

Occurrence of ^{210}Po and Biological Effects of Low-Level Exposure: The Need for Research

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BACKGROUND: Polonium-210 (^{210}Po) concentrations that exceed 1 Bq/L in drinking-water supplies have been reported from four widely separated U.S. states where exposure to it went unnoticed for decades. The radionuclide grandparents of ^{210}Po are common in sediments, and segments of the public may be chronically exposed to low levels of ^{210}Po in drinking water or in food products from animals raised in contaminated areas.

OBJECTIVES: We summarized information on the environmental behavior, biokinetics, and toxicology of ^{210}Po and identified the need for future research.

METHODS: Potential linkages between environmental exposure to ^{210}Po and human health effects were identified in a literature review.

DISCUSSION: ^{210}Po accumulates in the ovaries where it kills primary oocytes at low doses. Because of its radiosensitivity and tendency to concentrate ^{210}Po , the ovary may be the critical organ in determining the lowest injurious dose for ^{210}Po . ^{210}Po also accumulates in the yolk sac of the embryo and in the fetal and placental tissues. Low-level exposure to ^{210}Po may have subtle, long-term biological effects because of its tropism towards reproductive and embryonic and fetal tissues where exposure to a single alpha particle may kill or damage critical cells. ^{210}Po is present in cigarettes and maternal smoking has several effects that appear consistent with the toxicology of ^{210}Po .

CONCLUSIONS: Much of the important biological and toxicological research on ^{210}Po is more than four decades old. New research is needed to evaluate environmental exposure to ^{210}Po and the biological effects of low-dose exposure to it so that public health officials can develop appropriate mitigation measures where necessary.

KEY WORDS: cigarettes, drinking water, Fallon, human health, lead-210, leukemia, ovary, polonium-210. *Environ Health Perspect* 120:1230–1237 (2012). <http://dx.doi.org/10.1289/ehp.1104607> [Online 26 April 2012]

In 2007, very high levels of the naturally occurring radioisotope polonium-210 (^{210}Po) were discovered in drinking water from numerous private wells in Lahontan Valley, Churchill County, in northern Nevada. Of the 60 private wells and 3 public supply wells sampled in the valley (Seifer 2011), more than one-third of the private wells had ^{210}Po levels exceeding 0.55 Bq/L, and 10% had levels that exceeded 2 Bq/L. This level is extremely unusual—fewer than 100 wells in the United States have reported ^{210}Po activities that exceed 0.55 Bq/L, and the maximum value measured in Lahontan Valley, 6.59 Bq/L, is the fourth highest value reported in the United States (Seifer 2012).

^{210}Po is one of the most toxic substances known because of its intense radioactivity, with 1 μg of ^{210}Po having an activity of 1.66×10^6 Bq. After the death of Alexander Litvinenko from ^{210}Po poisoning in 2006, several papers were published that addressed the diagnosis, treatment, and toxicity of acute ^{210}Po poisoning (Harrison et al. 2007; Jefferson et al. 2009; Scott 2007) and the need for medical toxicology expertise about ^{210}Po because of its potential use in radiation terrorist events (Nernbauer 2010). The estimated acute lethal dose from oral ingestion for an adult if untreated is 10–30 μg (Jefferson et al. 2009), and as little as 1 μg

might be lethal to the most radiosensitive members of the population (Scott 2007).

As an alpha-particle-emitting decay product of radium-226 (^{226}Ra), ^{210}Po is classified as a Group 1 human carcinogen [International Agency for Research on Cancer (IARC) 2001]. Numerous epidemiological studies, which were reviewed by Carru et al. (2011), have investigated associations between exposure to members of the uranium-238 (^{238}U) decay series in drinking water and cancers such as leukemia (e.g., Hoffmann et al. 1993; Lyman et al. 1985; Ranschoo-Nielsen et al. 2008). Because ^{210}Po is the last radioactive member of the ^{238}U decay series, a common feature of all these studies is the presence of ^{210}Po in the environment, even if it was not measured. Because ^{210}Po is a human carcinogen and because information on environmental exposure to it is poorly known, we reviewed the literature on ^{210}Po .

In this paper, we summarize relatively unknown and disparate information on the environmental behavior, biokinetics, and toxicology of ^{210}Po and suggest supportive research that could help guide future investigations.

Environmental Behavior of ^{210}Po

^{210}Po has a relatively short half-life of 138.4 days and decays to lead-206 (^{206}Pb) by emitting an alpha particle. It is the last unstable

isotope in the ^{238}U decay series and is present in the environment whenever ^{238}U or any other members of the ^{238}U decay series, such as ^{226}Ra , radon, or ^{210}Pb , are present. The average crustal U concentration is approximately 2.7 mg/kg (Siegel and Bryan 2003), and > 99% of natural U is ^{238}U (Bordajenka 2002). Large areas in the United States have surficial uranium concentrations exceeding 2.7 mg/kg (Figure 1). The specific activity of ^{238}U is 12.4 Bq/mg, and in old sediments where radon is not lost to the atmosphere, the activity of ^{210}Po in secular equilibrium with 2.7 mg/kg of ^{238}U would be about 33.5 Bq/kg.

The main source of ^{210}Po in the atmosphere and oceans is from the emanation of radon gas from surficial sediments to the atmosphere where it is spread by diffusion and winds (Parfenov 1974; Persson and Holm 2011). In addition, high ^{210}Po can be introduced into the atmosphere in volcanic emissions because of the high volatility of ^{210}Po compared with ^{210}Pb (Kim et al. 2011). Radon's decay products, ^{210}Pb and ^{210}Po , have strong affinities for particles and become widely distributed on the earth's surface as the ^{210}Pb and ^{210}Po that are formed from decay of radon in the atmosphere adsorb to aerosol particles and fall onto the land or sea.

^{210}Po activities exceeding 1 Bq/L have been found in private wells in Florida and Nevada and public supply wells in Louisiana and Maryland (Seifer et al. 2011). ^{210}Po in groundwater is normally < 30 mBq/L because

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The authors thank the U.S. Environmental Protection Agency for funding their work on the Fallon Leukemia Cluster (grant EM-9696(2011), and J.L.W. thanks the Children with Cancer UK (formerly Children with Leukemia) for providing additional support (grant 08-14-179). R.L.S. thanks T. Rees for encouraging him to get involved in the Fallon Leukemia Cluster Investigation. An earlier version of this article was greatly improved by the valuable comments of three anonymous reviewers, and R.L.S. appreciates the helpful comments by former colleagues at U.S. Geological Survey (USGS).

R.L.S. is retired from the USGS, and the views expressed in this paper are those of the authors and do not reflect the position of the U.S. government or the USGS.

The authors declare they have no actual or potential competing financial interests.

Received 10 October 2011; accepted 26 April 2012.

Biological Effects Of Low Level Exposure

Guillaume Favre



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