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POTENTIAL HEALTH EFFECTS OF RADON-222 TO THE GENERAL PUBLIC FROM URANIUM MILLING[1]

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Abstract - The milling of uranium ores over the past 35 years has produced over 140 million tons of tailings materials. Since mill tailings contain over 85% of the natural radioactivity originally present in the ore, they have been identified as a potential source of long-term radiation exposure to the general public. Concern has been expressed that unless mill tailings are stabilized with a cover of earth or some other appropriate material, a major radiological impact of the nuclear fuel cycle may be the radon-222 released by this source.

This paper presents a discussion of the potential health risk that may result from present and future radon-222 releases at uranium mill tailings piles situated in the United States. These risks are contrasted with the health risk continually present as a consequence of background levels of radon-222 naturally present in the atmosphere. It is estimated that the current risk of lung cancer in the population due to uranium milling is less than 10^{-4} times the natural risk. In addition, it is estimated that future risks due to mill tailings will be approximately a factor of 10^5 lower than the natural radon-222 risk to the general public if stabilization of tailings piles is implemented. Thus, it appears the incremental population risk due to milling is insignificant with respect to the natural risk.

Concern that technology may inadvertently impair the health of mankind necessitates making assessments of the environmental changes technology induces. Technologically enhanced natural radiation is a term coined by Gesell and Prichard (1) to specify exposure from naturally occurring terrestrial and cosmic sources that would not normally occur without the presence of a "technological activity not expressly designed to produce radiation." One such technologically enhanced source of natural radiation which has aroused considerable interest in the United States is the mining and milling of uranium ore. The function of

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uranium mills is to extract uranium from uranium ore. The milling process removes about 90% of the uranium from the ore, but only a small percentage of other radionuclides present in the ore. Mill tailings, consequently, contain over 85% of the natural radioactivity originally present in the ore. This natural radioactivity in mill tailings, which without mining and milling would be isolated beneath the earth's surface, is now exposed to the above-ground environment.

The greatest concern regarding uranium milling has focused on the health hazard associated with the radioactive gas radon-222 (half-life, 3.8 days), which is produced continuously in mill tailings as part of the radionuclide chain that begins with uranium (half-life, 4.5 billion years) and contains many other long-lived radionuclides such as thorium-230 (half-life, 80,000 years) and radium-226 (half-life, 1600 years). This gas is readily dispersed over large geographic areas where it eventually decays into the radioactive particulate lead-210. The lead-210 is deposited on soil and vegetation where it can enter the terrestrial food chains. Uranium mills consequently represent not only a source of inhalation exposure from radon and its short-lived daughters (bismuth-214, lead-214, polonium-214,218), but also a source of inhalation and ingestion exposure from terrestrially-deposited lead-210.

Because of the long radioactive half-life of thorium-230, tailings piles will continue to release radon for more than 100,000 years. Some believe that health effects due to radon-222 released from uranium mill sites should be assessed for 10,000 to 100,000 years into the future to fully address the question of health impact. The failure of the Nuclear Regulatory Commission to consider future releases of radon-222 from uranium tailings has been cited by critics as cause to reevaluate licensing procedures for nuclear power plant construction permits (2). In April of 1978 the Nuclear Regulatory Commission voided their previously endorsed assessment of tailings piles, whereby effects of the nuclear fuel cycle were estimated for one year, and thereby left open the time period during which radon releases should be considered. This action by the Nuclear Regulatory Commission made way for litigation of the radon issue in individual licensing proceedings, of which 17 are currently pending (3).

One way of evaluating the radiological risk to inhabitants of the North American continent resulting from inhalation exposures due to radon-222 released from uranium mill sites is to contrast these health risks with those normally present as a result of natural background levels of atmospheric radon-222. A discussion of the results of this approach follows. Health effects associated with lead-210 which may be inhaled or ingested have been considered elsewhere (4), but will not be discussed at this time. It can be expected, however, that the health risks from lead-210 produced during radon-222 dispersion will follow the pattern established for inhalation of radon-222 and short-lived daughters.

The milling of uranium ores in the United States over the past 35 years has produced 140 million tons of tailings materials containing these radionuclides, all of it in surface disposal piles at 21 operating mill sites and 22 abandoned sites. Unless stabilized with a cover of earth or some other appropriate material, the radon flux (Curies/m^2-sec) at tailings piles may be up to 500 times the natural background rate for soil (5).

It is estimated that uranium tailings piles at active mill sites in the United States released about 1.5×10^5 Curies of radon-222 in 1978 (6). The largest number of health effects resulting from these releases will be within the continental United States where we estimate that 0.34 potential lung cancers may occur.* The corresponding figures for Mexico and Canada are 0.02 and 0.006

*Risk estimate assumed that 2.0×10^{-5} cancers to the bronchial epithelium of the lung may result from a continuous exposure over a one-year period to 1.0 nCi/m^3 of radon-222 (taken from the Rapporteur's Report by John Harley summarizing discussion of risk estimation for radon and daughters by the OECD-NEA Workshop on problems associted with radiation protection principles for naturally-occurring radionuclides in May of 1978).

potential lung cancers, respectively. Thus, of the total potential lung cancers, 93% will occur within the continental United States, while 5% and 2%, respectively, will occur in Mexico and Canada.

About a quarter of all accumulated uranium mill tailings are at inactive mill sites, several of which are located near large population centers. For example, some 30 city blocks from downtown Salt Lake City is a 128-acre abandoned mill site containing about 1.8 million tons of mill tailings. These inactive sites released about 5.1×10^4 Curies of radon-222 in 1978 (6). Due to the close proximity of the inactive sites to large population centers, the health effects from inactive mills are estimated to be somewhat greater than for active mills. We estimate that 0.5 lung cancers per year will result in the United States from these releases of radon. Thus, radon-222 released from active and inactive uranium mills during 1978 may result in a total of about 0.84 lung cancers in the United States.

We now address the problem of long-term releases of radon-222 associated with uranium milling. It was estimated (6) that radon-222 released from all uranium tailings generated in the United States during the time period 1978-2000 will reach a constant value of about 9.2×10^5 Curies per year, and thereafter remain approximately constant in future years. Assuming that the United States population stabilizes at about 290×10^6 persons in the year 2030 and that these uranium tailings are not stabilized, these radon releases will result in about 3.0 lung cancers per year in the United States. If uranium tailings generated during the period 1978-2000 are stabilized to reduce radon-222 flux to about twice the natural soil flux or 2 pCi/m^2-sec, the constant flux of radon reached in the year 2000 will be about 4.0×10^3 Curies per year. This would result in about 0.01 lung cancers per year of exposure.

To add perspective to these risk estimates, comparable estimates will be given for natural background levels of radon-222 in the atmosphere. These levels of radon-222 originate largely from decay of radium-226 in the soil and rocks of the earth's crust. The principal factors affecting ground-level air concentrations of radon-222 are the radium concentration of the soil, soil characteristics, atmospheric conditions, and vegetation cover (7). These factors combine to produce considerable variation in background levels of atmospheric radon. On the basis of existing data (6), however, we estimate that on the average 1.2×10^8 Curies of radon-222 are released annually by soils in the United States. If individuals were continuously exposed to this naturally present outdoor level of atmospheric radon, we estimate that 520 potential lung cancers might result annually in the United States.

Radon-222 concentrations in the interiors of buildings are a major technologically enhanced source of airborne radiation to which the general population is also exposed. The principal sources of indoor radon-222 concentrations are (a) radon flux through the floor of the building from soil emanation and subsequent buildup due to containment within the structure, (b) the domestic use of potable water containing radon, (c) natural radioactivity in building materials used in construction, and (d) background atmospheric concentrations of radon-222. Since the radon is confined to the interior of the buildings, the resulting indoor radon concentrations can be quite high. Recent measurements of 21 homes in the New York City area (8) found radon concentrations ranged from 2 to 15 times the outdoor concentrations at the same locations. Assuming that indoor concentrations of radon in the United States average four times outdoor concentrations (8), and that individuals spend about 70% of their time indoors (9-10), we estimate that about 1,600 lung cancers result each year in the United States from radon naturally present in the atmosphere and building interiors.

The question of the period of time over which potential health consequences of long-term releases of radon from uranium mill tailings piles should be assessed is a particularly sensitive one. It is extremely difficult, if not impossible, to make accurate predictions of health effects 10,000 to 100,000 years into the future, as some intervenors suggest. Major uncertainties inherent in such estimates include the inability to predict future population growth and distribution, and the almost certain possibility of future changes in food production and consumption patterns. However, some perspective of the long-term hazards associated with exposure to a particular radionuclide can be gained by expressing risk on a comparative basis. It is apparent that the potential health risks from releases of radon in 1978 from uranium mill tailings piles were 10^{-4} times less than the risk from natural background levels of radon. Assuming that uranium tailings generated during the period 1978-2000 are stabilized, the potential *health risks per year will be less than 10^{-5} times the risk from natural background* radon. This would appear to be an insignificant increment in the everyday risk to which the population, as a whole, is subjected from natural background radon.

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