To: BAPE Commissioners

From: Dale Dewar, MD

I attached the text of a document that I presented to the Uranium Development Partnership hearings in Saskatchewan in 2009 on behalf of the Saskatchewan Medical Association and a review of the literature which Drs Linda Harvey, Cathy Vakil and I performed in 2012 – published in May 2013.

My clinical history with uranium dates back to 1991 when I was working in Northern Saskatchewan serving a population of Cree, Metis and Dene peoples. Many of our patients worked in the Cluff Lake mine directly north of the community. We had four patients with lupus in one year – not very many but unusual for the community and, the elders told us, unusual for the North.

The interest in the connection between uranium and human health continued. When the Saskatchewan Medical Association had no one to take up medical and clinical health issues with the Uranium Development Partnership Commission, little did I realize how much work it would be prepare a non-controversial document for the medical association.

But, in any case, the SMA recommendations largely arose out of two statements which the SMA supported:

In 2004, the Canadian Medical Association (CMA) passed a motion which included

1. "the need for ongoing support of research related to the health aspects of nuclear power generation and to management of radioactive wastes in general, the management of wastes from uranium mines in particular and the need for the epidemiological surveillance of exposed populations."
2. The CMA also "recognizes the need to develop and enforce appropriate standards and regulations".

The recommendations from the SMA were:

1. That, before embarking upon any plan to "capture the full potential of the uranium value chain", the Government of Saskatchewan empower the Minister of health to:

    a) Initiate a baseline study of Saskatchewan residents using determinants of health and extend such a study for at least one generation,
    b) Establish mechanisms for the independent verification of levels of radiation at all steps of the "Uranium value stream".
    c) Monitor and report annually on the determinants of health in geographic locations affected by the "Uranium value stream".

2. That, given that the CNSC is under the same ministry as the resources it is empowered to regulate, creating an actual, or the appearance of, conflict of interest with respect to safety of people and the environment, the SMA recommends that a monitory body (such as a Saskatchewan Nuclear Safety Commission) be established under the auspices of the Department of Health.

The SMA concluded that "the health of the people of Saskatchewan should be paramount – those who work in the mining industry, their families, the environment around them and those who might be affect in the future."

The paper including the discussion is appended (A).

On behalf of the Ontario College of Family Physicians and then for the Canadian Association of Physicians for the Environment, Drs Linda Harvey and Cathy Vakil reviewed the literature to almost the same date as was done for the SMA paper. Accordingly we joined forces and updated the review, published as a "Commentary" in the Canadian Family Physician in May 2013, a "peer-reviewed scientific journal". (I want to point out that "peer review" for a scientific journal is entirely different from the "peer review" paid by the Canadian Nuclear Safety Commission for the "Synthesis Report" on Port Hope.)

We concluded that uranium had three specified types of characteristics, those of:
1. a heavy metal
2. a chemically reactive metal
3. a radioactive metal.

As a heavy metal, it would be expected to exhibit many of the same well-studied characteristics of lead or mercury. It is widely chemically reactive, reacting with almost all non-metal elements and their compounds including the walls and contents of biological cells. As a radioisotope, it has the potential to affect environmental or biological systems both by the radioactive particles or energy given off when it decays and by the elements in its decay chain as it becomes radium, radon, polonium, bismuth and lead. The spectrum of possible effects on health and the environment and the length of time that it might take to actually see them make their study a gargantuan task.

Uranium is known to be toxic to the kidney – this may the result of both its properties as a heavy metal and its chemical toxicity[i]. Working again as a relief doctor in Northern Saskatchewan in 2011, a miner was sent from Cluff Lake because he couldn't breath and was retaining water (all swollen up). He was diagnosed as being in kidney failure and sent to the tertiary centre for dialysis. Workmans' Compensation agreed that the high level of uranium in his urine and blood was related to his job.

Recently uranium has been found to mimic the effects of estrogen at concentrations below the safety limit. This may have been what was happening to our patients in Northern Saskatchewan; mimicking estrogen, the uranium may have caused diseases usually more prevalent in women to appear in the male population.[ii]

The review of the literature is appended. (B)

There are very few well-performed studies on the health and environmental effects of uranium in the environment. Aside from the very clear link between uranium mining and lung cancer as found in the studies of the Eldorado miners[iii], Those that have been done are not reassuring and show trends of multi-system influence on health. Studies largely financed by industry or the CNSC have been limited in scope or time (e,g, 1000 fathers in one five-year study showed a non-statistically significant trend in increased Downs' syndrome offspring), have erroneously combined rare with relatively common diseases (myeloid cancers with leukemia) and omitted significant parts of the populations (such as fetuses or miscarriages). The Synopsis report of the CNSC on Port Hope ignores the very statistically significant relationship between atherosclerosis and other diseases of the arteries in its own report[iv] while concluding that "no adverse health effects have occurred or are likely to occur in Port Hope as a result of the operations of the nuclear industry in the town"[v].

Finally, a brief comment on the tailings, the waste from uranium mining, which contain 85% of the original radioactivity of the ore – are now exposed to the elements – or placed in "ponds" to be protected from entering the environment for hundreds of years. Radioisotopes are known to cause biological damage – damage to cells, mitochondria and DNA. Since uranium has questionable value as a fuel for nuclear power and illegal use in nuclear weapons, the Precautionary Principle would conclude that it should be left in its natural state, bound in granite.

References:

[1] " 3 Toxic Effects of Uranium on the Kidneys ." *Review of Toxicologic and Radiologic Risks to Military Personnel from Exposure to Depleted Uranium During and After Combat* . Washington, DC: The National Academies Press, 2008 .
[2] American College of Rheumatology (ACR). "Uranium exposure linked to high lupus rates in community living near a former refinery." ScienceDaily. ScienceDaily, 10 November 2012. <www.sciencedaily.com/releases/2012/11/121110155813.htm>
[3] Howe D, Geoffrey R. Updated analysis of the Eldorado Uranium Miners' Cohort: part I of the Saskatchewan Uranium Miners' Cohort Study (RSP-0205). Ottawa, ON: Canadian Nuclear Safety Commission; 2006. <nuclearsafety.gc.ca/eng/readingroom/healthstudies/Eldorado/>

[4] "Understanding health Studies and Risk Assessments Conducted in the Port Hope Community from the 1950's to the Present", page 63, April 2009. <nuclearsafety.gc.ca/eng/pdfs/Info-0781-en.pdf>
[5] Ibid. page 39.

Appendix A

Submission of the Saskatchewan Medical Association to the Uranium Development Partnership public consultations:

Respected panel,

The Saskatchewan Medical Association (SMA) is pleased to provide the following submission for your consideration.

The Uranium Development Partnership advance documentation outlines the advantages of further development of the Uranium "chain" and proposes a nuclear power plant for Saskatchewan.

The SMA is the provincial affiliate of the Canadian Medical Association.

In 1982, the Canadian Medical Association passed the following motion:

That the Canadian Medical Association endorse the "Statement on Radiation Protection" as its policy on exposure to low levels of ionizing radiation.

Statement on Radiation Protection:

The Canadian Medical Association is aware of the potential health hazards associated with exposure to ionizing radiation and has examined the possibility that detrimental effects might result from the long term exposure of the general population to low-level radiation as a result of nuclear energy production.

The Association is satisfied that, where internationally recommended criteria for radiological protection have been adopted and effectively implemented, there is at present no conclusive evidence of a measurable increase, in the long or short term, of adverse effects due specifically to radiation in populations thus exposed.

The Association recognizes the need for ongoing support of research related to the health aspects of nuclear power generation, and to the management of radioactive wastes in general, the management of wastes from uranium mines in particular; and the need for the epidemiological surveillance of exposed populations.

The Association also recognizes the need to develop and enforce appropriate standards and regulations where indicated.

This resolution was confirmed in 2004. There are two clauses to which we wish to draw your attention: “the need for ongoing support of research related to the health aspects.....” and “the need to develop and enforce appropriate standards and regulations....”

Given that the entire executive summary of the Uranium Development Partnership does not once mention the issue of health and that there has never been a baseline health assessment of those who work and live near the uranium mining sites in Northern Saskatchewan, the SMA proposes the following recommendation:

1. **That, before embarking upon any plan to "capture the full potential of the Uranium value chain", the Government of Saskatchewan empowers the Minister of Health to :**

    - **Initiate a baseline study of Saskatchewan residents using determinants of health and extend such a study for at least one generation.**
    - **Establish mechanisms for the independent verification of level of ionizing radiation at all steps of the "Uranium value stream".**
    - **Monitor and report annually on the determinants of health in geographic locations affected by the "Uranium value stream".**

Given that the CNSC is a body under the same ministry, Natural Resources Canada, as the very resources it is empowered to regulate, creating an actual, or the appearance of, conflict of interest with respect to safety of people and the environment, the SMA recommends:

2. **That a monitoring body (such as a Saskatchewan Nuclear Safety Commission) be established under the auspices of Sask Health with input from Saskatchewan physicians.**

Discussion:

Physicians have known for years that increasing background radiation increases the incidence of cancers. Increased exposure to radon gas in the air causes an increase in lung cancer; increased exposure to the sun's radiation increases the incidence of skin cancer. Questions surrounding the mining, processing and use of radioactive substances have relied on speculation that very low levels of radiation had no measurable impact upon the health of populations.

Many studies have been conducted over the past several decades concerning radioactivity and human health. (Some are critiqued below.) All research has been retrospective. It is well established that radiation affects genetic material so a prospective approach is needed to determine exactly what that effect is and the extent to which it might be beneficial or detrimental. The literature abounds with conflicting reports, limited data and industry-influenced opinions. As physicians, we are looking for evidence.

BEIR VII (U.S. Academy of Science report on the Biological Effects of Ionizing Radiation) unequivocally states that “no low level of radiation exposure is safe”. We would expect that our proposed Saskatchewan prospective study would confirm increased effects on health. Should such a health effect be confirmed, we need to know what that effect might be for population health planning, health care costs and re-mediation.

If, as the UDP interprets the same BEIR VII (page 97) to mean that “the risk of health effects from exposure to low levels of radiation is small and..... current radiation protection standards for workers and the public remain appropriate”, our proposed study will simply accrue extensive population health information that can be used for many purposes (examination of various industries, urban-rural comparisons, racial tendencies, etc). A baseline health study, properly conducted, would employ hundreds of people and would, itself, have market trade value.

The nuclear industry has been plagued by a history of changing safety regulations. Allowable safe exposure has been lowered seven times since the 1950's. The ALARA principle raises some concern. “As Low As Reasonably Acceptable” is an industry standard, not a public health standard.

With respect to changing standards, on June 9, 2009, the Ontario Drinking Water Advisory Council, at the request of the Ontario Government, released its *Report and Advice on the Ontario Drinking Water Quality Standard for Tritium*, which, after 25 months of study, recommended that the current permissible limits of 7000 becquerels per litre be reduced to 20 becquerels per litre, a 350-fold decrease. This has direct implications for the production of medical radioisotopes as well as nuclear power.

To physicians, a constantly shifting baseline suggests that the science is uncertain at worst and based on theoretical models instead of population health at best. Where the health of populations may be affected irrevocably (radiation effects must be measured in decades or centuries rather than years), this sense of uncertainty is unacceptable. We believe that health care standards should not be set by industry but by health care professionals.

Research:

The following studies are reviewed briefly to illustrate the short-comings in research on the health of populations exposed to radioactivity. There are a number of studies which suggest that low level radiation exposure is safe but they are no more conclusive than those which suggest the opposite. On the other hand, there are no long term studies which exonerate the effects of ionizing radiation.

All research suffers from a single universal flaw in that it is dependent upon industrial self-reporting of emissions. The India study is included because nuclear power plants or industry is not involved.

References are listed with the study or studies to which they refer.

The KiKK study:

Kaatsch P., Kaletsch U., Meinert R., Michaelis J. An Extended Study on Childhood Malignancies in the Vicinity of German Nuclear Power Plants. Cancer Causes Control 1998; 9: 529-33

Hofmann W., Terschueren C., Richardson D. B., Childhood leukemia in the Vicinity of the Geesthacht Nuclear Establishments near Hamburg, Germany. Environmental Health Perspectives 2007; 115: 947-52

Spix C., Schmiedel S., Kaatsch P., Schulze-Rath R., Blettner M. Case-Control Study on Childhood Cancer in the Vicinity of Nuclear Power Plants in Germany 1980-2003. Eur. Journal of Cancer 2008; 44:275-284

Kaatsch P., Spix C., Schulze-Rath R., Schmiedel S., Blettner M. Leukemia in Young Children Living in the Vicinity of German Nuclear Power Plants. Int. J. Cancer 2008; 1220: 721-26

In 2008 the German KiKK study provided compelling evidence of an unequivocal positive relationship between a child's risk of leukemia, and residential proximity to a nuclear power plant. This effect was consistent across all sixteen nuclear power plants in Germany meeting the researchers' criteria for size and duration of operation, and was detectable as far as 50 km from the nuclear facility.

The KiKK study was a case-control study looking at individual cases of leukemia occurring in children living near one of 16 nuclear power plants between 1980 and 2003. The index cases were matched by age, gender, social status, parental smoking, etc with children who did not have the disease. The only variable was the residential distance to nuclear power plants. Distance from the power plant was measured in segments of 1 to 5 km, 5 to 10 km, 10 to 30 km, 30 to 50 km and greater than 50 km from the chimney of the power plant.

The study showed an unequivocal positive relationship between a child's risk of being diagnosed with leukemia, and residential proximity to the nearest nuclear power plant. This was statistically significant in the 0-5 and 5-10 km zones, and continued as a trend out to 50 km from the nearest nuclear power plant.

The authors state that these findings are compelling, that the elevated risk does indeed exist and that it is related to the nuclear facilities. No plants were particularly isolated. No unusual patterns of population migration existed.

The authors conclude that "the reason for the elevated risk is unexplained, as the levels of radioactive emissions from these facilities are considered too low to explain the increase in childhood leukemia".

Again, this assumes that the reported emissions are accurate.

This was an extremely thorough study. The conclusion by the authors is puzzling but was based, again, upon the impression that low levels of radioactivity posed no risk to health.

COMARE Studies:

> *Committee on Medical Aspects of Radiation in the Environment (COMARE), 10th Report, "The Incidence of Childhood Cancer around Nuclear Installations in Great Britain." 2005*
>
> *Black D., Investigation of Possible Increased Incidence of Cancer in West Cumbria. Report of the Independent Advisory Group. HMSO, London, 1984*

As a result of anecdotal reports of higher rates of childhood leukemia near the nuclear installation at Sellafield, formal studies were initiated in the U.K.. The government established the Committee on Medical Aspects of Radiation in the Environment (COMARE) in 1985. COMARE has released 11 reports examining childhood leukemia and solid cancers around reprocessing plants, enrichment facilities and weapons production facilities.

The COMARE studies are ecological studies, the weakest of population studies in terms of showing cause and effect. However, their results show excesses of leukemia and non-Hodgkins lymphoma in 12 of the 28 locations. They also studied a subset of leukemia, myloid leukemia, and found increases in incidence, none of which reached statistical significance largely because the rarity of the cancer meant that incidence is very low.

Besides the weakness of the studies, they can be criticized for lumping leukemia and non-Hodgkins lymphoma together. Because lymphoma is an uncommon cancer in childhood, this dilutes any increase in leukemia. Nor did the study differentiate between the type of nuclear facility – some are less likely to emit ionizing radiation to the environment than others – and it did not examine the effect of distance, within 25 km of the facility.

The authors note a "serious excess of childhood cancer might be related to radioactive emissions from the nuclear facilities" but state that the emissions measured at the facilities were too small to explain this finding.

India:

> *Padmanabhan V., Sugunan A., Brahmaputhran C., Nandini K., Pavithran K. Heritable Anomalies among the Inhabitants of Regions of Normal and High*

Background Radiation in Kerala: Results of a Cohort Study, 1988-94. International Journal of Health Services, 2004; 34(34):483-515

A cohort study in India compared an area of low natural background radiation to a nearby area with high background radiation. This indicated a statistically significant increase in Down's syndrome, autosomal dominant congenital anomalies and multifactoral disease.

The exposures in the “high” radiation area were well below the allowable level for nuclear workers in Canada.

Canadian Studies:

Most Canadian studies show small non-statistically significant increases of incidence and mortality of cancers and congenital abnormalities (neural tube defects and Down's Syndrome). The studies are small, usually ecological, and address diseases that are relatively rare. Lack of statistical significance of the findings can be neither cause for reassurance nor cause for major concern. To their credit, the Atomic Energy Control Board of Canada, now the Canadian Nuclear Safety Commission, has provided funding for several such studies.

Of particular concern for Canadians is the paucity of research on the health effects of tritium which is released in larger volumes in Canada than anywhere in the world.

Studies:

1. Clarke E., McLaughlin J., Anderson T. Childhood Leukemia Around Canadian Nuclear Facilities – Phase 1 and 2. Ontario Cancer Treatment and Research foundation, University of British Columbia. A report prepared for the Atomic Energy Control Board Ottawa, Canada. May 1989 (Phase 1), June 1991 (Phase 2)

This study is referenced on page 97 of the UDP (reference 143) as indicating **no** increase in childhood leukemias. It is a weak ecological study without case-matching. While it is true that the elevated rates – the observed number of cases exceeded the expected number of cases – of childhood leukemia within a 25 km radius of every nuclear facility in Ontario except Chalk River, were not statistically significant, the authors recommended, on the basis of their findings, that further investigations were warranted.

2. *Johnson K., Rouleau J. Tritium Releases from the Pickering Nuclear Generating Station and Birth Defects and Infant Mortality in Nearby Communities 1971 – 88. (AECB Project No. 7.156.1). Birth Defects and Poisonings Section, Disease of Infants and Children Division, Bureau of Chronic Disease Epidemiology, Laboratory Centre for Disease Control, Health Protection Branch, Health and Welfare Canada. A research report prepared for the Atomic Energy Control Board Ottawa, Canada. October 1991.*

The populations being studied were low and the incidences of the abnormalities were rare which also makes it a weak study. However, two statistically significant positive findings were found. There was a four-fold increase in central nervous system defects corresponding to the highest level of airborne tritium release during the pregnancies and a 1.85 relative risk for Down's syndrome not correlated to airborne tritium.

The authors note that the findings might be due to chance. However, there remains cause for concern given that studies of Chernobyl survivors have shown higher incidences of babies with Down's Syndrome.

3. *Green L., Dodd L., Miller A., Tomkins D., Jiehui L., Escobar, M. Risk of Congenital Anomalies in children of Parents occupationally exposed to Low Level ionizing Radiation. Occupation and Environmental Medicine 1997; 54: 629-35*

This case-control study looked at 763 father and 165 mothers of children born between 1979 and 1986 with congenital abnormalities. These parents of affected children were matched with unaffected children to see if parental exposure to radiation was higher in children with congenital abnormalities.

There were increases in different congenital anomalies in all three radiation exposure groups. Because of the small numbers, none reached statistical significance. The study can also be criticized for failing to include miscarriages or stillbirths and, hence, possibly underestimated the real number of congenital malformations or overestimating the safety of exposure.

4. *McLaughlin J., Anderson T., Clarke E., King W. Occupational Exposure of Fathers to Ionizing Radiation and the Risk of Leukemia in Offspring – A Case-Control Study, 1992 . (AECB Project No. 7.157.1) Ontario Cancer and Treatment Foundation, University of Toronto, University of British Columbia. A research report prepared for the Atomic Energy Control Board, Ottawa, Canada. Aug. 1992*

The scope of this study was very extensive. Time periods were divided into: father's lifetime exposure prior to the child's conception, 6 months prior to conception, three months prior to conception and total lifetime exposure until the child's diagnosis. This was further divided into categories of whole body external dose and tritium dose as well as radon and radon progeny exposures.

However, the extensive scope makes interpretation of the data difficult. The time-line was short and the index disease, leukemia, sufficiently rare so the study had only 80% power to detect a risk of 2.5. Confidence intervals were wide and, while several patterns were associated with higher rates of leukemia in children, none reached statistical significance.

The authors conclude that there is no evidence of a link – but also that definitive statements cannot be made.

5. Howe, Dr. Geoffrey R. Updated analysis of the Eldorado Uranium Miners' cohort: Part I of the Saskatchean Uranium Miners' cohort study, 2006

The UDP states that “the findings of the report, which are consistent with other studies, have indicated that underground miners have a higher incidence of lung cancer than the public”. Without referencing them, they also state that “a linear relationship” exists between “radon exposure and the risk of lung cancer”.

These conclusions are worrisome for the public who will undoubtedly experience an increase in background radiation with an increase in industrial transport and use of radioactive substances.

Conclusion:

The Province of Saskatchewan is in the business of mining uranium; whether it is in the business of producing nuclear power, value-added processing or geological deep storage of waste is the subject of this public consultation. The SMA believes that the health of the people of Saskatchewan should be paramount – those who work in the mining industry, their families, the environment around them and those who might be affected in the future.

As physicians we exhort the Government, through the Ministry of Health, to put in process a baseline study on the health of its people and to create a Branch that would independently verify the reported levels of ionizing radiation as well as report on the determinants of health for those residents living in places impacted by the nuclear industry. With the extensive resources and history of this province, we have an opportunity to be world leaders in responsible stewardship.

Appendix B

Dale Dewar, Linda Harvey and Cathy Vakil, "Uranium Mining and Health," *Canadian Family Physician Dewar*, May, 2013, cfp.ca/content/59/5/469.

Meeting the energy needs of our society is a controversial topic. One source, nuclear power, is entirely dependent upon uranium. Increasingly, physicians are opposing the mining of uranium. In the 1980's, a task force led by Dr. Robert Woollard led to a provincial moratorium on uranium mining in British Columbia.[1] In autumn 2009 in Sept-Îles, Quebec, more than twenty physicians threatened to leave if a uranium mine were opened 13 km upstream from the community in which they practiced.[2] In 2010, the International Physicians for Prevention of Nuclear War passed a motion opposing the mining of uranium.[3] Why would physicians oppose uranium mining?

Toxic Profile

Uranium is a heavy metal with the potential to cause a spectrum of adverse health effects ranging from behavioural and developmental challenges to renal failure, diminished bone growth, and damage to the DNA.[4,5] Because uranium possesses both chemical toxicity and radioactivity, assessing the relative contributions of each to its toxic profile is difficult. The effects of low level radioactivity include cancer, life shortening, and subtle changes in fertility or viability of offspring as determined from both animal studies and data on Hiroshima and Chernobyl survivors.[6,7] These effects can be delayed for decades or for generations and are not detected in short term toxicological studies.

Uranium is chemically toxic to the proximal tubules of the kidney, although the damage is reversible, at least in the early stages.[8] In terms of chemical toxicity, uranium causes damage to the proximal tubules of the kidney, reversible at least

in its early stages. Increased glucose in the urine and higher blood pressures have been found.[9] One study concluded that "uranium exposure is weakly associated with altered proximal tubular function without a clear threshold, which suggests that even low uranium concentrations in drinking water can cause nephrotoxic effects".[10]

Uranium is widespread in the earth's crust, and wherever aquifer and bedrock interface there can be some uranium in the water. Exploratory drilling or mining increases exposure of water to potential contamination.[11]

Radioactivity of Uranium

Uranium is an **α**-particle emitter, as are many of its radioactive decay products including radium and radon. Alpha particles are bulky (two protons and two neutrons) and cannot penetrate human skin. However, when particulate matter containing **α**-emitters is inhaled or ingested, it results in internal exposure to radiation from both the uranium and its radioactive decay products. The carcinogenicity of inhaled **α**-emitters is not in dispute. Radon gas was responsible for up to 20% of the lung cancers in Canada. Health Canada recently lowered the allowable limit in Canadian homes.[12]

A study of Czech and French uranium miners concluded: "A substantial excess of lung cancer, reduced pulmonary function and emphysema … has been reported. The excess has been attributed primarily to irradiation of the tracheobronchial epithelium by alpha particles emitted during the radioactive decay of radon and its daughter products."

Canadian studies have linked lung cancer in miners to their exposure to radiation.[13] Radon is a radioactive decay product of uranium and occurs wherever uranium does. Despite better management than in the past, it remains a hazard in both mines and homes.

In addition to **α**-particle, the radioactive decay products of uranium might emit **β**-particles or **γ**-rays, both ow which also have adverse effects on biological systems.

Uranium Mining

Methods employed for mining uranium in Canada are open cast (pit) mining, conventional underground mining.

Milling typically occurs close to the mine, and involves crushing the ore to a fine sand-like consistency. Alkali and acid washes isolate the uranium, now called *yellowcake*. The remaining 80-99.6% of the ore is referred to as *tailings*, and is stored in tailings ponds or containment fields to prevent wind and water erosion.

Besides chemicals used in washes, tailings contain sulfide ores, molybdenum, selenium, arsenic and mercury and approximately 85% of the radioactivity of the original ore.

The Canadian Nuclear Safety Commission (CNSC) has accepted plans to permanently and safely managed[x] by contouring the tailings, covering them with an impervious layer of clay-like material and a top-soil layer and planting them with trees and grasses.[15]

Discussion

Health and environmental concerns about uranium mining can be categorized as:

- health and safety of miners and mine site;
- health and safety of people in the immediate vicinity who might be affected by spread of radioactivity from the tailings or tailings ponds; and
- global health and environmental effects of increasing background radiation and water contamination.

The health of miners and effects on the immediate environment around the mine site are monitored by the companies involved, with oversight from the CNSC. Concerns about the freedom of the CNSC to act independently of government and industry were highlighted by the firing of the Commission's CEO by the federal government when she applied safety guidelines to shut down the Chalk River reactor.[16] It is concerning that health standards are set by physicists and industry, based on financial and technological convenience, rather than by those educated in and committed to public health and safety.

Political issues have hampered decommissioning and tailings management. Near Bancroft and Haliburton in Ontario, approximately 5 million tonnes of uranium mine tailings were left in jurisdictional limbo when uranium became a federal concern in 1977.[17]. Only through relentless prompting by citizens' groups has some of this remedial work begun. For older mines, neither governments nor companies have set aside sufficient funds for long term management.

The hazards of uranium mining to surrounding populations have not been studied, in part because mines have typically been located in remote areas with sparse populations. As richer ore bodies are exhausted, companies are now exploring marginal deposits, often in more populated regions (such as the Ottawa Valley near Sharbot Lake or upstream from Sept-Îles).

It is concerning that there is currently no plan in Canada to monitor uranium in drinking water near exploration and mining sites. There is no plan to deal with the effect of mining activity on Agriculture or residential populations. Uranium binds to soil and can be taken up by garden produce and forage crops.[18]

Contamination from uranium mining activity will persist for generations. The dust which blows away from the site and the copious amounts of water used for dust control and uranium extraction all contain long lived radioisotopes which are being disseminated into the environment. In the tailings, thorium-230 decays to produce radon gas. With a half-life of 76,000 years, it will produce radon for millennia. In the atmosphere, radon decays into the radioactive solids, polonium, bismuth and lead, airborne isotopes which enter water, crops, trees, soil, and animals, including humans.

In intact rock formations, radon gas is largely trapped within rock during its decay process. In finely ground tailings, it has multiple access routes to the surface and the atmosphere. Planting over the tailings results in the uptake of radioactive substances by vegetation which, in the usual cycle of growth and decay, will be deposited on the surface.

The effects of all these sources of contamination on human health will be subtle and widespread, and therefore difficult to detect both clinically and epidemiologically. Incidences of cancers, fertility problems, and inheritable defects can be expected to rise with the increasing background radiation.

Genetic effects have been clearly documented. A cohort study on a population in India exposed to higher levels of natural background radiation has shown increased incidences of Down syndrome and autosomal dominant congenital anomalies.[19] Transgenerational effects have been shown in non-human species with whom humans share many biochemical pathways. [7,20] We ask whether our increasing burden of cancer, intellectual disabilities, and metabolic diseases has any relationship to an increasingly radioactive environment.

Finally, the end uses of uranium in both nuclear weapons and nuclear power generation poses ethical questions. Byproducts of the nuclear power industry – enriched and depleted uranium and plutonium – are used in weapons, raising the issue of proliferation. Nuclear weapons are uniformly destructive and illegal according to the International Court of Justice.[20] In nuclear power generation, fuel rods produce up to 18 months of power but leave waste far more radioactive and toxic than natural uranium and remain radioactive and toxic for millennia.

Conclusion

Uranium mining has widespread effects, contaminating the environment with radioactive dust, radon gas, waterborne toxins and increased levels of background radiation.

Uranium mining is the first step in the generation of both nuclear power and nuclear weapons. Nuclear power plants produce routine radidoactive emissions in air and water, produce nuclear waste, and create conditions for disasters similar to Chernobyl and Fukushima.

Physicians should be concerned about the health effects in the uranium continuum. As advocates for the health of our patients, we have a duty to advocate for an environment clean of radioactive waste and insist that upon representation at environmental and policy levels of decision-making where health may be affected. We should press for base line health studies where uranium mining is planned. We should be demanding independently funded research into the effects of uranium – and the effects of all radionuclides - on health.

There are no boundaries for air and water; the addition of long-lived radioisotopes anywhere in the environment eventually affects the health of everyone.

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