$

RSL: 3.1E0 $\mu g/m^3$

Estimated Risk: The risk to members of the public cannot be estimated without specific information regarding the site; the concentrations of silica in workplace air must be maintained below the OSHA PEL. The OSHA PEL is identical to the ACGIH TLV. The TLV is the concentration to which most workers may be exposed without adverse health effects.

Bioassay: No specific bioassay to detect exposure; silicosis is diagnosed by lung function testing.

Laboratory Tests for Environmental Concentrations: No specific requirement exists for silica analysis of emissions for uranium facilities. Measurement of PM-10 and PM-2.5 concentrations in ambient air are discussed in WES Interim Report #2 (WES, 2012b).

Action Levels: See acceptable levels above.

Antidotes: No antidote for chronic silica intake.

Surveillance Systems: See WES Interim Report #2 (WES, 2012b).

1.7 Other Particulates

Airborne dusts are solids formed by disintegration processes like crushing, grinding, blasting, and drilling – all of which are associated with uranium mining/milling. Particles are small replicas of the parent material and the size can be submicroscopic to visible. For classifying dusts found in the workplace, there is no simple system based on their nature, toxic effects or size. All are important for different reasons. The three main factors for assessing the potential impact of inhaled dusts in the workplace are: chemical composition of the dust, particle size and shape, and exposure concentration and duration.

Of primary concern is airborne particulate matter with particle size less than 2.5 µm that can deposit deep in the lungs. $PM_{2.5}$ particulates are produced mainly by combustion of fossil fuel in vehicles including trucks and farm equipment. In contrast PM_{10} particulates are general derived from abrasion and crushing processes, soil disturbances common to mining as well as organic materials such as plant and insect fragments and pollens.

Toxicity: Particulates not otherwise classified (nuisance dust) are particulates for which there is no evidence of specific toxic effects, i.e., fibrosis or systemic effects. However such particulates may not be inert and may produce general toxic effects depending on concentration in air. High levels of nuisance dust may reduce visibility and can get into eyes, nose, and ears. The health effects of particulates are described in detail in Attachment 1 to WES Interim Report #2.

Health effects attributable to short-term exposure to $PM_{2.5}$ particulates include cardiovascular and respiratory effects and well as increased mortality. Respiratory effects include chronic obstructive pulmonary disease, respiratory infections, and asthma. The data with regard to health effects of short-term exposure to PM_{10} particulates, epidemiologic data suggests causal determinations for cardiovascular and respiratory effects including increased mortality.

Individuals more likely to be affected by exposure to particulates than the general population include children and the elderly, smokers, individuals with pre-existing disease and others as described in the Attachment to WES Interim Report #2

Acceptable Levels: OSHA PEL: 5 mg/m^3 respirable; 15 mg/m^3 total

EPA $PM_{2.5}$ standard: Maximum daily average no greater than 65 μ/m^3; annual average, 15 $\mu g/m^3$

PM_{10} standard: $150 \mu g/m^3$

Estimated Risk: See Appendix II to WES Interim Report #2

Bioassay: No specific bioassay for exposure to dust

Laboratory Tests for Environmental Concentrations: Size selective air particulate sampling and total mass measurements; silica concentration may be measured if the particulate is expected to include a significant fraction of crystalline silica.

Action Levels: See Appendix II to WES Interim Report #2

Antidotes: Not applicable

Surveillance Systems: See Section 7 WES Interim Report #2

1.8 Heavy Metals Including Lead

Heavy metals are constituents of most ores, including uranium. Lead has documented adverse health effects and is monitored as an industrial hazard in most mining operations. It should be noted that the initial assay data from 1984 noted that the uranium ore at Coles Hill was relatively devoid of heavy metals (UMETCO, 1984). VDH monitors water quality for most of the heavy metal analytes including (Arsenic, Lead, Copper, Selenium and others) in drinking water (COV, 2011).

The ATSDR (ATSDR, 2012) reports lead as a naturally occurring bluish-gray metal found in small amounts in the earth's crust and found in all parts of the environment. Lead is associated with the mining/milling of uranium. It has many uses including the production of batteries, ammunition, metal products (solder and pipes), and devices to shield X-rays. Because of health concerns, lead from gasoline, paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years.

The most common cause of lead exposure, principally for children, is lead-based paint. Inhalation of airborne particulates with lead may also result in adverse health effects.

Toxicity: Lead primarily affects the nervous system. Lead exposure may also lead to high blood pressure and anemia. At high levels lead can damage the brain and kidneys. There is no proof that lead causes cancer; however the EPA and IARC have concluded that lead is a probably carcinogen based on animal studies.

As noted in the ATSDR Public Health Statement, children are at greater risk from lead poisoning than adults because they are more likely to ingest lead and are more vulnerable to its health effects. Children ingesting large quantities of lead may develop anemia, kidney damage, colic, muscle weakness, and brain damage.

Further information on the toxicological profile for lead may be found at http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=96&tid=22.

Acceptable Levels: OSHA PEL for inorganic lead: 0.05 mg/m^3 (29 CFR 1910.1025)

RSL residential air: 1.5E-1 µg/m3; MCL drinking water = 0.015 mg/l

National Ambient Air Quality Standard (NAAQS): 0.15 µg/m^3 rolling 3-month average

Estimated Risk: The risk cannot be estimated without specific information regarding the mine and processing facility location in relation to the nearest residents, demographics of the surrounding area,

In response to public concerns, the blood lead levels in children living in the vicinity of the Cotter Canon City uranium mill were investigated by ATSDR. The study found that none of the 115 children tested had elevated blood lead levels but recommended that routine monitoring be carried out (ATSDR, 2006).

Bioassay: Blood samples are the most common method of assaying lead in the body. X-rays of finger, knee, or elbow may also be used but that type of assay is not routinely performed.

Laboratory Tests for Environmental Concentrations: Air sampling with analysis for lead by atomic absorption spectrometry.

Action Levels: See Acceptable Levels above

Antidotes: Chelation therapy for lead poisoning.

Surveillance Systems: Workplace air monitoring required; frequency is dependent on the measured concentration and other relevant considerations such as symptoms that might be attributable to lead. Medical surveillance required for employees who may be exposed at or above the action level for more than 30 days per year including blood lead monitoring.

Iron Oxide

Iron Oxide is not listed in the Toxic Substances Portal of the ATSDR. Iron, and Iron minerals would be expected as a constituent in uranium ores (or many kinds of metallic ores).

Toxicity: Although there is no information on Iron (Fe) alone in the ATSDR portal, iron oxide has been studied for many years. Chest x-ray abnormalities in miners, welders, and other iron oxide workers have been noted and ascribed to siderosis, a pigmentation of the lung. Siderosis is not believed to progress to fibrosis. Exposure to iron oxide is often combined with exposure to other more toxic dusts. The American Conference of Governmental Industrial Hygienists (ACGIH) and OSHA have determined that exposure to iron oxide dust or fume has not been shown to cause cancer. NIOSH provides hazard information on iron oxide dust and fume.

Acceptable Levels: OSHA PEL: 10 mg/m^3 measured as total particulate; ACGIH TLV and NIOSH REL: 5 mg/m^3

RSL: none for air; 5.5E4 mg/kg residential soil; RfD – 0.7 mg/kg-day

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site specific information. However, exposure to iron oxide dust is not believed to result in pulmonary impairment but only in siderosis, a benign pneumoconiosis. A six to ten year exposure to concentrations at 15 mg/m^3 is required to produce siderosis.

Bioassay: none applicable

Laboratory Tests for Environmental Concentrations: Iron is not routinely analyzed in air.

Action Levels: see Acceptable Levels above

Antidotes: not applicable for environmental or occupational exposures

Surveillance Systems: not generally included in routine air quality analyses

Barium

Barium and compounds are present in the Coles Hill ore at a concentration up to 0.11% and may also be used in mine water treatment for precipitation of radium and other radionuclides. Barium is a silvery-white metal. Barium sulfate and barium carbonate are often found in ore deposits.

Toxicity: The potential health effects of inhalation or ingestion of barium are dependent on the solubility of the particular compound. Ingestion of large quantities of soluble barium compounds can cause changes in heart rhythm or paralysis. Smaller amounts can cause short term gastrointestinal symptoms, difficulty in breathing, changes in blood pressure, numbness and muscle weakness. Barium has not been shown to cause cancer in humans or experimental animals.

Acceptable Levels:

OSHA PEL: soluble barium compounds: 0.5 mg/m^3; barium sulfate is treated as nuisance dust.

REL: 0.52µg/m^3

Estimated Risk: Low risk except at very high levels of soluble barium compounds

Bioassay: not applicable

Laboratory Tests for Environmental Concentrations: dust concentration measurements, i.e., air sampling and total mass analysis

Action Levels: See above acceptable levels

Antidotes: not applicable

Surveillance Systems: Total dust monitoring

1.9 Trace Metals

Trace metals potential present in uranium ore include beryllium, cadmium, chromium, cobalt vanadium, nickel, silver, manganese, molybdenum, and zinc. Mercury is not reported as a constituent of the ore and is not expected to be present in the mining or milling environment except possibly in instrumentation. The list of constituents includes trace metals that are present in the Coles Hill ore at background concentrations in Table IV.7.

Table IV.7 Selected Metallic Constituents of Interest Identified within the Ore Body (From Marline 1984)

Element (Symbol)	% in Ore	Sample Element (Symbol)	% in Ore Sample
Uranium (U)	0.025–0.5	Copper (Cu)	0.00971–0.012
Zinc (Zn)	0.023–0.0030	Tin (Sn)	0.0003–0.003
Lead (Pb)	0–0.025	Barium (Ba)	0.0733–0.11
Strontium (Sr)	0.0427–0.073	Zirconium (Zr)	0.0065–0.046
Molybdenum (Mo)	0.0004–0.01	Manganese (Mn)	0.029–0.0525
Yttrium (Y)	0.002	Nickel (Ni) 0–0.0008	
Arsenic (As)	0–0.001	Cobalt (Co)	0–0.0015
Silver (Ag)	0–0.0005	Vanadium (V)	0–0.0102
Thorium (Th)	0–0.005	Beryllium (Be)	0.000197
Chromium (Cr)	0.025–0.5	Cadmium (Cd)	0–0.0001

Note: Ranges given show variability observed from different ore samples.

It should be noted that the concentrations of some of the trace metals are within the range of background soils. For example, the concentration of arsenic is up to 0.001% or 10 mg/kg in Coles Hill ore. The 95th percentile for arsenic in eastern soils is approximately 12 mg/kg (EPA, 2003). The 95th percentile for beryllium is 2 mg/kg or approximately the same as the concentration in the Coles Hill ore. Toxicological profiles for trace metals with concentrations below the 95th percentile of eastern background soils are not relevant but are included as per the Virginia Department of Health suggested table. The background concentrations will be taken into account as the risk is determined for each of the constituents listed in Table IV.7.

Vanadium

Vanadium and its compounds occur in nature as a metal, and is present in many uranium ores. The concentration in Coles Hill ore is up to 100 mg/kg. The 95th percentile for eastern soils is approximately 100 mg/kg. Vanadium usually combines with other elements such as oxygen, sodium, sulfur, or chloride. Vanadium is mostly combined with other metals to make alloys, is used in ceramics and as a catalyst. Most foods, especially seafood, have low natural concentrations of vanadium.

Toxicity: According to ATSDR (2012) vanadium can affect the cardiovascular, gastrointestinal, renal, reproductive and respiratory systems, but has no demonstrated carcinogenic effects. However, based on lung cancer in mice exposed to vanadium pentoxide, the International Agency for Research on Cancer (IARC) has determined that vanadium is possibly carcinogenic to humans. Workers breathing air with vanadium pentoxide can experience coughing that can last several days after exposure. Respiratory tract damage has been observed in experimental animals. Gastro-intestinal effects have been observed in individuals who ingested vanadium compounds for treatment of diabetes. Information on the toxicological profile for vanadium may be found in the ATDR website: http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=276&tid=50.

Acceptable Levels:

OSHA PEL: 0.5 mg/m^3 for respirable dust; 0.1 mg/m^3 for vanadium pentoxide fume

RSL: 2.9E-4 $\mu g/m^3$ for residential air

Estimated Risk: The risk cannot be estimated without site specific data on potential releases

Bioassay: not applicable

Laboratory Tests for Environmental Concentrations: ICP-MS is often used for analysis of trace metals

Action Levels: See Acceptable Levels

Antidotes: not applicable

Of primary concern is airborne particulate matter with particle size less than 2.5µm that can deposit deep in the lungs. $PM_{2.5}$ particulates are produced mainly by combustion of fossil fuel in vehicles including trucks and farm equipment. No specific monitoring for vanadium or other trace metals is performed routinely.

Beryllium

Beryllium is the lightest metal and is naturally occurring in the earth's crust, typically at a concentration in the range of 0.003 g/kg of soil. The average concentration in air is approximately 0.03 ng/m^3. It is mined commercially for the recovery of beryllium which is used in alloys for a variety of purposes including cars, bicycles, computers, sports equipment and other items such as ceramics. It is present in Coles Hill ore at background concentrations.

Toxicity: Inhaled beryllium can cause damage to lungs resembling pneumonia with reddening and swelling of the lungs at levels greater than 1 mg/m^3. It can also cause hypersensitivity in some individuals resulting in chronic beryllium disease, primarily seen as lung granulomas. Beryllium can cause skin ulcers in sensitive individuals. The short-term pneumonia and the chronic beryllium disease can be fatal. Beryllium is considered a probable carcinogen. Ingestion of beryllium has not been shown to cause adverse health effects in humans as it is not readily absorbed from the stomach or intestines (ATSDR, 2002)

Acceptable Levels:

OSHA PEL: 2µg/m^3 (8-hour time-weighted average) NIOSH REL: 0.5 µg/m^3; ACGIH TLV: 0.05µg/m^3

RSL: 1.0E-3 µg/m^3

Estimated Risk: Risk cannot be estimated without site-specific information. Since the concentrations are expected to be in the range of background, no risk from uranium recovery facilities would be expected. EPA estimated that exposure to 0.04 µg/m^3 for a lifetime can result in a 1 in 1,000 risk of cancer.

Bioassay: Urine bioassay; not applicable for environmental levels.

Laboratory Tests for Environmental Concentrations: Atomic Absorption Spectrometry, ICP-MS

Action Levels: See Acceptable Levels above

Antidotes: Not applicable

Surveillance Systems: No surveillance systems required for Be.

Cobalt

Cobalt is found in rocks and soil. It has properties similar to iron and nickel. (Naturally occurring cobalt should not be confused with radioactive cobalt that is produced in reactors. There would be no radioactive cobalt associated with uranium recovery operations.) Cobalt is mixed with other metals to form alloys that are resistant to corrosion and wear. It is also used as a colorant, commonly a blue color, and may be present as an additive in agricultural and medical products (ATSDR, 2004). The cobalt concentration in Coles Hill ore is in the range of background.

Toxicity: Inhalation of high concentrations of cobalt may cause asthma, pneumonia and wheezing. As with other trace metals, exposure to cobalt may result in allergic reactions. In the 1960s cobalt was added to beer to stabilize the foam. Some individuals drinking large quantities of beer (8-25 pints/day) experienced effects on the heart resulting in death; however, nausea and vomiting were reported before effects on the heart were noted (ATSDR, 2004). Cobalt has not been found to cause cancer. Children are likely affected in the same way as adults.

Acceptable Levels:

OSHA PEL: 0.1 mg/m^3

RSLair: 2.7E-4 µg/L RLSwater: 4.7 µg/L

Estimated Risk: Cobalt is present in Coles Hill ore at levels in the range of background. There is no incremental risk from uranium recovery operations.

Bioassay: No specific information with regard to cobalt; however, as with other metals, urine bioassay may be effective.

Laboratory Tests for Environmental Concentrations: Graphite Furnace – Atomic Absorption Spectrometry (GF-AAS) or Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES).

Action Levels: See Acceptable Levels above.

Antidotes: chelating agents.

Surveillance Systems: No specific surveillance required.

Manganese

Manganese is a trace element in rocks and soil and is essential for human health. Manganese occurs naturally in food. It is used in steel production, dry cell batteries fertilizer, paints, and other consumer products. It occurs at concentrations up to 0.05 % Coles Hill ore.

Toxicity: High levels of manganese exposure may cause behavioral changes and other nervous system effects including slow and clumsy movements. Inhalation may cause irritation of the lungs leading to pneumonia. Reproductive effects, including loss of sex drive and sperm damage have been observed in men exposed to high levels. Manganese may produce effects on brain development in children exposed to extremely high levels of manganese. Children may be more sensitive to the adverse effects than adults (ATSDR, 2008b).

Acceptable Levels:

OSHA PEL: 5 mg/m^3

EPA RSLair: 5.2E-2 µg/m3 RSLwater: 3.2E2 µg/L

Estimated Risk: The levels of manganese in the ore are low and are not likely to cause adverse health effects in either workers or members of the public from uranium recovery operations.

Bioassay: Analyses of blood, urine, hair, or feces may be used to detect high levels of intake. However, manganese is normally present in the body and is found in tissues and fluids (ATSDR, 2008b).

Laboratory Tests for Environmental Concentrations: ICP-AES

Action Levels: See Acceptable Levels

Antidotes: Chelating agents

Surveillance Systems: No environmental surveillance systems are required because the levels of manganese are low in the ore. Manganese is naturally present in the environment.

Selenium

Selenium is a naturally occurring element in the earth's crust but is unevenly distributed. Selenium occurs as a by-product of copper refining. It is generally found combined with other substances such as sulfide minerals, silver, copper, lead and nickel. It forms various species of oxides. Selenium is used in photographic devices, plastics, paints, anti-dandruff shampoo, vitamin and mineral supplements and nutritional feed supplements in agriculture. It is not listed among the constituents of Coles Hill ore.

Toxicity: Selenium is an essential element for the human body. However, high levels of selenium dust in the workplace have been shown to cause dizziness, fatigue, irritation of mucous membranes, and in extreme cases, pulmonary edema and severe bronchitis (ATSDR, 2003). Health effects of high oral exposure include brittle hair, deformed nails (selenosis) and excessive tooth decay. Selenium has not been found to be carcinogenic. There are no studies on effects in children or reproductive effects. Excess selenium in the diet of cattle causes "blind staggers".

Acceptable Levels: OSHA PEL: 0.2 mg/m^3;

EPA REL air: 0.021 mg/m^3; EPA REL tap water: 0.078 mg/l

Estimated Risk: Selenium is an essential element and is found in food and nutritional supplements. It is not a risk at environmental levels. As noted above, selenium is not listed among the constituents in Coles Hill ore. It does not pose a potential risk in regard to processing of uranium ore. Selenium has been found in groundwater in the vicinity of uranium facilities. It is an element of interest and should be included in monitoring programs.

Bioassay: Selenium can be detected in blood, urine, fingernails, and toenails; but since it is a normal constituent of the human diet and an essential mineral, such measurements are not likely to be predictive of health effects.

Laboratory Tests for Environmental Concentrations: ICP-MS

Action Levels: See acceptable limits above

Antidotes: No specific antidotes

Surveillance Systems: Measurement of concentrations in air are not necessary; measurements in groundwater or surface water may be advisable for protection of domestic animals if selenium is found in elevated concentrations in ore to be processed.

Silver

Silver is a rare precious metal used for jewelry, silverware, electronic equipment, and dental fillings. Photographic materials are the main source of release of silver to the environment (ATSDR, 1990). Silver may be released into the environment by natural processes such as rain washout from soils.

Toxicity: Silver compounds can cause skin to become gray or blue gray (argyria). This is not known to be harmful to the skin (ATSDR, 1990). Exposure to high levels of airborne silver may cause respiratory problems as well as throat irritation and stomach pains. Ingestion of high concentrations of silver in water may have an impact on the brain or heart based on animal studies (ATSDR, 1990). Such effects have not been reported in humans. Silver is not known to be a carcinogen.

Acceptable Levels: OSHA PEL: 0.01 mg/m^3.

EPA RSL air: Not listed; RSL tap water: 0.071 mg/l.

Estimated Risk: The silver concentration in the Coles Hill ore is very low and it is not likely to present a risk in uranium recovery processes.

Bioassay: Blood, urine, and feces for recent exposure. Analysis of skin sample can detect past exposures.

Laboratory Tests for Environmental Concentrations: No tests required for uranium processing.

Action Levels: see Acceptable Concentrations above.

Antidotes: No specific antidote found.

Surveillance Systems: No surveillance is required for uranium processing based on the low concentration in Coles Hill ore and the low toxicity.

Zinc

Zinc is a common constituent in the earth's crust and is present in food, air, soil, and water. Metallic zinc is used to coat steel and iron to prevent corrosion (galvanization) and may be mixed with other metals to form alloys. Zinc is used in dry cell batteries. Zinc compounds are used to make white paints, and ceramics as well as common household products such as sun block, vitamin supplements, diaper rash ointments.

Toxicity:

Inhaling large concentrations of zinc dust or fumes from smelting or welding can cause metal fume fever, a short-term respiratory disease. According to the ATSDR little is known about the long-term effects of breathing zinc dust or fumes (ATSDR, 2005). Zinc, taken in large doses can cause stomach cramps, nausea and vomiting. Long term ingestion of high levels of zinc can cause anemia, damage to the pancreas, a decrease in high-density-lipoprotein (HDL) cholesterol. Zinc is an essential element, with deficiency causing loss of appetite, decreased sense of taste and smell, decreased immune function, slow wound healing, and skin sores. Zinc deficiency in pregnant women may result in birth defects. Zinc is not classifiable as a human carcinogen (ATSDR, 2005).

Acceptable Levels: OSHA PEL: Zinc chloride fume: 1 mg/m^3; zinc oxide fume: 5 mg/m^3; zinc oxide respirable fraction: 5 mg/m^3; total dust: 15 mg/m^3.

EPA RSL: air: no value; tap water: 4.7 mg/l

Estimated Risk: The concentration of zinc in the Coles Hill ore is low, therefore, there is essentially no risk to members of the public. Zinc exposure to workers may result from welding operations that use flux containing zinc if proper protective equipment and procedures are not used.

Bioassay: Blood, feces, urine and saliva

Laboratory Tests for Environmental Concentrations: Not applicable.

Action Levels: See acceptable levels above.

Antidotes: Not applicable

Surveillance Systems: No environmental surveillance required due to the low toxicity of zinc.

2.0 Risks and Hazards Present in Uranium Milling

Studies that accompanied the 1980s application to mine uranium suggested that there were two methods of recovery for the extraction of uranium, alkaline carbonate and acid. A test program was conducted on the methods, and results suggested that while both methods were effective, the alkaline recovery was more environmentally suitable. These issues would be discussed as alternatives in an Environmental Assessment of Impacts, when initiated. The substances discussed below result from the lrecovery process, and may vary depending on which method is used.

2.1 Ammonia

Ammonia affects the dermal, ocular, and respiratory systems, with no known cancer effects.

Ammonia occurs naturally and is produced by human activity. It is an important source of nitrogen which is needed by plants and animals. Bacteria found in the intestines can produce ammonia. Ammonia is a colorless gas with a very distinct odor. This odor is familiar to many people because ammonia is used in smelling salts, many household and industrial cleaners, and window-cleaning products. Ammonia gas can be dissolved in water. This kind of ammonia is called liquid ammonia or aqueous ammonia. Once exposed to open air, liquid ammonia quickly turns into a gas. Ammonia is applied directly into soil on farm fields, and is used to make fertilizers for farm crops, lawns, and plants. Many household and industrial cleaners contain ammonia (ATSDR 2012).

Further information is available is ATSDR Toxic Substances Portal: http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=11&tid=2.

Acceptable Levels: Minimum Risk Level = 1.7 parts per million (ppm) (14-day inhalation); MRL = 0.1 ppm for chronic duration exposure (> 365 days); TLV-TWA = 25 ppm for workers.

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: Quantitative determination of ammonia/ammonium concentration by colorimetric (340nm) or fluorimetric (360nm/450nm) methods. After exposure to low levels, ammonia is either rapidly cleared or metabolized to compounds found endogenously at appreciable levels.

Laboratory Tests for Environmental Concentrations: Not useful due to quick interaction in the environment.

Action Levels: See above acceptable levels.

Antidotes: No antidote to ammonia poisoning; ammonia's effects may be treated successfully.

Surveillance Systems: Hand held monitors available for a range of 0-100 ppm with resolution of 0.1 ppm.

2.2 Ammonia Sulfate

Ammonia and ammonium ions can change back and forth in water. In wells, rivers, lakes, and wet soils, the ammonium form is the most common. Ammonia can also be combined with other substances to form ammonium compounds, including salts such as ammonium chloride, ammonium sulfate, ammonium nitrate, and others. Often used as a fertilizer. See Ammonia for general information.

Acceptable Levels: Acute oral toxicity (LD50): 640 mg/kg [Mouse].

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None available.

Laboratory Tests for Environmental Concentrations: None available. Acute hazard.

Action Levels: Acute oral toxicity (LD50): 640 mg/kg [Mouse].

Antidotes: **Eye Contact**: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention.

Skin Contact: In case of contact, immediately flush skin with plenty of water. Cover the irritated skin with an emollient. Remove contaminated clothing and shoes. Cold water may be used. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.

Serious Skin Contact: Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek medical attention.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Surveillance Systems: No ambient measurement systems found.

2.3 Sodium Hydroxide

The ATSDR (2012) defines sodium hydroxides as a white crystalline odorless solid that absorbs moisture from the air (at room temperature). It is a manufactured substance. When dissolved in water or neutralized with acid it liberates substantial heat, which may be sufficient to ignite combustible materials. Sodium hydroxide is very corrosive. It is generally used as a solid or a 50% solution. Other common names include caustic soda and lye. Sodium hydroxide is used to manufacture soaps, rayon, paper, explosives, dyestuffs, and petroleum products. It is also used in processing cotton fabric, laundering and bleaching, metal cleaning and processing, oxide coating, electroplating, and electrolytic extracting. It is commonly present in commercial drain and oven cleaners.

Further information of sodium hydroxide is available is ATSDR Toxic Substances Portal: http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=248&tid=45.

Acceptable Levels: No affected organ systems.

Estimated Risk: No cancer effects.

Bioassay: N/A

Laboratory Tests for Environmental Concentrations: N/A

Action Levels: N/A

Antidotes: N/A

Surveillance Systems: N/A

2.4 Sodium Carbonate

Sodium Carbonate is mined from Trona ($Na_3(CO_3)(HCO_3){\bullet}2H_2O$), which is an evaporate mineral. It is a white alkaline compound, Na2CO3, with many commercial applications including the manufacture of soap and glass. An MSDS sheet providing health concerns may be found at: http://www.sciencelab.com/msds.php?msdsId=9927263. See excerpts below.

Acceptable Levels:

Sodium carbonate: ORAL (LD50): Acute: 4090 mg/kg [Rat]. 6600 mg/kg [Mouse].

DUST (LC50): Acute: 2300 mg/m 2 hours [Rat]. 1200 mg/m 2 hours [Mouse].

Estimated Risk:

Bioassay: None found.

Laboratory Tests for Environmental Concentrations: None found. Likely worker hazard only.

Action Levels: Do not ingest. Do not breathe dust. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and show the container or the label. Avoid contact with skin and eyes. Keep away from incompatibles such as acids.

Antidotes: **Eye Contact**: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention.

Skin Contact: In case of contact, immediately flush skin with plenty of water. Cover the irritated skin with an emollient. Remove contaminated clothing and shoes. Cold water may be used to wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.

Serious Skin Contact: Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek immediate medical attention.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Surveillance Systems: None found.

2.5 Sodium Chlorate

The ATSDR website provides information on Perchlorates including sodium chlorate at their website: http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=895&tid=181.

The predominant commercial method for the manufacture of perchlorates begins with the production of the most soluble salt, sodium perchlorate. Electrochemical oxidation of an aqueous solution of sodium chloride is the most common method of producing sodium perchlorate (Schilt 1979; Vogt et al. 2005). Western Electrochemical Co (a subsidiary of the AMPAC Corp) is the main manufacturer of percolates and MSDS sheets may be found at: http://msdsreport.com/browse.cfm?dType=product&mfg=WESTERN%20ELECTROCHEMICAL%20CO. See excerpts below.

Acceptable Levels:

Sodium chlorate: ORAL (LD50): Acute: 1200 mg/kg [Rat]. 3600 mg/kg [Mouse (RTECS)]. 7200 mg/kg [Rabbit]. DUST (LC50): Acute: >28000 mg/m 1 hours [Rat].

Estimated Risk: TLV not established. As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None found.

Laboratory Tests for Environmental Concentrations: None found.

Action Levels: See acceptable levels.

Antidotes: **Eye Contact**: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention.

Skin Contact: In case of contact, immediately flush skin with plenty of water. Cover the irritated skin with an emollient. Remove contaminated clothing and shoes. Cold water may be used to wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.

Serious Skin Contact: Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek immediate medical attention.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention if symptoms appear.

Serious Inhalation: Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek medical attention.

Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Surveillance Systems: None found.

2.6 Hydrogen Peroxide

Hydrogen peroxide is a colorless liquid at room temperature with a bitter taste. Small amounts of gaseous hydrogen peroxide occur naturally in the air. Hydrogen peroxide is unstable, decomposing readily to oxygen and water with release of heat. Although nonflammable, it is a powerful oxidizing agent that can cause spontaneous combustion when it comes in contact with organic material. Hydrogen peroxide is found in many households at low concentrations (3-9%) for medicinal applications and as a clothes and hair bleach. In industry, hydrogen peroxide in higher concentrations is used as bleach for textiles and paper, as a component of rocket fuels, and for producing foam rubber and organic chemicals. According to ATSDR it is not cancer-causing (ATSDR 2012). MSDS: www.sciencelab.com/**msds**.php?**msds**Id=9924299. Excerpts below.

Acceptable Levels: OSHA standard 1ppm TWA.

Acute oral toxicity (LD50): 6667 mg/kg (Mouse) (Calculated value for the mixture). Acute dermal toxicity (LD50): 6667 mg/kg (pig) (Calculated value for the mixture).

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None found.

Laboratory Tests for Environmental Concentrations: None found.

Action Levels: See acceptable levels and antidotes.

Antidotes/First Aid: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention immediately.

Skin Contact: In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Cover the irritated skin with an emollient. Cold water may be used. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

Serious Skin Contact: Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek immediate medical attention.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.

Serious Inhalation: Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. WARNING: It may be hazardous to the person providing aid to give mouth-to-mouth resuscitation when the inhaled material is toxic, infectious or corrosive. Seek immediate medical attention.

Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Surveillance Systems: OSHA method ID-126-SG.

2.7 Sulfuric Acid

According to ATSDR (2012) sulfur trioxide (SO_3) is generally a colorless liquid. It can also exist as ice- or fiber-like crystals or as a gas. When SO_3 is exposed to air, it rapidly takes up water and gives off white fumes. It can react with water to form sulfuric acid. SO_3 is also called sulfuric oxide and sulfuric anhydride. It is used in the production of sulfuric acid and other chemicals, and explosives. Sulfuric acid is a clear, colorless, oily liquid that is very corrosive. It is also called sulphine acid, battery acid, and hydrogen sulfate. It is used in the manufacture of fertilizers, explosives, other acids, and glue; in the purification of petroleum; in the pickling of metal; and in lead-acid batteries (used in most vehicles). ATSDR (2012) shows sulfuric acid to affect dermal and respiratory systems, and is a known human carcinogen.

Sulfuric acid has been used for leaching of uraninite (Uox) – which is usually in sandstone uranium ore (SME handbook). It may not be applicable to the uranium ore found in the Piedmont Region of Virginia.

MSDS: www.sciencelab.com/msds.php?msdsId=9925146. Excerpts below.

Acceptable Levels: OSHA Standard: 1 mg/m^3 in air.

Toxicity to Animals: WARNING: THE LC50 VALUES HEREUNDER ARE ESTIMATED ON THE BASIS OF A 4-HOUR EXPOSURE. Acute oral toxicity (LD50): 2140 mg/kg [Rat.]. Acute toxicity of the vapor (LC50): 320 mg/m3 2 hours [Mouse].

Chronic Effects on Humans: CARCINOGENIC EFFECTS: Classified 1 (Proven for human.) by IARC, + (Proven.) by OSHA. Classified A2 (Suspected for human.) by ACGIH. May cause damage to the following organs: kidneys, lungs, heart, cardiovascular system, upper respiratory tract, eyes, and teeth.

Other Toxic Effects on Humans: Extremely hazardous in case of inhalation (lung corrosive). Very hazardous in case of skin contact (corrosive, irritant, permeator), of eye contact (corrosive), of ingestion.

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None available.

Laboratory Tests for Environmental Concentrations: Numerous methods. See Table 6-1 of ATSDR Toxicology Profile (http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=256&tid=47)

Action Levels: See acceptable levels.

Antidotes/First Aid: Eye Contact: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention immediately.

Skin Contact: In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Cover the irritated skin with an emollient. Cold water may be used. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

Serious Skin Contact: Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek immediate medical attention.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.

Serious Inhalation: Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. WARNING: It may be hazardous to the person providing aid to give mouth-to-mouth resuscitation when the inhaled material is toxic, infectious or corrosive. Seek immediate medical attention.

Ingestion: Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Surveillance Systems: OSHA Method ID-113 uses mixed cellulose ester filter (MCEF).

2.8 Sulfur Dioxide

Sulfur dioxide in the air comes mainly from activities such as the burning of coal and oil at power plants or from copper smelting. In nature, sulfur dioxide can be released to the air from volcanic eruptions. Sulfur dioxide is a colorless gas with a pungent odor. It is a liquid when under pressure, and it dissolves in water very easily. It could easily be associated with uranium mining/milling. ATSDR (2012) reports sulfur dioxide to affect the human immunological and respiratory system, but has no known cancer effects.

Further information on the toxicological profile for sulfur dioxide may be found at: http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=253&tid=46.

MSDS: www.airgas.com/ documents/pdf/001047.pdf. Excerpts below.

Acceptable Levels:

ACGIH TLV (United States, 1/2009); STEL: 0.25 ppm 15 minute(s).

OSHA PEL 1989 (United States, 3/1989); TWA: 2 ppm 8 hour(s); TWA: 5 mg/m³ 8 hour(s); STEL: 5 ppm 15 minute(s);STEL: 10 mg/m³ 15 minute(s).

NIOSH REL (United States, 6/2009); TWA: 2 ppm 10 hour(s); TWA: 5 mg/m³ 10 hour(s); STEL: 5 ppm 15 minute(s); STEL: 13 mg/m³ 15 minute(s).

OSHA PEL (United States, 11/2006); TWA: 5 ppm 8 hour(s); TWA: 13 mg/m³ 8 hour(s).

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None found.

Laboratory Tests for Environmental Concentrations: OSHA Method 1011. Target concentration 5 ppm.

Action Levels: See Acceptable Levels.

Antidotes/First Aid: Eye contact: Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention immediately.

Skin contact: In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Clean shoes thoroughly before reuse. Get medical attention immediately.

Frostbite: Try to warm up the frozen tissues and seek medical attention.

Inhalation: Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.

Surveillance Systems: Multiple monitoring systems available. (http://www.professionalequipment.com/sulfur-dioxide-monitor/related.html)

2.9 Acrylamide or Polymeric Flocculants

Acrylamide is a white or colorless, odorless crystalline solid that can violently react when melting. When heated, acrid fumes may be released. Used in industry, including mining and milling, Acrylamide is used to make polyacrylamide, which is mainly used in treating effluent from water treatment plants and industrial processes. It may affect the neurological and reproductive systems, and is reasonable anticipated to be a human carcinogen (ATSDR 2009 and ATSDR 2012). Further information may be found for toxicology of sulfur dioxide at: http://www.atsdr.cdc.gov/ToxProfiles/ tp.asp?id=253&tid=46.

MSDS: www.sciencelab.com/msds.php?msdsId=9927422

Acceptable Levels: OSHA PEL: 0.3 mg/m^3 (0.10 ppm) (OSHA PEL): ORAL (LD50): Acute: 124 mg/kg [Rat.]. 107 mg/kg [Mouse]. 150 mg/kg ; [Rabbit]. DERMAL (LD50): Acute: 400 mg/kg [Rat]. 1680 mg/kg [Rabbit].

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: No methods for assessing the concentration of acrylamide metabolites in urine are available. (International Programme on Chemical Safety, Environmental Health Criteria 49. http://www.inchem.org/documents/ehc/ehc/ehc49.htm#SubSectionNumber: 1.2.1).

Laboratory Tests for Environmental Concentrations: OSHA Method 21. Target concentration = 0.3 mg/m^3 (0.10 ppm) (OSHA PEL).

Methods for the Determination of Hazardous Substances (MDHS) 57 (HSE 1987).

Action Levels: See Acceptable Levels.

Antidotes/First Aid: Eye Contact: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention.

Skin Contact: In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Cover the irritated skin with an emollient. Cold water may be used to wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

Serious Skin Contact: Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek immediate medical attention.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

Serious Inhalation: Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek medical attention.

Ingestion: If swallowed, do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.

Surveillance Systems: No systems found.

2.10 Tertiary Amines

Tertiary Amines would be present if uranium were extracted by acid leaching in the milling process. Tertiary and quaternary amines and the organic phosphates have found widespread commercial acceptance in the recovery of uranium from ores. Solvent extraction (SX) recovery of uranium is restricted to acid leach solutions. Carbonate leach recovery systems do not use SX as a recovery or purification stage. By far the most widely used extractants for uranium are the tertiary amines specifically the C8-C10 symmetrical amines. (Mackenzie, 1997).

Exposure to tertiary amines at a printing operation (SLS) was found to be associated with visual and ocular changes. Although printing is not directly related to uranium processes, the study may be applicable. The visual and ocular changes appear to be a reversible phenomenon, these visual changes pose a safety hazard, both on the job and when driving home. NIOSH has drafted applicable BMPs (CDC, NIOSH 2002).

A publication is available regarding the Health hazards of tertiary amine catalysts (Stephenson, 1988). The abstract may be found at: http://www.ncbi.nlm.nih.gov/ pubmed/3051334. An excerpt is as follows:

"Tertiary amine catalysts are widely employed in foundry and polyurethane foam manufacture operations. These highly reactive amines have been associated with graphic disturbances in vision and systemic health effects. Prominent among the reported effects on vision are mydriasis (dilated pupils), cycloplegia (loss of accommodation), and corneal edema, which may result in hazy (looking through smoke) or blurry (out of focus) vision and halo perception. Systemic symptoms, possibly due to a release of endogenous histamine, are consistent with pharmacologic actions of amines and have also been described. These symptoms, as well as the disturbances in vision, are transient. Nevertheless, employees who work with or around machinery, or drive vehicles, may be at an increased risk of accident and injury when experiencing these symptoms."

MSDS available at www.bayermaterialsciencenafta.com/.../d/document.cfm

Acceptable Levels: OSHA PEL = 25 ppm in air.

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for triphenyl amine of 5 milligrams per cubic meter (mg/m(3)) of air as a TWA for up to a 10-hour workday and a 40-hour workweek [NIOSH 1992]. The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned triphenyl amine a threshold limit value (TLV) of 5 mg/m(3) as a TWA for a normal 8-hour workday and a 40-hour workweek [ACGIH 1994, p. 35].

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None found.

Laboratory Tests for Environmental Concentrations: Diethylnitrosamine in air. OSHA Method 13; target concentration 1.4 ppb.

Action Levels: See acceptable levels.

Antidotes/First Aid: (See http://www.osha.gov/SLTC/healthguidelines/triphenylamine/recognition.html

If triphenyl amine contacts the skin, workers should flush the affected areas immediately with plenty of water, followed by washing with soap and water.

Clothing contaminated with triphenyl amine should be removed immediately, and provisions should be made for the safe removal of the chemical from the clothing. Persons laundering the clothes should be informed of the hazardous properties of triphenyl amine.

A worker who handles triphenyl amine should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, using toilet facilities, applying cosmetics, or taking medication.

Surveillance Systems: None found.

2.11 Decanol or Isodecanol

Decanol is not listed in the Toxic Substances Portal of the ATSDR. However, under a Health Effects study on Carbon Tetrachloride indicates that Methanol, ethanol, isopropanol, or decanol in combination with carbon tetrachloride caused massive liver damage, but failed to increase carbon tetrachloride induced lethality (CDC, 2012). Whether or not this toxin is related to the uranium mining/milling processes is unknown and probably unlikely. Carbon Tetrachloride is rarely used in everyday operations such as cleaning, but could be used in industrial applications.

Acceptable Levels: No information on OSHA website.

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None found,

Laboratory Tests for Environmental Concentrations: None found.

Action Levels: Nothing listed here!

Antidotes/First Aid: **Inhalation**: Get victim to fresh air.

Ingestion: Immediately give a couple of glasses of water or milk, provided the victim is fully conscious. Try to induce vomiting. Take to hospital.

Skin: Wash off promptly and flush contaminated skin with water. Promptly remove clothing if soaked through and flush skin with water.

Eyes: Promptly wash eyes with plenty of water while lifting the eye lids. Contact physician if discomfort continues.

Surveillance Systems: None found.

2.12 Kerosene/Fuel Oils

Fuel Oils/Kerosene is listed in the Toxic Substances Portal of ATSDR (2012). In summary, fuel oils come from crude petroleum. Some chemicals found in fuel oils may evaporate easily, while others may more easily dissolve in water. Fuel oils may be used as fuel for engines, lamps, heaters, furnaces, and stoves, or as solvents. Some commonly found fuel oils include kerosene, diesel fuel, jet fuel, range oil, and home heating oil. These fuel oils differ from one another by their hydrocarbon compositions, boiling point ranges, chemical additives, and uses. One of the only references to health effects from uranium operations involving kerosene is from a 2004 ATSDR study that references Ritz 1999, as follows:

"In a cohort mortality study of 3,814 white male employees at a uranium processing plant, (Fernald Feed Materials Production Center) Ritz (1999) reported that the main exposures (classified into "light," "moderate," and "heavy;" actual exposure concentrations not reported) were to kerosene, trichloroethylene, and cutting fluids (complex mixtures of variable composition classified as straight oils, soluble, or synthetic fluids; no information was available

regarding the specific cutting oils used at the plant being studied over the 30-year exposure period). Considerable overlap in exposures occurred between these three substances, though primarily only at the "light" exposure level. Moderate exposure to trichloroethylene for 5 or more years was associated with increased incidence of liver (relative risk [RR] 12.1, 95% confidence interval [CI] 1.03–144) and brain (RR 14.4, 95% CI 1.24–167) cancer, though these increases were each the result of a single case. Both light (RR 3.46, 95% CI 1.22–9.80) and moderate (RR 7.71, 95% CI 2.04–29.1) exposures to kerosene (>2 years duration) were associated with increases in cancers of the esophagus and stomach. However, no inferences as to potential joint toxic actions can be made for trichloroethylene and kerosene from this study due to co-exposure to other chemicals (i.e., cutting fluids)."

Acceptable Levels: National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL): 100 mg/m^3 TWA ACGIH Threshold Limit Value (TLV): 200 mg/m3 (TWA), (Application restricted to conditions in which there are negligible aerosol exposures).

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None found.

Laboratory Tests for Environmental Concentrations: OSHA Analytical Method PV2139

Action Levels: See Acceptable Levels.

Antidotes/First Aid: Inhalation: Move to fresh air. If not breathing, give artificial respiration. If necessary, provide additional oxygen once breathing is restored if trained to do so. Seek medical attention immediately.

Skin contact: Take off all contaminated clothing immediately. Wash off immediately with soap and plenty of water. Wash contaminated clothing before re-use. If skin irritation persists, seek medical attention.

Eye contact: Remove contact lenses. In case of eye contact, immediately flush with low pressure, cool water for at least 15 minutes, opening eyelids to ensure flushing. Seek medical advice.

Ingestion: Do NOT induce vomiting. If vomiting does occur naturally, keep head below the hips to reduce the risks of aspiration. Obtain medical attention. Do not give liquids. Small amounts of material which enter the mouth should be rinsed out until the taste is dissipated.

Surveillance Systems: None found.

2.13 Sodium Hydroxide/Hydrogen Peroxide/Ammonia (as gases)

The ATSDR (2012) reports that small amounts of gaseous hydrogen peroxide occur naturally in the air. Hydrogen peroxide is unstable, decomposing readily to oxygen and water with release of heat. Although nonflammable, it is a powerful oxidizing agent that can cause spontaneous combustion when it comes in contact with organic material.

Acceptable Levels: **Hydrogen peroxide**: OSHA permissible exposure limit (PEL) for hydrogen peroxide is 1 ppm parts of air (1.4 milligrams per cubic meter (mg/m(3))) as an 8-hour time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1].

Sodium hydroxide: OSHA 2 mg/m^3. [29 CFR 1910.1000, Table Z-1].

Ammonia: OSHA 50 ppm [29 CFR 1910.1000, Table Z-1].

Estimated Risk: As with other potential constituents of concern, there is no way of assessing the risk without site-specific information. Not likely a risk for members of the public. More likely for workers.

Bioassay: None found.

Laboratory Tests for Environmental Concentrations: **Hydrogen peroxide**: flourometric analysis.

Action Levels: See Acceptable Levels.

Antidotes/First aid: Ammonia

Eyes: Flush contaminated eye(s) with copious quantities of water. Part eyelids to assure complete flushing. Continue for a minimum of 15 minutes.

Skin: Remove contaminated clothing as rapidly as possible. Flush affected area with copious quantities of water. In cases of frostbite or cryogenic "burns" flush area with lukewarm water. Do not use hot water. A physician should see the patient promptly if the cryogenic "burn" has resulted in blistering of the dermal surface or deep tissue freezing.

Ingestion: Not specified. Seek immediate medical attention.

Inhalation: Prompt medical attention is mandatory in all cases of overexposure. Rescue personnel should be equipped with self-contained breathing apparatus. Conscious persons should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, given mouth-to-mouth resuscitation and supplemental oxygen. Keep victim warm and quiet. Assure that mucus or vomited material does not obstruct the airway by positional drainage.

Surveillance Systems: EPA has identified a series of ammonia gas monitors, see www.epa.gov/etv/pubs/600s07009.pdf for a description.

3.0 Risks Hazards Present in General Industrial Activities (mining/milling)

3.1 Physical Injury, Electrical Hazards, Noise and Vibration, and Welding and Metal Working

MSHA, (http://www.msha.gov/.) along with the OSHA (http://www.osha.gov/) provides regulations, enforcement, training, and data regarding health and safety in mining and industry, respectively. Electrical, Noise and Vibration, Welding, Metalworking, and General Physical injuries are covered by these programs to the worker.

3.2 Emissions (Diesel and Particular Matter)

$PM_{2.5}$ is produced mainly by combustion of fossil fuels, either by stationary sources or by transportation (mobile sources such as trucks, farm equipment, and locomotives rely on diesel engines). A relatively small number of broadly defined source categories, account for the majority of the observed Particulate Matter (PM) mass. A compilation of study results shows that secondary SO_2– (derived mainly from SO_2 emitted by Electricity Generating Units [EGUs]), NO_3– (from the oxidation of NO_x emitted mainly from transportation sources and EGUs), and primary mobile source categories, constitute most of $PM_{2.5}$ (and PM_{10}) in the Eastern United States.

PM_{10} is mainly primary in origin, having been emitted as fully formed particles derived from abrasion and crushing processes, soil disturbances, plant and insect fragments, pollens and other microorganisms, desiccation of marine aerosol emitted from bursting bubbles, and hygroscopic fine PM expanding with humidity to coarse mode. Gases such as HNO_3 can also condense directly onto preexisting coarse particles. Suspended primary coarse PM can contain Fe, Si, Al, and base cations from soil, plant and insect fragments, pollen, fungal spores, bacteria, and viruses, as well as fly ash, brake lining particles, debris, and automobile tire fragments.

Historically, it has been recognized that agents produced during combustion of coal (and other substances) are carcinogenic for the dermal and respiratory systems (NIOSH, 1973). The NIOSH has researched and recommended safety and health standards for emissions (beginning with coal mining) for several decades. Recently, the EPA has recognized sources of emissions to the public as a health concern, including mobile sources (vehicles, accidental releases (spills), routine emissions from stationary sources, and fires (such as forest fires), and regulates particulate matter as one of six criteria pollutants under the NAAQS. Recently, the EPA has completed an extensive assessment of human health risks related to particulate matter exposures (*Quantitative Health Risk Assessment for Particulate Matter*, EPA Agency Office of Air and Radiation Office of Air Quality Planning and Standards Health and Environmental Impacts Division Research Triangle Park, North Carolina, Final Report published June 2010). Uranium mining and milling would undoubtedly produce some typical types of emissions; however these would be recognized by monitoring systems that already exist if there were to be an increase related to the uranium mining/milling processes.

Acceptable Levels: Ambient air quality standards for PM_{10} and $PM_{2.5}$ are in the process of being revised by the EPA. Please see the information below for a discussion of human health impacts related to certain levels of PM in respirable air.

Estimated Risk: Health Risks associated with fine ($PM_{2.5}$) and coarse (PM_{10}) particulates and diesel exhaust particles -- Reference: Integrated Science Assessment for Particulate Matter, National Center for Environmental Assessment-RTP Division, Office of Research and Development, EPA, Research Triangle Park, NC, December 2009, EPA/600/R-08/139F.

Summary of causal determinations for short-term exposure to $PM_{2.5}$.

Outcome	Causality Determination
Cardiovascular Effects	Causal
Respiratory Effects	Likely to be causal
Mortality	Causal

Cardiovascular Effects

Epidemiologic studies that examined the effect of $PM_{2.5}$ on cardiovascular emergency department (ED) visits and hospital admissions reported consistent positive associations (predominantly for ischemic heart disease [IHD] and congestive heart failure [CHF]), with the majority of studies reporting increases ranging from 0.5 to 3.4% per 10 $\mu g/m^3$ increase in $PM_{2.5}$. These effects were observed in study locations with mean 24-h avg $PM_{2.5}$ concentrations ranging from 7-18 $\mu g/m^3$. Results of multicity epidemiologic studies demonstrated consistent positive associations between short-term exposure to $PM_{2.5}$ and cardiovascular mortality and also reported regional and seasonal variability in risk estimates. The multicity studies evaluated reported consistent increases in cardiovascular mortality ranging from 0.47 to 0.85% in study locations with mean 24-h avg $PM_{2.5}$ concentrations above12.8 $\mu g/m^3$.

Controlled human exposure studies have demonstrated $PM_{2.5}$-induced changes in various measures of cardiovascular function among healthy and health-compromised adults. Altered vasomotor function was observed following exposure to diesel exhaust (DE). It is important to note that the DE used in the controlled human exposure studies evaluated contained gaseous components (e.g., CO, NO_x), and therefore, it is possible that some of the changes in vasomotor function might be due to gaseous components in the DE. In addition, the prevalence of ultrafine particles (UFPs) in the DE limits the ability to conclusively attribute the observed effects to either the UF fraction or $PM_{2.5}$ as a whole. An evaluation of toxicological studies found evidence for altered vessel tone and microvascular reactivity, which provide coherence and biological plausibility for the vasomotor effects that have been observed in both the controlled human exposure and epidemiologic studies. However, most of these toxicological studies exposed animals via intratracheal (IT) instillation or using relatively high inhalation.

In addition to the effects observed on vasomotor function, myocardial ischemia has been observed across disciplines through $PM_{2.5}$ effects on ST-segment depression, with toxicological studies providing biological plausibility by demonstrating reduced blood flow during ischemia. There is also a growing body of evidence from controlled human exposure and toxicological studies demonstrating $PM_{2.5}$-induced changes on heart rate variability (HRV) and markers of systemic oxidative. Additional, but inconsistent effects of $PM_{2.5}$ on blood pressure (BP), blood coagulation markers, and markers of systemic inflammation have also been reported across disciplines. Toxicological studies have provided biologically plausible mechanisms (e.g., increased right ventricular pressure and diminished cardiac contractility) for the associations observed between $PM_{2.5}$ and CHF in epidemiologic studies.

Together, the collective evidence from epidemiologic, controlled human exposure, and toxicological studies is sufficient to conclude that a causal relationship exists between short-term exposures to $PM_{2.5}$ and cardiovascular effects.

Respiratory Effects

Recent epidemiologic studies report consistent positive associations between short-term exposure to $PM_{2.5}$ and respiratory ED visits and hospital admissions for chronic obstructive pulmonary disease (COPD) and respiratory infections. Positive associations were also observed for asthma ED visits and hospital admissions for adults and children combined, but effect estimates are imprecise and not consistently positive for children alone. Most studies reported effects in the range of ~1% to 4% increase in respiratory hospital admissions and ED visits for study locations with mean 24-h avg $PM_{2.5}$ concentrations ranging from 6.1-22 $\mu g/m^3$. Additionally, multi-city epidemiologic studies reported consistent positive associations between short-term exposure to $PM_{2.5}$ and respiratory mortality as well as regional and seasonal variability in risk estimates. The multi-city studies evaluated reported consistent, precise increases in respiratory mortality ranging from 1.67 to 2.20% in study locations with mean 24-h avg $PM_{2.5}$ concentrations above 12.8 $\mu g/m^3$. Evidence for $PM_{2.5}$-related respiratory effects was also observed in panel studies, which indicate associations with respiratory symptoms, pulmonary function, and pulmonary inflammation among asthmatic children. Although not consistently observed, some controlled human exposure studies have reported small decrements in various measures of pulmonary function following controlled exposures to $PM_{2.5}$.

Controlled human exposure studies using adult volunteers have demonstrated increased markers of pulmonary inflammation following exposure to a variety of different particle types; oxidative responses to DE and wood smoke; and exacerbations of allergic responses and allergic sensitization following exposure to diesel exhaust (DE) particles. Toxicological studies have provided additional support for $PM_{2.5}$-related respiratory effects through inhalation exposures of animals to criteria air pollutants (CAPs), DE, other traffic-related PM and wood smoke. These studies reported an array of respiratory effects including altered pulmonary function, mild pulmonary inflammation and injury, oxidative responses, airway hyperresponsiveness (AHR) in allergic and non-allergic animals, exacerbations of allergic responses, and increased susceptibility to infections.

Overall, the evidence for an effect of $PM_{2.5}$ on respiratory outcomes is somewhat restricted by limited coherence between some of the findings from epidemiologic and controlled human exposure studies for the specific health outcomes reported and the sub-populations in which those health outcomes occur. Epidemiologic studies have reported variable results among specific respiratory outcomes, specifically in asthmatics (e.g., increased respiratory symptoms in asthmatic children, but not increased asthma hospital admissions and ED visits). Additionally, respiratory effects have not been consistently demonstrated following controlled exposures to $PM_{2.5}$ among asthmatics or individuals with COPD. Collectively, the epidemiologic, controlled human exposure, and toxicological studies evaluated demonstrate a wide range of respiratory responses, and although results are not fully consistent and coherent across studies the evidence is sufficient to conclude that a causal relationship is likely to exist between short-term exposures to $PM_{2.5}$ and respiratory effects.

Mortality

An evaluation of the epidemiologic literature indicates consistent positive associations between short-term exposure to $PM_{2.5}$ and all-cause, cardiovascular-, and respiratory-related mortality. The evaluation of multi-city studies found that consistent and precise risk estimates for all-cause (non-accidental) mortality that ranged from 0.29 to 1.21% per 10 $\mu g/m^3$ increase in $PM_{2.5}$ at lags of 1 and 0-1 days. In these study locations, mean 24-h avg $PM_{2.5}$ concentrations were 12.8 $\mu g/m^3$ and above. Cardiovascular-related mortality risk estimates were found to be similar to those for all-cause mortality; whereas, the risk estimates for respiratory-related mortality were consistently larger (i.e., 1.01-2.2%) using the same lag periods and averaging indices. The studies evaluated that examined the relationship between short-term exposure to $PM_{2.5}$ and cardiovascular effects provide coherence and biological plausibility for $PM_{2.5}$-induced cardiovascular mortality, which represents the largest component of total (non-accidental) mortality (~ 35%) (American Heart Association, 2009, 1989). However, there is limited coherence between some of the respiratory morbidity findings from epidemiologic and controlled human exposure studies for the specific health outcomes reported and the subpopulations in which those health outcomes occur, complicating the interpretation of the $PM_{2.5}$ respiratory mortality effects observed. Regional and seasonal patterns in $PM_{2.5}$ risk estimates were observed with the greatest effect estimates occurring in the eastern U.S. and during the spring. An examination of effect modifiers (e.g., demographic and socioeconomic factors), specifically air conditioning use as an indicator for decreased pollutant penetration indoors, has suggested that $PM_{2.5}$ risk estimates increase as the percent of the population with access to air conditioning decreases. Collectively, the epidemiologic literature provides evidence that a causal relationship exists between short-term exposures to $PM_{2.5}$ and mortality.

Summary of causal determinations for long-term exposure to $PM_{2.5}$.

Outcome	Causality Determination
Cardiovascular Effects	Causal
Respiratory Effects	Likely to be causal
Mortality	Causal
Reproductive and Developmental	Suggestive
Cancer, Mutagenicity, and Genotoxicity	Suggestive

Cardiovascular Effects

The strongest evidence for cardiovascular health effects related to long-term exposure to $PM_{2.5}$ comes from large, multi-city U.S.-based studies, which provide consistent evidence of an association between long-term exposure to $PM_{2.5}$ and cardiovascular mortality. These associations are supported by a large U.S.-based epidemiologic study (i.e., Women's Health Initiative [WHI] study) that reports associations between $PM_{2.5}$ and cardiovascular disease (CVD) among post-menopausal women using a 1-yr avg $PM_{2.5}$ concentration (mean = 13.5 $\mu g/m^3$). However, epidemiologic studies that examined subclinical markers of CVD report inconsistent findings. Epidemiologic studies have also provided some evidence for potential modification of the $PM_{2.5}$-CVD association when examining individual-level data, specifically smoking status and the use of anti- hyperlipidemics. Although epidemiologic studies have not consistently detected effects on markers of atherosclerosis due to long-term exposure to $PM_{2.5}$, toxicological studies have provided strong evidence for accelerated development of atherosclerosis in $ApoE^{-/-}$ mice exposed to CAPs and have shown effects on coagulation, experimentally-induced hypertension, and vascular reactivity . Evidence from toxicological studies provides biological plausibility and coherence with studies of short-term exposure and cardiovascular morbidity and mortality, as well as with studies that examined long-term exposure to $PM_{2.5}$ and cardiovascular mortality. Taken together, the evidence from epidemiologic and toxicological studies is sufficient to conclude that a causal relationship exists between long-term exposures to $PM_{2.5}$ and cardiovascular effects.

Respiratory Effects

Recent epidemiologic studies conducted in the U.S. and abroad provide evidence of associations between long-term exposure to $PM_{2.5}$ and decrements in lung function growth, increased respiratory symptoms, and asthma development in study locations with mean $PM_{2.5}$ concentrations ranging from 13.8 to 30 μg/m^3 during the study periods. These results are supported by studies that observed associations between long-term exposure to PM_{10} and an increase in respiratory symptoms and reductions in lung function growth in areas where PM_{10} is dominated by $PM_{2.5}$. However, the evidence to support an association with long-term exposure to $PM_{2.5}$ and respiratory mortality is limited. Subchronic and chronic toxicological studies of CAPs, DE, roadway air and woodsmoke provide coherence and biological plausibility for the effects observed in the epidemiologic studies. These toxicological studies have presented some evidence for altered pulmonary function, mild inflammation, or responses, immune suppression, and histopathological changes including mucus cell hyperplasia. Exacerbated allergic responses have been demonstrated in animals exposed to DE and wood smoke. In addition, pre- and postnatal exposure to ambient levels of urban particles was found to affect lung development in an animal model. This finding is important because impaired lung development is one mechanism by which PM exposure may decrease lung function growth in children. Collectively, the evidence from epidemiologic and toxicological studies is sufficient to conclude that a causal relationship is likely to exist between long-term exposures to PM and respiratory effects.

Mortality

The recent epidemiologic literature reports associations between long-term $PM_{2.5}$ exposure and increased risk of mortality. Mean $PM_{2.5}$ concentrations ranged from 13.2 to 29 μg/m^3 during the study period in these areas. When evaluating cause-specific mortality, the strongest evidence can be found when examining associations between $PM_{2.5}$ and cardiovascular mortality, and positive associations were also reported between $PM_{2.5}$ and lung cancer mortality. The cardiovascular mortality association has been confirmed further by the extended Harvard Six Cities and American Cancer Society studies, which both report strong associations between long-term exposure to $PM_{2.5}$ and cardiopulmonary and IHD mortality. Additional new evidence from a study that used the WHI cohort found a particularly strong association between long-term exposure to $PM_{2.5}$ and CVD mortality in post-menopausal women. Fewer studies have evaluated the respiratory component of cardiopulmonary mortality, and, as a result, the evidence to support an association with long-term exposure to $PM_{2.5}$ and respiratory mortality is limited. The evidence for cardiovascular and respiratory morbidity due to short- and long-term exposure to $PM_{2.5}$ provides biological plausibility for cardiovascular- and respiratory-related mortality. Collectively, the evidence is sufficient to conclude that a causal relationship exists between long-term exposures to $PM_{2.5}$ and mortality.

Reproductive and Developmental Effects

Evidence is accumulating for $PM_{2.5}$ effects on low birth weight and infant mortality, especially due to respiratory causes during the post-neonatal period. The mean $PM_{2.5}$ concentrations during the study periods ranged from 5.3-27.4 μg/m^3, with effects becoming more precise and consistently positive in locations with mean $PM_{2.5}$ concentrations of 15 μg/m^3 and above.

Exposure to $PM_{2.5}$ was usually associated with greater reductions in birth weight than exposure to PM_{10}. The evidence from a few U.S. studies that investigated PM_{10} effects on fetal growth, which reported similar decrements in birth weight, provide consistency for the $PM_{2.5}$ associations observed and strengthen the interpretation that particle exposure may be causally related to reductions in birth weight. The epidemiologic literature does not consistently report associations between long-term exposure to PM and preterm birth, growth restriction, birth defects or decreased sperm quality. Toxicological evidence supports an association between $PM_{2.5}$ and PM_{10} exposure and adverse reproductive and developmental outcomes, but provide little mechanistic information or biological plausibility for an association between long-term PM exposure and adverse birth outcomes (e.g., low birth weight or infant mortality). New evidence from animal toxicological studies on heritable mutations is of great interest, and warrants further investigation. Overall, the epidemiologic and toxicological evidence is suggestive of a causal relationship between long-term exposures to $PM_{2.5}$ and reproductive and developmental outcomes**.**

Cancer, Mutagenicity, and Genotoxicity

Multiple epidemiologic studies have shown a consistent positive association between $PM_{2.5}$ and lung cancer mortality, but studies have generally not reported associations between $PM_{2.5}$ and lung cancer incidence. Animal toxicological studies have examined the potential relationship between PM and cancer, but have not focused on specific size fractions of PM. Instead they have examined ambient PM, wood smoke, and diesel exhaust particulates. A number of studies indicate that ambient urban PM, emissions from wood/biomass burning, emissions from coal combustion, and gasoline and DE are mutagenic, and that PAHs are genotoxic. These findings are consistent with earlier studies that concluded that ambient PM and PM from specific combustion sources are mutagenic and genotoxic and provide biological plausibility for the results observed in the epidemiologic studies. A limited number of epidemiologic and toxicological studies examined epigenetic effects, and demonstrate that PM induces some changes in methylation. However, it has yet to be determined how these alterations in the genome could influence the initiation and promotion of cancer. Additionally, inflammation and immune suppression induced by exposure to PM may confer susceptibility to cancer. Collectively, the evidence from epidemiologic studies, primarily those of lung cancer mortality, along with the toxicological studies that show some evidence of the mutagenic and genotoxic effects of PM is suggestive of a causal relationship between long-term exposures to $PM_{2.5}$ and cancer.

Summary of causal determinations for short-term exposure to PM_{10}.

Outcome	Causality Determination
Cardiovascular Effects	Suggestive
Respiratory Effects	Suggestive

Mortality	Suggestive

Cardiovascular Effects

Generally positive associations were reported between short-term exposure to PM_{10} and hospital admissions or ED visits for cardiovascular causes. These results are supported by a large U.S. multicity study of older adults that reported PM_{10} associations with CVD hospital admissions, and only a slight reduction in the PM_{10} risk estimate when included in a co-pollutant model with $PM_{2.5}$. The PM_{10} associations with cardiovascular hospital admissions and ED visits were observed in study locations with mean 24-h avg PM_{10} concentrations ranging from 7.4 to 13 $\mu g/m^3$. These results are supported by the associations observed between PM_{10} and cardiovascular mortality in areas with 24-h avg PM_{10} concentrations ranging from 6.1 to 16.4 $\mu g/m^3$. The results of the epidemiologic studies were further confirmed by studies that examined dust storm events, which contain high concentrations of crustal material, and found an increase in cardiovascular-related ED visits and hospital admissions. The potential for PM_{10} to elicit an effect is supported by dosimetry studies, which show that a large proportion of inhaled particles the 3-6 micron (d_{ae}) range can reach and deposit in the lower respiratory tract, particularly the tracheobronchial (TB) airways. Collectively, the evidence from epidemiologic studies, along with the more limited evidence from controlled human exposure and toxicological studies is suggestive of a causal relationship between short-term exposures to PM_{10} and cardiovascular effects.

Respiratory Effects

A number of recent epidemiologic studies conducted in Canada and France found consistent, positive associations between respiratory ED visits and hospital admissions and short-term exposure to PM_{10} in studies with mean 24-h avg concentrations ranging from 5.6-16.2 $\mu g/m^3$. In these studies, the strongest relationships were observed among children, with less consistent evidence for adults and older adults (i.e., ≥ 65). In a large multi-city study of older adults, PM_{10} was positively associated with respiratory hospital admissions in both single and copollutant models with PM_{10}. In addition, a U.S.-based multicity study found evidence for an increase in respiratory mortality upon short-term exposure to PM_{10}, but these associations have not been consistently observed in single-city studies. A limited number of epidemiologic studies have focused on specific respiratory morbidity outcomes, and found no evidence of an association with lower respiratory symptoms, wheeze, and medication use. While controlled human exposure studies have not observed an effect on lung function or respiratory symptoms in healthy or asthmatic adults in response to short-term exposure to PM_{10}, healthy volunteers have exhibited an increase in markers of pulmonary inflammation. Overall, epidemiologic studies, along with the limited number of controlled human exposure and toxicological studies that examined PM_{10} respiratory effects provide evidence that is suggestive of a causal relationship between short-term exposures to PM_{10} and respiratory effects.

Mortality

The majority of studies evaluated in this review provide some evidence for mortality associations with PM_{10} in areas with mean 24-h avg concentrations ranging from 6.1-16.4 μg/m^3. However, uncertainty surrounds the PM_{10} associations reported in the studies evaluated due to the different methods used to estimate PM_{10} concentrations across studies. In addition, only a limited number of PM_{10} studies have investigated potential confounding by gaseous co-pollutants or the influence of model specification on PM_{10} risk estimates. Although consistent positive associations have been observed across both multi- and single-city studies, more data are needed to adequately characterize the chemical and biological components that may modify the potential toxicity of PM_{10} and compare the different methods used to estimate exposure. Overall, the evidence evaluated is suggestive of a causal relationship between short-term exposures to PM_{10} and mortality**.**

Potentially Susceptible Populations

Upon evaluating the association between short- and long-term exposure to PM and various health outcomes, studies also attempted to identify populations that are more susceptible to PM (i.e., populations that have a greater likelihood of experiencing health effects related to exposure to an air pollutant (e.g., PM) due to a variety of factors including, but not limited to: genetic or developmental factors, race, gender, life stage, lifestyle (e.g., smoking status and nutrition) or preexisting disease; as well as, population-level factors that can increase an individual's exposure to an air pollutant (e.g., PM) such as socioeconomic status [SES], which encompasses reduced access to health care, low educational attainment, residential location, and other factors). These studies did so by conducting stratified analyses; by examining effects in individuals with an underlying health condition; or by developing animal models that mimic the pathophysiologic conditions associated with an adverse health effect. In addition, numerous studies that focus on only one potentially susceptible population provide supporting evidence on whether a population is susceptible to PM exposure. These studies identified a multitude of factors that could potentially contribute to whether an individual is susceptible to PM.

During specific periods of life (i.e., childhood and advanced age), individuals may be more susceptible to environmental exposures, which in turn can render them more susceptible to PM-related health effects. An evaluation of age-related health effects suggests that older adults have heightened responses for cardiovascular morbidity with PM exposure. In addition, epidemiologic and toxicological studies provide evidence that indicates children are at an increased risk of PM-related respiratory effects. It should be noted that the health effects observed in children could be initiated by exposures to PM that occurred during key windows of development, such as *in utero*. Epidemiologic studies that focus on exposures during development have reported inconsistent findings, but a recent toxicological study suggests that inflammatory responses in pregnant women due to exposure to PM could result in health effects in the developing fetus.

Epidemiologic studies have also examined whether additional factors, such as gender, race, or ethnicity modify the association between PM and morbidity and mortality outcomes. Although gender and race do not seem to modify PM risk estimates, limited evidence from two studies conducted in California suggest that Hispanic ethnicity may modify the association between PM and mortality.

Collectively, the evidence from epidemiologic and toxicological, and to a lesser extent, controlled human exposure studies, indicate increased susceptibility of individuals with underlying CVDs and respiratory illnesses (i.e., asthma) to PM exposure. Controlled human exposure and toxicological studies provide additional evidence for increased PM-related cardiovascular effects in individuals with underlying respiratory health conditions.

Recently studies have begun to examine the influence of preexisting chronic inflammatory conditions, such as diabetes and obesity, on PM-related health effects. These studies have found some evidence for increased associations for cardiovascular outcomes along with pathophysiologic alterations in markers of inflammation, oxidative stress, and acute phase response. However, more research is needed to thoroughly examine the affect of PM exposure on obese individuals and to identify the biological pathway(s) that could increase the susceptibility of diabetic and obese individuals to PM.

There is also evidence that SES, measured using surrogates such as educational attainment or residential location, modifies the association between PM and morbidity and mortality outcomes. In addition, nutritional status, another surrogate measure of SES, has been shown to have protective effects against PM exposure in individuals that have a higher intake of some vitamins and nutrients.

Overall, the epidemiologic, controlled human exposure, and toxicological studies evaluated in this review provide evidence for increased susceptibility for various populations, including children and older adults, people with pre-existing cardiopulmonary diseases, and people with lower SES.

Bioassay: none (other than experimental lung lavage).

Laboratory Tests for Environmental Concentrations: air filter sampling from air monitoring systems.

Action Levels: set by EPA for ambient air quality (NAAQS).

Particle Pollution [71 FR 61144, Oct 17, 2006]	$PM_{2.5}$	primary and secondary	Annual	15 µg/m^3	annual mean, averaged over 3 years
			24-hour	35 µg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24-hour	150 µg/m^3	Not to be exceeded more than once per year on average over 3 years

Both OSHA and MSHA regulate diesel particulate matter (DPM) exposures in occupational settings (http://www.dieselnet.com/standards/us/ohs.php; http://www.msha.gov/01-995/Dieselpartmnm.htm).

General Occupational Settings (Non-Mining)

There are no legal exposure limits for DPM in general occupational settings in the U.S.

Underground Mining

On January 19, 2001, MSHA published final diesel regulations for underground metal/nonmetal (i.e., non-coal) and for underground coal mines. The metal/nonmetal mine rule adopts exposure limits for diesel particulates. MSHA has not introduced exposure limits for coal mines, due to the lack of a suitable DPM measuring method in the presence of coal dust.

The underground metal/nonmetal mine rule establishes a concentration limit for diesel particulate matter and requires mine operators to use engineering or work practice controls to reduce DPM exposure to that limit. The 2001 rule introduced two DPM limits: (1) an “interim” DPM concentration limit of 400 µg/m^3 effective July 19, 2002 and (2) a final DPM concentration limit of 160 µg/m^3 effective January 19, 2006. For the purpose of ambient sampling (according to NIOSH method 5040), DPM was defined as total carbon (TC). This definition includes both elemental and organic (i.e., hydrocarbon derived) carbon, and excludes inorganic ash and sulfates from the TLV.

The 2001 rule has been subject to legal challenges and negotiations between MSHA, mining industry, and labor, resulting in several amendments:

In 2005, the interim limit was changed from 400 µg/m^3 of TC to 308 µg/m^3 expressed as elemental carbon (EC), based on a TC:EC conversion factor of 1.3.

On May 18, 2006, MSHA promulgated a final rule which:

Changed the interim limit to 350 µg/m^3 EC and its effective date to January 20, 2007.

Extended the effective date of the 160 µg/m^3 TC standard to May 20, 2008.

The 400 µg/m^3 TC and 350 µg/m^3 EC limits are of a similar stringency, but the EC measurement eliminates potential non-diesel sources of organic carbon particulates, for instance oil mist.

The final DPM exposure limit of 160 µg/m^3 TC will also be converted to an equivalent EC-based limit in a separate rule to be issued by MSHA.

Antidotes: not relevant; the only "antidote" is removal from area with high levels of particulate matter.

Surveillance Systems: continuous and "grab sample" air monitoring.

3.3 Nitrogen Oxides, Explosive Gases

Nitrogen oxides are gases composed of nitrogen and oxygen released to the air from motor vehicle exhaust, coal, oil and natural gas burning and other processes such as dynamite blasting, welding, and metalworking that may occur in the mining/milling of uranium. According to ASTDR (2012), nitric oxide and nitrogen dioxide are toxicologically significant. A fact sheet from ATSDR is available at http://www.atsdr.cdc.gov/toxfaqs/tfacts175.pdf.

Nitrogen oxides are a mixture of gases that are composed of nitrogen and oxygen (ASTDR, 2012). Two of the most toxicologically significant nitrogen oxides are nitric oxide and nitrogen dioxide; both are nonflammable and colorless to brown at room temperature. Nitric oxide is a sharp sweet-smelling gas at room temperature, whereas nitrogen dioxide has a strong, harsh odor and is a liquid at room temperature, becoming a reddish-brown gas above 70 degrees Fahrenheit. Nitrogen oxides are released to the air from the exhaust of motor vehicles, the burning of coal, oil, or natural gas, and during processes such as arc welding, electroplating, engraving, and dynamite blasting. They are also produced commercially by reacting nitric acid with metals or cellulose. Nitrogen oxides are used in the production of nitric acid, lacquers, dyes, and other chemicals. Nitrogen oxides are also used in rocket fuels, nitration of organic chemicals, and the manufacture of explosives.

Acceptable Levels:

Nitric Oxide: OSHA PEL (permissible exposure limit) = 25 ppm (averaged over an 8-hour workshift).

NIOSH IDLH (immediately dangerous to life or health) = 100 ppm.

Nitrogen Dioxide: OSHA PEL (permissible exposure limit) = 5 ppm (Ceiling).

NIOSH IDLH (immediately dangerous to life or health) = 20 ppm.

Estimated Risk: Information on the health effects associated with exposure to nitrogen oxides is taken from the ATSDR Tox Profiles for Nitrogen Oxides (http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=69).

Most of the higher oxides of nitrogen are eye, skin, and respiratory tract irritants. Nitrogen dioxide is a corrosive substance that forms nitric and nitrous acids upon contact with water; it is more acutely toxic than nitric oxide, except at lethal concentrations when nitric oxide may kill more rapidly. Nitric oxide is a potent and rapid inducer of methemoglobinemia.

Exposure to nitrogen oxides may result in changes of the pulmonary system including pulmonary edema, pneumonitis, bronchitis, bronchiolitis, emphysema, and possibly methemoglobinemia. Cough, hyperpnoea, and dyspnea may be seen after some delay.

Damage to, and subsequent scarring of, the bronchioles may result in a life-threatening episode several weeks following exposure involving cough, rapid, shallow breathing, rapid heartbeat, and inadequate oxygenation of the tissues.

Populations that may be particularly sensitive to nitrogen oxides include asthmatics and those with chronic obstructive pulmonary disease or heart disease.

Acute Exposure

Nitrogen dioxide is thought to damage lungs in three ways: (1) it is converted to nitric and nitrous acids in the distal airways, which directly damages certain structural and functional lung cells; (2) it initiates free radical generation, which results in protein oxidation, lipid peroxidation, and cell membrane damage; and (3) it reduces resistance to infection by altering macrophage and immune function. There may be an immediate response to exposure to nitrogen oxide vapors that may include coughing, fatigue, nausea, choking, headache, abdominal pain, and difficulty breathing. A symptom-free period of 3 to 30 hours may then be followed by the onset of pulmonary edema with anxiety, mental confusion, lethargy, and loss of consciousness. If survived, this episode may be followed by bronchiolitis obliterans (fibrous obstruction of the bronchioles) several weeks later. Any of these phases can be fatal.

Respiratory

The higher nitrogen oxides are respiratory irritants. The primary site of toxicity is the lower respiratory tract. Low concentrations initially may cause mild shortness of breath and cough; then, after a period of hours to days, victims may suffer bronchospasm and pulmonary edema. Inhalation of very high concentrations can rapidly cause burns, spasms, swelling of tissues in the throat, upper airway obstruction, and death.

Exposure to certain chemicals can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children also may be more vulnerable because of relatively increased minute ventilation per kilogram and failure to evacuate an area promptly when exposed.

Cardiovascular

Absorption of nitrogen oxides can lead to a weak rapid pulse, dilated heart, chest congestion, and circulatory collapse.

Hematologic

High-dose exposure may convert Fe^{+2} in hemoglobin to Fe^{+3}, by virtue of the presence of nitric oxide (NO), causing methemoglobinemia and impaired oxygen transport.

Dermal

Higher nitrogen oxides are skin irritants and corrosives. Skin moisture in contact with liquid nitrogen dioxide or high concentrations of its vapor can result in nitric acid formation, which may lead to second-and third-degree skin burns. Nitric acid may also cause yellowing of the skin and erosion of dental enamel.

Because of their relatively larger surface area, body weight ratio, children are more vulnerable to toxicants affecting the skin.

Ocular

Liquid nitrogen oxides cause severe eye burns after brief contact. High concentrations of the gas cause irritation and, after prolonged exposure, may cause clouding of the eye surface and blindness.

Potential Sequelae

Obstruction of the bronchioles may develop days to weeks after severe exposure. Patients suffer malaise, weakness, fever, chills, progressive shortness of breath, cough, hemorrhage of the lungs or bronchioles, blue or purple coloring of the skin, and respiratory failure. This condition may be confused with the adult respiratory distress syndrome secondary to infectious diseases such as miliary tuberculosis.

Victims of inhalation exposure may suffer reactive airways dysfunction syndrome (RADS) after a single acute, high-dose exposure.

Chronic Exposure

Chronic exposure to nitrogen oxides is associated with increased risk of respiratory infections in children. Permanent restrictive and obstructive lung disease from bronchiolar damage may occur.

Carcinogenicity

Nitrogen oxides have not been classified for carcinogenic effects.

Reproductive and Developmental Effects

Nitric oxide and nitrogen dioxide are not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Methemoglobin inducers are considered harmful to the fetus and nitrogen dioxide has been shown to be fetotoxic in rats and has affected behavior and growth statistics in newborn mice. Nitrogen dioxide also causes DNA damage, mutations, sister chromatid exchanges, and other DNA aberrations.

Special consideration regarding the exposure of pregnant women may be warranted, since nitrogen oxides have been shown to be mutagenic and clastogenic, and fetotoxic in rats; thus, medical counseling is recommended for the acutely exposed pregnant woman

Bioassay: The diagnosis of acute nitrogen oxide toxicity is primarily based on respiratory symptoms and establishing a history of exposure to nitrogen oxides. Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to nitrous oxides include determination of methemoglobin levels. The condition of victims who have respiratory complaints should be evaluated with pulse oximetry (or ABG measurements), chest radiography, spirometry, and peak flow measurements. Pulse oximetry is not reliable if methemoglobin is present.

NO and NO_2 are metabolized to nitrite (NO_{2-}) and nitrate (NO_{3-}) and are excreted in the urine. The levels of these urinary metabolites are not medically useful but may be helpful in documenting exposure.

Laboratory Tests for Environmental Concentrations: http://www.osha.gov/SLTC/healthguidelines/nitrousoxide/recognition.html. Determination of a worker's exposure to airborne nitrous oxide can be made using one of the following techniques: 1) a Landauer Passive Dosimeter badge, which can be used for a minimum sampling duration of 1 hour (maximum duration 40 hours). Analysis is performed by the manufacturer of the badge as described in the OSHA Computerized Information System [OSHA, 1994], or 2) an ambient air or bag sample with a minimum collection volume of two spectrophotometer cell volumes. Analysis is conducted using a long-pathlength portable infrared spectrophotometer as described in NIOSH Method No. 6600 [NIOSH, 1994b].

Action Levels:

Nitric Oxide: NIOSH IDLH (immediately dangerous to life or health) = 100 ppm.

Nitrogen Dioxide: NIOSH IDLH (immediately dangerous to life or health) = 20 ppm.

Antidotes: There is no antidote for nitrogen oxides. Primary treatment consists of respiratory and cardiovascular support. Methylene blue may be necessary to treat methemoglobinemia, which may occur if nitric oxide is present in the gas mixture.

Surveillance Systems: See above (Laboratory Tests for Environmental Concentrations) for information about monitoring worker exposure using passive dosimeters or ambient air samplers. The EPA, under the authority of the Clean Air Act, regulates nitrogen oxide levels in air as one of six "criteria pollutants" covered by the NAAQS. The Commonwealth of Virginia State Air Pollution Control Board and the Virginia Department of Environmental Quality are responsible for setting emission standards for industrial sources and for modeling and monitoring ambient levels of NO_X.

3.4 Carbon Monoxide

Carbon monoxide is a colorless, nonirritating, odorless and tasteless gas found in both indoor and outdoor air. It affects the cardiovascular, developmental, neurological and respiratory systems. No known cancer effects are associated with carbon monoxide according to ASTDR (2012). It is generally ubiquitous and would be present in uranium milling/mining. More information on the toxicological profile from ASTDR is available at: http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=1145&tid=253.

3.5 Diesel Fumes

Diesel fumes are a complex mixture of gases and ultrafine particles that contains more than 40 toxic air contaminants. The EPA has determined that diesel fumes are carcinogenic, i.e. cause lung cancer. Diesel fumes are produces by diesel-powered machinery that might be used in mines as well as trucks and other heavy equipment. The short term health effects of exposure to diesel exhaust include irritation of eyes, nose, throat, and lungs. Inhalation can cause coughs, headaches, lightheadedness and nausea as well as increased sensitivity to allergens and may have a greater impact on children (OEHHA, 2012).

The following information and additional references are available at http://www.cdc.gov/niosh/mining/topics/DieselExhaust.html. "Exposure to elevated diesel exhaust concentrations has been linked to negative health effects such as eye and nose irritation, headaches, nausea, and asthma. Diesel particulate matter (DPM) has been classified as a possible carcinogen by both the NIOSH and the EPA. Diesel engines are a major contributor to elevated concentrations of carbon monoxide, carbon dioxide, oxides of nitrogen, and hydrocarbons in underground coal and metal/nonmetal mines. Currently, underground miners can be exposed to more than 100 times the typical environmental concentration of diesel exhaust and more than 10 times what might be found in other workplaces. As mines add more and more pieces of diesel equipment the potential overexposure becomes an even greater risk."

The Office of Mine Safety and Health Research (OMSHR) is working to reduce respiratory diseases in miners associated with diesel emissions by reducing miners' exposure to these emissions in underground mines. The OMSHR is evaluating methods to control emissions from diesel equipment and new monitoring techniques that identify exposure limits in order to reduce potential overexposures. OMSHR research has resulted in a method to continuously monitor personal exposure to diesel particulate matter in underground mines. In addition, OMSHR has evaluated numerous control technologies to reduce emissions from diesel equipment, including diesel particulate filters, alternative fuels (biodiesel), emissions-assisted maintenance programs, and fuel additives.

3.6 Mold –related Illness

Mold-related illness is associated with construction activities but no reports have identified the illness specifically with mining and milling. Histoplasmosis and blastomycosis are fungal infections that occur commonly in the central and southeastern United States. Individuals with weakened immune systems or chronic lung disease are most susceptible to infection. Histoplasmosis is most common when old buildings are torn down or in areas with bird and bat droppings. Histoplasmosis and blastomycosis produce flu-like symptoms. In general the infection is limited to individuals actually excavating the soil or tearing down buildings but occasionally can occur in observers immediately adjacent to the activity (PubMed Health, 2012).

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