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Review Paper

Identification and Assessment of Emerging Threats from Radio Nuclides in Drinking Water

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Abstract

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

Keywords: Radio nuclides, Radiation, Ionization, Reverse Osmosis.

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]. Radiation exposure may results from ionizing (alpha and beta particles, gamma rays or X-rays) or non-ionizing materials. Radiation of radioactive materials is measured either in curie (US system) or in Becquerel (SI unit) and the risk of radiation exposure to human being is measured either in REM (Roentgen Equivalent Man) or in Sievert (Sv) in (SI unit) with conversion adjustment of 1 Sv =100 REM. Deposition of radiation in human body is measured in Radiation Absorbed Dose (RAD). Gross alpha and Gross beta measurements are useful for screening to determine whether further analysis for specific radio nuclides is required. However, gross measurements give no information about the isotopic composition of the sample and have poor sensitivity if the concentration of dissolved solids is high. Therefore, understanding the characteristics of individual radio nuclides in drinking water are also important from health risk of the people. Some of the important radio nuclides - elemental as well as compound forms, in drinking water are:

Uranium: Uranium is the heaviest naturally occurring element on the earth. It is a mixture of 3 radioactive isotopes –Uranium 238 (99.27 %), Uranium 235 (0.72%) and Uranium 234 (0.005 %). Ground waters, which are rich in soluble carbonates and bicarbonates, may complex and keep uranium in solution. It comes from natural sources like mountain rivers and non-natural sources such as phosphate fertilizer (nitrates), uranium mining and from nuclear power plant accident contamination. 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 in several country. In India, Atomic Energy Regulatory Board suggests, 60 µg/L as a guideline value for drinking water. World Health Organization (WHO) recommends a guideline value of maximum permissible limit of 15 µg/L for uranium in drinking water while USEPA has a maximum limit of 30 µg/L. 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[2]. 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[3].

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/Canada/EU. Maximum concentration of Uranium (40µg/L) in drinking water has been reported in Germany. Uranium forms soluble complexes particularly with carbonates under oxygen-rich conditions, and precipitates from ground water under oxygen-poor conditions[4]. The concentration of uranium in water and rock can thus be expected to range widely with different geochemical environments.

Radon: Radon is the densest gas known ever. It is colorless at standard temperature and pressure. At temperature below its 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. It has also been found in bottled water in the range of 0.12–18 Bq/L in Austria[5]. Ingesting drinking water that contains radon presents a risk of internal organ cancers, primarily stomach cancer[6]. 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 to be investigated in water/air.

Iodine-131: Fission products from nuclear testing or during the use and processing of reactors may contain Radio-iodines ranging from Iodine 129 to 135, of which Iodine 131 only, is likely to be found in water. 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. The EPA drinking water maximum contaminant level for Iodine-131 is 3 pCi/L.

Cesium-137: Caesium-137 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[7].

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.

Radium : Radium has 4 naturally occurring isotopes: 11.6 days Ra-223, Ra-224, 3.6 days 1602 years -Ra-226 and 5.75 years Ra-228. Radium-223 is a member of the U-235 decay series and rarely occurs in the environment in high concentrations. Radium-224 is the fifth member of the Th-232 decay series 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 half life. 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 United States Environmental Protection Agency (US EPA) has specified the maximum contaminant level for Radium-226 and Radium-228 in drinking water is 5 pCi/L and 3 pCi/L for Radium 226. 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.

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. Under oxidizing conditions technetium exists as the anionic species TcO4- whereas 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 $TcO_2 \cdot nH_2O$.

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 x 10^5 TU (1.7 x 10^4 Bq/L) is acceptable in drinking water. 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[8-9]. 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.

Polonium-210: Polonium was discovered by Marie Curie and her husband Pierre in 1898 by purifying it from pitchblende. The element was named in honor of Marie's homeland Poland. Polonium-210 is the most important alpha emitting radionuclide in uranium series due to its high toxicity. It is considered to be even more toxic than Hydrogen Cyanide (HCN). Of the 20 types of different isotopes of Polonium, its 210 isotope, which has a half life period of 138 days, is considered to be most stable. It is highly soluble in water and readily deposited in soft tissues. High concentration of Po-210 (290 to 607 pCi/L) has been reported from a well used for drinking water in Louisiana in USA and also in some wells in the Grants Mineral Belt of New Mexico. Groundwater at shallow aquifer in west-central Florida has also been reported containing Po-210[10]. 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[11].

Conclusion

Radionuclides measurement in drinking water has not 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 radio nuclides. There are plenty of data available on general physico-chemical and microbiological studies of surface and groundwater in India. However, migration and distribution plume studies of radio nuclides 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 radio nuclides 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 behavior, interaction and finally, optimum removal from aqueous ecosystem.

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