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ENVIRONMENTAL RADIONUCLIDES

INTRODUCTION

Exposure to radionuclides in the Great Lakes area was recently reviewed by scientists at Health Canada. The sources of environmental radiation exposure include natural radioactivity, fallout from atmospheric weapons testing, nuclear fuel cycle activities, and other low-level radiation sources such as hospitals or laboratories. Some natural radiation sources are products from natural radioactive decay chains (such as radon, Rn^{222}, and radium, Ra^{226}), radioactive potassium (K^{40}) in the soil, and cosmic radiation or radionuclides produced in the atmosphere from cosmic radiation. Natural radiation sources are estimated to provide the major contribution to radionuclide exposure in the Great Lakes basin.[1]

Atmospheric weapons testing is the source for most of the anthropogenic radionuclides exposure in the Great Lakes basin; most weapons testing has ceased since the Limited Test Ban Treaty of 1963 went into effect. There are presently 19 operating nuclear electricity-generating stations in the Great Lakes basin, and there are also related facilities involved in uranium mining, nuclear fuel preparation or reprocessing. Levels of ambient radioactivity in the atmosphere peaked in the 1960's, and a similar pattern was seen for hydrogen (H^3), strontium (Sr^{90}), cesium (Cs^{137}) and plutonium ($Pu^{239,240}$) in water samples from the Great Lakes.[2]

Health risks associated with radiation exposure include cancer, developmental effects (such as mental retardation in Hiroshima/Nagasaki), and non-genetic effects. Cancer is the endpoint studied in most recent reports of low-level radiation exposure. Few studies have been conducted on non-genetic effects, with the exception of acute radiation exposure incidents such as the explosion at the nuclear facility in Chernobyl in April 1986.

A quarterly summary of recent findings in the scientific literature on human health effects and environmental pollutants, with an emphasis on pollutants of the Great Lakes ecosystem. Prepared under the direction of the Health Professionals Task Force of the International Joint Commission. This does not represent the official position of the International Joint Commission.

Health Professionals Task Force Secretary: Jim Houston
International Joint Commission
Canada Section
100 Metcalfe Street
Ottawa, Ontario K1P 5M1
phone (613) 995-0230
fax (613) 993-5583

Health Physics Measurements: the units used to measure exposure and dose for radionuclides are different from those used for chemical pollutants, and a brief summary follows:

Activity is a measure of radioactive decay: a Curie (Ci) is equal to 3.7×10^{10} disintegrations per second, and a ***Becquerel*** (Bq) is 1 disintegration /second (3.7×10^{10} Bq = 1Ci).

Absorbed dose is measured in rads or grays. The ***Gray*** (Gy) is the more modern unit, and it refers to the deposition of 1 joule of energy in 1 kilogram of tissue (1 gray=100 rads).

Equivalent dose is a radiation-weighted dose unit, while ***effective dose equivalent*** is a tissue-weighted dose unit; the unit for both is the rem or ***Sievert*** (Sv) (1 Sv=100 rem). 1 Gray of X-ray radiation is equivalent to 1 Sievert, and weighting factors are used to establish equivalent dose for other types of radiation. The effective dose equivalent relates equivalent dose to different tissues or organs to a whole body dose using tissue-weighting factors the exposed organs or tissues. For radon exposure, the unit of ***Working Level Month*** (WLM) is approximately equal to an alpha dose to the lung of 0.01 Gy.

EXPOSURE STUDIES

It has been estimated that the average person's annual radiation dose from natural radiation exposures is 2.5 mSv/year. The cumulative dose from atmospheric weapons testing is estimated to be 1.9 mSv/year for the period 1950-2050. Doses to the public living near uranium and milling facilities could be as high as 0.7 mSv/year. Doses near nuclear reactors are estimated to be 0.01 to 0.04 mSv/year. Some radionuclides, such as Ra^{226}, can be found in waterbodies, both as a result of natural decay series and from uranium mining wastes. Activity levels from sites across Canada ranged from 1 to13 mBq/L, while concentrations in Elliot Lake, Ontario, were as high as 18 mBq/L.[1] Another radionuclide of potential concern in the Great Lakes basin is Rn^{222}, an airborne radionuclide that is released from water or soils and can accumulate in buildings. In a survey[3] of data collected across the U.S., four regions were identified as having high radon levels: (1) the Appalachian mountain area; (2) the Rocky Mountains and an eastward extension into Colorado, Texas and New Mexico; (3) a region extending from northern Alabama through most of Indiana; and (4) a region including Iowa and western portions of Illinois and Minnesota. A recent survey of water treatment plants in Iowa found Rn^{222} levels that exceed the U.S. standard for miners' exposure (100 pCi/L), though the plant operators' exposures did not exceed the OSHA standard because they spent only short periods of time in the treatment plant.[4]

As one indicator of radiation exposure, Canadian scientists[5] measured radionuclide concentrations and doses in 15 caribou populations in northern Canada. Caribou were studied because lichens are a main component of their diet during the colder months, and previous studies have shown that the slow-growing lichens tend to accumulate long-lived pollutants. The authors found that Cs^{137} activity in caribou peaked in the 1960's, due largely to global atmospheric weapons testing fallout, and has been declining since, with a small increase after the Chernobyl accident. A large portion of the current radiation exposure is attributable to naturally-occurring radionuclides such as Rn^{222}. There are apparently higher levels of natural emissions in the central regions of Canada. For some herds, exposures exceeding 500 mGy/year were found, while the authors report no observable adverse health effects in the caribou.

Exposure to Ra^{226} was measured in cattails and muskrat living in the vicinity of uranium mining facilities near Elliot Lake, Ontario.[6] Mining waste deposits had accumulated over a period of 40 years, with surface water Ra^{226} concentrations of up to 978 mBq/L in a highly-contaminated area in Quirke Lake. Radium uptake by muskrats was found to be a highly localized phenomenon; animals living only a few hundred meters from highly contaminated areas did not have increased Ra^{226} burdens. The ICRP maximum permissible intake by ingestion for Ra^{226} for the general public is 4,000 Bq/year. Disregarding other sources of radium exposure, the authors conclude that a human consumer would have to eat more than 60 kg of raw muskrat bone per year to approach the lower value for the ICRP's maximum permissible intake.

Waterborne radionuclides were found to be a significant source of radiation exposure for residents of Ukraine.[7] Cs^{137} and Sr^{90} levels were measured in drinking water, irrigation water, and fish in the Dnieper River basin; the Dnieper River is currently a major pathway for Cs^{137} and Sr^{90} transport out of the Chernobyl area. The maximal individual doses (for the year 1986) were predicted to be 0.027 mSv and 0.017 mSv for Cs^{137} and Sr^{90}, respectively, with higher doses (up to 2 mSv/year) expected for fishermen who rely heavily on fish in their diets.

LOW-LEVEL EXPOSURE STUDIES

Concern about the health effects of low-level radiation was raised with the publication of findings of increased leukemia and lymphoma in children with increased paternal exposure at a nuclear fuel reprocessing plant in Sellafield, UK.[8] However, this association has not been found in all studies, and one reviewer has concluded that existing studies do not support an association between childhood cancer and parental radiation exposure.[9] In an Ontario study,[10] childhood leukemia cases were paired with controls from the same geographic areas, and paternal radiation exposure was not associated with leukemia in children. In Scotland, researchers found no evidence for an increased incidence of leukemia and non-Hodgkin's lymphoma incidence in children less than 15 years of age in areas near nuclear facilities.[11] A significant increase (p=0.030) in leukemia incidence was found in the 25-km area surrounding the nuclear reprocessing plant at Dounreay, but the test for diminishing risk with distance from the plant was not significant (p=0.356). No significant differences were found in the areas around nuclear submarine bases or nuclear electric power generating stations.

In contrast, Massachusetts Department of Public Health researchers found evidence for increased rates of leukemia in adults near a nuclear power plant in Plymouth, MA.[12] Using cancer cases reported between 1978 and 1986, and four geographic proximity measures (from <4 miles to >23 miles), a trend of increasing risk was found (ORs of 1.72, 2.44 and 3.46 for the three closer areas, compared with >23 miles from the plant). The authors note that the estimated dose due to the nuclear plant's emissions is small, and urge "cautious interpretation of associations."

Some evidence for increased bone cancer in young people (<26 years) with Ra^{226} exposure was found in Ontario. On the basis of Ra^{226} levels in tapwater samples from each individual's home, a significant trend was found for all sarcomas (p=0.029) and osteosarcoma (p<0.01). Positive, but not statistically significant, associations were found when the authors used calculated estimates of lifetime exposure.[13]

Researchers at Columbia University conducted a review of cancer incidence records for the years 1975-1985 found no evidence for an association between increased cancer rates with radiation exposure related to the nuclear accident at Three Mile Island in March 1979.[14] However, when comparing areas with different exposure levels from routine emissions, there was an elevated, but not significant, odds ratio for leukemia in young children (OR 2.33, 95% CI 0.59-9.23) and an association between lung cancer and increased exposure (OR 1.55, 95% CI 1.18-2.03). In a reanalysis of the data regarding pre- and post-accident exposures in adults, significant associations were found for all cancers, lung cancer and leukemia.[15] An earlier nationwide survey of cancer rates in counties across the U.S.[16] found no evidence of increased rates of cancer in counties with nuclear facilities, compared with counties not near nuclear facilities.

Some evidence for increased cancer risk with low-level radiation exposure has been found in studies of nuclear industry workers. When data from studies of health effects in nuclear industry workers from seven facilities in three countries were combined, increased risks were found for leukemia excluding chronic lymphocytic leukemia (p=0.046) and multiple myeloma (p=0.037), but not for other forms of cancer or all cancers combined.[17] A recent study of mortality in workers at the Oak Ridge facility in Tennessee (time period 1947-1990) showed a significantly increased risk of lung cancer for all workers (OR 1.17, 95% CI 1.01-1.34), and an increased risk of pancreatic cancer in white male workers (OR 1.19, 95% CI 1.03-1.36).[18] In contrast, a previous study on this cohort (for years 1947-1986) found only a significant increase in leukemia (SMR 1.63, 95% CI 1.08-2.35) in white males.[19] When divided into dose categories, all-cancer and leukemia mortality increased by 4.94% and 9.15%, respectively, with each 10 mSv increase. In an Italian study of male hospital workers with x-ray exposures, significantly more thyroid nodules were found in men with higher exposures (p<0.01) and the risk increased with length of occupational exposure period after adjusting for age.[20]

HIGH-LEVEL EXPOSURES

Hiroshima/Nagasaki: A recent review of health effects studies on survivors of the nuclear bombing in 1947 found that leukemia and cancers of the breast, lung and thyroid were increased among survivors.[21] The excess risk for death from solid cancers has been nearly constant in successive follow-up studies for those exposed as adults, but has decreased over time for those exposed as children.[22]

Chernobyl: In April 1986, an explosion at the nuclear electricity generating plant in Chernobyl resulted in a large release of radionuclides into the environment. Acute radiation poisoning symptoms were seen in over 200 people at or near the facility, and 31 persons died with days or weeks of the accident. In the first decade after the accident, a marked increase in thyroid cancer among children has been observed in Ukraine and Belarus. Most authorities attribute this, at least in part, to exposure to radioiodine emitted from the Chernobyl reactor. As yet, no increases have been apparent in other forms of cancer.[23]

In a study of residents in the Chernobyl area, increases in chromosomal abnormalities were found among those who were subject to high radiation doses but survived the accident, as well as in schoolchildren from villages near the nuclear plant.[24]

As a result of the Chernobyl accident, airborne radionuclides were deposited in many areas throughout the Northern hemisphere. In a recent study in Sweden, brain tumor incidence in children in the more highly-contaminated region was studied for the time period of 1978 to 1992. There was a statistically significant yearly increase in childhood brain tumor incidence (p=0.002), but the trend was already apparent prior to the Chernobyl accident in 1986.[25]

RISK ASSESSMENT

The International Committee on Radiological Protection recommends a dose limit of 1 mSv/year for the general population, and the water quality guidelines or standards developed by U.S. or Canadian agencies have been based on the need to limit dose to less than 100 μSv/year.[2] Ahier and Tracy[1] estimate that the total average dose received from drinking Great Lakes water is about 1.2 μSv for Lakes Ontario, Erie and Huron, and 1.0 μSv for Lake Michigan. At these levels, the maximum estimated effect is 3 fatal or nonfatal cancers or hereditory disorders per year in the Great Lakes basin population.[1] The risks associated with current exposures to water-borne radionuclides in the Great Lakes basin are thus low. However, accidents such as Chernobyl, while unlikely, illustrate the potential for human radiation exposures through this route.

Great Lakes Center
for Occupational and Environmental Safety and Health
UIC School of Public Health

PREPARED BY:

Great Lakes Center for Occupational and Environmental Safety and Health
School of Public Health
University of Illinois at Chicago
2121 West Taylor Street
Chicago, Illinois 60612-7260
(312) 996-7887
email: mross1@uic.edu

Project Coordinator:
Mary A. Ross, MA
Senior Science Advisor:
Daniel O. Hryhorczuk, MD, MPH

World Health Organization
Collaborating Centre for Occupational and Environmental Health

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