Human Health Implications of Uranium Mining and Nuclear Power Generation

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ABSTRACT

Radiation: (for references, go to the website above)

There are three types of atomic radiation of concern to human health and safety in regard to uranium mining and nuclear power generation: alpha, beta and gamma radiation. Alpha and beta radiation involve high-speed electrically charged particles with mass, and gamma radiation involves electromagnetic energy. Neutron radiation is a fourth type of atomic radiation, involving particles with mass but no charge. All are capable of displacing electrons from atoms and molecules, and are referred to as ionizing radiation.

Alpha particles, composed of 2 protons and 2 neutrons, and being bulky, are the most biologically destructive of the three. They are up to 20 times more damaging to intracellular structures than gamma rays. They were once considered to be safe by the nuclear industry because they do not normally penetrate skin. Ingested or inhaled, however, and positioned within living tissue, they discharge their alpha particles directly into the structures of the cell, damaging the cell's contents, including mitochondria, enzymes and DNA. Radon, the second leading cause of lung cancer after smoking, is an alpha emitter, as are plutonium 239, uranium 238, uranium 234, thorium 230, radium and polonium.

DNA damage is reparable by the cell, but alpha particles are more likely than other forms of radiation to cause double-strand DNA breaks which are not readily repaired. Attempts at repair can lead to deletions, inversions, acentric fragments and cross-linking, as repair enzymes try to work with missing and scrambled pieces. Damaged DNA can trigger diseases in humans such as cancer (13), teratogenic effects including mental retardation and birth defects (14), chromosomal abnormalities (15) and inheritable disease (7,13).

Beta particles are high-speed electrons, with a small amount of mass and considerable energy. Their effects on biological tissue are somewhat intermediate between alpha and gamma radiation, although closer to those of gamma radiation.

Gamma rays are very high-energy photons with good penetrating power and no mass. They are similar to X-rays. They are more likely to cause single point damage in DNA, and single-strand DNA breaks which are more readily repaired. If the repair is imperfect, a mutation arises and persists. There is evidence now that gamma rays may also be absorbed by certain structures in the cell and give rise to local cascades of high

energy electrons which can be more damaging than the gamma ray itself (16). As well as being emitters of alpha radiation uranium atoms lodged in tissue can absorb gamma rays in this way, and produce such electrons. To the extent that it occurs in living tissue, it may make uranium more genotoxic than previously suspected. The techniques necessary to properly investigate these genetic effects are in the process of being developed.

Natural background levels in most parts of the world are considered to be in the order of 2.4 mSv/yr, with about 1.0 mSv being gamma radiation, mostly from cosmic rays, and the remainder being alpha radiation, largely from radioactive radon gas. This varies somewhat with elevation and other geographic features. Background levels of radiation are thought to contribute to background rates of cancers and genetic defects, and the aging process. According to nuclear regulatory agencies, an acceptable exposure for the public is currently an additional 1.0 mSv/yr above background. It must be borne in mind that any exposure created by human sources, such as nuclear weapons testing fallout or emissions resulting from nuclear reactor accidents, will be added to background exposures.
Nuclear industry workers are allowed to receive 20 mSv/yr averaged over 5 years. Such an exposure, according to ICRP 60 guidelines (17) would be expected to generate 3.2 excess cases of fatal cancer per 100 workers over a 40 year career. This is in contrast to other industrial toxicological situations in which 1/10,000 to 1/million fatalities are considered acceptable (18).

At the low, chronic levels of exposure relevant to uranium mining and nuclear power installations, the principal radiation effects of concern are cancers, genetic damage, birth defects and mental retardation due to in utero exposure. Other more subtle and less well studied effects of radiation include a general life-shortening effect, and a role in some forms of immune system dysfunction, such as autoimmune disorders and decreased resistance to disease. Intracellular free radicals, well known byproducts of ionizing radiation acting upon tissue, play a role in generating oxidative stress which accounts for an increase in disorders such as atherosclerotic vascular disease (19). Even diabetes has been linked to radiation exposure in some studies (20).

Damage to the DNA of germ cells (eggs and sperm) by ionizing radiation can be passed on to future generations, and can be expected to give rise to increases in levels of malformations and genetic disease. Initially, much of this genetic damage will likely be silent. The human body has two copies of every gene, except those on the X and Y chromosomes in the male. Damaged recessive genes, with undamaged partners that can take over function, will go undetected, until they accumulate in a population to the point where two of these recessive genes end up in the same person at the same time, one from each parent. Even then, many of these mutations will be lethal to the developing embryo and will manifest not as defective offspring but as reduced fertility or early miscarriage, events easily missed in epidemiological studies. It must be kept in mind that eggs develop in a female fetus' ovaries during gestation. Therefore a pregnant woman's exposures may affect not only

herself and her children, but her grandchildren as well by damaging the eggs in her unborn daughter's ovaries.

The mutagenic effects of radiation in fruit flies were demonstrated as far back as 1928 by Hermann Muller (26). More recently, Cornelia Hesse- Honegger has documented patterns of malformations in insects throughout Europe based on proximity to nuclear facilities (27). These observations raise concern about the effects of radiation from nuclear facilities on human reproductive cells, and on fetuses due to prenatal exposure.

Uranium mining is the messiest and most contaminating stage of nuclear power generation. Yet, without it, the whole process cannot go ahead. The cost to the global environment, and to persons, of this stage must be factored into the cost of nuclear power generation.

Uranium mining, in particular open pit mining, which is what is currently proposed in several locations in southern Ontario, involves digging thousands of tons of radioactive rock out of a giant hole. (The Rossing uranium mine in Namibia is 1 km wide, 3 km long and 1/3 km deep (28)). Large quantities of this rock are dumped onto the earth's surface. The ore is then transported to a milling facility, usually nearby, and crushed to a fine sand-like consistency, creating radioactive dust and finely ground mill tailings. The uranium is separated out, usually with strong acids or alkalis. The sand-like tailings, containing about 85% of their original radioactivity, and often the chemicals used in the extraction process, are deposited in large tailings ponds or containments nearby.

Dust containing uranium and its progeny is produced in large quantities by rock-crushing operations. This particulate matter, containing long-lived radioactive isotopes, can leave the site on wind. Wind erosion of tailings piles can be significant as long as these remain exposed to weather. Radon gas is continuously produced by the decay of thorium 230, a radioactive decay product of uranium 238, through radium into radon. Thorium 230 has a half-life of 76,000 years, and will produce radon gas unabated for millennia.

In undisturbed uranium deposits, most of the radon gas is trapped within rock formations until it decays into other radioactive byproducts. However, crushed tailings on or near the earth's surface allow considerable radon to escape. In a 10 km/hr breeze, it can travel 960 km within 4 days; much further in higher winds. Radon gas decays sequentially into several other solid radioactive isotopes of polonium, bismuth and lead, before finally becoming the non-radioactive lead 206. These radioactive progeny of radon settle onto crops, bodies of water and soil. Their patterns of accumulation in the biosphere, including our food species, are not well known. The three isotopes of polonium produced by radon, in addition to being radioactive, are among the most toxic naturally occurring substances on earth. The toxicity of lead is well documented.

Radon is a major contributor to the excess of lung cancer seen in uranium miners (4, 5, 6). Radon at levels seen in some residences also carries a risk

(29). Radon emanations from bedrock in certain areas may be unavoidable, however these can be greatly increased in the presence or proximity of crushed mine tailings or abandoned mine workings which provide pathways of migration to the surface. Some high residential radon readings are being found by homeowners near old mine sites in the Bancroft/Haliburton area (30).
Groundwater and surface water in the vicinity of uranium mining operations frequently become contaminated (31). At the advanced exploration stage of mine development, holes about 1-2" in diameter and up to 1200 feet deep are drilled into rock, usually into the most concentrated deposits. A hole of this depth is almost certain to penetrate aquifers, giving water access to radioactive rock surfaces. Many uranium compounds and decay products are soluble, toxic and radioactive. In an area of fractured granite bedrock, as found in some uranium bearing areas of Ontario, many of the aquifers interconnect and contamination quickly becomes widespread.

Uranium is a heavy metal which means that it is toxic in addition to its radioactivity. In drinking water, at levels in excess of the safe drinking water standard of .02 mg/L or 20 ppb, it is principally toxic to the kidney, in particular the proximal tubules (32). Uranium can also affect fertility, fetal growth and postnatal viability (33). It may cause malformations in fetuses and might be associated with reproductive cancers. It concentrates in bone and may interfere with the activity of osteoblasts, possibly contributing to bone cancers and osteoporosis (32).

Uranium in well water is often associated with some of its highly dangerous daughter elements such as radium and radon (18). Their combined radioactivity may be a limiting factor in water quality. Radon in well water is a significant contributor to radon levels in houses (34).

During the operation of a mine, the use of copious amounts of water to control dust, or to create a slurry for the extraction of uranium, can contaminate large quantities of water, which then need to be disposed of. Tailings impoundments containing liquid material can leach contaminants into the soil and groundwater. Tailings dams can fail, releasing massive quantities of radioactive material into local waterways (35). Near the decommissioned mines at Elliot Lake, tailings piles were covered with water to prevent the escape of radon gas, a standard procedure. Recent drought has caused serious difficulties with this maintenance protocol. A mere 15 years into the thousand-year period for which it was designed, this environmental safeguard system is underperforming (36). Over 100 million tons of uranium tailings are stored in the Elliot Lake area (37).

Dry piles of uranium mill tailings are subject to erosion by wind and water. Tree roots and plants take up this radioactive material, often concentrating it (38, 39), and are eaten by biological organisms - birds, insects, mice, deer, etc. - which disperse it in their feces or their bodies. Root systems help to bring radon up to the leaves where it can be transpired into the air.

In Ontario, near Bancroft and Haliburton, there are about 5 million tons of uranium mine tailings. Many of these were abandoned by mines which closed before 1977, and as such they are under the jurisdiction of neither the federal nor the provincial governments (40). In 1977, the federal government created the Atomic Energy Control Board (AECB), later replaced by the Canadian Nuclear Safety Commission (CNSC). Uranium mines thus fell under a federal mandate, whereas before this they were a provincial responsibility. Because of this shift, federal and provincial agencies have been locked in a jurisdictional struggle over these older mine tailings. As a result, according to a study by the Canadian Institute for Radiation Safety (CAIRS) (40), many of the tailings "have not undergone any remedial work designed to place them in a safe condition."

Tons of radioactive rock are laying around unprotected, with contaminants leaching out, wind blowing dust, radon gas escaping, fencing and signage falling into disrepair and the area being used more and more for hunting, hiking and recreation. It is possible that fill is being taken for construction purposes from unmarked radioactive sites.

What are the risks from these tailings? According to the CAIRS study, a person walking over a typical tailings pile for 1 hr every day will absorb a gamma radiation dose of, on average, 0.73 mSv/yr (41). This would be in addition to the ~1.0 mSv/yr of background gamma radiation we all receive. Consider that doubling a person's exposure will in general double his/her cancer risk, and that this person will also be exposed to higher than normal levels of radon gas near the tailings.

If a house were built on the tailings, or if substantial amounts of radioactive fill were used near this house, or to mix concrete for the house, and a person or family spent between 8 and 24 hrs/day in this house, their radiation exposure could be substantial. It might well be over the maximum of 1.0 mSv/yr above background recommended for the general public (8). (In this scenario, it could be up to 0.73mSv/yr X 24 =17.52 mSv/yr per person.)

Use of contaminated materials in construction has been a problem not only in the Bancroft area, but in Elliot Lake, in Port Hope, where there is a uranium conversion facility dealing with highly radioactive material, and in the United States in Navaho territory where there was intensive uranium mining in the past (42).

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