Canadian Nuclear Safety Commission / Commission canadienne de sûreté nucléaire

CMD 20-H2.245B

File / dossier : 6.01.07
Date: 2020-02-18
Edocs: 6241435

Supplementary Information
Oral Presentation

Written submission from Citizens Against Radioactive Neighbourhoods (CARN)

Renseignements supplémentaires
Exposé oral

Mémoire de Citizens Against Radioactive Neighbourhoods (CARN)

In the Matter of the

À l'égard de

BWXT Nuclear Energy Canada Inc., Toronto and Peterborough Facilities

BWXT Nuclear Energy Canada Inc., installations de Toronto et Peterborough

Application for the renewal of the licence for Toronto and Peterborough facilities

Demande de renouvellement du permis pour les installations de Toronto et Peterborough

Commission Public Hearing

Audience publique de la Commission

March 2 to 6, 2020

Du 2 au 6 mars 2020

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Protecting the health and safety of Canadians

a supplementary submission by

Gordon Edwards Ph.D.

to accompany the original submission

Health Implications of Pelleting Operations at the BWXT-Peterborough plant

that was included as part of the CARN/CELA submission to CNSC

February 18 2020

Protecting the health and safety of Canadians

The CNSC was created under the terms of the Nuclear Safety and Control Act. Its primary mission, under Article 9 of the Act, is "to prevent unreasonable risk, to the environment and to the health and safety of Canadians…." In making their licensing decisions, Commissioners are charged to be the champions defending the health and safety of Canadians. This is especially true for the most vulnerable members of our society, such as pregnant women, fetuses, and young children.

Exposure to ionizing radiation can harm the health of persons in various ways, generally classified as stochastic (i.e. probabilistic, or random) and non-stochastic (deterministic) effects. It has been long recognized by scientists that non-stochastic effects (e.g. prompt death, radiation sickness, radiation burns, hair loss, etc.) can be prevented by limiting individual radiation doses to levels well below a certain "threshold level", whereas stochastic effects (e.g. cancers and genetic damage) do not have any such "safe threshold". In fact, the same is true for most other carcinogenic agents; because the damage is done at the cellular level, involving random alterations to the DNA of one cell (according to the monoclonal nature of cancerous growths), any exposure can trigger a cancer. If there is an increase in the exposure of a given population to a given carcinogen, it is expected to increase the frequency of cancers in the exposed population.

The linear no-threshold (LNT) model of radiation carcinogenesis, which is the basis of radiation protection policy for the CNSC and other regulatory bodies, implies that the number of radiation-induced cancers in an exposed population can be reduced by limiting the total population dose. But the severity of a radiation-induced cancer is unaffected by the dose that caused it. In other words, cancers caused by a low-dose exposure are indistinguishable from cancers caused by a high-dose exposure.

The Need for Justification

For this reason, one of the cardinal principles of radiation protection is that all unnecessary exposures to ionizing radiation should be eliminated or avoided when possible, and no additional exposures to ionizing radiation should be allowed by the regulator without a very clear justification in terms of explicit benefits to the individuals being exposed or to society at large. The profitability or the convenience of the enterprise that gives rise to such radiation exposures should not be a matter of concern. The justification of otherwise preventable exposures to ionizing radiation must be expressed in terms of benefits to the affected individuals and/or benefits to society.

These considerations led the International Commission on Radiological Protection (ICRP) to recommend as follows in ICRP 26 (1976):

> *"For the above reasons, the Commission recommends a system of dose limitation, the main features of which are as follows:*
>
> *"(a) no practice shall be adopted unless its introduction produces a positive net benefit;*
>
> *"(b) all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account; and*
>
> *"(c) the dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission."*
>
> *ICRP 26 (1977) p.3*
> https://journals.sagepub.com/doi/pdf/10.1177/ANIB_1_3

The same system of dose limitation was upheld and reinforced in ICRP 60 (1990), where the need for explicit formal justification for new and existing ongoing radiation exposures was spelled out in more detail:

> "The process of justification is required, not only when a new practice is being introduced, but also when existing practices are being reviewed in the light of new information about their efficacy or consequences. If such a review indicates that a practice could no longer be claimed to produce sufficient benefit to offset the total detriment, withdrawal of the practice should be considered. This option should be treated in the same way as the justification of a new practice, but it must be remembered that the disadvantages of withdrawing a well-established practice may be more obvious than the advantages of introducing a comparable new one and withdrawal of the practice may not result in the withdrawal of all the associated sources of exposure. Preventing the further extension of an existing practice that is no longer justified may sometimes be a reasonable compromise…."

https://www.bfs.de/EN/topics/ion/radiationprotection/introduction/principles/principles.html

The German government has enshrined into law the need for a formal justification of any new radiation exposure to a previously unexposed population:

> "In order to keep the risk of stochastic damage from ionising radiation as low as possible, three general principles have been set out in radiation protection for dealing with ionising radiation.
>
> "These principles are based on recommendations from the **International Commission on Radiological Protection** (ICRP).
>
> "The German **Radiation Protection Act** and the European Directive 2013/59/Euratom make these principles legally binding:
>
> 1. Justification
> 2. Dose limitation
> 3. Optimisation

"Every new application of ionising radiation or each new use of radioactive materials by man must be justified in advance. This legal requirement for justification also applies when, due to new activities, people are occupationally exposed to existing, mostly natural radiation at an increased level….

"The legal requirement for justification means that new activities are permitted only when they are associated with a reasonable benefit for the individual and for society. In this case, 'reasonable' means that the benefit outweighs any health detriment possibly caused by the activity."

Bundesamt für Strahlenschutz, Principles of Radiation Protection
https://www.bfs.de/EN/topics/ion/radiation-protection/introduction/principles/principles.html

Pelleting in Peterborough – Where is the Justification?

In the context of the current licence renewal. BWXT has asked the Commissioners to approve a special provision that would be added to the existing licence to allow the company to commence pelleting at its Peterborough plant if and when management decides to do so.

The pelleting operation in Toronto emits about 3000 times as much airborne uranium as the non-pelleting operations that currently take place in Peterborough. Thus BWXT is, in effect, asking the Commissioners to approve an increase in airborne uranium emissions in Peterborough by three orders of magnitude.

grams of uranium into the air	2014	2015	2016	2017	2018
BWXT-Toronto	10.9	10.8	10.8	7.4	6.3
BWXT- Peterborough	0.003	0.003	0.004	0.002	0.002
Ratio : T/P	3633	3600	2700	3700	3150

Table 1. Source: BWXT 2018 Compliance Report, Figures 10 and 11

As it happens, the Prince of Wales Elementary School is situated adjacent to the BWXT Peterborough plant, right across the street on Monaghan Avenue. The outdoor school playground faces the facility with the BWXT smokestack clearly visible. The school has a student body of about 600 students, aged 4 to 14 years, who will be attending classes and playing in close proximity to the BWXT plant for up to nine or ten years (from kindergarten to grade eight). Over a period of nine years, there will be a total of about 1200 young schoolchildren exposed to airborne emissions from the BWXT plant, as there is a turnover of about 75 children in the student body each year.

These children and their teachers – and to a lesser degree their parents or caregivers as well as neighbours – will undoubtedly be exposed to increased airborne radioactive emissions and consequently increased exposure to ionizing radiation if pelleting begins at the Peterborough plant. The Commissioners are duty-bound to determine whether there is an adequate justification for this new exposure to ionizing radiation on the part of hundreds of young children. Where is the benefit? Evidently there is none for the children, their teachers, or their families. Does society need another pelleting plant, when the demand for CANDU fuel pellets is on the decline? Does BWXT need to put its pelleting operation in such a thoroughly residential area, and so close to an elementary school? Can BWXT not rent or build other facilities that are further removed from downtown Peterborough with a suitable exclusion zone surrounding the plant?

Of course, the existing pelleting operation in Toronto is also located in a densely built-up residential area, which is hardly ideal. However, poor siting decisions in the past should not be used to justify even poorer siting decisions going forward. The only thing worse than siting the plant in a downtown residential area is citing it right beside an elementary school full of young vulnerable children. As was stated in ICRP 60 (see citation above): “Preventing the further extension of an existing practice that is no longer justified may sometimes be a reasonable compromise….”

Is uranium a human carcinogen?

Uranium is an alpha-emitting radionuclide. Alpha-emitters are harmless outside the body but can be especially harmful inside the body, when in contact with radiosensitive tissue. Radon gas, radium, polonium, thorium and plutonium are all examples of alpha-emitters that are well-documented human carcinogens.

All alpha particles are identical in nature, regardless of the alpha-emitting material that is the source of those ionizing projectiles. When an alpha particle comes to rest it is simply a helium nucleus, consisting of two protons and two neutrons bound tightly together. But when it is emitted from the nucleus of a radioactive atom it has enormous energy, measured in units of “millions of electron-volts”, or MeV. An alpha particle given off by a uranium atom has an energy of about 4.2 MeV, and has a range of less than 30 microns in soft tissue.

The International Agency for Cancer Research (IARC), operating under the aegis of the World Health Organization (WHO), says this about alpha-emitting materials:

"Internalized radionuclides that emit α-particles are *carcinogenic to humans (Group 1).* In making this overall evaluation, the Working Group took into consideration the following:

"• α-Particles emitted by radionuclides, irrespective of their source, produce the same pattern of secondary ionizations, and the same pattern of localized damage to biological molecules, including DNA. These effects, observed *in vitro*, include DNA double-strand breaks, chromosomal aberrations, gene mutations, and cell transformation.

"• All radionuclides that emit α-particles and that have been adequately studied, including radon-222 and its decay products, have been shown to cause cancer in humans and in experimental animals.

"• α-Particles emitted by radionuclides, irrespective of their source, have been shown to cause chromosomal aberrations in circulating lymphocytes and gene mutations in humans *in vivo*.

"• The evidence from studies in humans and experimental animals suggests that similar doses to the same tissues — for example lung cells or bone surfaces — from α-particles emitted during the decay of different radionuclides produce the same types of non-neoplastic effects and cancers."

IARC Monograph 100D-9 (2012) p.275
https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100D-9.pdf

This statement clarifies the basic scientific fact that all alpha-emitters are human carcinogens when they become internalized. This is because all alpha particles are fundamentally the same, no matter what alpha-emitting material they come from, as indicated in the above passage. Moreover, all alpha particles do the same kind of damage to living cells – random damage involving DNA molecules that in some cases results in cancer many years later. Given the very short range of alpha particles in soft tissue, however, the fundamental consideration becomes how close the alpha-emitting material is able to come to radiosensitive tissues. The dangers from some of the more infamous alpha emitters like radon, radium, polonium, plutonium and thorium, have been very well-documented in large part because sizable populations have been exposed internally to these materials – through breathing (radon), ingesting (radium), smoking (polonium), medical injections (thorium), machining of nuclear weapons components (plutonium), or absorption through cuts and wounds (laboratory work). In many cases there have been methodologies to estimate with reasonable accuracy the exposures of the people involved, and good follow-up procedures to match cancers that occur decades after the exposure may took place.

Are the children at Prince of Wales Elementary School in any way at risk of developing cancer as a result of airborne emissions from BWXT Peterborough if pelleting begins there? As the CNSC staff has pointed out: "The primary hazard is radiation dose to the lungs from UO_2 [uranium dioxide], which is an insoluble form of uranium." (pp. 32-33, CMD H-22). As long as the Peterborough plant handles only pre-fabricated ceramic uranium dioxide pellets, there is little to no chance that the schoolchildren will have an opportunity to internalize that uranium dioxide into their lungs. Once pelleting begins, however, uranium dioxide emissions will occur routinely in the form of a very fine powder consisting of particulates with diameters of less than 10 microns. The HEPA filters will trap well over 99.9 percent of the coarser particles, and so it is reasonable to presume that those particles that escape will have diameters less than 2.5 microns. Such particles are ideally suited to be inhaled into the deepest parts of the lung, where they can lodge for a very long time because of their high degree of insolubility. Children inhaling such particles will carry with them an internalized body burden of uranium that will continue to irradiate their lung tissue even on the weekends or when they are sleeping or when they are on summer vacation. Is such exposure justified?

Evidence of uranium as a lung cancer carcinogen

The epidemiological evidence of lung cancer carcinogenesis in the case of uranium dust is somewhat inconclusive, in part due to the fact that few populations have been exposed to uranium dust in a form that is sufficiently finely subdivided to be inhaled into the deepest parts of the lung and so insoluble that it can lodge in the lung tissue for a long time. The residence time is important because uranium has a very long half-life and so its alpha particles are emitted much more slowly than is the case with other alpha-emitters. It is worth noting however that thorium (Th-232) has an even longer half-life than uranium and yet its carcinogenic characteristics have been convincingly demonstrated.

The 2012 IARC monograph 100D-9 refers to

> "... a pooled study of seven uranium miller cohorts, [in which] a significant excess of lung cancer mortality was observed in analyses using state mortality rates as a comparison (SMR, 1.51; 95%CI: 1.19–1.89). Potential confounding by smoking, silica exposure, or other occupational hazards complicated the interpretation of these results, and these studies lacked a direct measure of cumulative exposure to uranium."
>
> IARC 100D-9 p. 261
> https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100D-9.pdf

Uranium millers are involved in the crushing of uranium ore, the chemical separation of uranium from residues (which become the tailings), and the production of yellowcake powder that is shipped in drums to a uranium refinery. It is worth noting that the particulate sizes in the case of yellowcake are often larger, and the chemical form of uranium is often more soluble, than is the case with the uranium dioxide powder used in pelleting. The finer insoluble particulates from pelleting have easier access to the radiosensitive lung tissue and the residence time is likely to be considerably longer, as soluble forms of uranium are more easily cleared from the lungs.

The same IARC monograph also reports that

> "Uranium ore dust containing 44% elemental uranium induced bronchioalveolar carcinomas, bronchial carcinomas and squamous cell carcinomas in rats by inhalation (Mitchel *et al.*, 1999)."
>
> IARC 100D-9 p. 264

and that

> "Overall, two epidemiological cohort studies of uranium enrichment workers reported significant positive associations between the radiation dose quantified by personal dosimeters and lung cancer (McGeoghegan & Binks, 2000b; Richardson & Wing, 2006). Lung cancer risk could be caused either by external exposure to γ-radiation, or by α-particles emitted by uranium particles inhaled into the lung, or both. In addition, an excess of lung cancer mortality was observed in cohorts of mortality among uranium millers. However, these associations are not consistent across all studies, and there is the potential for confounding of these associations by smoking as well as occupational hazards other than uranium." IARC 100D-9 pp. 263-264

Since the IARC monograph was published, there have been newer studies that document a significant increase In human cancers from exposure to uranium.

Here is a passage from a European Study published in ***Epidemiology*** on May 17 2017, entitled "Risk of lung cancer mortality in nuclear workers from internal exposure to alpha particle-emitting radionuclides", by Grellier J, Atkinson W, Bérard P, et al. The study shows that Internal exposure to alpha particles emitted by radionuclides (particularly plutonium and uranium) is associated with an increased risk of lung cancer mortality. The results are consistent with estimates of risk from other types of radiation and compatible with current Radiation Protection recommendations.

> "Knowledge of the long-term health effects of ionizing radiation (i.e. radiation with enough energy to break chemical bonds such as those in DNA molecules) derives mainly from populations exposed to gamma and X-rays, particularly Japanese atomic bomb survivors, and populations receiving external doses due to occupational, medical and environmental exposures.
>
> "However, very little is known about the long-term effects of low level internal exposure to alpha particles. In contrast with neutrons, gamma or X-rays, alpha particles only travel a few centimetres in air and are unable to penetrate the skin. However, they can cause serious cellular damage if ingested or inhaled**.**
>
> The goal of the study was to estimate the risk of lung cancer in populations exposed to low doses of alpha particles through inhalation. The authors conducted a case-control study of lung cancer mortality among Belgian, French and UK cohorts of uranium and plutonium workers, for which they determined individual lung doses from alpha-emitters.
>
> Most subjects in the study had low doses from uranium and/or plutonium. However, a dose-related increased risk of lung cancer was still observed. 'This study is the first in which individual estimates of

dose have been reconstructed to estimate the risk of lung cancer mortality among European nuclear workers exposed to these radionuclides' says Elisabeth Cardis, coordinator of the study."

https://www.isglobal.org/en/-/la-inhalacion-de-particulas-alfa-emitidas-por-uranio-y-plutonio-aumenta-el-riesgo-de-cancer-pulmonar-en-trabajadores-nucleares

This European study associates, for the first time, low to moderate doses of alpha-emitters with lung cancer risk. Elisabeth Cardis**,** coordinator of the study, is Research Professor in Radiation Epidemiology at ISGlobal. Until April 2008, she was the head of the Radiation Group at IARC in Lyon, where she coordinated studies of ionising and non-ionising radiation for over 20 years.

"METHODS:

"We conducted a case-control study, nested within Belgian, French, and UK cohorts of uranium and plutonium workers. Cases were workers who died from lung cancer; one to three controls were matched to each. Lung doses from alpha-emitters were assessed using bioassay data. We estimated excess odds ratio (OR) of lung cancer per gray (Gy) of lung dose.

"RESULTS:

"The study comprised 553 cases and 1,333 controls. Median positive total alpha lung dose was 2.42 mGy (mean: 8.13 mGy; maximum: 316 mGy); for plutonium the median was 1.27 mGy and for uranium 2.17 mGy. Excess OR/Gy (90% confidence interval)-adjusted for external radiation, socioeconomic status, and smoking-was 11 (2.6, 24) for total alpha dose, 50 (17, 106) for plutonium, and 5.3 (-1.9, 18) for uranium.

"CONCLUSIONS:

"We found strong evidence for associations between low doses from alpha-emitters and lung cancer risk. The excess OR/Gy was greater for plutonium than uranium, though confidence intervals overlap. Risk estimates were similar to those estimated previously in plutonium workers, and in uranium miners exposed to radon and its progeny. Expressed as risk/equivalent dose in sieverts (Sv), our estimates are somewhat larger than but consistent with those for atomic bomb survivors. See video abstract at, http://links.lww.com/EDE/B232 ."

The epidemiological evidence for lung cancer carcinogenesis from uranium is growing. There can be little doubt that alpha radiation from uranium can and does trigger lung cancer. Consequently no unnecessary exposure is justified.

Children are not young adults

Researchers in the field of ionizing radiation have long known that children are much more susceptible to radiation damage, including cancer induction, than adults are. The World Health Organization has issued a Training Package for the Health Sector entitled “Children's Health and the Environment” that says in part:

> “Ionizing radiation is a known carcinogen to which children are particularly vulnerable. Relevant exposures include pre- and postnatal irradiation for medical reasons, radon in the home, and accidental radiation releases. In some cases, children may receive higher doses than adults because of higher intake and accumulation. Furthermore, sensitivity to radiation is highest early in life.
>
> “Although the mechanism of greater susceptibility is not well understood, it is likely to be linked to greater cell division in growing and developing tissues. In addition, a longer expected lifetime, with a resultant increased chance of repeated exposure and accumulated damage, also leads to higher cancer risk for children.
>
> The absorbed dose is a measure of the amount of energy actually absorbed in a material, and is used for any type of radiation and any material. Gray (Gy) is the unit of measurement for absorbed dose in the International System of Units (SI).
>
> “One gray is equal to one joule of energy deposited in one kilogram of a material. The unit gray can be used for any type of radiation, but it does not describe the biological effects of the different radiations.
>
> “The equivalent dose is the product of the absorbed dose and a ‘radiation weighting factor’ depending on the quality of the particular

type of radiation (e.g. "1" for X-rays, gamma rays and beta particles, "20" for alpha radiation, between "1-10" for neutrons). This weighting factor relates the absorbed dose in human tissue to the effective biological damage of the radiation.

"Ionizing radiation is a complete carcinogen since it can act to initiate, promote and progress cellular changes that lead to cancer. The dose of radiation received by an individual affects the probability of cancer, but not its aggressiveness. Radiation-induced cancer is indistinguishable from cancer from other causes. The probabilistic nature of this risk means that children have more time to accumulate exposures and damage, and more time after exposure to develop the disease."

WHO Children's Health and the Environment
https://www.who.int/ceh/capacity/radiation.pdf

If we calculate the absorbed dose delivered to a tiny volume of lung tissue in a child who has inhaled a one-micron diameter particulate of uranium oxide that has lodged in his lung for a year, we arrive at a figure of 22.5 milligrays. If the particulate were two microns in diameter, the absorbed dose during one year would be 142 milligrays. Bearing in mind the "radiation weighting factor" of 20 (mentioned above in the WHO Training Package), we see that these doses of alpha radiation would be equivalent to 450 milligrays of beta or gamma radiation for a one-micron particle, and 2,840 milligrays of beta or gamma radiation for a two-micron particle.

These are very large doses, delivered to a very small volume of tissue. Moreover, any one of the cells in that tiny volume of lung tissue could be damaged in such a way as to yield a full-blown case of lung cancer twenty years (or more) later. We do not have any epidemiological studies of children exposed to the routine inhalation of insoluble particulates of uranium dioxide. Surely it is not justifiable, given that there are no discernible benefits to the children or to society for pelleting to take place at this location, to make these children the potential cohort for a future lung cancer epidemiological study!

The ALARA principle is invoked by CNSC staff to keep all radiation exposures "As Low As Reasonably Achievable". In this case, ZERO is the number that fits the ALARA principle the best. If the Commissioners do not give permission for BWXT to commence pelleting in Peterborough, then all these calculated exposures can very easily be reduced to zero.

Summary and Conclusion

The purpose of the CNSC as stated in the Nuclear Safety and Control Act is to "prevent unreasonable risk ... to the health and safety of persons" [Article 9].

Photo by Robert Del Tredici

The Peterborough plant is right next to an elementary school with about 600 young children, aged 4 to 14, in close proximity to the plant for years – from kindergarten to grade 8. The smokestack is quite close to the playground.

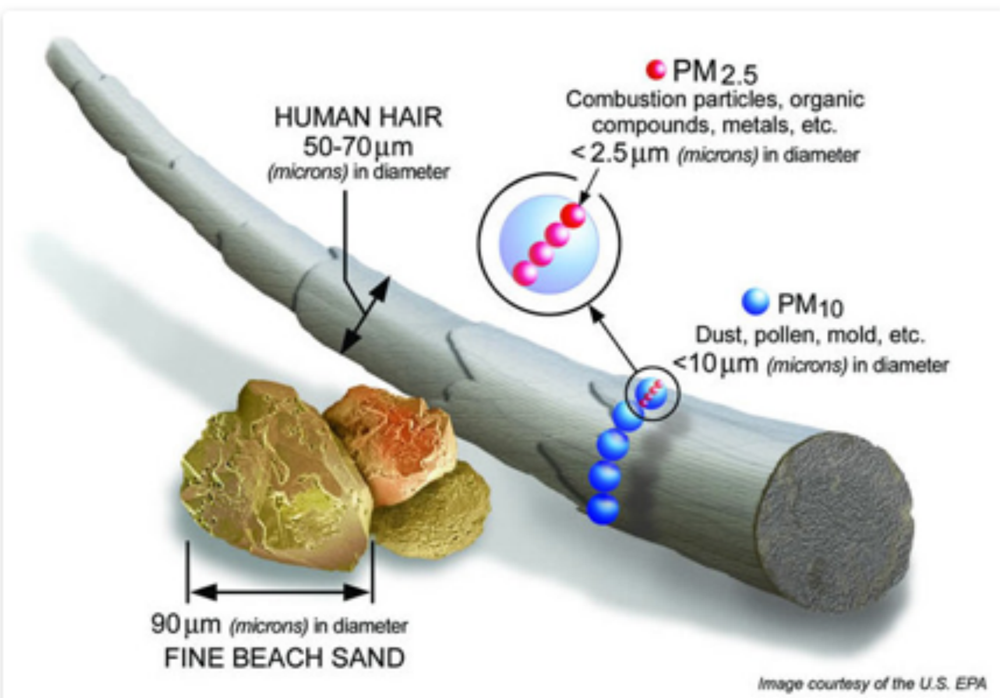
Over a nine-year period about 1200 children will be exposed to airborne emissions on a daily basis at school if pelleting occurs.

It is a fundamental principle of radiation protection that no unnecessary exposure should be allowed if it can be prevented or avoided. Unjustified exposures are unreasonable.

If these children are protected from unnecessary risk, then others will be protected also.

Pelleting in Peterborough will increase airborne emissions of uranium by a factor of about 3000.

This is an image of the tiny particulates of size PM2.5 (less than 2 1/2 microns in diameter) that will be emitted by the hundreds of billions every year from BWXT Peterborough if it begins pelleting.



These particulates of uranium dioxide (in red) are much smaller than the finest human hair and can only be seen by an electron microscope.

Such particles are uniquely suited to be inhaled into the deepest parts of the lung and lodge there for a very long time.

This will give hundreds of schoolchildren an unnecessary radiation exposure with no benefit to them and no justification offered by BWXT.

Uranium gives off alpha particles that travel a very short distance in living tissue.

The next photograph shows the tracks made by alpha particles emitted from an alpha-emitting particulate lodged in the lung tissue of an experimental animal, irradiating a very tiny region of the lung.

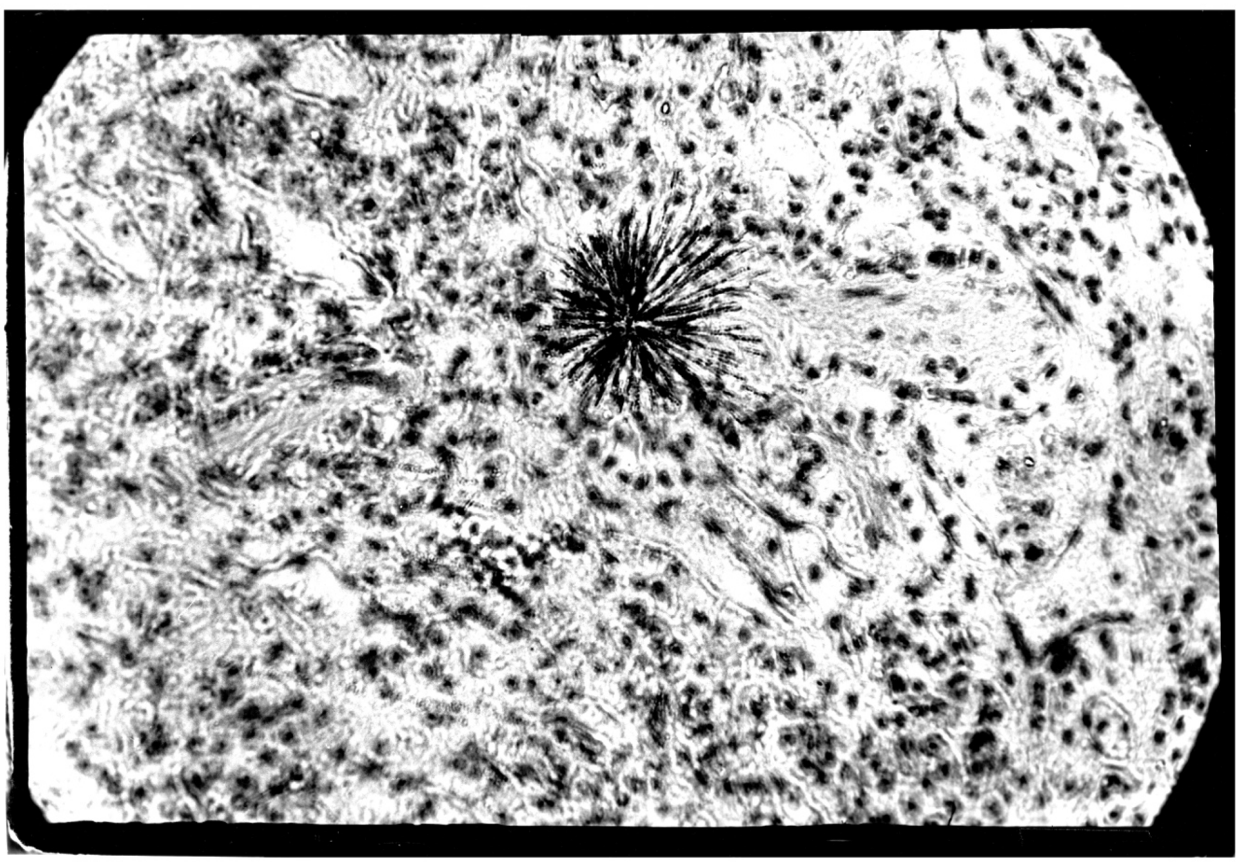


photo by Robert Del Tredici

A single one-micron diameter particle of uranium dioxide dust will give a very large absorbed dose in one year to a very small volume of lung tissue. (more than 22 Grays of absorbed dose).

WHO asserts that all alpha-emitting materials are carcinogenic in contact with radiosensitive tissues like lung tissue (IARC 100D-9).

A single alpha radiation-damaged cell can develop into a cancer years or decades later.

Young children are known to be far more susceptible to radiation-induced cancers than adults.

Conclusion

** CNSC has a duty "to prevent unreasonable risk to … the health and safety of Canadians" (NSCA Art.9)*

• *A basic principle of radiation protection is: "All unnecessary exposures should be eliminated or prevented".*

• *There is no justification of any kind offered for the commencement of pelleting in Peterborough.*

• *BWXT should not be given permission to expose hundreds of schoolchildren to needless risk*

• *All unjustified radiation exposures, with no specified benefits, are unreasonable.*

***Recommendation**. The Commissioners are urged not to approve the special pelleting provision in the BWXT licencing application, thereby preventing and eliminating all future routine exposures of hundreds of schoolchildren at Prince of Wales elementary school to elevated levels of respirable particulates of uranium dioxide dust in the $PM_{2.5}$ category as a result of pelleting at BWXT-Peterborough.*