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Emerging Threats: Radionuclides in Drinking Water

Brajesh K. Shrivastava*

Ministry of Drinking Water & Sanitation, Government of India, New Delhi, India;
brajesh979@rediffmail.com, brajeshchem@gmail.com

Abstract

The Research paper undertakes theoretical review of the characteristics of few radionuclides in aqeous system. These radionuclides have been identified due to their potential health effects and widespread concern. The radionuclides are: Uranium, Tritium, Cesium-137, Radon, Strontium-90, Radium, Iodine-131, Technetium and Polonium-210.

Keywords: Ionization, Radionuclides, Radiation, Reverse Osmosis

1. Introduction

Radioactive isotopes released from nuclear power plants/ nuclear testing /medical facilities may wind up in drinking water sources and thereby can pose risk for human life[1,4]. The two types of isotopes with radioactive decay that carry the most health risk due to ingestion of water are alpha- particle emitters and beta/photon-particle emitters (Lappenbusch et al, 1985). Many radionuclides are mixed emitters with either an alpha or beta emission coupled with gamma (photon) emission, or in some cases, all three. Radionuclides of greatest concern from health perspective in terms of the potential for normal or accidental release from nuclear fuel cycle industries into drinking water supplies are:

1.1 Uranium

Uranium is a radioactive contaminant that could be found or released in both groundwater and surface water. It comes from natural sources like mountain rivers, non-natural from phosphate fertilizer (nitrates), uranium mining and from nuclear power plant accident contamination. The distinct feature of uranium is that unlike other heavy metals (cadmium, mercury, lead), it is not regulated. The safe concentration of uranium in drinking water is between 2-30 µg/L. In practice, recommendations limits of 10 µg/L for adults and for babies 2 µg/L is applied. At high exposure levels, uranium is believed to cause bone cancer and other type of cancers in humans. Uranium is also toxic to the kidneys (Kurtio et al, 2002). Enriched uranium exposure alters the spatial working memory capacities of rats when these rats are exposed for 9 months to drinking water contaminated with enriched Uranium at a dose of 40 mg/L[7].

In general, levels of uranium in both surface water and groundwater have been found less than 1 µg/L; however, substantially higher concentrations have also been reported in both private and community groundwater sources across USA/

* *Author for correspondence*

Canada/EU. Maximum concentration of Uranium (40µg/L) in drinking water has been reported in Germany (Foodwatch, 2008) .Uranium forms soluble complexes particularly with carbonates under oxygen-rich conditions, and precipitates from ground water under oxygen-poor conditions (Zapecza and Szabo, 1987; Cothern and Rebers, 1990). The concentration of uranium in water and rock can thus be expected to range widely with different geochemical environments.

1.2 Radon

Radon is is the most dense gas known ever.It is colorless at standard temperature and pressure. At temperature below it's freezing point, is has a brilliant yellow phosphorescence. It is chemically unreactive, highly radioactive and has a short half life (3.8 days). Radon can be found in some spring water ,hot springs and also in drinking water.(Meringera et al, 2009). It has also been found in bottled water in in the range of 0.12–18 Bq/L in Austria (Kralic et al, 2003). Ingesting drinking water that contains radon presents a risk of internal organ cancers, primarily stomach cancer[8]. The U.S. Environmental Protection Agency (EPA) and the U.S. Surgeon General recommend testing indoor air for radon in all homes and apartments located below the third floor. Background levels of radon in outside air are generally quite low, but in indoor locations, radon levels in air may be higher. Some of the deep wells that supply us with drinking water may also contain radon. As a result, a number of people may be exposed to radon through drinking water, as well as through breathing air and hence it is an important radionuclide progeny tobe investigated in water/air.

1.3 Iodine-131

Radioactive iodine-131 was discovered by Glenn T. Seaborg and John Livingood at the University of California - Berkeley in the late 1930's. It is produced by the fission of uranium atoms during operation of nuclear reactors and by plutonium (or uranium) in the detonation of nuclear weapons. Whenever spent nuclear fuels are handled, there are chances that iodine-129 and iodine-131 will escape into the environment. Nuclear fuel reprocessing plants dissolve the spent fuel rods in strong acids to recover plutonium and other valuable materials. In the process, they also release iodine-129 and -131 into the airborne, liquid, and solid waste processing systems. Iodine-131 is important in terms of its mobility in the environment and its selective irradiation of the thyroid gland when taken into the body. As a result of its short half-life (eight days), Iodine-131 is of concern only immediately following a significant release from a reactor.

1.4 Cesium-137

Caesium-137 was discovered in the late 1930s by Glenn T. Seaborg and Margaret Melhase. It is the most dangerous of all caesium isotopes as it not only decays by emitting beta particles but also releases high-energy gamma radiation. It has also long half-life period of 30 years. It is produced by the fission of plutonium and uranium in nuclear reactors or nuclear explosions. As most caesium compounds dissolve in water, the ingestion of contaminated drinking water or food grown on contaminated land is the main route of exposure. Cesium-137 is strongly affixed to sediments in aquatic environments, which reduces its concentration in the water column little bit. Once inside the body, caesium-137 is distributed fairly uniformly throughout the body's soft tissues, particularly muscle, and those tissues can be damaged by the beta and gamma radiation. It is listed by the US Center for Disease Control as one of the isotopes that may be released by a terrorist attack.

Exposure to large amounts of radioactive

caesium in or near the body can result in acute radiation sickness, the symptoms of which are nausea, vomiting, diarrhoea, bleeding, coma, and even death. Study on exposure of caesium-137 on the testicular or adrenal steroidogenesis on animal @ a dose of 6500 Bq/L (610 Bq/kg per day) in drinking water show alterations of sperm parameters, along with perturbations within the levels of cortisol, ACTH, and testosterone[5].

1.5 Strontium-90

Strontium is a soft, silver-gray metal that occurs in nature as four stable isotopes. Strontium-88 is the most prevalent form, comprising about 83% of natural strontium. The other three stable isotopes and their relative abundance are strontium-84 (0.6%), strontium-86 (9.9%), and strontium-87 (7.0%). Total, there are sixteen major radioactive isotopes of strontium but only strontium-90 is of concern due to its long half-life period (29 years). The half-lives of all other strontium radionuclides are less than 65 days. Strontium-90 decays to yttrium-90 by emitting a beta particle, and yttrium-90 decays by emitting a more energetic beta particle with a half-life of 64 hours to zirconium-90.The main health concerns for strontium-90 are related to the energetic beta particle from yttrium-90. Isotopes of strontium can be found in the water column because many strontium compounds are water soluble. Comparative study of ^{90}Sr with ^{137}Cs indicates that these two have similar mobility on deposition but, as time passes, the relative mobility of ^{90}Sr increases with respect to ^{137}Cs over a period of 5–8 years.(Otosaka et all, 2006).

1.6 Radium

Radium in nature is composed of four isotopes: Ra-223, Ra-224, Ra-226, and Ra-228. Radium-223 is a member of the U-235 decay series and, therefore, rarely occurs in the environment in high concentrations. Radium-224 is the fifth member of the Th-232 decay series, has a half-life of 3.64 days, and decays by alpha-particle emission. Radium-226 is the fifth member of the U-238 decay series, has a half-life of about 1,602 years, and decays by alpha-particle emission.Radium-226 is the most abundant radium isotope in the environment in terms of actual mass because of its long halflife. Radium-228 is the second member of the Th-232 decay series, has a half life of 5.75 years, and decays by beta-particle emission.

The maximum contaminant level for Radium-226 and Radium-228 in drinking water is 5 pCi/L (US EPA, 2000). At high exposure levels, Radium-226 and Radium-228 can cause bone cancer in humans and are believed to cause stomach, lung, and other cancers as well. The contribution of drinking water to total Radium-226 intake is small when supplies are drawn from surface waters. Concentrations in groundwater sources, however, are highly variable and result mainly from the interaction between the groundwater aquifer and radium-bearing materials, such as rock, soil and ore deposits. In general, higher levels of Ra-226 can be expected in areas containing uranium mining and milling operations or where rock containing high concentrations of the natural radionuclides is in contact with the water.

1.7 Technetium-99

The long-lived fission product Tc-99 is present in large quantities in nuclear wastes and its chemical behaviour in aqueous solution is of considerable interest for scientists (Blidogio et al, 1983). Under oxidizing conditions technetium exists as the anionic species TcO_4^- where as under the reducing conditions, expected to exist in a deep geological repository, it is generally predicted that technetium will be present as $TcO_2 \cdot nH_2O$. Hence, the mobility of Tc(IV) in reducing groundwater may be limited by

the solubility of $TcO_2 \cdot nH_2O$ under these conditions. Due to this fact it is important to investigate the solubility of $TcO_2 \cdot nH_2O$.

1.8 Tritium

The World Health Organization guidelines for drinking water quality do not specify any limit for tritium, but the National Radiological Protection Board, Scotland (1991) suggests a tritium exposure limit of 10^7 Bq per year for the public. On this basis and assuming a standard drinking rate of 584 l/ year, a tritium concentration of maximum 1.4×10^5 TU (1.7×10^4 Bq/L) is acceptable in drinking water (Robinson and Gronow, 1996).The major source of tritium in air/water is Nuclear fall-out and GTLD's (Gaseous Tritium Light Devices) such as watches, clocks, compasses and electron Tubes. Tritium moves environmentally mainly as a tritiated water molecule, HTO. Its measurement has been a challenge to the scientists because environmental measurements of tritium began only after the onset of nuclear weapons testing and its complete chemistry is still unknown. Higher concentration of tritium in aqeous system has been found at few places across the world[11,12] (Chant et al. 1993). The natural concentration of tritium in lakes, rivers, and potable waters has been found between 0.2-1.0 Bq/L (5-25 pCi/L) prior to the advent of weapons testing (UNSCEAR report,1982).

1.9 Po-210

Polonium was discovered by Marie Sklodowska Curie and her husband Pierre in 1898 by purifying it from pitchblende. The element was named in honor of Marie's homeland Poland. It could be present in uranium and because of the radioactive decay of the uranium-series radionuclides, very low levels of Po-210 are naturally in air we breathe, the water we drink, biota, and foods we ingest (Stannard 1988; Cohen 1989). Po-210 was found first at an unusually high concentration (290 to 607 pCi/L) in a well used for drinking water in Louisiana (Mullin, 1982) and was above 2 pCi/L in some wells in the Grants Mineral Belt of New Mexico (Kaufmann and others, 1976). The source of Po-210 in the well in Louisiana is unknown. Uranium ore of mineable grade was presumed to be the source of Po-210 in the wells in New Mexico. It is not known if changes in water quality as a result of mining increases the mobility of the Po-210. Po-210 has also been found in a shallow aquifer in west-central Florida (Harada and others, 1989). The incident in London during November 2006 involving a lethal intake by Mr. Alexander Litvinenko of the highly-radioactive, alpha-particles-emitting polonium-210 (Po-210) isotope, presumably via ingestion has sparked renewed interest in the area of Po-210 toxicity to humans. It has been found that ingestion of 1MBq/ kg-body-mass of Po-210 causes death to human being within one year while ingestion/inhalation of 0.1 to 0.2 MBq/kg-body-mass can cause death in one year or little over one year (Scott, 2007).

2. Conclusion

Radionuclides measurement in drinking water hasn't gained much importance in India except some areas which are adjacent to nuclear power plants. For example, In India, the raw water for manufacturing bottled water are sent only once in two years for only radiation measurement, and never for individual radionuclides. There are plenty of data's available on general physico-chemical and microbiological studies of surface and groundwater in India. However, migration and distribution plume studies of radionuclides in surface and groundwater in India are limited and the available studies do not

give complete status of existing or potential threats. It is high time that modeling and dispersion studies of specific radionuclides are undertaken extensively for surface and ground water in India as well. The review is expected to provide more focused study of these radionuclides in India regarding their behaviour, interaction and finally, optimum removal from aqueous ecosystem.

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