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NATURALLY OCCURRING ASBESTOS IN AN OUTDOOR SETTING

Naturally Occurring Asbestos in an Outdoor Setting

Primary inquiry: Heavy rains caused a river to flood and overflow its banks. Soil containing naturally occurring asbestos (NOA) was deposited onto the surrounding land. This land is used for farming, and includes the backyards of private dwellings and areas used for various recreational pursuits. What are the potential public health risks from exposure to NOA in these outdoor settings? What methods are available for sampling airborne NOA in outdoor settings?

Background

Asbestos is a naturally occurring silicate mineral comprising fibres of various-sized dimensions. Asbestos minerals are divided into two groups – amphibole and serpentine[1] – comprised of six types of fibres. There are five amphibole fibres – amosite, crocidolite, actinolite, tremolite, and anthophyllite. Chrysotile, known as white asbestos, is the only serpentine fibre, and accounts for more than 90% of asbestos production in the world.[1] Until recently, Canada was one of the world's largest asbestos exporters.[2]

Asbestos is used in industrial products, such as building and insulation materials, and auto parts, due to its heat resistance, insulation characteristics, and tensile strength.[3] Asbestiform fibres occur naturally in soils and rocks, and are known as naturally occurring asbestos, or NOA. However, NOA does not refer to commercially processed materials.[4] NOA is found in three rock types – serpentine, altered ultramafic, and some mafic rocks. NOA is formed from geological processes involving the

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fracturing and faulting of these rocks, combined with increased temperature and pressure, and the presence of water.[5] Deposits of NOA can be found across Canada, and are concentrated close to the west and east coasts in seismically active areas.[6] When these rocks are broken apart or weathered, NOA can be released into the environment from existing deposits. A potential health risk may arise when NOA particles become airborne close to where people are present.

To assess risks to public health from outdoor exposure to NOA, and methods to measure airborne NOA outdoors, a rapid academic literature search and an internet search for public health or grey literature documents applying to naturally occurring asbestos was carried out. An early version of this document was reviewed by two NOA experts at the US EPA.

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Methods for the Internet Searches

The literature scan conducted to obtain this information was not limited to a specific date parameter. Literature was identified through UBC EbscoHost, which provides access to Medline, CINAHL, and Biomedical Reference Collection; Web of Science, Google Scholar, and Google. Terms used in the search included variants and Boolean operator combinations of:

- asbestos AND
- (soil OR sediment OR air* OR outdoor OR naturally-occurring OR water)
- AND (determin* OR estimat* OR monitor OR measur* OR surveillance)
- (protocol OR guidance OR guideline OR regulation OR operation OR standard OR legislation)
- (risk OR assessment OR mitigation OR management).

Thirty publications/websites/grey literature documents were selected for their relevance to this inquiry. Specific organizational websites, e.g., the US Environmental Protection Agency (US EPA), who have conducted extensive work on this topic, were targeted. Information provided below pertains specifically to NOA, not to industrially processed asbestos.

1. Potential public health risks from exposure to NOA in outdoor settings

Asbestos in all its forms, i.e., both in man-made materials and NOA, has been classified as Group 1, "carcinogenic to humans," by the World Health Organization's International Agency for Research on Cancer.[7] Asbestos exposure is associated with lung cancer, laryngopharyngeal cancer, and mesothelioma, a rare form of cancer specifically caused by asbestos exposure.[4] Asbestosis, which is inflammation and collagen formation in the lung tissue, is also directly linked to asbestos exposure. Other respiratory symptoms have been observed in children exposed to NOA, especially pleuritic chest pains.[8] Nonetheless, exposure to asbestos in any setting should be minimized as there is no known safe exposure limit.[9] Cancers or other symptoms developing due to asbestos exposure typically have a long latency period,[7] i.e., the time of first exposure until the discovery of the illness.

TOXICITY

Asbestos toxicity is determined by three key factors: fibre concentration; fibre dimensions (length and width); and durability in the lungs.[10] For US EPA risk assessment purposes, asbestiform fibres longer than 5µm with a width between 0.25 and 3 µm, inclusive, and an aspect ratio greater than 3:1, are assessed for cancer potency.[11] Macrophages (large white blood cells formed in response to infection) that normally remove particles from the lungs cannot engulf fibers with lengths greater than the macrophage diameter. In the process of trying to engulf the asbestiform fibres, the macrophages themselves die, releasing inflammatory cytokines into the lungs, initiating tissue inflammation.[12] Thus, longer fibers likely remain in the lungs for an extended period of time and cause more damage.[4]

EXPOSURE TO NOA

Natural phenomena that release NOA deposits can include, e.g., rock or landslides washing sediments into rivers, subsequent low river levels, river dredging, or floods depositing material on adjacent land. Asbestos fibres must be released from their source material and become airborne before they present a hazard.[3] Once airborne, inhalation is considered the primary route of exposure.[13] Emission of NOA from these deposits can be influenced by different fibre factors, e.g., the type of asbestiform fibres present (e.g., chrysotile, or amphibole fibres); a greater ability to crumble (friability); and a higher concentration of asbestos fibres present.

Site-specific factors impacting exposure include soil characteristics, such as soil composition and humidity; local weather conditions; the extent (depth and breadth) of contamination in the soil; and type and duration of activities conducted in the area.[4,13] With increased humidity, the amount of NOA released from the soil is reduced, while dry, windy weather can increase the amount of NOA available for inhalation. A person's breathing rate, their height above the soil, the length of time a dust-creating activity occurs, and how the activity is conducted all impact exposure.[13] Additionally, NOA fibres and soil can cling to clothing and shoes, pet fur and paws, and be tracked indoors, creating an indoor air issue and exposing other household members.

Once soil containing NOA has been deposited, asbestiform fibres can be stirred up by common outdoor activities that generate dust, such as walking, jogging, playing, gardening, yard work, dirt or quad biking, or driving on unpaved roads.[14,15] Information on how to reduce exposure to NOA has been extensively covered elsewhere.[4,16] Some suggestions include, e.g., conducting activities (jogging, walking, biking) in areas free from NOA; paving driveways or walkways; covering gardens and yards with NOA-free soil or vegetation, and watering gardens or yards before digging; reducing driving speed on unpaved roads; and closing windows and doors on windy days.[4]

RISK ASSESSMENT

Risk assessments conducted by the US EPA (2005, 2007a, 2010a, 2011)[11,14,15,17,18] used activity-based sampling and stationary sampling, focussing on sites where NOA is a known issue. The conclusion was that when conducting any activities at a site that might disturb NOA (e.g., walking, jogging, riding dirt bikes, conducting farm work, children playing, outdoor sport games, gardening, etc.), elevated levels of asbestos fibres were found in the breathing zone. Stationary air samples that provided background NOA concentration were typically one order of magnitude lower (i.e., 10 times lower) compared to activity-based sampling.[11] Given the shorter height of children, they are more at risk of inhalation exposure because their breathing zone is closer to the ground, and they typically have higher respiration rates compared to adults. Further, the younger the age at which exposure occurs, the greater the lifetime risk for cancer[14] because the exposed individual has more time to develop disease, which typically has a long latency period.[7]

The US EPA "considers cancer risks less than 1×10^{-6} (1 per one million) as *de minimis*, while cancer risks greater than 1×10^{-4} (1 per 10,000) generally require some level of response."[17] Results from sampling are specific to the activities and sites where they were conducted. Examples of findings from activity-based sampling are as follows:

- daily farm work, e.g., raking, hauling, loading of NOA-contaminated soil, conducted for 8 hours a day over 25 years, resulted in the highest exposure risk ($1x10^{-4}$ chance of developing disease);
- most other activities, such as children's play or other recreational activities, had a $1x10^{-6}$ risk of developing disease.[14]

There is a lot of uncertainty when conducting risk assessments. For example, differences in risk would occur with exposure to NOA of certain fibre dimensions, different activities carried out at different intensities for different lengths of time, and the specific concentration of NOA in the soil. Regardless, this extensive work shows that an elevated level of risk arises from conducting activities that raise NOA-containing dust.

OTHER EXAMPLES OF STUDIES ON HEALTH RISKS FROM NOA EXPOSURE

- A case-control study examining residential proximity to NOA in California and malignant mesothelioma risk showed that living closer to NOA sources was significantly associated with an increased risk of malignant mesothelioma. However, a limitation of this study was incomplete information on lifetime occupational asbestos exposure, and lack of lifetime information on residential history.[19]
- Swartjes & Tromp (2008)[13] used a worst case scenario (dry air, a leaf blower, and loose asbestos fibres) to examine health risks from asbestiform exposure. The airborne fibre concentration decreased rapidly with distance from the disturbance, and by 100 m from the source was below 1000 fibre equivalents per cubic meter (the "negligible risk" level for a one-year exposure, as detailed in Swartjes & Tromp 2008)[13].
- Bassanese et al. (2008)[20] used dog lungs as a proxy for human lungs in an area where NOA was present. Evidence of an elevated health risk was found based on an increased number of asbestos fibres in dog lungs compared to control dogs from a non-NOA affected area.
- Johnson et al. (2009)[21] examined popular outdoor recreational activities, specifically four-wheel driving, dirt bike use, and ATV use, in a NOA-contaminated area of San Benito County, California. The concentration of asbestos fibres raised by these activities sometimes exceeded the OSHA 30-minute occupational excursion limit of 1.0 asbestos fibres per cubic centimetre in this period. No activity or combination of activities resulted in asbestos exposure that was below the US EPA's acceptable lifetime cancer risk of 10^{-6}. Consequently, this area was closed for further public use. However, recently, a bill was passed to reopen the area for recreational use.[22]
- In an examination of dust, soil, and both indoor and outdoor air in an asbestos mining town in Quebec, Canada, asbestos fibres were found to be elevated in around half of these samples. Over the long term, this exposure posed a 1×10^{-4} risk of developing lung cancer.[23]
- Children's exposure to NOA via digging, gardening, raking, or lawn mowing[24] was significantly associated with an elevated risk of respiratory symptoms in young adulthood, especially pleuritic chest pains.[8]
- A review of off-road vehicle use as an outdoor recreational pursuit in the United States, in areas where NOA occurs, showed that individuals who partake in these activities are at risk of elevated exposure to NOA fibres, and education about the risks should be communicated.[25]

WATER

The US EPA (2009)[26] conducted sampling of surface water (creek and river) known to transport NOA-containing sediments. Chrysotile asbestos fibre concentrations ranging from 363 million fibres per litre, to 1,483 million fibres per litre were found. Use of these waters for agricultural purposes could spread NOA beyond the immediate creek/river area. Further, this surface water is considered unfit for drinking. However, in Canada, no limits are set for asbestos in drinking water because there is "no evidence of adverse health effects from exposure through drinking water."[27]

2. Methods for sampling airborne NOA in outdoor settings

Although various methods exist to sample NOA, the two most commonly used methods for sampling in outdoor settings are activity-based and stationary sampling.

ACTIVITY-BASED SAMPLING

Activity-based sampling (ABS) is a method used whereby specific activities relevant to the area where NOA is present are carried out, e.g., children's play, jogging, walking, biking, gardening, work-related (typically farm-related) activities, to assess the personal exposure to NOA during a specific period of time. During the selected activities, air samples are taken in the breathing zone of those conducting the activities (i.e., approximately 1.5 metres for adults, or a height of 90 cm if investigating what children are exposed to). Results are then used to determine the amount of NOA fibres potentially available for inhalation during a particular activity, compared to what is present in the air at background concentrations.

This type of sampling should be conducted under "worst case scenario" conditions, i.e., when it is dry and windy.[4,13] However, ABS provides only a "snapshot" of potential exposure in one place and time, i.e., results are not generalizable to other sites, and it is labour-intensive. Trained personnel carry out the specified activities for a predesignated amount of time while wearing personal protective equipment, including respirators, and personal sample pumps in their breathing zone. Air samples are collected by pumping air through a filter during each activity. Environmental conditions that could interfere with sampling include strength and direction of wind, activity being carried out, and recent rain fall. Further details for preparing an ABS plan for individual sites is given in the US EPA's (2008)[3] framework for investigating asbestos-contaminated superfund sites.

STATIONARY SAMPLING

A stationary sampler stays fixed in one location[11] and is used to characterize ambient air concentrations.[3] However, personal sample pumps worn during ABS consistently produce "higher and more representative measurements of exposure than stationary air samples in the same vicinity." Stationary air sampling, performed at the same time as ABS, involves the placement of an air sampling pump containing an appropriate filter at a fixed location, near where the activity is occurring, or another suitable location for a specific period of time. The duration of air collection using stationary samplers varies depending on the activity being investigated. For example, when investigating asbestos exposure via daily farm-work activities, a stationary sampler may be run for 8 to 10 hours, to simulate the length of an average work day.[14]

RELEASABLE ASBESTOS FIELD SAMPLER (RAFS)

The RAFS was developed as a less expensive and less labour-intensive alternative sampling method to ABS for use in soil.[28] This machine uses a raking motion to disturb the soil and release any NOA fibres contained within, which are then sucked up by "a gentle airflow" and passed over a filter sampling cassette. Despite asbestos concentrations collected via RAFS versus ABS being highly correlated, concentrations measured by RAFS were "several orders of magnitude higher than the ABS levels under the same conditions."[29] The RAFS is not being further tested or used by the US EPA (Julie Wroble, Toxicologist, US EPA, personal communication).

FLUIDIZED BED ASBESTOS SEGREGATOR (FBAS)

The FBAS has become the more favoured method of testing the amount of respirable asbestos in soils (Julie Wroble, Toxicologist, US EPA, personal communication). The FBAS is a "benchtop instrument used for determining the concentration of mineral fibres that can become airborne if the soil is disturbed."[30] Coupled with transmission electron microscopy (an analytical method), there is "an approximate linear relationship between asbestos concentration in performance evaluation standards (…) and the mean concentration estimated by transmission electron microscopy analysis following preparation by FBAS…."[30]

WATER SAMPLING

Surface water sampling has been conducted by the US EPA (2009)[26] in an area where NOA fibres are carried in water and sediments. Water sampling was conducted using grab samples from as near to the centre of the river as possible, using an extendable arm. Mid-stream water samples were taken first, prior to any riverbank sampling or ABS occurring, to prevent accidental cross-contamination.[26]

Summary

Public health risks from exposure to asbestos, a Group 1 carcinogen, are well known. However, the risk to human health from exposure to NOA in an outdoor setting is not straightforward and depends on the type of activity being conducted, for how long and how frequently the activity occurs, the type and concentration of asbestos present in the soil, soil type, weather conditions, age at first exposure, etc. The US EPA risk assessments found that the risks for cancer to the general public seldom exceed the *de minimis* of 1×10^{-6}. However, exposure to asbestos at any level is not acceptable and should be kept as low as reasonably achievable (ALARA principle).

It is difficult to know if NOA is present, thus testing of the media of concern to determine concentration of NOA must be carried out to determine what areas to conduct sampling in and what sampling strategy to use. When investigating NOA in outdoor settings, activity-based sampling and stationary sampling are the two most common methods and are typically used in combination. However, no single method reliably predicts the concentration of asbestos fibres in the air based on the concentration in the soil; hence, site sampling must be conducted.[3] Generating reproducible results in soil is difficult.[30] There are also many variables to be considered before conducting sampling, such as changing weather conditions, the type of activities commonly carried out in the affected area, and the population (adult or children) who are most likely to be exposed.

To avoid unnecessary exposure, public areas may be closed to certain activities; remediation work/soil removal may be carried out by qualified professionals; people can reduce the amount of time spent in NOA areas; and other precautions can be taken as outlined by the US EPA.[4,16]

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