NewFields

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REPORT FOR LONG BASELINE NEUTRINO FACILITY (LBNF)

BY:
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FOR:
Fermi Research Alliance, LLC in Lead, SD

SEPTEMBER 1, 2022

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ACRONYMS

ED	Emergency Department
HQ	Hazard Quotient
FRA	Fermi Research Alliance
HHRA	Human Health Risk Assessment
LBNF	Long Baseline Neutrino Facility
NAAQS	National Ambient Air Quality Standards
PCOC	Potential Chemical of Concern
PM	Particulate Matter
PM 2.5	Particles less than or equal to 2.5 microns
PM 10	Particles less than or equal to 10 microns
Pb	Lead
RBSL	Risk Based Screening Level
RSL	Residential Screening Level
SURF	Sanford Underground Research Facility
µm	Micron

REPORT OF GARY R. KRIEGER, MD, MPH, DABT, DTM&H

1.0 Executive Summary

Soils and air monitoring data related to LBNF excavation activities were reviewed by NewFields. These objective environmental data were assessed for the potential to cause adverse health impacts to local community residents. NewFields' assessment was performed using USEPA human health risk assessment (HHRA) methodology. HHRA is designed to be health protective and is highly unlikely to underestimate actual health risks to a potentially exposed community. The key findings of NewFields' assessment are:

1. LBNF excavation soils do not present a health hazard via either inhalation or direct ingestion pathways to children or adults in Lead, SD. There is no significant increased risk of cancer or non-cancer health effects to children or adults living on or near excavated soils/rock. The measured soil concentrations for potential metals of concern potentially attributable to LBNF excavation activities are well below human health risk-based screening concentrations. Similarly, continuously measured levels of fine ($PM_{2.5}$) or coarse (PM_{10}) particulates are not at a concentration that would produce significant short-term health effects in nearby community members. Finally, crystalline silica concentrations in air do not pose a health risk to the community.
    a. **LBNF fine PM contribution ($PM_{2.5}$)** will not produce significant human health impacts, particularly with short-term exposures of < 24 hours. The $PM_{2.5}$ concentrations are quite low and well below health-based National Ambient Air Quality Standards (NAAQS) regulations. In a comparative analysis with the State of South Dakota's nearest $PM_{2.5}$ monitor(s) in Rapid City, measured Lead SD $PM_{2.5}$ concentrations are not significantly different from regional background.
    b. **LBNF coarse PM contribution (PM_{10})** will not produce significant human health impacts, particularly with short-term exposures of < 24 hours. The PM_{10} concentrations are quite low and well below health-based National Ambient Air Quality Standards (NAAQS) regulations.
    c. **Lead (Pb) particulate concentrations** are extremely low and well below health protective EPA risk based screening levels (RBSLs) or National Ambient Air Quality Standards (NAAQS) regulations.
    d. **LBNF measured crystalline silica concentrations** are extremely low and well below health protective risk screening levels.

Finally, NewFields does endorse the LBNF plan to continue the current community air monitoring program. An air monitoring system during excavation activities will (i) allow for objective measurement of exposures and (ii) provide reassurance for residents that the current LBNF practices are not generating significant health risks to the community.

2.0 Statement of Qualifications

I am Gary R. Krieger MD, MPH, DABT, Principal and Senior Partner at NewFields, LLC. In addition, I am an Associate Professor, adjunct, at the University of Colorado, Department of Toxicology. I have over 25 years of experience related to the investigation and evaluation of exposure to potentially hazardous materials in both community and occupational settings. I have both published and presented extensively in the fields of public and community health, toxicology, and occupational/environmental medicine. I have co-edited and/or authored over ten books/monographs in environmental management, health & safety, occupational medicine, and medical toxicology. These books have been sponsored by the National Safety Council, *Clinics in Occupational and Environmental Medicine* series and other well-known publishers in the fields of occupational/environmental medicine and toxicology.

- For over 30 years, I have been involved in multiple public health evaluations (including epidemiology studies), health impact assessments and risk assessments in both the United States and international settings. I have been the lead and/or co-author for (i) the State of Alaska HIA Guidance for extractive industry projects (2011); (ii) the International Finance Corporation "Health Impact Assessment "Toolkit (2008)" and Good Practice Notes related to "Community Health Performance Standards (No.4); and (iii) the International Petroleum Industry Environmental Conservation Association (IPIECA, 2005 & 2015) "Health Impact Assessment Guidelines."
- I have extensive experience both in the USA and internationally related to fine and coarse particulate matter ($PM_{2.5}$, and PM_{10}) exposures and potential health impacts in a community setting.
- I have current board certification in internal medicine, occupational medicine, and toxicology. In addition, I am a specialist in tropical medicine and hygiene and certified by the Royal College of Physicians (U.K).

3.0 Scope

The scope of work for this project includes:

- Evaluating data provided by FRA (Fermi Research Alliance) including (i) geochemical analysis, continuous PM10 data from 24 December 2020- 27 July 2022, (ii) continuous PM_{10} and $PM_{2.5}$ data collected in 2022, (iii) chemical analysis of both crushed rock and dust from the park, (iv) gradation, X-ray diffraction, and scanning electron microscopy analysis of samples collected with Total Suspended Particulate Hi-Vol Samplers for silica samples. NewFields understands that LBNF continues to collect and evaluate relevant air station monitoring data.

- Development of preliminary findings regarding potential exposures and risks from Long Baseline Neutrino Facility (LBNF) excavation activities leading to community meeting technical presentations;

- Participation in two community meetings in Lead, SD– (i) 20 April 2022 and (ii) 27 July 2022; and,

- Final summary report September 1, 2022.

4.0 Materials Considered

Technical materials and air and soils data were provided by the LBNF site team. In addition, I have performed an independent literature review and analysis of the relevant medical and toxicological literature for fine and coarse particulate matter ($PM_{2.5}$, and PM_{10}), relevant metals of potential concern, and crystalline silica.

5.0 Background Information

5.1 LBNF Soil Excavation

There are multiple publicly available reports surrounding the history of LBNF soil excavation activities. The different actions, including dust mitigation steps, are available in numerous site documents many of which have been publicly released and presented in open forums. From a human health perspective, the key events are:

- May 2021 soil excavation activities began with discharge to the open cut area; Background coarse particulate (PM_{10}) monitoring had started in December 2020.

- July 2021 City of Lead raises concerns surrounding dust in the city park proximate to the open cut discharge area;

- February 2022 fine particulate ($PM_{2.5}$) network established included downwind sampling for key locations;
- March 2022 city park direct soils metals concentrations and Toxicity Characteristic Leaching Procedure(TCLP) data;
- April 20th, 2022, community open house meeting with emphasis on potential health issues/concerns; Screening level risk calculations presented for soils and fine and coarse particulates; and,
- July 27th, 2022, community open house meeting with presentation of crystalline silica data.

5.2 Methods Used by Scientists Assessing Potential Toxicologic Risks

Health regulatory agencies throughout the world have agreed on a consensus conceptual framework and methodology for assessing potential toxicological risks. This standard framework is described in many textbooks of occupational and environmental medicine and toxicology (Sullivan and Krieger 2001, Klaassen 2019) and integrated into international regulatory and other guidance documents published by (among many others) the NRC (NRC 1983, 1991a), EPA (EPA 1989, 2014), the World Health Organization (World Health Organization (WHO) 1999, 2000, 2010), the Agency for Toxic Substances and Disease Registry (Agency for Toxic Substances and Disease Registry (ATSDR) 2005), and many state regulatory agencies. According to this consensus approach, a scientifically defensible conclusion that a chemical exposure put any individual or group at significantly increased risk of adverse health effects, requires analysis of each element of the following logical sequence:

Source → Exposure[1] → Dose[2] → Potential Health Effect(s)

Thus, an investigation to determine if individuals or a community are at increased risk caused by exposure to chemicals must proceed in a logical fashion that (i) establishes the presence of a

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[1] Exposure: Contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (*e.g.*, skin, lungs, gut). (EPA IRIS Glossary March 11, 2021).

[2] Dose: The amount of a substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism. (EPA IRIS Glossary March 11, 2021).

complete exposure pathway[3] linking a chemical source(s) to the human receptor, (ii) estimates the concentration(s) of any source-related chemical(s) under investigation at the receptor's location via measurements or modeling over the exposure period, (iii) calculates or measures the dose received by the individual(s) at the exposure point, and (iv) characterizes the potential health effects of the chemical(s) under investigation based upon the route of exposure and chemical-specific dose-response relationship(s). This logical sequence is the basis for performing a health risk assessment.

5.3 Basic Principles of Toxicology

Toxicology is the field of science that investigates and describes whether and how exposure to environmental factors causes adverse (toxic) effects in organisms, including humans. The first tenet of toxicology is that the effect of any chemical in a biological system—*i.e.*, the hazard it poses—is determined by the magnitude and timing of exposure (dose rate) and exposure route (ingestion, inhalation, dermal absorption), not simply by the fact of exposure itself. This central dose-response concept was famously articulated in the 16th century by the physician Paracelsus (Klaassen 2019):

> "What is there that is not poison? All things are poison, and nothing is without poison: the dose alone makes a thing not poison."

Simply put, the toxic effects of a given chemical depend on **dose** (how much), **frequency of exposure** (how often), **duration of exposure** (how long), and the **route** by which the chemical enters the body. Defining and understanding "duration" is critical. In the particulate matter (PM) literature (US EPA 2019, 2022) the most common "duration" descriptors are "short-term" and "long-term." From a standard toxicology/risk assessment perspective, the three duration descriptors are (i) acute- <14 days, (ii) intermediate 14-365 days and (iii) chronic- >365 days[4]. From a PM literature perspective "short-term" subsumes both acute and intermediate while long-term is "chronic." The *current analysis* for the LBNF site is driven by "short-term" (acute and intermediate) exposures versus chronic; however, the risk screening for potentially impacted soils uses the chronic (long-term) exposures. In general chronic screening levels are lower (more conservative/health protective) than short-term concentrations.

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[3] Defined as "the course a chemical or physical agent takes from a source to an exposed organism." A complete exposure pathway includes a source or release from a source, an environmental transport/exposure medium (or media), an exposure point (location of potential contact between an organism and a chemical or physical agent), and an exposure route (*i.e.*, ingestion, inhalation, dermal contact). (EPA 1989 Risk Assessment Guidance for Superfund (RAGS) Part A).

[4] https://www.atsdr.cdc.gov/glossary.html

As will be discussed in subsequent sections of this report, all of the available air monitoring data are less than 365 days(1year) in duration; hence, they are considered "short-term." The excavation process will clearly continue for > 1 year; therefore, at some point it will be appropriate to consider and discuss chronic inhalation exposure comparisons as these data become available. Based on the current data, NewFields does not anticipate that there will be chronic exposure problem as short-term measured PM concentrations are well below NAAQS.

It should be noted that dose-dependence is a general characteristic of biological responses, including all forms of adverse effects. Accordingly, estimation of the risk of any adverse effect resulting from exposure to a chemical requires knowledge of (i) the intrinsic hazard posed by a chemical, and (ii) the dose or concentration that people are exposed to.

It is critical to clearly distinguish between the concepts of "hazard" and "risk" in this context. The term "hazard" refers to the effect(s) *potentially* caused by a chemical, without regard to the dose or exposure. "Risk" refers to the *likelihood* that an adverse health effect will occur under defined exposure conditions (Figure 1).

Figure 1: How Do We Estimate Risks?

Source: NewFields, 2022

Hazard is not synonymous with risk but is rather, a component of risk whose importance is strictly determined by exposure. From a clinical perspective (Becker 2001),

> "Toxicology is the study of the probability, not the possibility, of physical or chemical agents causing effects (*i.e.*, toxicity) at a specific dose and under the conditions of use…."

The second tenet of toxicology is that individual chemicals or materials exert specific toxic effects that are determined by their size characteristics (*e.g.*, fine PM (2.5 µm) versus coarse PM (10 µm) and/or chemical composition (Rozman and Doull 2000, Goldstein and Gallo 2001). For example, amorphous silica is quite different toxicologically versus crystalline silica.

There are thus two fundamental elements involved in the interaction between a chemical and an organism: (i) what the organism does to the chemical (pharmacokinetics), and (ii) what the chemical does to the organism (pharmacodynamics). Both are dependent on the specific characteristics of the chemical and the organism. All of these considerations (*i.e.,* dose, exposure frequency and duration, pharmacokinetics, and pharmacodynamics) are critical in order to assess potential human health risk.

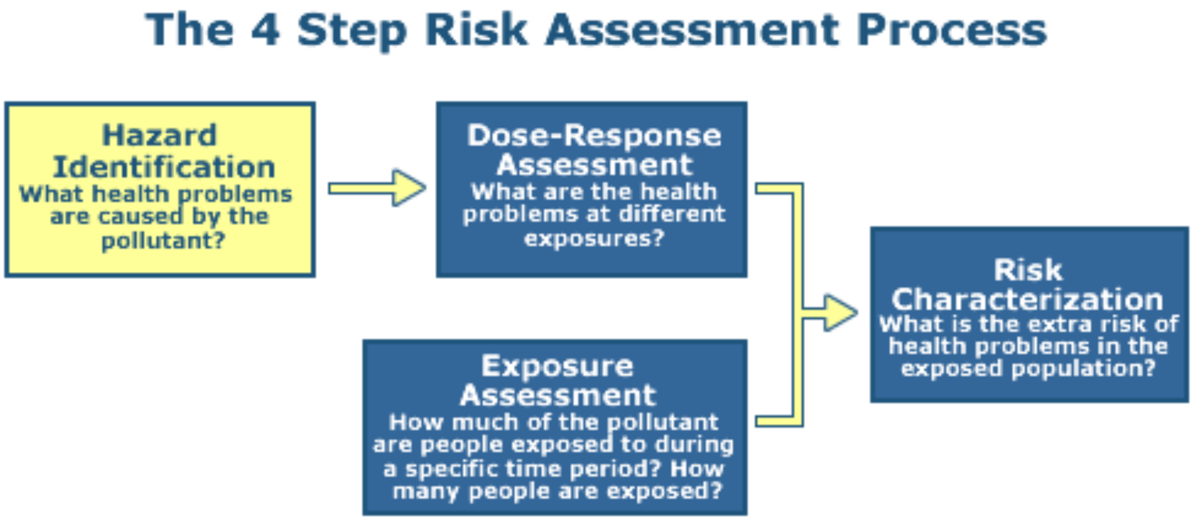
6.0 Basics of Human Health Risk Assessment

For the LBNF soils excavation community health analysis, a human health risk assessment strategy has been utilized. This strategy consists of two parts: (i) utilization of the basic "4 Step Risk Assessment Process", and (ii) performance of a basic risk-based screening analysis using the most current US EPA toxicity values, default exposure assumptions and physical and chemical properties of the chemicals of concern.

Human health risk assessment (HHRA) is fundamentally a four step process (Figure 2) that considers:

- Hazard Identification
- Dose-Response Assessment
- Exposure Assessment
- Risk Characterization

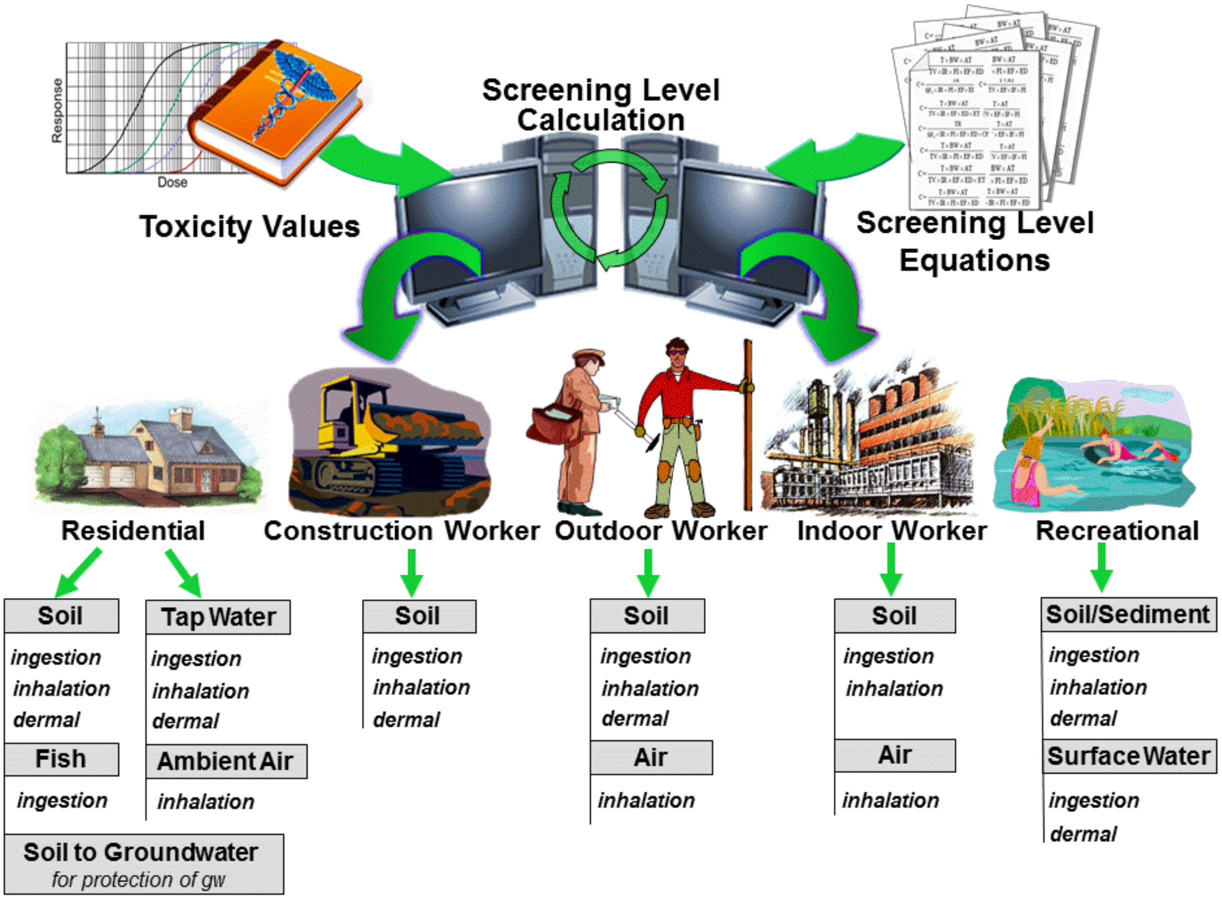
Figure 2: Four Step Risk Assessment Process



Source: US EPA https://www.epa.gov/risk/conducting-human-health-risk-assessment

Risk based screening is illustrated in Figure 3. The RBSL is focused on chronic *residential screening*, which is inherently more stringent than short-term recreational exposures, i.e., if a chemical concentration “passes” a chronic exposure residential screen it is highly unlikely that a short-term recreational exposure would be a health concern.

Figure 3: Risk Based Screening Process



Basic risk assessment screening will be applied to assessing whether the current excavation activities at the LBNF site are generating significant short-term or chronic risks for the proximate local community. Where chemical concentrations fall below RBSLs, no further action or study is warranted, so long as the exposure assumptions at a site match those taken into account by the RBSL calculations. The EPA default residential exposure assumptions are extremely conservative, i.e., 26 years of continuous exposure. The LBNF excavation activities will be much shorter and likely be complete in 2024. Hence, the RBSL will not underestimate risk associated with LBNF excavation.

The overall assessment has considered these questions and answers:

1. **Who/What/Where is at potential risk?**

Local community members (including short-term visits to relevant local playground) proximate to LBNF excavation activities

2. **What is the environmental hazard of concern?**

The potential chemicals of concern (PCOCs) in soils are metals. The critical constituents in air are particulate matter (fine and coarse) and crystalline silica. The PCOC selection is based on community input/concerns and relevant environmental measurement data.

3. What is the source of the PCOCs?

The assessment considers both general background conditions (baseline/background levels) and incremental contribution to background due to LBNF excavation activities.

4. How does exposure occur?

The key pathways are air and soil. The primary routes of exposure are inhalation and ingestion of soils/dusts. Dermal (skin) exposure for the chemicals of concern is not considered to be toxicologically/medically significant. The exposure periods under consideration for the air pathway is short-term, i.e., less than 1 year as the relevant LBNF excavation activities have occurred for ~1 year.

5. Are there available objective measurement data for the PCOCs?

Yes there are continuous air monitors and available soil measurements.

6. Is the underlying toxicology of the PCOCs understood?

Yes, there is extensive knowledge, in humans, regarding metals, particulate matter and silica.

7. Are there available (i) health protective, risk-based screening (comparison) values and/or (ii) health protective national ambient air quality standards?

The EPA has published health protective risk based screening levels (RBSLs)[5] in various environmental media (including soil) for the metals of potential concern. There are health protective national ambient air quality standards (NAAQS) that are available for particulate matter (fine and coarse) and also lead. There are published risk-based inhalation exposure levels for crystalline silica applicable to the general community.

The EPA RBSLs are available for both air and ingestion exposure pathways; however, for the metals of potential concern associated with LBNF excavation activities, the critical route of exposure is soil ingestion. The inhalation exposure pathway is focused on (i) fine particulates ($PM_{2.5}$) (ii) coarse particulates(PM_{10}), (iii) lead and (iv) crystalline silica.

National Ambient Air Quality Standards (NAAQS) and risk-based screening levels (RBSLs) are extremely health protective and highly unlikely to underestimate risk—if a measured

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[5] https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

concentration is below NAAQS or RBSL there is an assumption that significant risk is not occurring.

The soil risk-based screening levels assumes/considers: (i) daily exposure from ages 0-26, (ii) continuous exposure, (iii) intake via ingestion, (iv) all of the metal enters the body and (v) a variety of COPC-specific cancer (if relevant) and non-cancer effects

8. **How are the risks calculated?**

(a) For soil PCOCs, risk are calculated for each metal using a “hazard quotient” (HQ) where a level <1 is considered to be an insignificant risk.

$$HQ = \frac{\text{Measured concentration in soil}}{\text{Safe concentration in soil (RSL)}} = \frac{\text{LBNF sampling result}}{\text{EPA non-cancer Residential Screening Level}}$$

(b) For soils, cancer hazard is considered by using a target “acceptable” excess increase in cancer in a population over a lifetime. This “excess risk” is thousands of times below the background cancer risk in the US. The target excess risk range is between 1 in 1 million (0.000001) to 1 in ten thousand (0.0001). The US background cancer risk is 0.30. So the “excess risk” is between 0.3001 and 0.3000001.

$$\text{Cancer risk} = \frac{\text{Measured concentration in soil}}{\text{Safe concentration in soil (RSL)}} \times 0.000001 \text{ (target risk level)} = \frac{\text{LBNF sampling result}}{\text{EPA cancer Residential Screening Level}} \times 0.000001$$

(c) Particulate matter risks are considered by analyzing how the “source”(LBNF excavation activities) changes the existing background levels, i.e., does the background + “new source” activity significantly raise the overall exposure level to levels above NAAQS thereby placing individuals at increased risk. The NAAQS typically consider 24 hour and 1 year exposure periods.

(d) The crystalline silica risk is evaluated by comparing the measured air concentration versus a risk-based (safe) inhalation screening level. This is the same process previously described for soils.

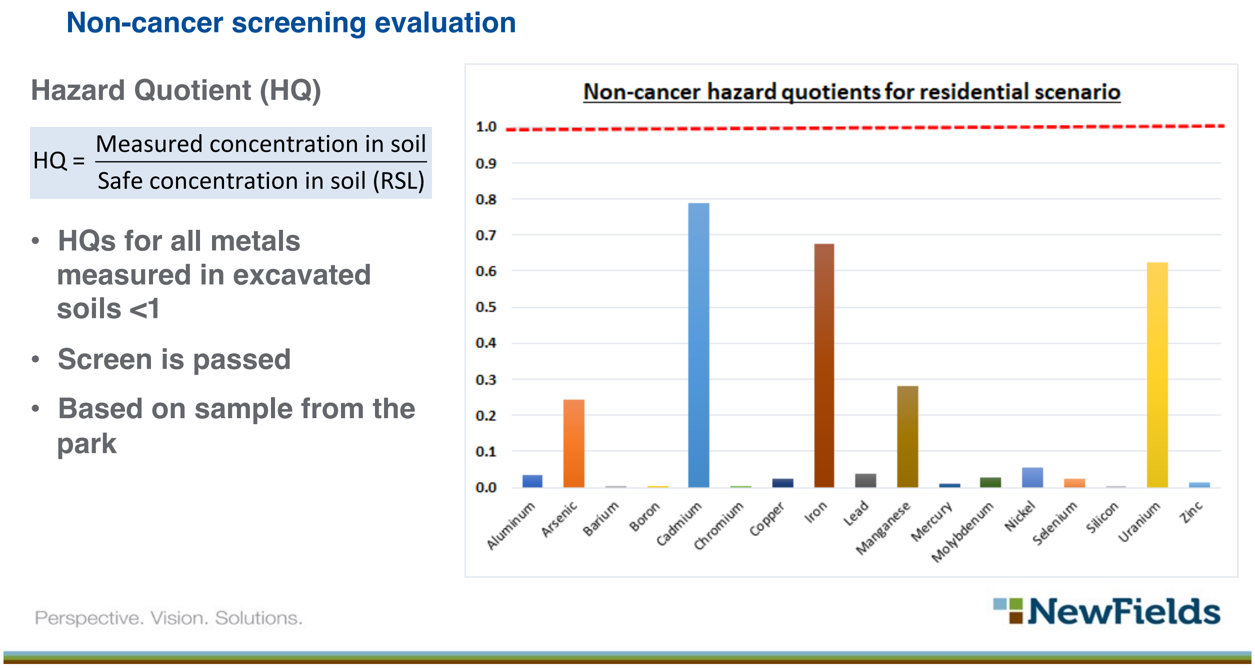
9. **Was this 4-step process followed for the LBNF excavation materials?**

Yes, based on the available objective, measured data, an appropriate screening risk assessment was performed.

7.0 Screening Risk Assessment Results for Soils

As previously described (Section 6) city park soils metals were measured and concentrations were compared against standard EPA residential RBSLs for both non-cancer and cancer effects. Figure 4 presents the non-cancer screening evaluation using hazard quotients (HQs). As illustrated, all HQ were <1, i.e., a significant risk is not expected based on chronic exposure. Short-term exposure risks would be substantially lower as the exposure duration and frequency are much less versus continuous residential assumptions.

Figure 4: Non-cancer Soils Screening Evaluation



Non-cancer screening evaluation

Hazard Quotient (HQ)

$$HQ = \frac{\text{Measured concentration in soil}}{\text{Safe concentration in soil (RSL)}}$$

- HQs for all metals measured in excavated soils <1
- Screen is passed
- Based on sample from the park

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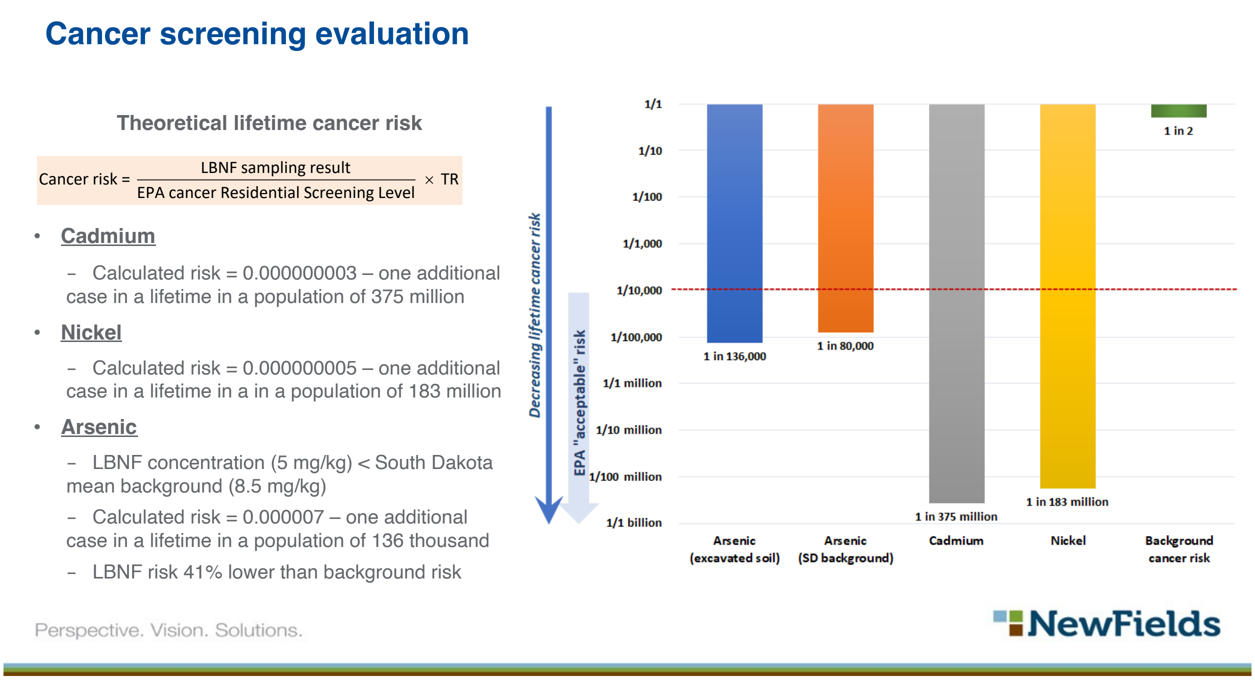
Figure 5 presents the cancer screening evaluation which is only relevant for arsenic, cadmium and nickel. As illustrated, the levels of key metals do not pose a significant cancer risk to the community under chronic (long-term) exposure conditions. Short-term exposure risks would be extremely low and insignificant from a health perspective.

Figure 5: Cancer Soils Screening Evaluation



Cancer screening evaluation

Theoretical lifetime cancer risk

$$\text{Cancer risk} = \frac{\text{LBNF sampling result}}{\text{EPA cancer Residential Screening Level}} \times \text{TR}$$

- **Cadmium**
  - Calculated risk = 0.000000003 – one additional case in a lifetime in a population of 375 million
- **Nickel**
  - Calculated risk = 0.000000005 – one additional case in a lifetime in a in a population of 183 million
- **Arsenic**
  - LBNF concentration (5 mg/kg) < South Dakota mean background (8.5 mg/kg)
  - Calculated risk = 0.000007 – one additional case in a lifetime in a population of 136 thousand
  - LBNF risk 41% lower than background risk

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Overall, risk-based screening demonstrates insignificant risks to the community:

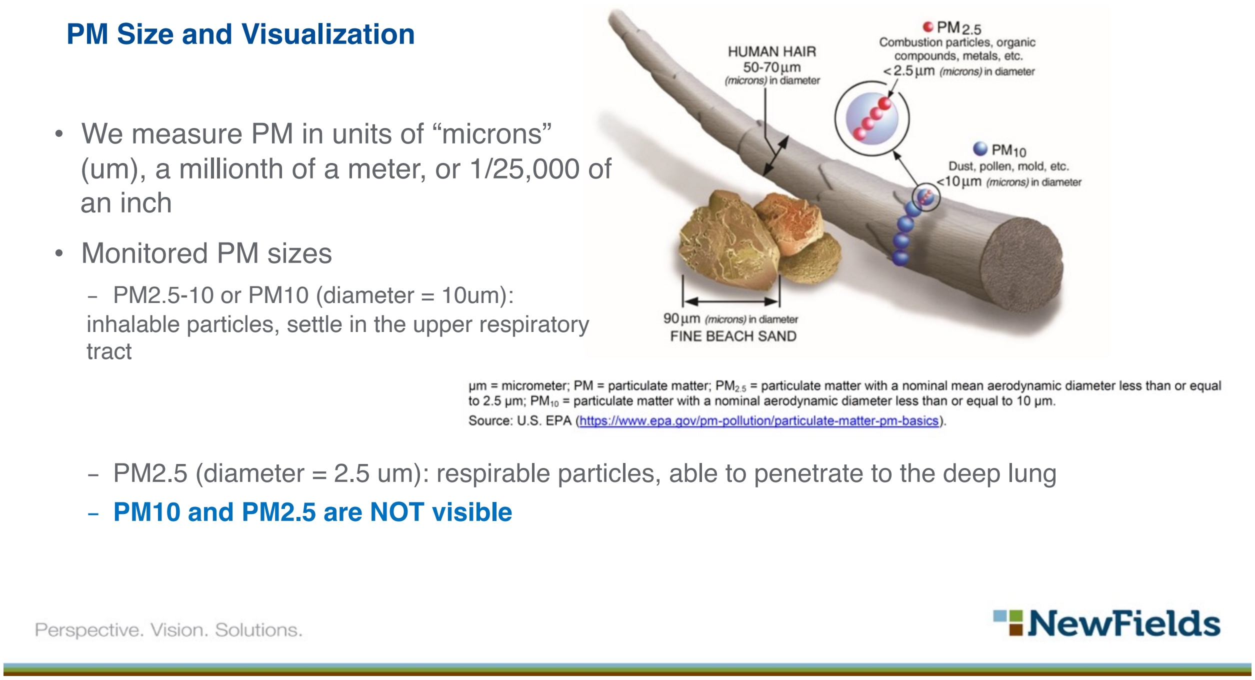
- LBNF excavation soils passed risk screening:
  - Excavation soils do not present increased risk of cancer or non-cancer health effects to children or adults living on or near the excavated soil.
- Naturally occurring arsenic is often present in concentrations greater than the cancer residential RSL, as it is in South Dakota soil.
  - Cancer risk calculated for arsenic in LBNF excavated soil is “acceptable” per EPA policy.
- Lead was not present (non-detect), so no risk calculation was performed.

8.0 Screening Risk Assessment for Particulate Matter (PM)

Airborne PM is a complex mixture of organic and inorganic, solid and liquid, primary and secondary particles that can vary greatly in composition and concentration depending on source, geographic location, season, weather conditions, and time of day.

Figure 6 presents an illustration of PM size. Figure 7 illustrates the relationship between PM size and distribution in the human respiratory system. $PM_{2.5}$ and PM_{10} are not visible with the human eye.

Figure 6: PM Size and Visualization



PM Size and Visualization

- We measure PM in units of "microns" (um), a millionth of a meter, or 1/25,000 of an inch
- Monitored PM sizes
  - PM2.5-10 or PM10 (diameter = 10um): inhalable particles, settle in the upper respiratory tract
  - PM2.5 (diameter = 2.5 um): respirable particles, able to penetrate to the deep lung
  - **PM10 and PM2.5 are NOT visible**

µm = micrometer; PM = particulate matter; $PM_{2.5}$ = particulate matter with a nominal mean aerodynamic diameter less than or equal to 2.5 µm; PM_{10} = particulate matter with a nominal aerodynamic diameter less than or equal to 10 µm.
Source: U.S. EPA (https://www.epa.gov/pm-pollution/particulate-matter-pm-basics).

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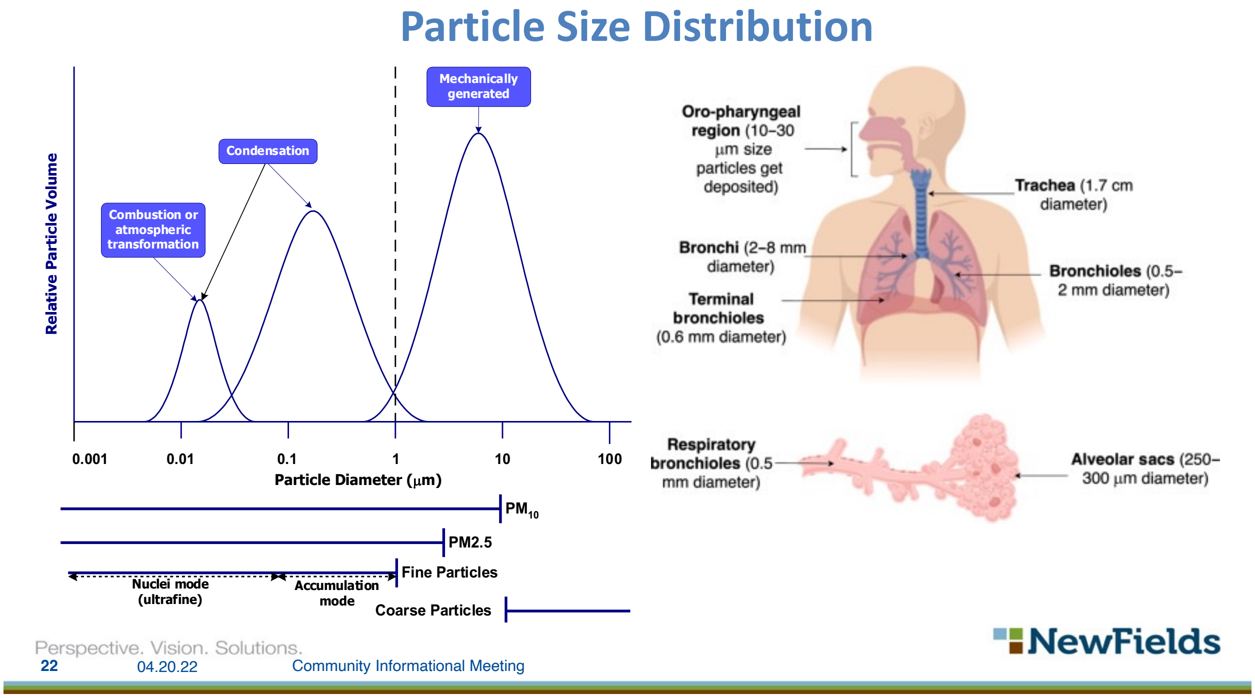
Figure 7: PM Size and the Human Respiratory System



Particle Size Distribution

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Heightened short-term $PM_{2.5}$ exposure can result in a range of (i) morbidity health effects, chiefly respiratory and cardiovascular; and (ii) changes in all-cause mortality, particularly cardiovascular. Short-term exposure to high levels of $PM_{2.5}$ and/or PM_{10} can trigger reversible symptoms of cough, irritation, and possibly triggering pre-existing asthma.

The strength of the $PM_{2.5}$ exposure-health effects relationships varies, as does the evidence supporting biological plausibility (EPA 2019, 2022). Respiratory effects that can be associated with short-term $PM_{2.5}$ at certain concentrations include exacerbation of asthma, allergies, chronic obstructive pulmonary disease (COPD), respiratory infections, and combinations of respiratory-related diseases, as well as increases in respiratory mortality (EPA 2019, 2022). In terms of the lag between $PM_{2.5}$ exposure and respiratory-related hospital admissions and emergency department (ED) visits, studies have indicated positive associations across lags ranging from zero to four days, with the strongest association generally within a few days after exposure (US EPA 2019, 2022)

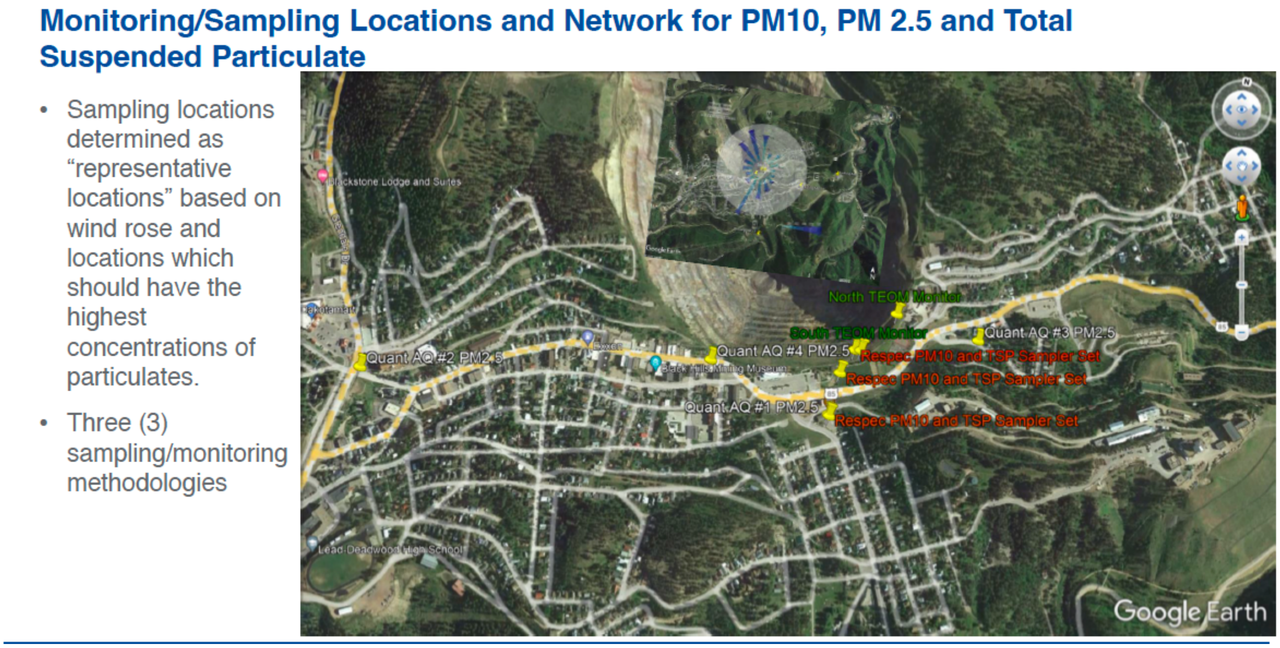
Cardiovascular effects that can be associated with short-term $PM_{2.5}$ at certain concentrations include ED visits and hospital admissions for ischemic heart disease, myocardial infarction, heart failure, impaired heart function, disturbances in cardiac electrophysiology, arrhythmia, cerebrovascular disease and stroke, increased blood pressure and hypertension, peripheral vascular disease, venous thromboembolism and pulmonary embolisms, and cardiovascular-related mortality (EPA 2019, 2022). Lag times between $PM_{2.5}$ exposure and cardiovascular effects appear to differ by endpoint, ranging from immediate to one or two days (EPA 2019, 2022).

In evaluating potential exposure to outdoor pollutants such as $PM_{2.5}$ or PM_{10} released from LBNF excavation activities, it is crucial to recognize that (1) most people spend the great majority of their time indoors (Klepeis *et al.* 2001, Harrison *et al.* 2009, Su *et al.* 2013), where $PM_{2.5}$ arises from various indoor sources (including cooking; burning candles and incense; smoking; dust; biological materials such as dander, bacteria, fungi, viruses, pollen, and plant fibers; and reactions of precursor gases) (Hodas *et al.* 2016). Thus, PM in indoor air comes from a mixture of indoor and outdoor sources, with outdoor contributions dependent upon a complex array of factors governing infiltration rates.

A recent meta-analysis of studies estimated that outdoor sources contribute approximately 44% (range 33.3 to 54.8%) of total $PM_{2.5}$ exposure (Evangelopoulos *et al.* 2020). Home-level particle infiltration is quite variable and is influenced by home construction, air conditioning practices, etc. (Meng *et al.* 2005). Thus, the proportion of $PM_{2.5}$ exposure derived from outdoor air in communities near the LBNF excavation discharge point is likely variable and dependent on the foregoing factors, but may be on the *lower end* of the range identified by Evangelopoulos *et al.* (2020). **Overall, the likely indoor exposure to LBNF generated PM is expected to be extremely low.**

Figure 8 illustrates the overall monitoring/sampling locations.

Figure 8: Air Monitoring/Sampling Locations

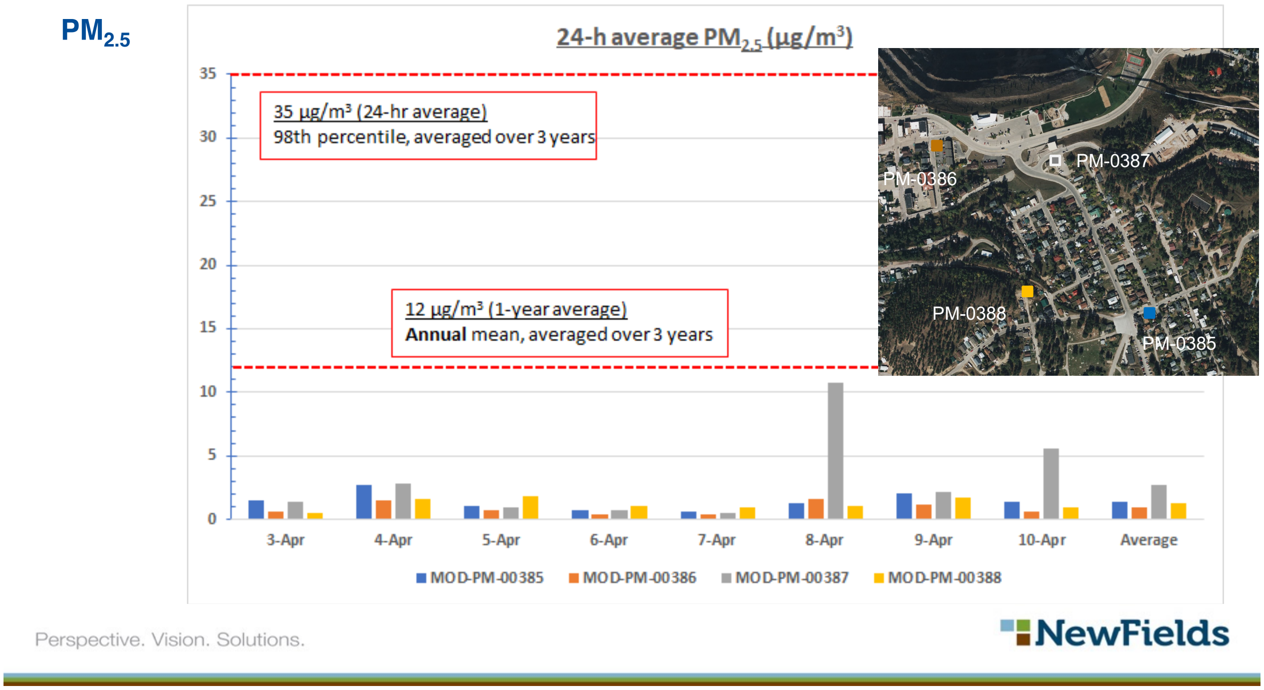


Monitoring/Sampling Locations and Network for PM10, PM 2.5 and Total Suspended Particulate

- Sampling locations determined as "representative locations" based on wind rose and locations which should have the highest concentrations of particulates.
- Three (3) sampling/monitoring methodologies

Figure 9 illustrates the short-term (24 hour) $PM_{2.5}$ outdoor monitoring data for April 2022. Figure 10 presents the $PM_{2.5}$ rolling average May-July 2022. Figure 11 illustrates the $PM_{2.5}$ concentrations May-July 2022.at the discharge point.

Figure 9: 24 Hour $PM_{2.5}$ Monitoring Data April 2022



$PM_{2.5}$

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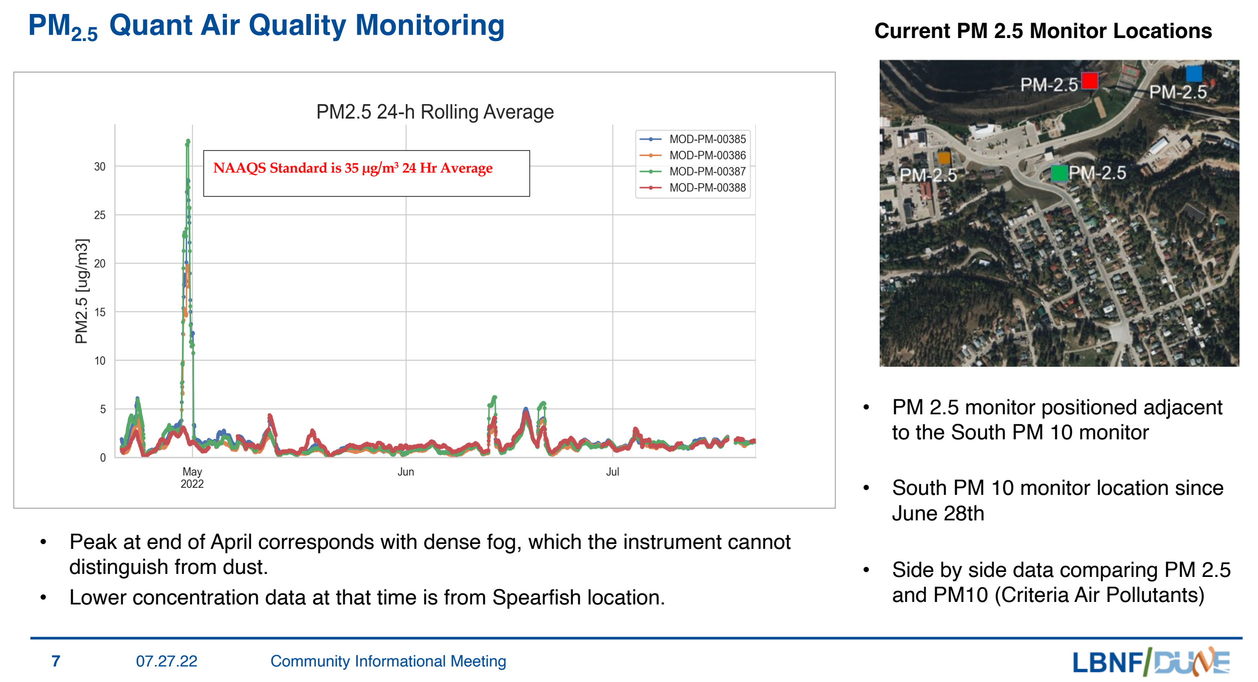
Figure 10: $PM_{2.5}$ 24-hour Rolling Average May-July 2022



$PM_{2.5}$ Quant Air Quality Monitoring

- Peak at end of April corresponds with dense fog, which the instrument cannot distinguish from dust.
- Lower concentration data at that time is from Spearfish location.

Current PM 2.5 Monitor Locations

- PM 2.5 monitor positioned adjacent to the South PM 10 monitor
- South PM 10 monitor location since June 28th
- Side by side data comparing PM 2.5 and PM10 (Criteria Air Pollutants)

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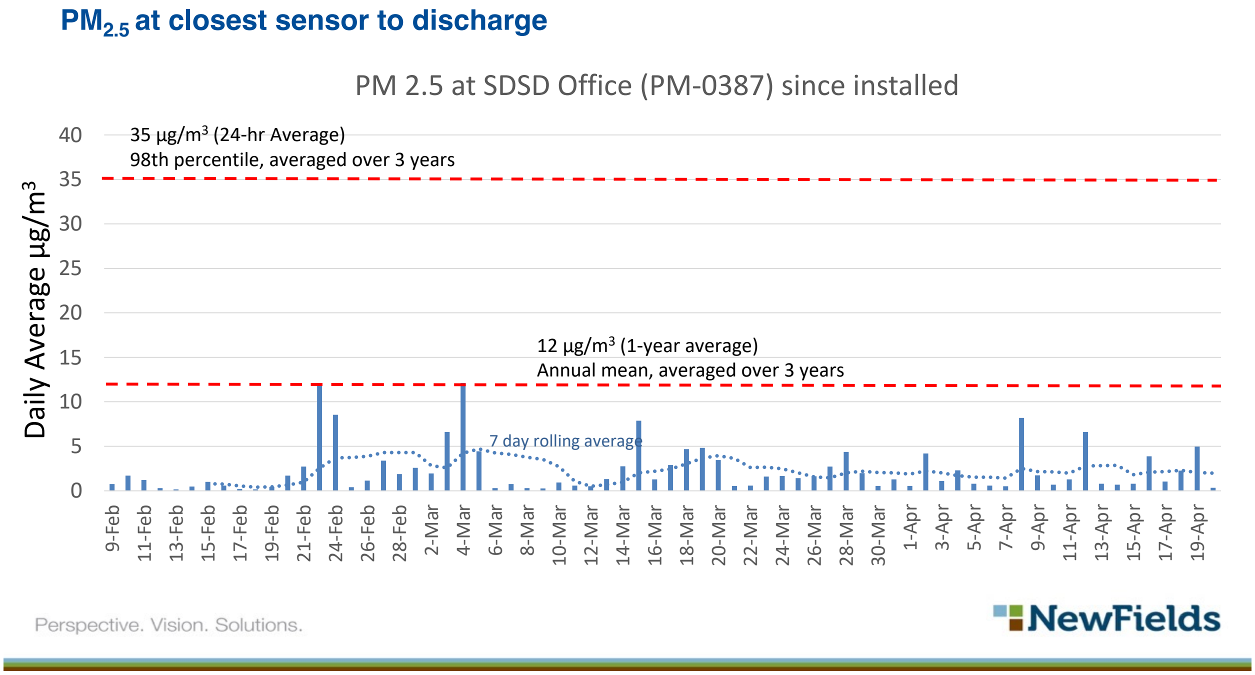
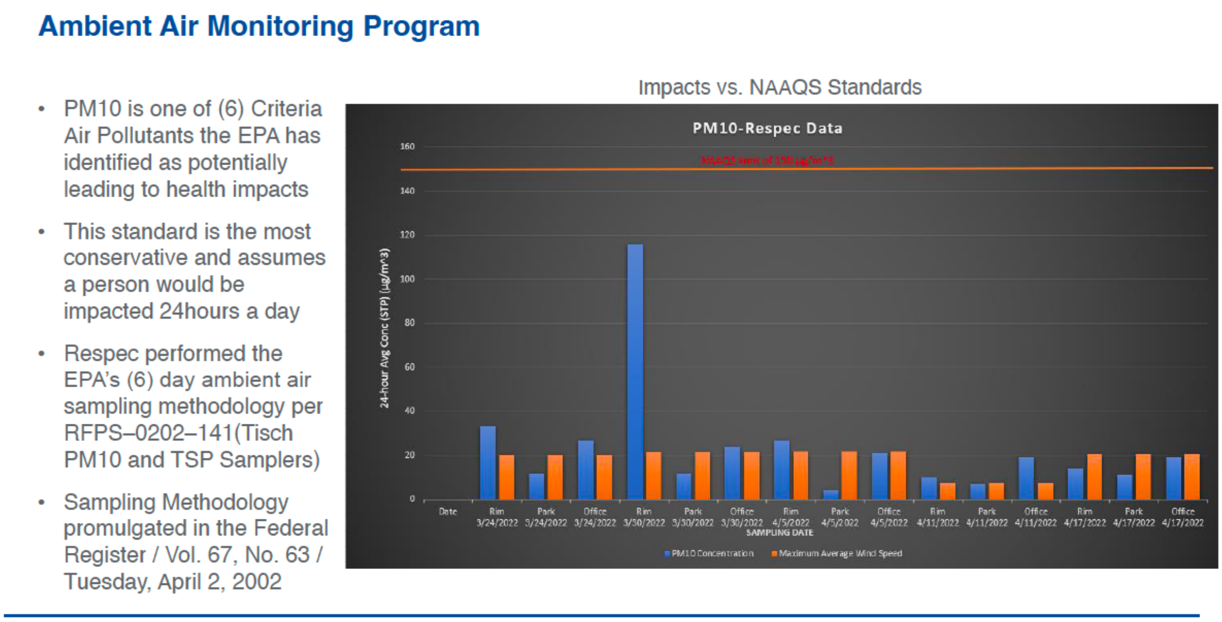
Figure 11: PM$_{2.5}$ at Discharge Point



As illustrated in Figures 8 and 9, the daily 24-hour fine PM concentrations are extremely low and consistent with background fine PM levels. The extremely low PM$_{2.5}$ concentrations would not be expected to produce significant short-term health effects. Similarly, the 7-day rolling average (Figures 10 and 11) suggest that intermediate health impacts would also be extremely unlikely. When a full years data are available, NewFields believes that it is extremely unlikely that the annual measured concentration will be at a level associated with significant health impacts.

Figures 12 and 13 illustrate the coarse (PM$_{10}$) monitoring data over March-April (Figure 11) and April-July (Figure 12). As shown in figures 12-Figure 13, the monitored PM$_{10}$ levels are very low and well below health protective NAAQS.

Figure 12: PM$_{10}$ Monitoring (March-April 2022)

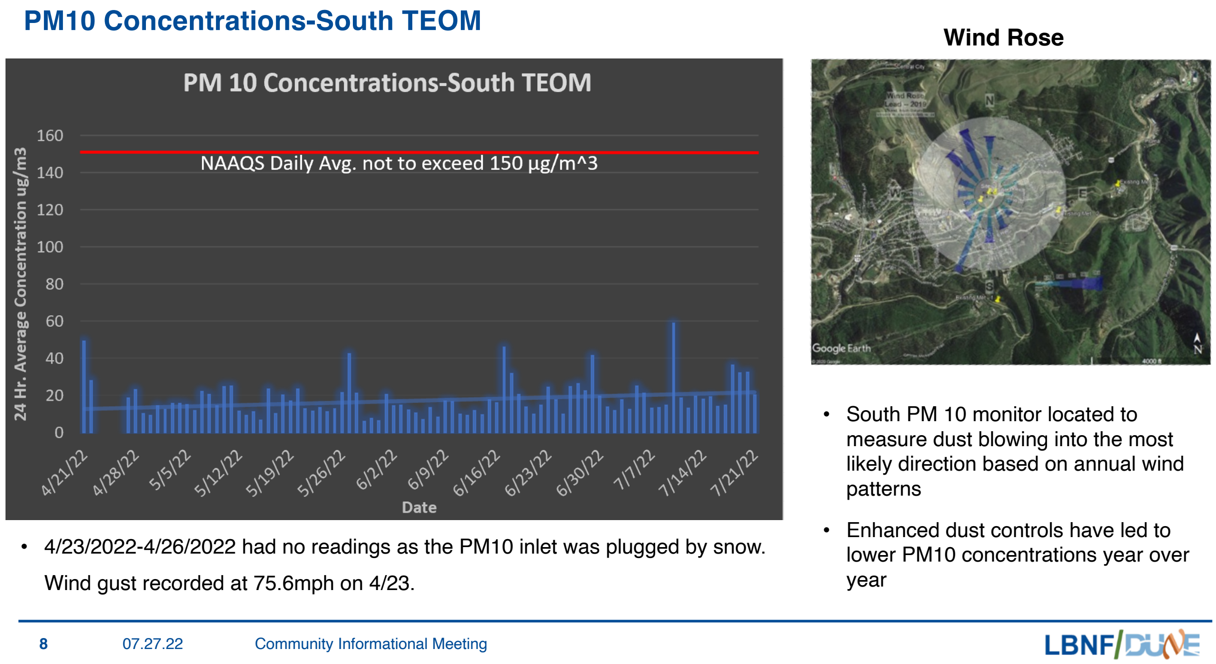


Ambient Air Monitoring Program

- PM10 is one of (6) Criteria Air Pollutants the EPA has identified as potentially leading to health impacts
- This standard is the most conservative and assumes a person would be impacted 24hours a day
- Respec performed the EPA's (6) day ambient air sampling methodology per RFPS–0202–141(Tisch PM10 and TSP Samplers)
- Sampling Methodology promulgated in the Federal Register / Vol. 67, No. 63 / Tuesday, April 2, 2002

Impacts vs. NAAQS Standards

Figure 13: PM$_{10}$ Monitoring (April-July 2022)



PM10 Concentrations-South TEOM

- 4/23/2022-4/26/2022 had no readings as the PM10 inlet was plugged by snow. Wind gust recorded at 75.6mph on 4/23.

- South PM 10 monitor located to measure dust blowing into the most likely direction based on annual wind patterns
- Enhanced dust controls have led to lower PM10 concentrations year over year

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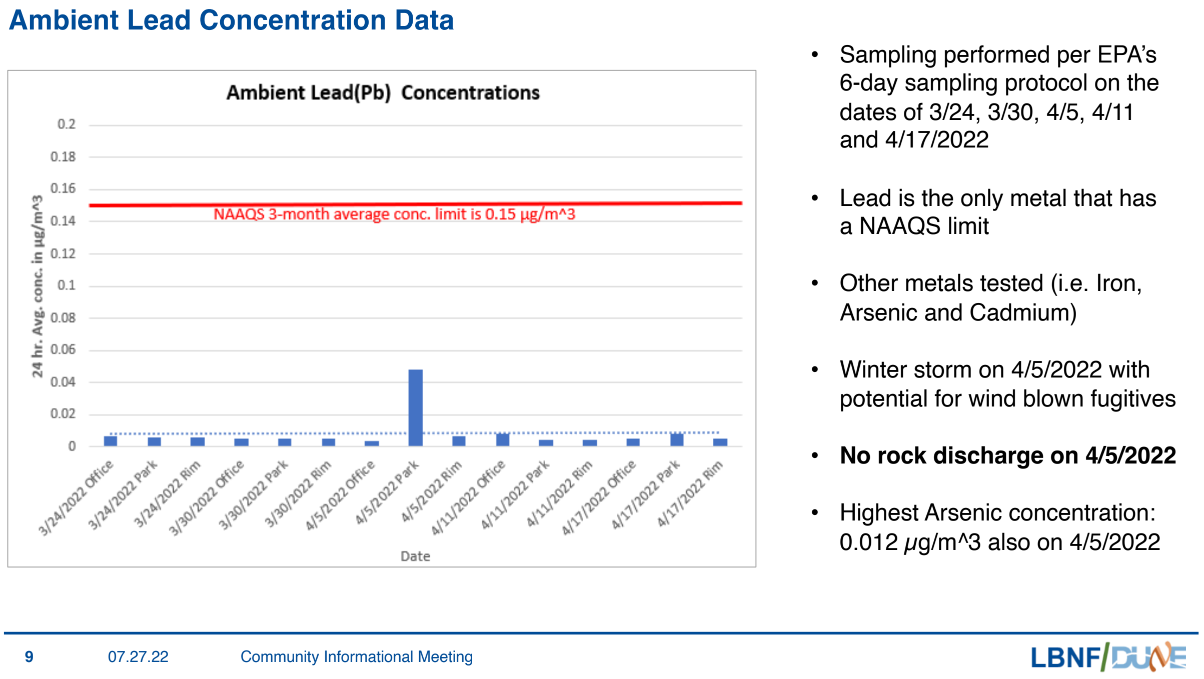
Figure 14 presents the measure ambient lead (Pb) concentrations. The measured Pb air concentrations are extremely low and well below health protective NAAQS.

Figure 14: Ambient Air Lead Concentration Data



Ambient Lead Concentration Data

- Sampling performed per EPA's 6-day sampling protocol on the dates of 3/24, 3/30, 4/5, 4/11 and 4/17/2022
- Lead is the only metal that has a NAAQS limit
- Other metals tested (i.e. Iron, Arsenic and Cadmium)
- Winter storm on 4/5/2022 with potential for wind blown fugitives
- **No rock discharge on 4/5/2022**
- Highest Arsenic concentration: 0.012 *µ*g/m^3 also on 4/5/2022

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Overall, the ambient air monitoring data for PM and metals (Pb) illustrate that concentrations are low and well below health protective NAAQS.

9.0 Screening Risk Assessment for crystalline silica

Community members raised concerns regarding potential exposures to crystalline silica associated with LBNF excavation activities. Hence, the LBNF team commissioned a variety of studies performed by RESPEC[6] (and their subcontractor the South Dakota School of Mines) that included direct air monitoring, optical imagery, X-ray diffraction and scanning electron microscopy. The RESPEC report was issued in July 2022 prior to the 27 July community meeting in Lead SD. NewFields analyzed the RESPEC report and utilized RESPEC's findings in our analysis.

9.1 Silica Effects on Human

The human health effects of crystalline exposure are well known (OEHHA 2005). Inhalation of crystalline silica initially can cause respiratory irritation and an inflammatory reaction in the lungs. Acute exposures to high concentrations cause cough, shortness of breath, and pulmonary alveolar lipoproteinosis (acute silicosis). After chronic but lower workplace exposures to silica for *six to sixteen years*, the small airways become obstructed as measured by pulmonary function tests, i.e., silicosis

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[6] RESPEC July 2022 "Dust Measurements at the Conveyor Discharge Location in Lead, South Dakota"

can also result from chronic (long-term) exposure. As opposed to work related silicosis, “environmental silicosis” is extremely uncommon but has been reported in locations that have significant dust storms associated with free silica in the 60-70% range (OEHHA, 2005).

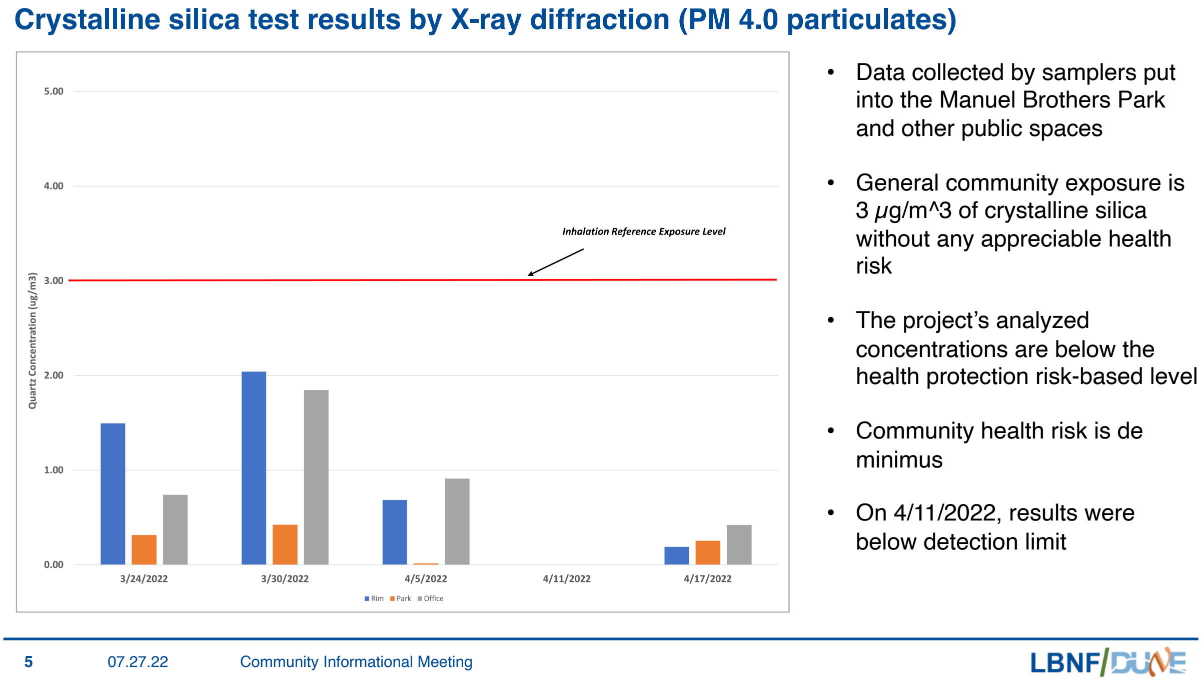
Silica has been classified as a known human carcinogen by international and US health agencies because of an observed increase in lung cancers in occupationally exposed workers. There is, however, a large body of evidence that indicates that lung cancer attributed to silica occurs only after repeated exposure leading to silicosis. While some controversy remains, state health agencies, i.e., California (2005) and Minnesota (2013), have determined that if exposure to silica at size <4 um are maintained at levels below those that result in silicosis the likelihood of increased risk of developing lung cancer is minimal. Both California and Minnesota have published risk based chronic exposure levels that would be protective for chronic general community exposure. The chronic inhalation reference exposure level is 3ug/m^3 for particles <4 um. NewFields has used the California/Minnesota chronic reference exposure level of 3 ug/m^3 as a health protective risk-based screening value that would be compared against the actual measured/calculated fine particle size air crystalline concentration.

In the April community meeting, NewFields noted that if all of the measured LBNF PM$_{2.5}$ were crystalline silica it would still not pose a significant health hazard as the PM$_{2.5}$ levels are consistently below 3 ug/m^3 and exposure is not continuous nor expected to occur for the number of years need to produce a risk of silicosis. The point of the RESPEC study was to provide the objective data needed to perform a more refined crystalline silica analysis.

Figure 15 provides a summary of the air monitoring results for five measurement periods in April 2022. The quartz silica concentration for the fine fraction was calculated using data provided in the RESPEC report. The quartz silica concentration for fine PM was calculated with the quartz standard concentration of each PM$_{10}$ filter multiply by the weigh percentage of PM$_{2.5}$. The dominant form of silica was crystalline rather than amorphous.

As illustrated in Figure 15, the objective data indicated that crystalline quartz levels were well below a 3 ug/m^3 risk-based screening level. **The actual exposure-dose to any individual would be substantially lower as there is not continuous LBNF excavation activity; hence, potential cumulative exposure-dose from LBNF excavation activities to community members would be extremely small and would not pose a health concern.**

Figure 15: Crystalline Silica test results (PM 4 um)



Crystalline silica test results by X-ray diffraction (PM 4.0 particulates)

- Data collected by samplers put into the Manuel Brothers Park and other public spaces
- General community exposure is 3 μg/m^3 of crystalline silica without any appreciable health risk
- The project's analyzed concentrations are below the health protection risk-based level
- Community health risk is de minimus
- On 4/11/2022, results were below detection limit

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10.0 Conclusions

NewFields reviewed the key air and soils measurement data related to LBNF excavation activities. A screening level human health risk assessment was performed for key chemical constituents of the LBNF excavation materials. The risk analysis demonstrates that community residents were not exposed to concentrations of excavation materials that would have produced significant short-term or intermediate health risks. While monitoring has not yet continued for 1 year (chronic duration of exposure), based on the current available data, the likelihood of significant chronic exposure is minimal assuming that exposure conditions continue at the current level.

NewFields does believe that continuing the current air monitoring system is prudent as it will (i) allow for objective measurement of exposures and (ii) provide reassurance for residents that the current LBNF excavation practices are not generating significant health risks to the community.

11.0 References

Agency for Toxic Substances and Disease Registry (ATSDR) (2005). Public Health Assessment Guidance Manual (Update).

Becker, C.E. (2001). Foreword. In *Clinical Environmental Health and Toxic Exposures*, 2nd, edited by J.B. Sullivan and G.R. Krieger. Lippinicott Williams & Wilkins.

Belson, M.G., Schier, J.G., and Patel, M.M. (2005). Case definitions for chemical poisoning. *Morb Mortal Weekly Rep* **54:**1-24.

California OEHHA, (2005) Chronic Toxicity Summary. Silica (Crystalline, Respirable) February 2005

Dalton, P. (1996). Odor perception and beliefs about risk. *Chem Senses* **21:**447-58.

Evangelopoulos, D., Katsouyanni, K., Keogh, R.H., Samoli, E., Schwartz, J., Barratt, B., Zhang, H., and Walton, H. (2020). PM2. 5 and NO2 exposure errors using proxy measures, including derived personal exposure from outdoor sources: A systematic review and meta-analysis. *Environ Int* **137:**105500.

Goldstein, B.D., and Gallo, M.A. (2001). Pare's law: the second law of toxicology. *Toxicol Sci* **60:**194-5.

Harrison, R., Delgado-Saborit, J., Baker, S., Aquilina, N., Meddings, C., Harrad, S., Matthews, I., Vardoulakis, S., and Anderson, H. (2009). Measurement and Modeling of Exposure to Selected Air Toxics for Health Effects Studies and Verification by Biomarkers. Research report (Health Effects Institute). 143.

Hodas, N., Loh, M., Shin, H.M., Li, D., Bennett, D., McKone, T.E., Jolliet, O., Weschler, C.J., Jantunen, M., and Lioy, P. (2016). Indoor inhalation intake fractions of fine particulate matter: review of influencing factors. *Indoor Air* **26:**836-856.

Klaassen, C.D. (2019). *Casarett and Doull's Toxicology: The Basic Science of Poisons*. 9th: McGraw-Hill Education.

Klepeis, N.E., Nelson, W.C., Ott, W.R., Robinson, J.P., Tsang, A.M., Switzer, P., Behar, J.V., Hern, S.C., and Engelmann, W.H. (2001). The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *J Expo Anal Environ Epidemiol* **11:**231-252.

Mayer, S. 2019. The risk behind the risk—The fine line between raising awareness and creating anxiety. Wiley Online Library.

Meng, Q.Y., Turpin, B.J., Polidori, A., Lee, J.H., Weisel, C., Morandi, M., Colome, S., Stock, T., Winer, A., and Zhang, J. (2005). $PM_{2.5}$ of ambient origin: estimates and exposure errors relevant to PM epidemiology. *Environ Sci Technol* **39:**5105-5112.

Minnesota Department of Health , (2013) Silica, Crystalline (respirable PM4) July 2013

National Research Council (NRC) (1983). *Risk Assessment in the Federal Government: Managing the Process*. Washington, D.C.: The National Academies Press.

National Research Council (NRC) (1991a). *Environmental Epidemiology. Volume 1, Public Health and Hazardous Waste Sites*. Washington, D.C.: The National Academies Press.

National Research Council (NRC) (1991b). *Human Exposure Assessment for Airborne Pollutants: Advances and Opportunities*. Washington, D.C.: The National Academies Press.

Page, L.A., Petrie, K.J., and Wessely, S.C. (2006). Psychosocial responses to environmental incidents: a review and a proposed typology. *J Psychosom Res* **60:**413-422.

Rozman, K.K., and Doull, J. (2000). Dose and time as variables of toxicity. *Toxicology* **144:**169-178.

Shusterman, D. (1992). Critical review: the health significance of environmental odor pollution. *Arch Environ Health* **47:**76-87.

Su, F.C., Mukherjee, B., and Batterman, S. (2013). Determinants of personal, indoor and outdoor VOC concentrations: an analysis of the RIOPA data. *Environ Res* **126:**192-203.

Sullivan, J.B., and Krieger, G.R., eds. (2001). *Clinical Environmental Health and Toxic Exposures*. 2nd ed: Lippinicott Williams & Wilkins.

U.S. Environmental Protection Agency (2014). Framework for Human Health Risk Assessment to Inform Decision Making. Washington, D.C.: Risk Assessment Forum. Report No.: EPA/100/R-14/001.

U.S. Environmental Protection Agency (EPA) (1989). Risk Assessment Guidance for Superfund Volume I, Human Health Evaluation Manual (Part A). Washington, D.C.: Office of Emergency and Remedial Response. Report No.: EPA/540/1-89/002.

U.S. Environmental Protection Agency (EPA) (2019). Integrated Science Assessment for Particulate Matter. Research Triangle Park, NC: Center for Public Health and Environmental Assessment and Office of Research and Development. Report No.: EPA/600/R-19/188.

U.S. Environmental Protection Agency (EPA) (2022). Supplement to the 2019 Integrated Science Assessment for Particulate Matter. Research Triangle Park, NC: Center for Public Health and Environmental Assessment and Office of Research and Development. Report No.: EPA/600/R-22/028.

Winters, W., Devriese, S., Van Diest, I., Nemery, B., Veulemans, H., Eelen, P., Van de Woestijne, K., and Van den Bergh, O. (2003). Media warnings about environmental pollution facilitate the acquisition of symptoms in response to chemical substances. *Psychosom Med* **65:**332-8.

Witthöft, M., Freitag, I., Nußbaum, C., Bräscher, A.-K., Jasper, F., Bailer, J., and Rubin, G.J. (2018). On the origin of worries about modern health hazards: Experimental evidence for a conjoint influence of media reports and personality traits. *Psychology & health* **33:**361-380.

World Health Organization (WHO) (1999). Principles for the Assessment of Risks to Human Health from Exposure to Chemicals. World Health Organization. Geneva. EHC No. 210.

World Health Organization (WHO) (2000). Human Exposure Assessment. World Health Organization. Geneva. Environmental Health Criteria 214.

World Health Organization (WHO) (2010). WHO Human Health Risk Assessment Toolkit: Chemical Hazards.