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Wellness Webinars

Radiation Safety Institute of Canada
Institut de radioprotection du Canada

June 10, 2021

Mining – All About Airborne Hazards

Followed by Salem Dance Co.

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Webinar Functionality

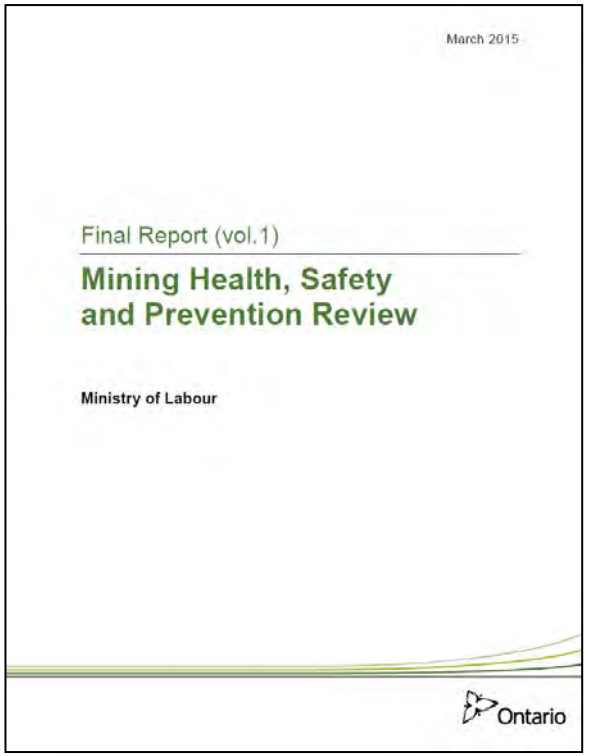
- Audio and video
  - Will be from the presenters only
  - Use computer or telephone (call in)
  - Computer seems to give the best sound quality
- Use the “Chat” feature to enter comments
- Use the “Questions” feature to ask questions
- Posted on webinar page
  - Video, Q&A answers, copy of the slides
- Follow up email will be sent
  - Topics covered, time of attendance
- It may be possible to change your Zoom view if the controls are hiding the closed captioning.

Overview

- Mining Health and Safety Hazards
  - Coal Dust
  - Diesel exhaust
  - Metalliferous mine dust
  - Nitrogen dioxide
  - Radon
  - Silica
  - Sulfur dioxide
  - Other mine gases
- Health Effects
  - Respiratory system
  - Particle size and lung entry
  - Lung disease related to mining
  - Cancer
- Regulation
- Detection
- Mitigation

Project Origins

- Mining Health, Safety and Prevention Review
  - Ontario Ministry of Labour
  - Review launched 2014 January
  - Intensive study into wide range of issues affecting health and safety in underground mines in Ontario
  - 6 aspects reviewed, including health and safety hazards

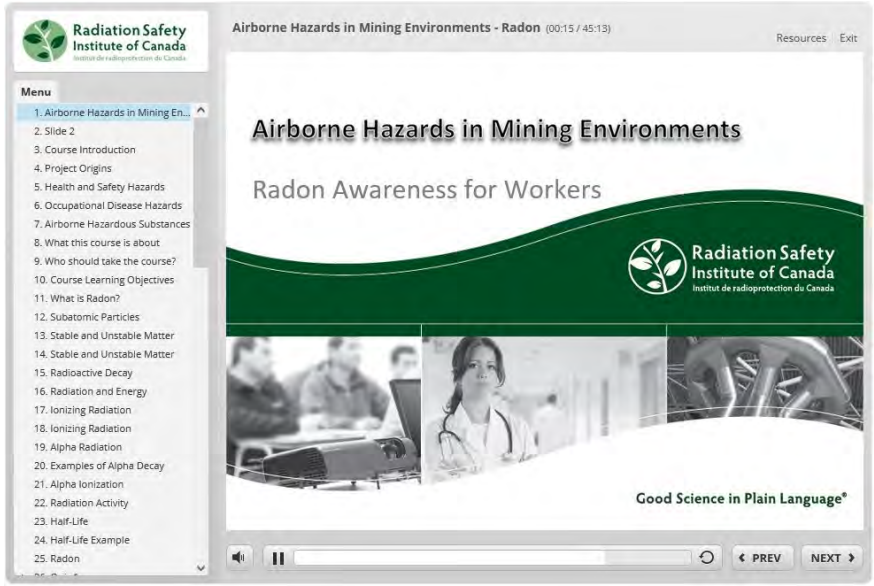


Health and Safety Hazards

- Mining Sector Risk Assessment found 5 key hazards giving the most risk to health & safety:
  - Ground control, including risk associated with seismicity and rock bursts
  - **Occupational disease focusing particularly on exposure to airborne hazards**
  - Water management, particularly problematic water in ore and waste passages
  - Mobile equipment and risk of collisions
  - Worker fatigue

Airborne Hazardous Substances

- Priority hazards review identified:
  - Silica
  - Nitrogen dioxide
  - Diesel particulate matter
  - Sulphur dioxide
  - Radon gas
- Additional hazards in webinar
  - Coal dust
  - Metalliferous mine dust
  - Other mine gases



https://onlinelearning.radiationsafety.ca

Coal Dust

US National Institute for Occupational Safety and Health, Public domain

- Sedimentary rock
- Fossil fuel
- Contains carbon
- Burned for heat and electricity generation

The Use of Diesel in Underground Mining

Since their introduction into mining operations in the mid-1960s, diesel-equipment has become increasingly employed and recognized as the workhorse in mining

Diesel Particulate Matter/Soot

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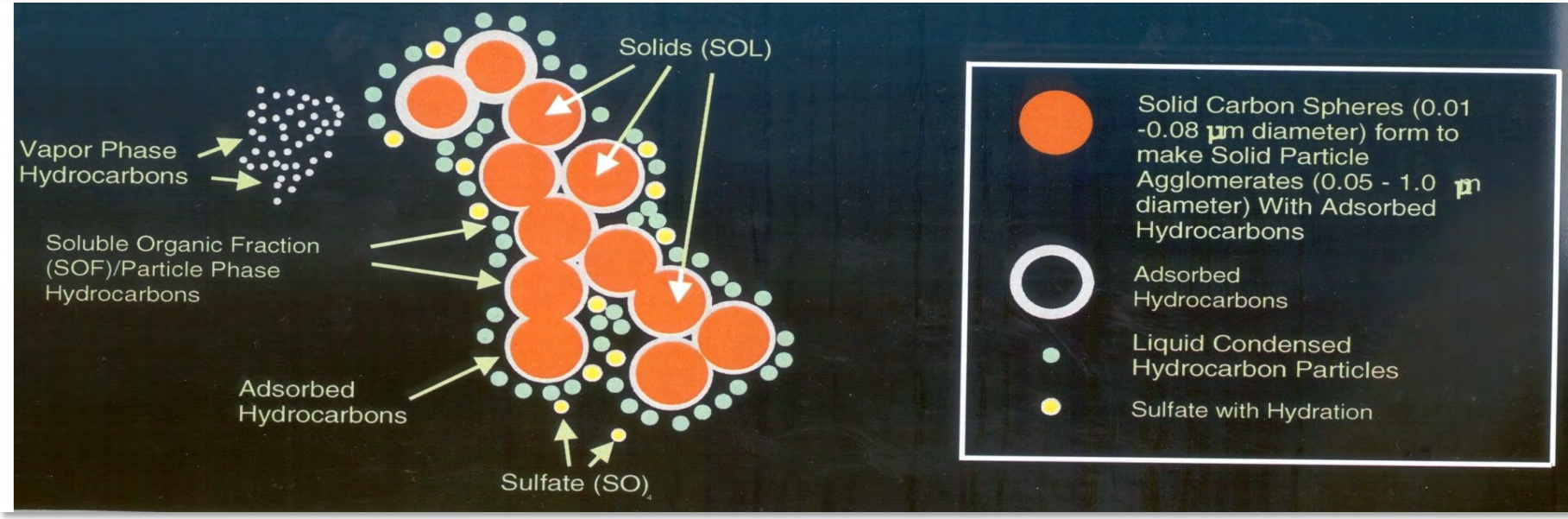


- Most of the mass is composed of carbonaceous agglomerates
- The average diameter of the above "diesel exhaust cluster"/diesel "soot " is about **0.15 micron** (µm)
- One micron is one-millionth of a meter
- There are ***25,400 microns*** **in one inch**, or 10,000 in one cm.

Diesel Exhaust: A Critical Analysis of Emissions, Exposure, and Health Effects, Kathleen Nauss, Health Effects Institute (HEI) (http://pubs.healtheffects.org/getfile.php?u=354)

Metalliferous Mine Dust

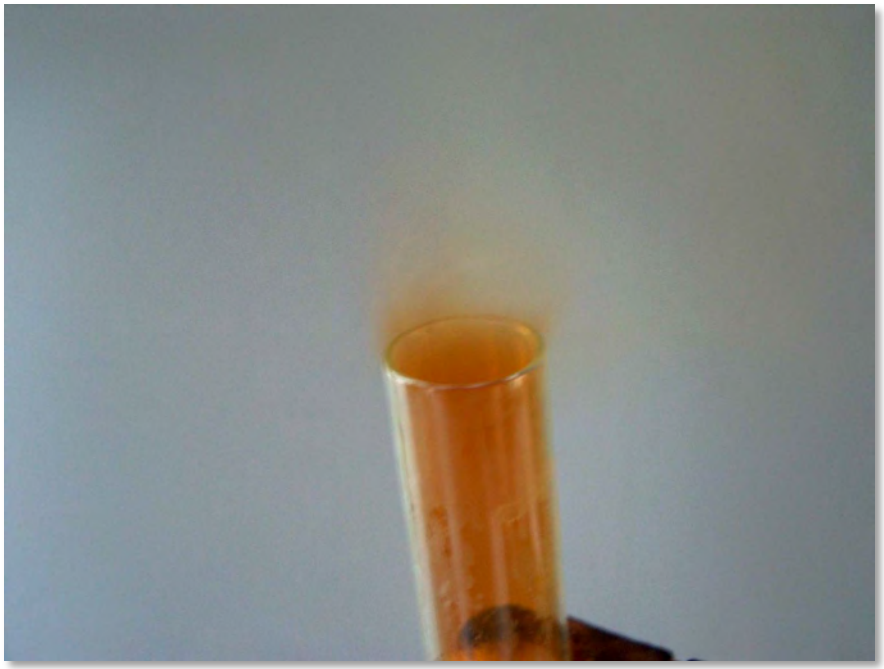
James St. John, CC BY 2.0

- Arsenic
- Cadmium
- Cobalt
- Chromium
- Copper
- Iron
- Mercury
- Nickel
- Lead
- Uranium
- Zinc

See https://doi.org/10.1007/s40726-019-00108-5 for more information.

Nitrogen Dixoide

- Diesel exhaust
- Blasting
- Toxic
- Difficult to detect with senses
- Temperature determines state and color
  - Colourless solid
  - Yellow liquid
  - Reddish-brown gas
- Acidic



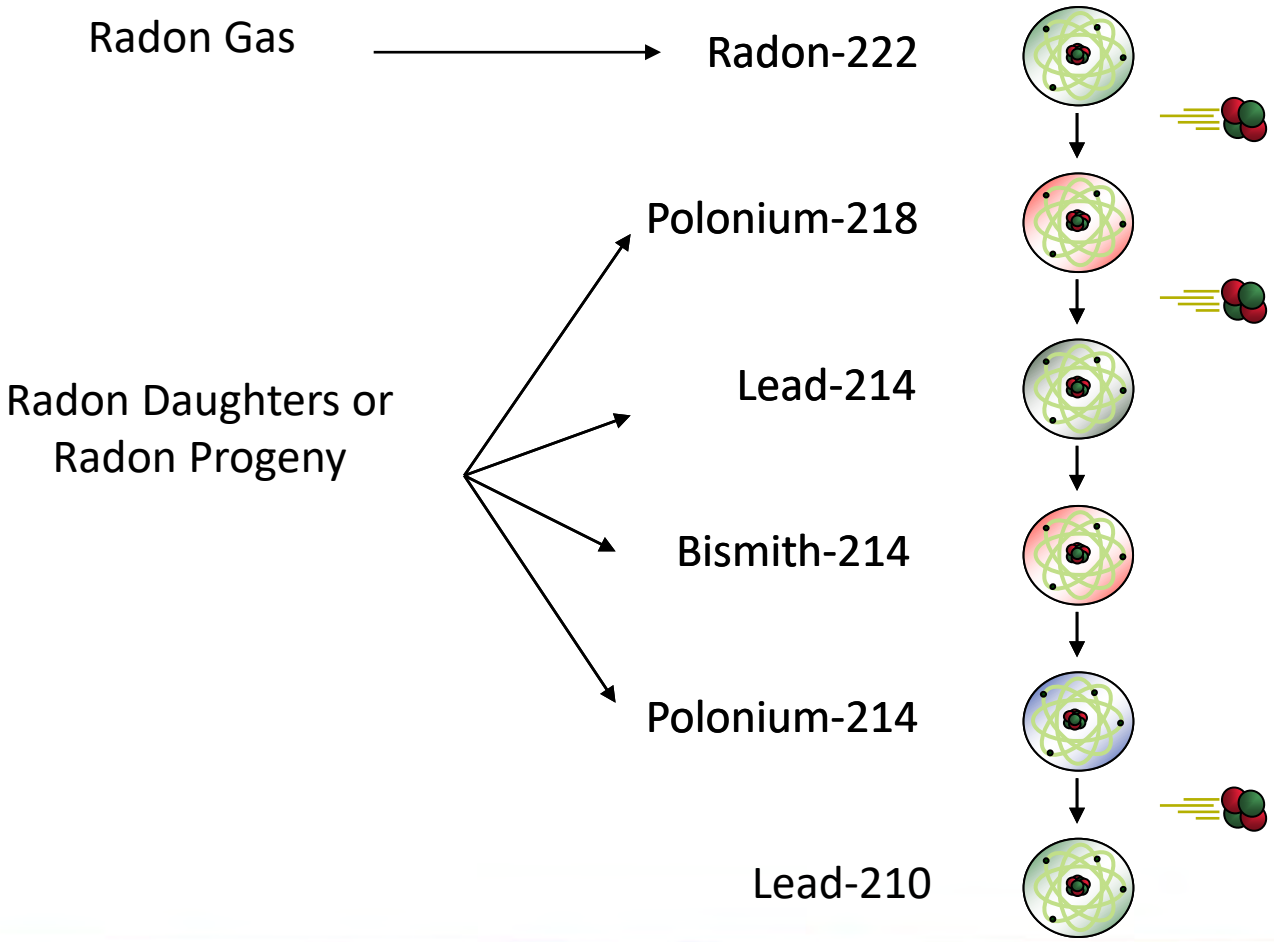
Radon

- Radon is an odourless, colourless radioactive gas that is formed naturally by the breakdown of uranium in soil, rock and water
  - Alpha emitter
  - Half life of 3.8 days
  - Inert gas (non-reactive)
  - Water soluble
  - More dense than air
  - Accumulates in enclosed spaces

Radon Progeny

- Radon progeny are the radioactive daughters of radon gas
  - For health-effects, only the short-lived daughters are considered
  - Are solids
  - Attach to dust particles in the environment
  - When inhaled, tend to remain in the lungs
  - Two are high-energy emitters

Radon-222 and Short-Lived Daughters



Radon Sources

- How does radon enter a mine?
  - Dissolves in underground water when the water passes through a radon source (rocks or soil with some uranium)
  - Easily escapes from the water into the air
    - More radon escapes from water into the air when the water is agitated (splashing, spraying, etc.)
    - Ease of radon transfer to air depends on water and air temperature, the degree of agitation

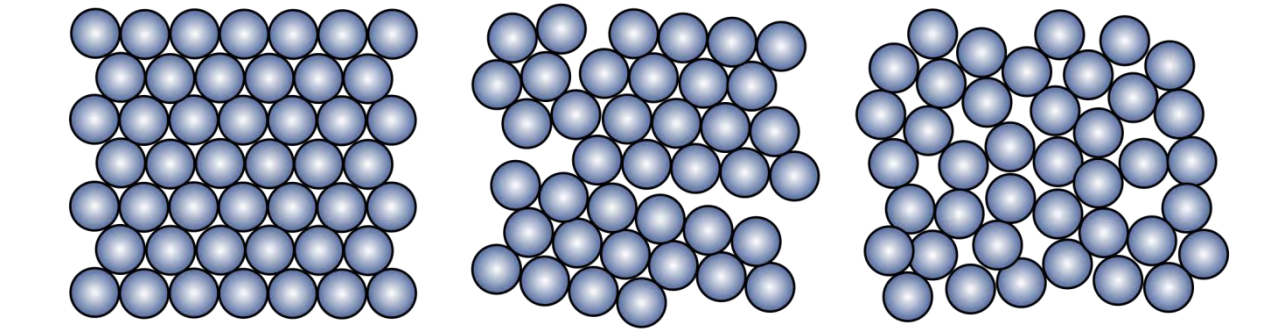
Hollingsworth John and Karen, U.S. Fish and Wildlife Service, Public domain

Mine Radon Concentration

- Radon concentration in mine air is affected by
  - Uranium concentration in nearby rock
  - Rock characteristics
  - Radon concentration in water, and amount of water entering the mine
  - Ventilation in the mine
  - Environmental conditions
    - Temperature
    - Barometric pressure
    - Humidity

What is Silica?

- **SiO2 = silicon dioxide = free silica**
  - About 1/10 of earth's crust
  - Crystalline silica is most common form
  - Amorphous (non-crystalline) silica exists but is less common and much less hazardous



Monocrystalline | Polycrystalline | Amorphous

Crystalline Silica

- Three forms of crystalline silica:
  - Quartz
  - Cristobalite
  - Tridymite
- Quartz is by far most common
- All forms can cause silicosis

James St. John, CC BY 2.0

What are Silicates?

Aram Dulyan (User:Aramgutang), Public domain

- Names “silica” and “silicates” can be confusing
- Silicates are minerals made from silica chemically combined with other elements such as aluminum, calcium, and iron
- Most are less dangerous to health than quartz
  - Some are very dangerous – e.g., asbestos

Where is Crystalline Silica Found?

- All soils contain some quartz
- Quartz is abundant in all 3 types of rock:
  - Igneous rock
  - Sedimentary rock
  - Metamorphic rock
- As crystalline silica (quartz) is such a common component in rocks, mine workers are potentially exposed to it in airborne dust when rock is cut, drilled, crushed, and transported

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Where is Crystalline Silica Found in Mining?

- High concentrations
  - Uranium ores (up to 70% silica)
- Medium concentrations
  - Gold and copper (15-35% silica)
- Low concentrations
  - Nickel and iron ores (under 10% silica)
- Low concentrations
  - Coal, limestone
- Any material with more than 1% silica is considered hazardous

Sizes of Silica

>10 mm (>1 cm):	1 – 10 mm	0.1 – 1 mm	0.01 – 0.1 mm (10 – 100 microns)
Stones	Pebbles	Sand	Silica Flour (Powder)

< 0.01 mm (< 10 microns)	< 0.0001 mm (< 0.1 micron)
Respirable Range	Nanoparticles

Respirable particles are too small to see by eye

Uses of Silica

- High quality quartz crystals
  - Gemstones (e.g., amethyst)
  - Precision oscillators (quartz watches)
- Silica flour
  - Thickener in paints and adhesives
- Silica Sand
  - Glass making
  - Foundry moulds
  - Petroleum recovery by “fracking” (hydraulic fracturing)
  - Making concrete and bricks

Sulfur Dioxide

- Burning fuel with high sulfur content
- Extracting metal from ore
- Dissolves in water
  - Sulfuric acid

Tony Webster, CC BY 2.0

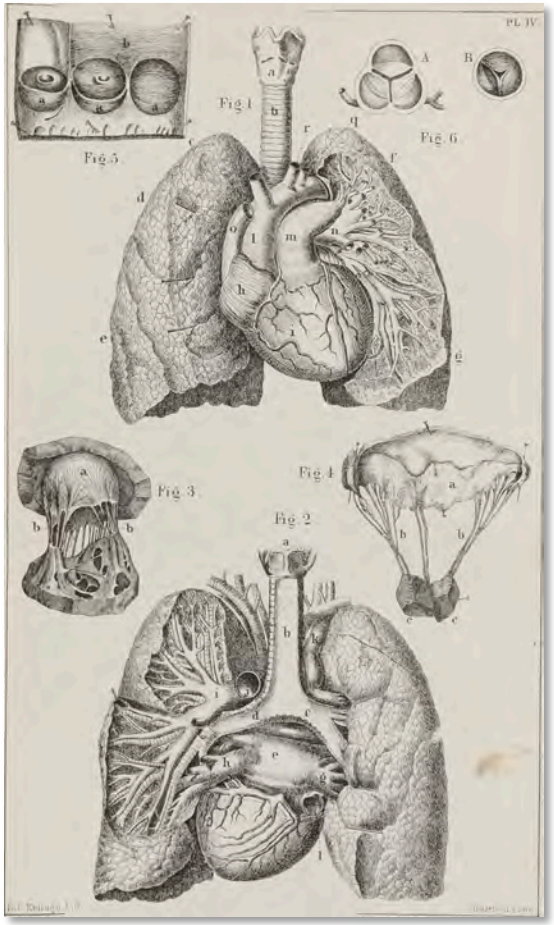
Other Mine Gases

Gas	Source	Health Hazard
Carbon Dioxide (CO_2)	Oxide of coal blasting, mine fires, timber decay, diesel engines, breathing	Respiratory/cardiovascular in high concentrations
Methane (CH_4)	Coal & rock strata, carbonaceous shale, rotting mine timbers	Asphyxiant in higher concentrations due to oxygen displacement; explosive
Carbon Monoxide (CO)	Incomplete combustion, mine fires, explosions, blasting, diesel engines	Highly toxic to cardiovascular system even in low concentrations; explosive
Hydrogen (H_2)	Charging batteries, mine fires, explosions, strong acids on metal	Asphyxiant in higher concentrations due to oxygen displacement; explosive
Hydrogen Sulfide (H_2S)	Explosions, mine fires, blasting	Highly toxic to respiratory system even in low concentrations; explosive
Acetylene (C_2H_2)	Formed when methane is burned, welding	Asphyxiant in higher concentrations due to oxygen displacement; explosive

Data compiled from https://miningquiz.com, which is maintained by the United States Mine Rescue Association.

Respiratory System

- Structures include nose, mouth, throat, voice box, trachea, lungs, bronchi, bronchioles, alveoli
- Alveoli surrounded by capilliaries, site of gas exchange
- Lungs are not empty. Surface area ~50 to 75 m^2
- Cilia sweep debris and microorganisms from bronchi
- Other defenses production of mucus and coughing



Internet Archive Book Images, via Wikimedia Commons

Particle Size and Lung Entry

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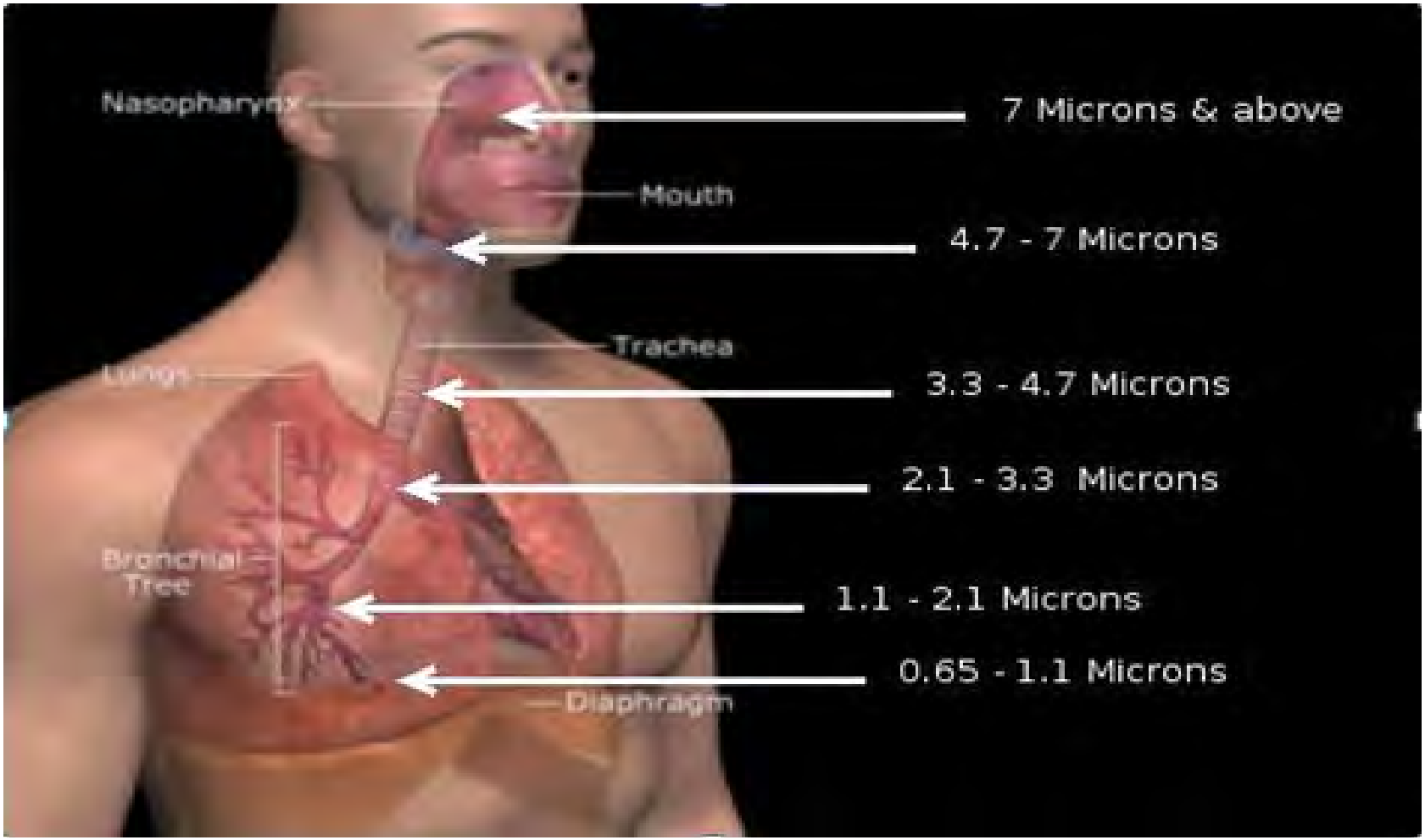

Image from Ventilation issues in mining – diesel exhaust emissions.

Size comparison of various classes of PM

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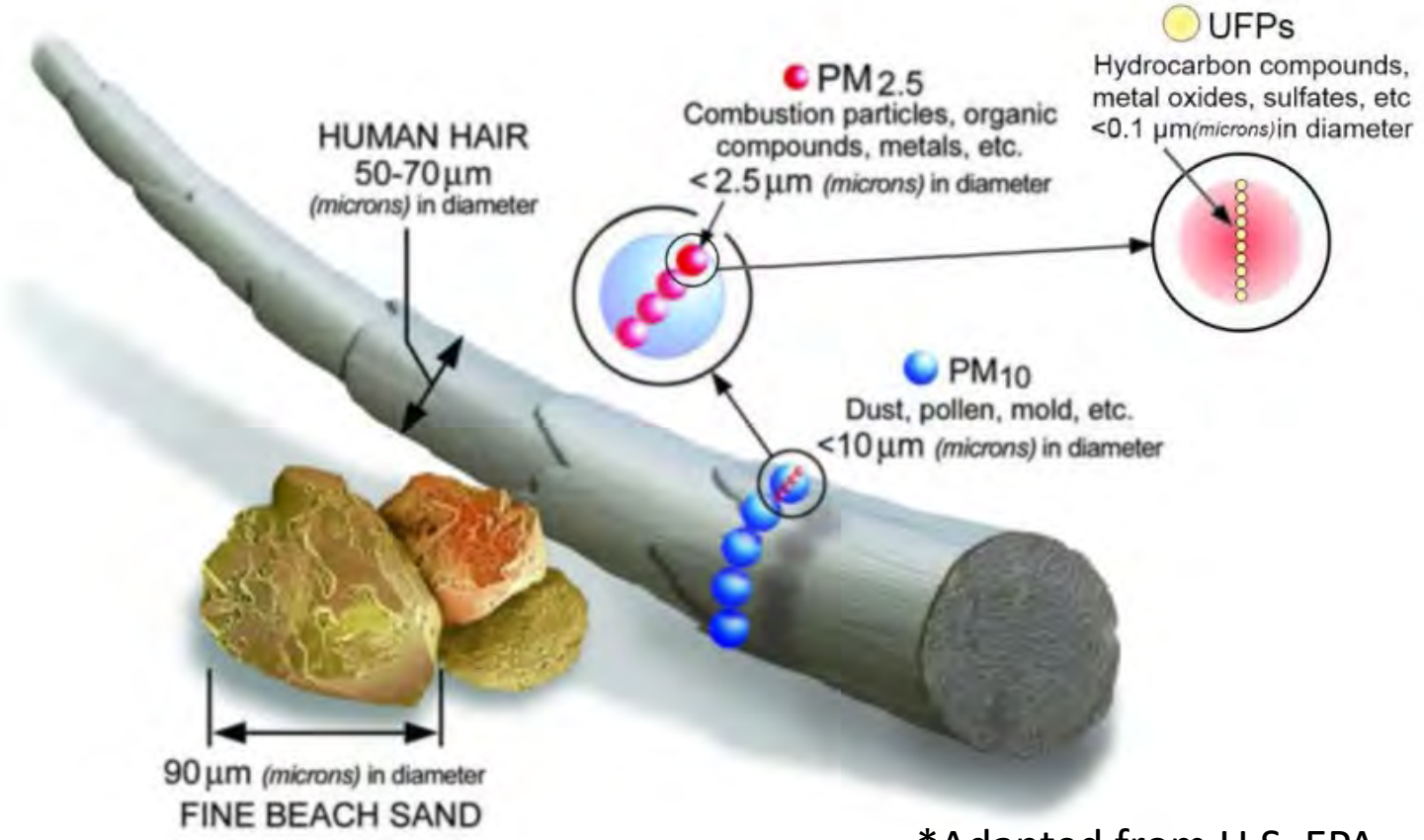
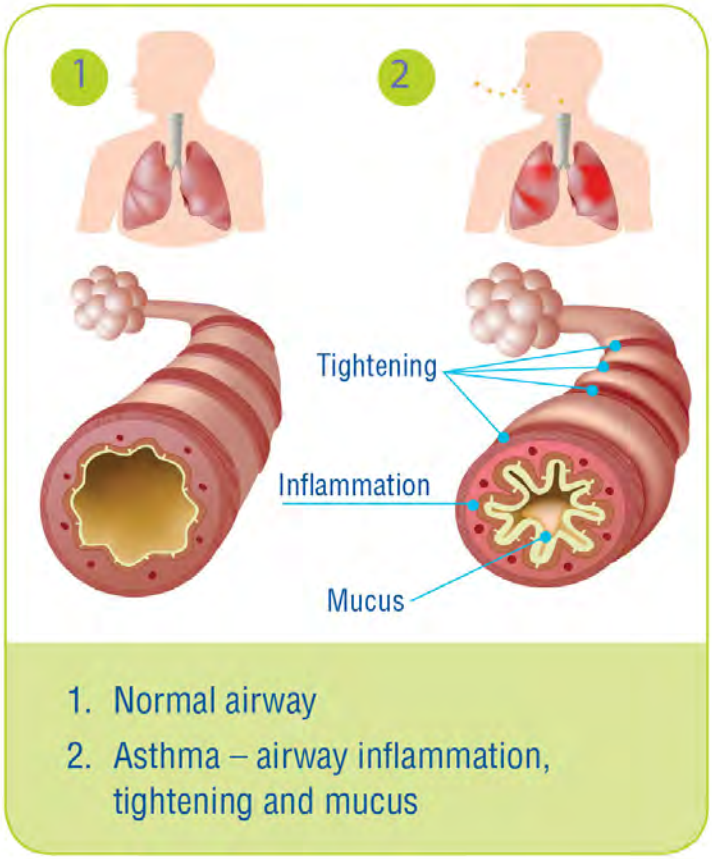


*Adapted from U.S. EPA

Asthma

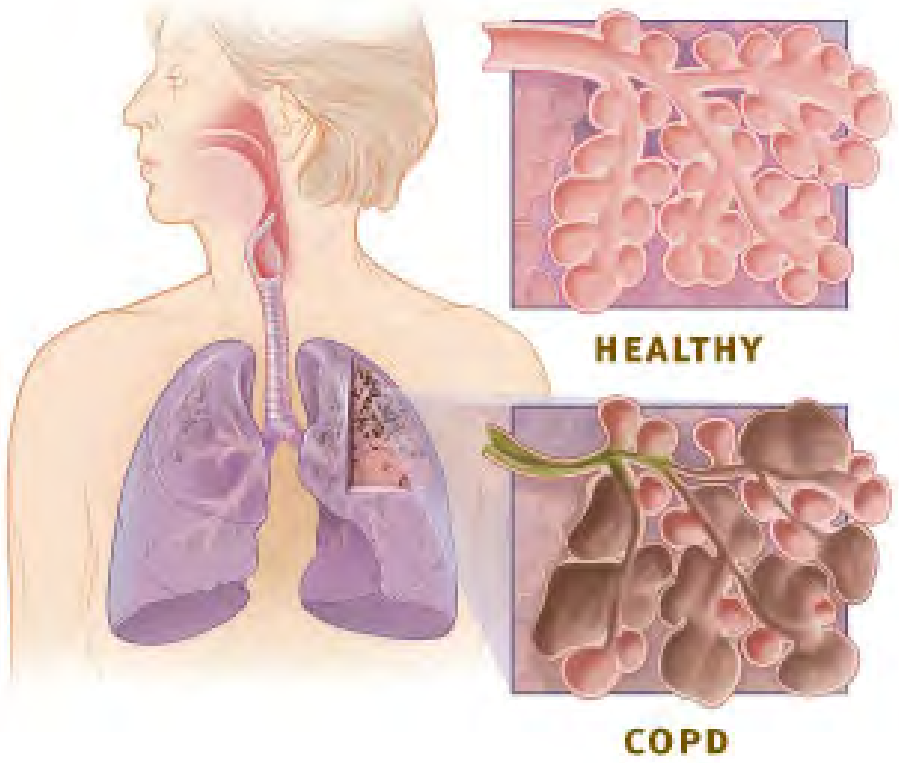


https://www.lung.ca/sites/default/files/Asthma_airway_E.jpg

- Triggers such as allergens, particulate matter or environmental factors (exercise/cold air)
- Airways narrow
- Excess mucus
- Restricts airflow
- Ranges from minor irritation to fatal condition
- Both childhood and adult onset
- Management, not cure

COPD

- Chronc Obstructive Pulmonary Disease
- Emphysema
- Chronic bronchitis
- Destroyed alveoli = less surface area for gas exchange
- Inflammation and narrowing = mucus buildup
- Causes: cigarette smoking, chemical fumes, air pollution, dust
- Alpha-1-antitrypsin higher risk
- Progressive if not treated
- Treatments: lifestyle changes, medications, oxygen therapy, surgery



http://www.nhlbi.nih.gov/health/public/lung/copd/campaign-materials/html/copd-patient.htm

Pneumoconiosis

https://collection.sciencemuseumgroup.org.uk/, CC BY 4.0

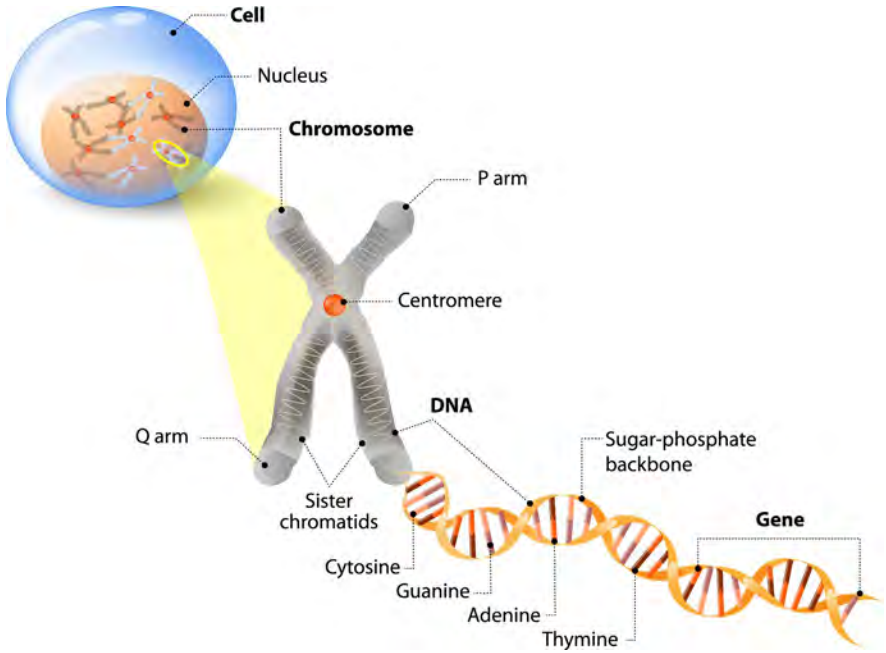
- Lung disease caused by dust
- Inflammation and scarring
- Loss of blood vessels and alveoli
- Group of interstitial lung diseases
- Symptoms: shortness of breath, chronic cough, weakness
- Range from not-noticeable to fatal
- Many types depending upon cause
- X-ray visibly different than a normal x-ray

Silicosis

Gumersindorego, CC BY-SA 3.0

- Form of pneumoconiosis
- Sharp edges of crystalline silicia dust cut and irritate
- Nodules form and grow with time
- Lungs scar and lose flexibility
- Can take years to develop symptoms
- X-rays show fibrous nodules or scarring
- 3 forms: chronic, accelerated, acute
- No cure, only treatment to manage symptoms and prevent complications

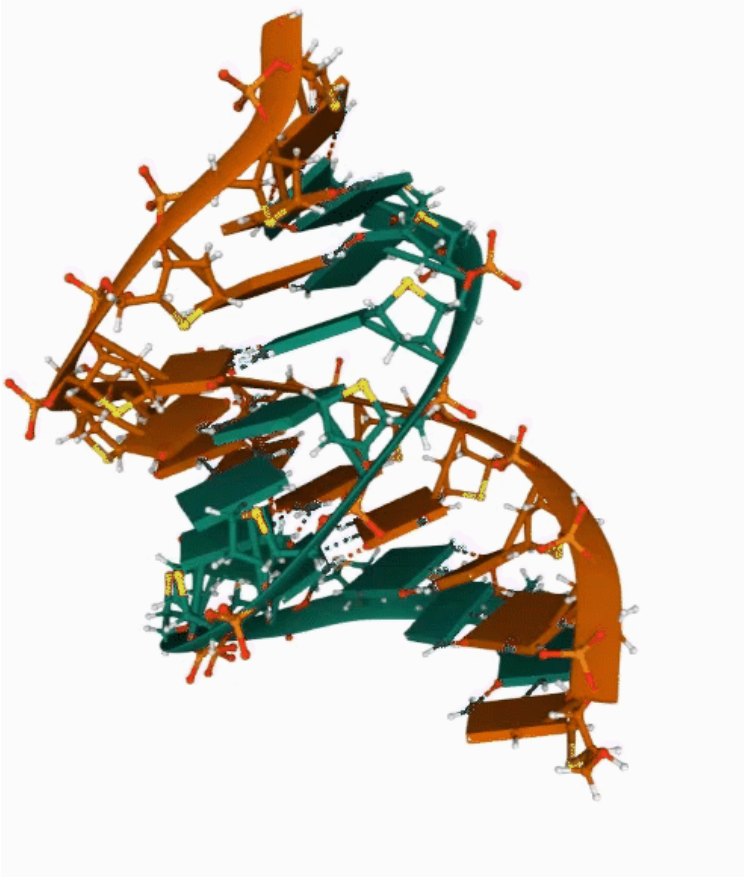
What is Cancer?



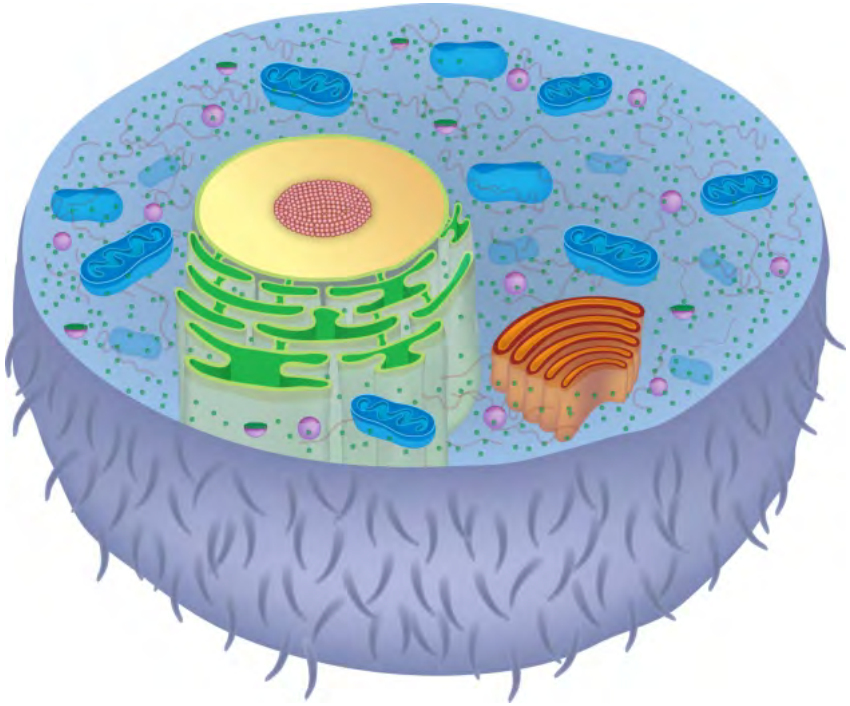
- A cell contains giant molecules called chromosomes.
- Chromosomes contain information required to create another cell identical to the original cell.
- The units of information in the chromosome are called the genes.
- Each gene is a segment of a complex molecule called DNA (deoxyribonucleic acid).

What is Cancer?

- Environmental agents may produce alterations in the biological properties of the cell.



Interaction with the Body

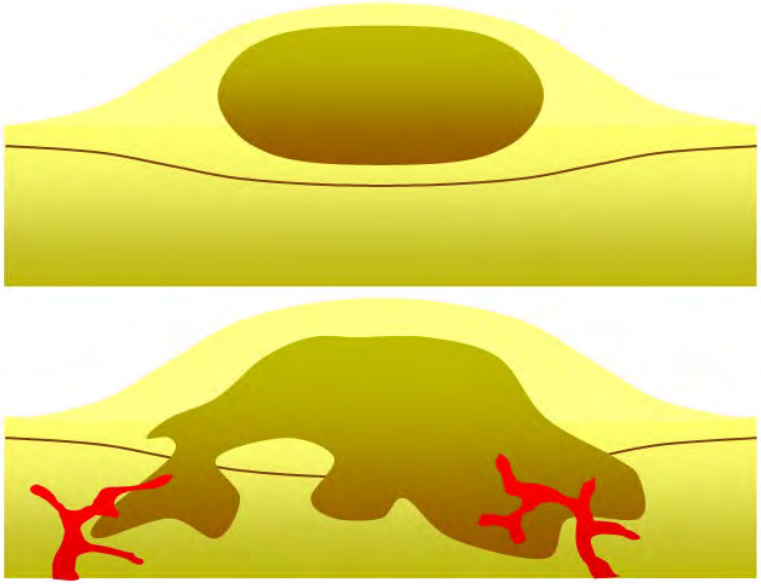


- When agent interacts with living tissue, there are several possible outcomes:
  - No damage at all
  - Damage to cells that is repaired
  - Damage to cells that leads to cell death
  - Damage to cell chromosomes that is incorrectly repaired (“mutated”).

Benign or Malignant

- Tumour: abnormal growth
  - Benign: local
  - Malignant: spreads

Benign



Malignant

Mechanisms of Carcinogenesis

Electrophilic or can be metabolically activated to electrophiles	Genotoxic	Alters DNS repair or causes genomic instability	Induces epigenetic alterations
Induces oxidative stress	Induces chronic inflammation	Immunosuppresive	Modulates receptor-mediated effects
	Causes immortalization	Effects cell proliferation, cell death, or nutrient supply	

From https://publications.iarc.fr/Book-And-Report-Series/Iarc-Scientific-Publications/Tumour-Site-Concordance-And-Mechanisms-Of-Carcinogenesis-2019

Stochastic Effects

- We know that smoking causes lung cancer.
  - But, Joe smoked sixty a day and lived to be 95!
- Some people develop lung cancer in their life regardless.
  - Only some of these people are smokers.
- Smoking increases the likelihood of developing lung cancer.
  - This is a stochastic effect.

Disease Association

Airborne Hazard	Possible Associated Health Condition
Coal Dust	Coal workers' pneumoconiosis (CWP), COPD
Diesel Exhaust	Lung cancer, possibly bladder cancer, aggravation of heart conditions, aggravation of respiratory illnesses such as asthma
Metalliferous Mine Dust	Potentially toxic (As, Cd, Cr, Co, Cu, Pb, Hg, Ni, U, Zn), lung inflammation (Fe-bearing minerals), cancer (Cr, Ni, As) (See https://doi.org/10.1007/s40726-019-00108-5 for more in-depth information)
Nitrogen Dioxide	Aggravation of respiratory illnesses such as asthma and COPD
Radon	Lung cancer
Silica (Crystalline)	Silicosis, lung cancer, tuberculosis, inflammatory diseases such as kidney disease and rheumatoid arthritis
Sulfur Dioxide	Irritation of skin, eyes, lungs, throat, and nose, bronchoconstriction, coughing, shortness of breath, increased asthma symptoms, inflammation of respiratory system (From https://doi.org/10.1016/B978-0-12-804040-9.00004-8.)

Current Mining Regulation in Canada

- Mining Health and Safety is regulated at the provincial and territorial level
- In mechanized mines, diesel is seen as the large pressure or stress on mine ventilation systems
- Many provinces require use of certified engines underground, and this is reflected in the regulations

Current Diesel Regulation in Canada

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- DPM Exposure Limits and Guidelines
- Limits of airborne concentration for DPM for mine workers
- Calculated on a full shift average exposure

Province/Territory	DPM Exposure Limit/Guideline
Most Provinces/Territories	1.5 mg/m^3 (early1990's)
Québec	0.6 mg/m^3 (Spring 2003)
Ontario	0.4 mg/m^3 (January 2012)
MSHA	American mines 0.16 mg/m^3

M. Grenier; 2015, the 36th ICSM in Mines research institutes, Oct . 2015

Detection

J Organiscak, A Cecala, R Hall / U.S. National Institute for Occupational Safety and Health, Public domain

Radon Daughters Detection

- Radon daughters can be measured in a few ways
  - Short term
    - Grab sample with immediate radiation measurement
  - Long term
    - Retrospective sampler with alpha track detector
  - Continuous
    - Electronic Monitor
  - Individual Dosimetry
    - Individual personal radon progeny dosimeters

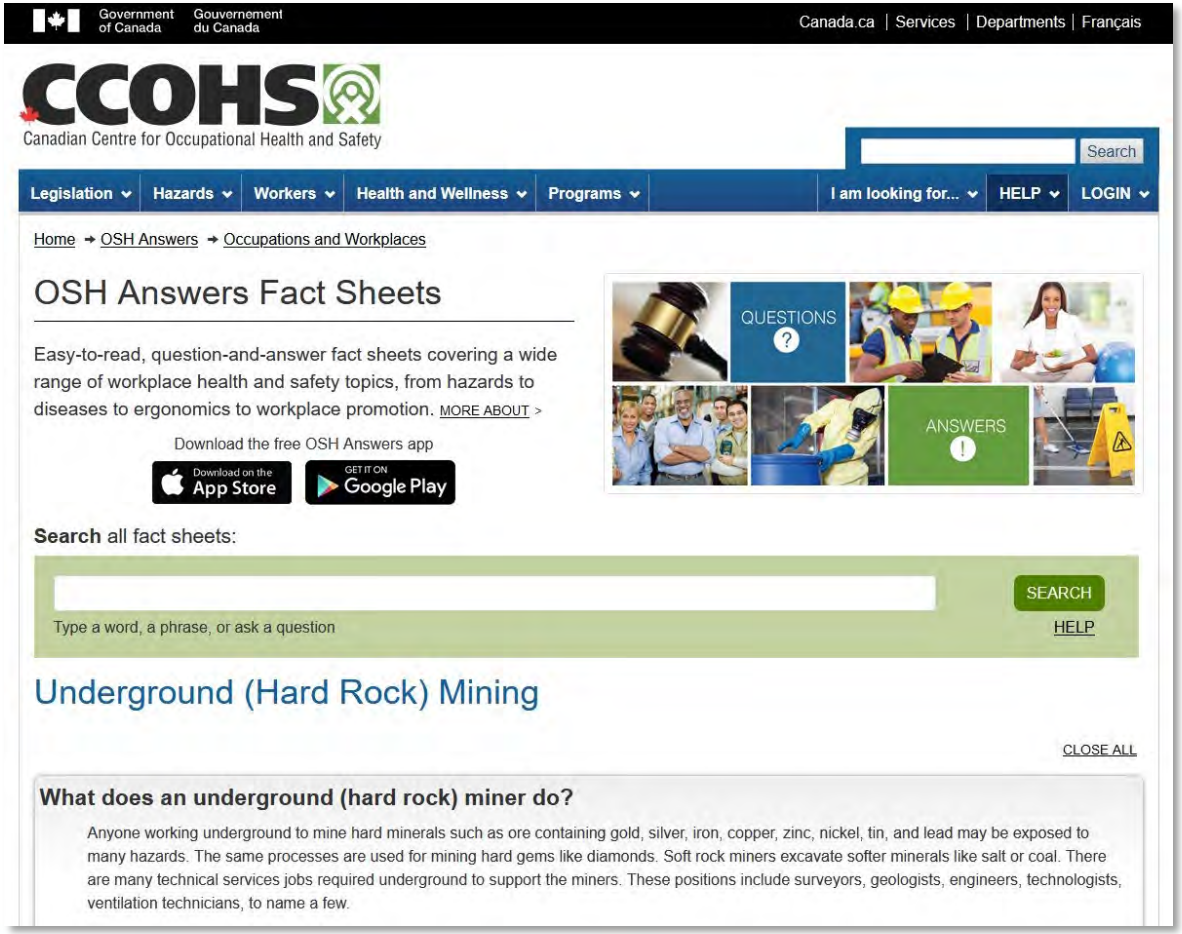
Radon Progeny Dosimeters

- This type of dosimeter measures the total exposure to radon daughters over a time interval
- Dose can be calculated from the exposure
- Mandated for use in Uranium mines
- For formal records for doses above a certain value (generally 5 mSv), the dosimetry service provider must be licensed

Personal Alpha Dosimeter

Protection Measures

- Mine/mill design
- Mining methods
- Ventilation
- Workplace monitoring
- Operational controls and work practices



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HELP

Underground (Hard Rock) Mining

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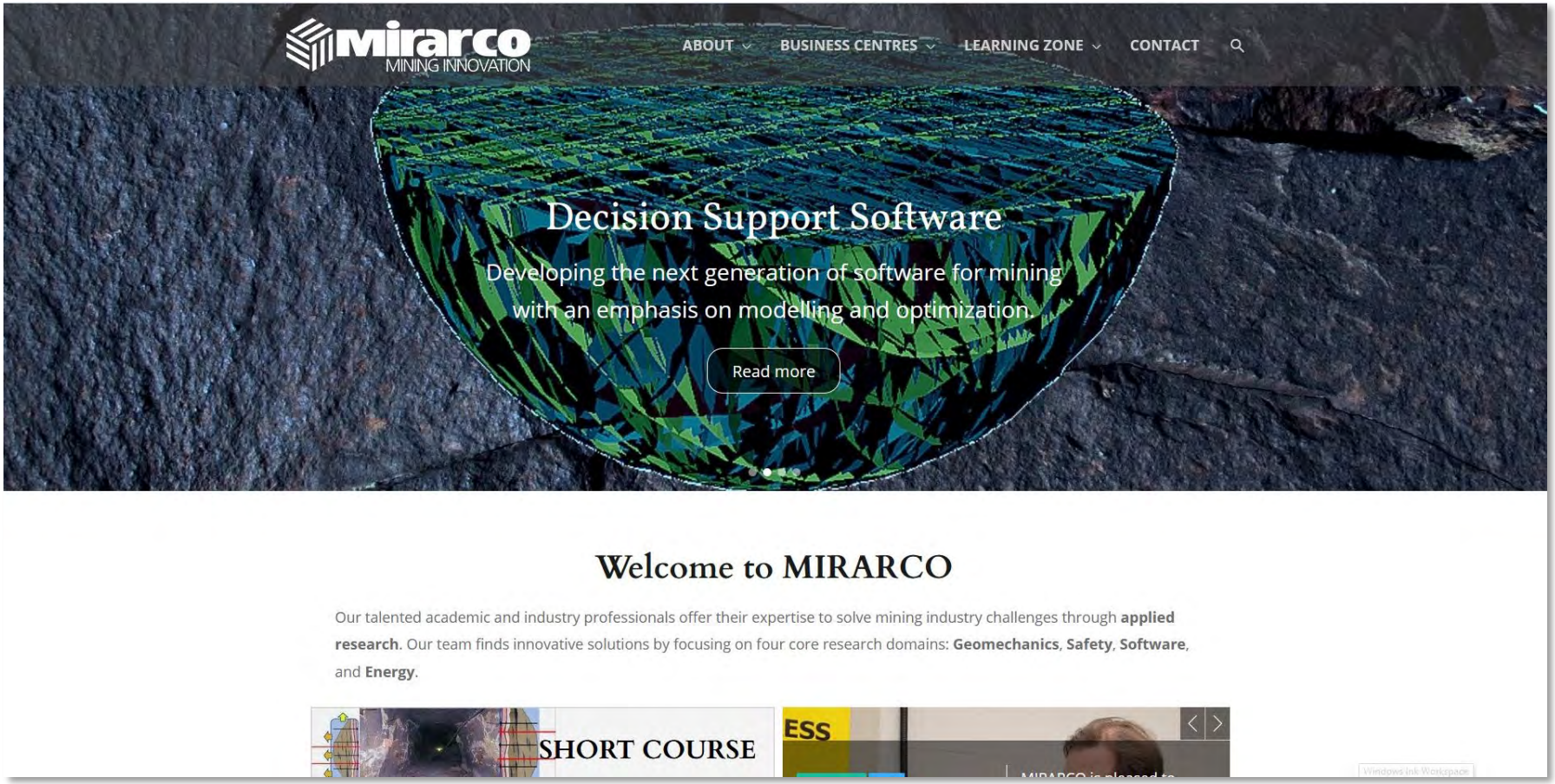
What does an underground (hard rock) miner do?

Anyone working underground to mine hard minerals such as ore containing gold, silver, iron, copper, zinc, nickel, tin, and lead may be exposed to many hazards. The same processes are used for mining hard gems like diamonds. Soft rock miners excavate softer minerals like salt or coal. There are many technical services jobs required underground to support the miners. These positions include surveyors, geologists, engineers, technologists, ventilation technicians, to name a few.

Miraraco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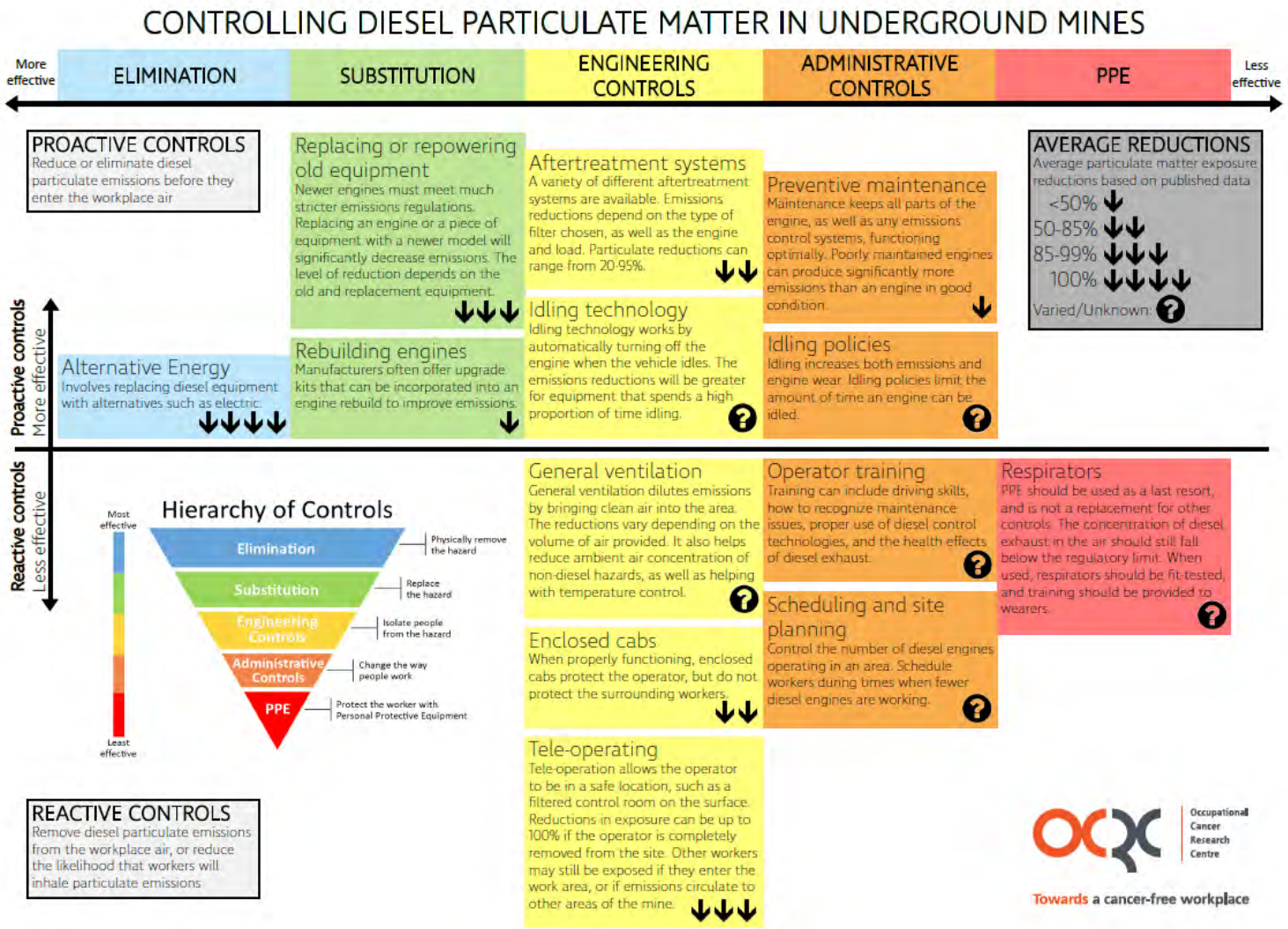

From http://www.occupationalcancer.ca/wp-content/uploads/2017/04/Mining_Diesel-Particulate-Control-Strategies.pdf

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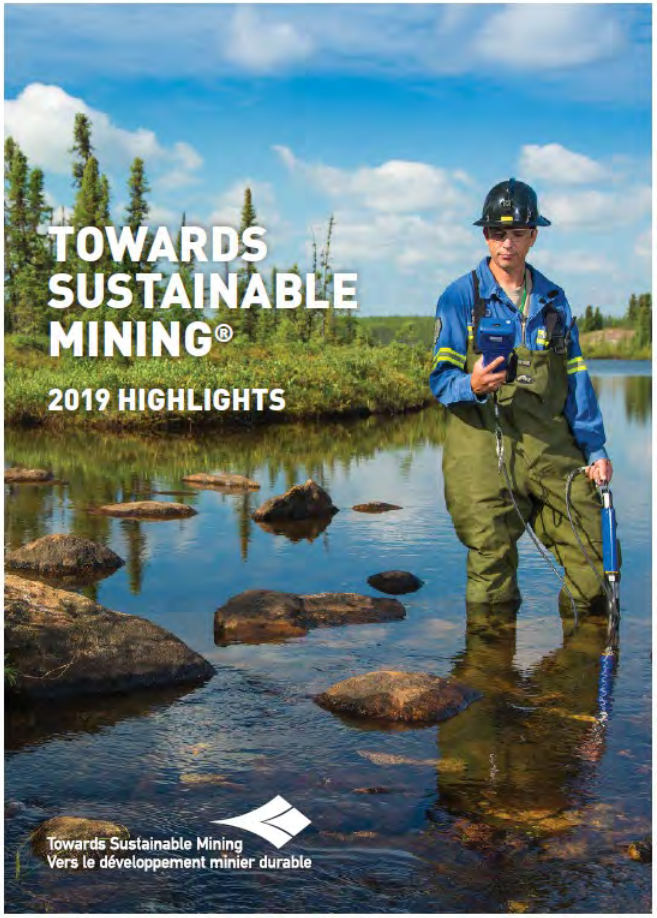


https://mining.ca/wp-content/uploads/2019/12/TSM-Booklet-EN-Web-1.pdf

Fact Sheet

Radon in Canada's Uranium Industry

March 2012

What is radon?

Radon is an odourless and colourless radioactive gas that occurs naturally in the environment as a result of the decay of uranium in soils and rocks. Uranium is widely dispersed throughout the Earth's crust and can be more concentrated in certain locations due to natural variation.

Radon emits alpha radiation and has a short half-life, meaning that it emits radiation at a fast rate.

This fact sheet uses the term "radon" to refer to both radon and radon progeny in order to simplify the text.

How does radon form?

Radon comes from the decay of uranium, part of a series of 14 transformations, called a decay chain. This process takes several billion years to complete. At the end of its decay chain is lead-206 — a stable, non-radioactive element.

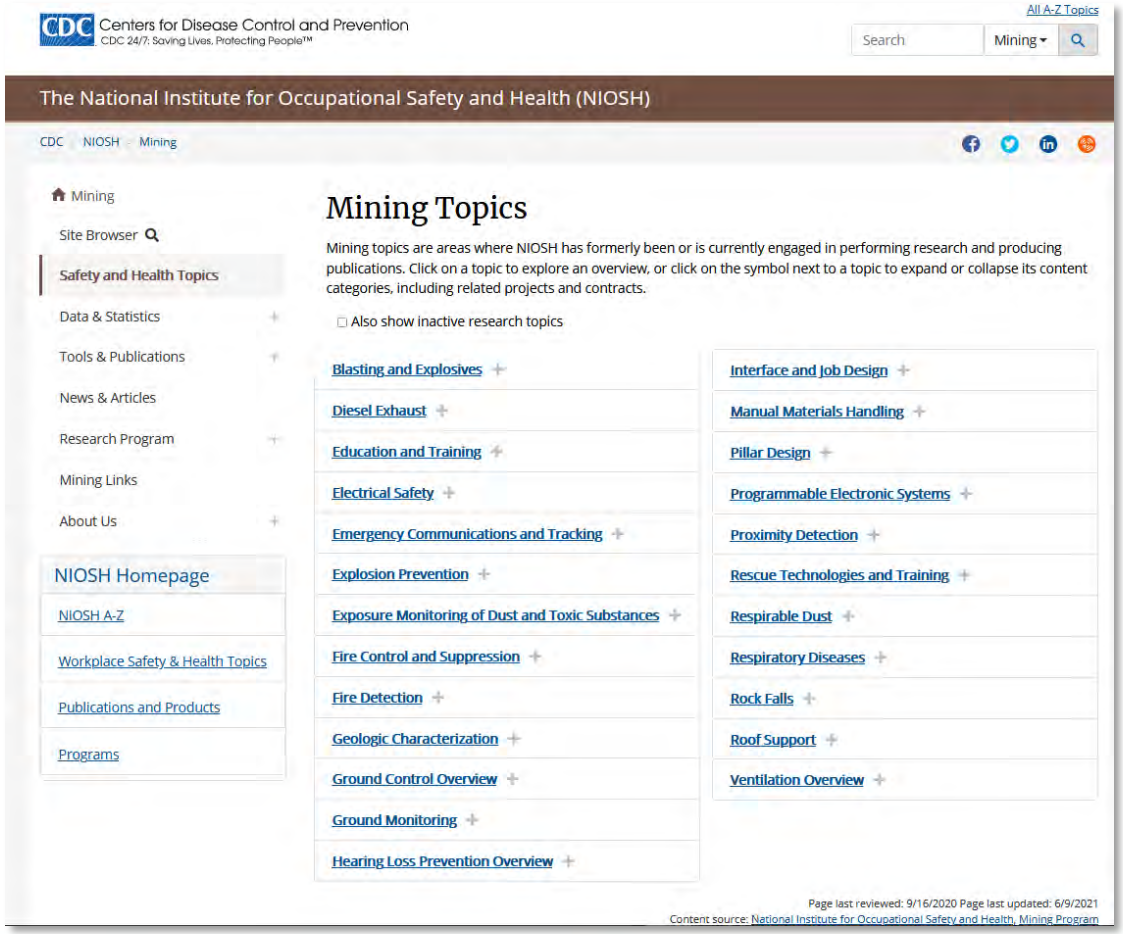
As uranium undergoes radioactive decay, it emits alpha, beta and gamma radiation, along with a series of products that include radon. In turn, radon decays through a series of four very short-lived radioactive radon decay products, in the form of solid, electrically-charged particles that are called radon progeny: polonium-218, lead-214, bismuth-214, and polonium-214.

Because of their short half-lives, radon progeny emit radiation more

Quick facts

- Radon is produced by the decay of uranium, which is naturally present in rock and soil. Radon gas is released into the air when uranium ore is mined and, to a lesser extent, during the production of uranium fuel for nuclear power plants.
- The CNSC regulates radon in Canada's nuclear facilities to protect workers, members of the public and the environment.
- Long-term exposure to elevated levels of radon increases the risk of developing lung cancer, which is why the CNSC ensures that the air quality in a uranium mine is tightly controlled with good ventilation.
- As a result, the lung cancer risk for today's uranium mining and processing workers is the same as that for the general Canadian public.
- Presently, worker exposures to radon in the uranium mining and processing industry are as low as, or only slightly greater than, public exposure from natural radon.
- Radon exposure to members of the public from CNSC-regulated

Mitigation: NIOSH



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Mining Topics

Mining topics are areas where NIOSH has formerly been or is currently engaged in performing research and producing publications. Click on a topic to explore an overview, or click on the symbol next to a topic to expand or collapse its content categories, including related projects and contracts.

☐ Also show inactive research topics

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- Explosion Prevention
- Exposure Monitoring of Dust and Toxic Substances
- Fire Control and Suppression
- Fire Detection
- Geologic Characterization
- Ground Control Overview
- Ground Monitoring
- Hearing Loss Prevention Overview
- Interface and Job Design
- Manual Materials Handling
- Pillar Design
- Programmable Electronic Systems
- Proximity Detection
- Rescue Technologies and Training
- Respirable Dust
- Respiratory Diseases
- Rock Falls
- Roof Support
- Ventilation Overview

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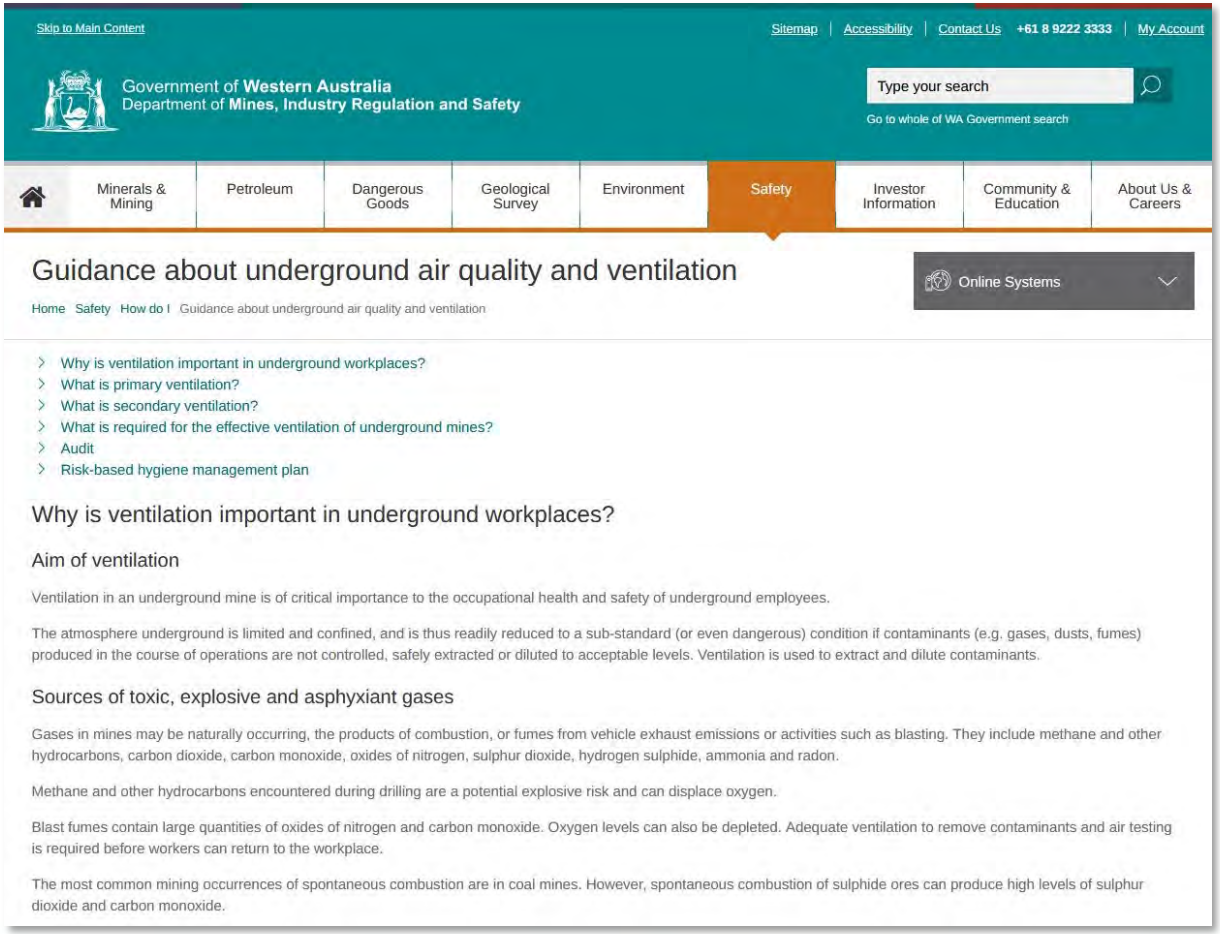
Content source: National Institute for Occupational Safety and Health, Mining Program

Air Quality and Ventiliation: Western Australia



https://www.dmp.wa.gov.au/Safety/Guidance-about-underground-air-6889.aspx

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Thank you for listening!

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