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Review Article

Radionuclides: A synopsis of Distribution, Epidemiology, Importance, Public Health Significance and Control Measures

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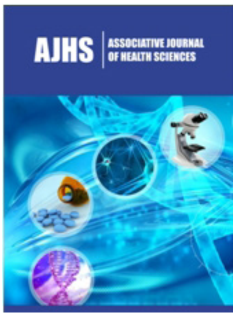

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Abstract

Radionuclides are atoms which possess excess energy emitted in the form of radiation (gamma), particles (alpha or beta) or conversion electrons. They are being discharged into large water bodies and are absorbed by aquatic organisms which form part of the food chain. These contaminated waters and aquatic organisms are further consumed by higher organisms leading to the accumulation of these radionuclides. Radionuclides have shown application in biology, nuclear medicine, food preservation, industries, aeronautics and ecology. Despite these applications, they tend to produce harmful effects in humans and animals following uncontrolled exposure. These effects depend on dose and elapsed time after exposure, and include skin redness, hair loss, radiation burns and acute radiation syndrome. However, prolonged exposure can lead to cell destructions and consequential cancer develops. Hence in this article, radionuclides are discussed with a focus on their distribution, epidemiology, importance, public health significance and prevention/control measures.

Keywords: Radionuclides, water, effects, exposure, public health

Introduction

Radionuclides, also known as radioactive nuclides, radioisotopes or radioactive isotopes, are highly unstable atoms possessing excess nuclear energy [1]. The excess energy has been documented to be emitted from the nucleus as gamma radiation or transferred to one of its electrons leading to the formation of conversion electron following ejection. Also, there is possible creation and emission of a new particle (alpha particle or beta particle) from the nucleus by the energy [2]. All these processes constitute radioactive decay of the radionuclide and lead to formation of a more stable nucleus [2,3]. However, radioactive decay is spontaneous due to the uncertainty in predicting the actual time an atom will decay [1]. In reality, radionuclides are believed to be widely associated with all chemical elements as observed in hydrogen (tritium) and elements heavier than lead (technetium and promethium) [4,5].

Geographic distribution

There has been a global occurrence of radionuclide exposure resulting from dumping/discharge of radioactive material into the oceans [6]. Documented evidences of this situation include frequent radioactive waste discharges into the Irish Sea by British nuclear fuels plant across the United States, discharge by French nuclear reprocessing plant into the English Channel and dumping of large quantities of radioactive material into the Arctic Ocean, Kara Sea, and Barents Seas by Soviets [7,8]. Also, there have been reports of discharge of radioactively contaminated water from the damaged Fukushima Daiichi nuclear power plants into the ocean [9]. Despite the diluting capacity of the ocean to nuclear contaminants, there have been signs resulting from spread of radioactive materials and these included elevated concentrations of radioactive cesium and iodine, and high levels of radioactivity in seawater in Japan [9]. These radioactive elements, when absorbed by phytoplankton, zooplankton, kelp, and other marine life, are transmitted up the food chain, to fish, marine mammals, and humans with detrimental effects. Marine lives are also threatened with the involvement of radioactive elements such as plutonium [10,11].

Epidemiology of radionuclides

The absorption of radionuclides by aquatic organisms is dependent on the form of the radionuclide and these aquatic organisms are part of the human food chain [4]. Shellfish and other filter-feeding organisms concentrate particulate, and these are passed to terrestrial farm when these contaminated fish bones are used as feed [9]. In contrast, the uptake of radionuclides by aquatic organisms has been altered to a larger extent by the presence of chemically stable similar elements, thus affecting their concentrations in the food chain [12]. This is so as the degree of uptakes of Cs-137, and Sr-90, by freshwater fish have been demonstrated to show inverse variations with potassium, and stable calcium concentrations in water, respectively [9]. Hence, the bioaccumulation of cesium and strontium isotopes is greatly decreased in marine systems compared to fresh water due to the larger amounts of potassium and calcium in seawater [13]. Therefore, an estimate of the radionuclide losses during food preparation will give an indication of the radionuclide intake from aquatic food chains [14].

Importance of radionuclide

Low levels of radionuclide exposure occur naturally without harm although unplanned exposure is generally believed to pose harmful effects on living organisms including humans and fish [6]. The harmful effects induced by these radionuclides depend on the nature and extent of the radiation produced, the amount and nature of exposure (close contact, inhalation or ingestion), and the biochemical properties of the element. Increased risk of cancer has been reported to constitute the most usual consequence of radionuclide exposure [15]. Despite these harmful effects, radionuclides have found applications in nuclear medicine in terms of diagnosis and therapy. Radioactive tracers, and radiopharmaceuticals, are imaging tracers, and pharmaceutical drugs, respectively, made with radionuclides [1]. The importance of radionuclides can be described in terms of their use for their radiation alone (irradiation, nuclear batteries) or for the combination of chemical properties and their radiation (tracers, biopharmaceuticals) as follows;

A. In biology; Radionuclides can be used to monitor processes such as DNA replication or amino acid transport [6].

B. In nuclear medicine; radioisotopes are used for diagnosis, treatment, and research as adopted in some forms of tomography, hemopoietic forms of tumors, and sterilization of syringes and other medical equipment [1,9,16].

C. In food preservation; the stoppage of root crops sprouting post-harvest, killing of parasites and pests, and control of the ripening of stored fruit and vegetables have been achieved through the use of radiation [5].

D. In industry and in mining; radionuclides have been used in the examination of welds, detection of leaks, studying the rate of metal wear, erosion and corrosion as well as for on-stream analysis of a wide range of minerals and fuels [9].

E. In spacecraft and elsewhere; radionuclides are used to provide power and heat, notably through radioisotope thermoelectric generators (RTGs) [5].

F. In astronomy and cosmology; radionuclides play a role in understanding stellar and planetary process [1].

G. In particle physics; radionuclides have helped to discover new physics (physics beyond the Standard Model) by measuring the energy and momentum of their beta decay products.

H. In ecology; radionuclides are used to trace and analyze pollutants, study the movement of surface water and measure water runoffs from rain and snow, as well as the flow rates of streams and rivers [9].

I. In geology, archaeology, and paleontology; natural radionuclides have been utilized to age rocks, minerals and fossil materials [1].

Side effects of radionuclide

The adverse biological responses resulting from the exposure of people to internally deposited radioactive materials depend on the temporal pattern of dose to sensitive cells, tissues, or organs [17]. The manifestation of these responses also depends on the complex relationship of risks associated with the different possible competing effects as a function of elapsed time after intake [18]. Such competing biological effects can include different forms of radiation-induced cancer and non-neoplastic systemic or functional injury [17].

Radionuclides that find their way into the environment may cause harmful effects as radioactive contamination [13]. They can also cause damage if they are excessively used during treatment or in other ways exposed to living organisms, by radiation poisoning. Potential health damage from exposure to radionuclides depends on a number of factors and can damage the functions of healthy tissue/organs. Radiation exposure can produce effects ranging from skin redness and hair loss to radiation burns and acute radiation syndrome. Prolonged exposure can lead to cells being damaged and in turn lead to cancer. Signs of cancerous cells might not show up until years, or even decades, after exposure [18].

Public health significance

Radiation exposure through drinking water results from naturally occurring radionuclides in drinking water sources, especially alpha-radiation-emitting uranium, radium, and their progeny, including radon [17]. According to the WHO, when activity concentration in drinking water exceeds the recommended level of 0.5Bq/L for gross-〈 or 1Bq/L for gross-® activities [simultaneously measured activity from a mixture of natural alpha [uranium-238 (238U), 234U, thorium-232 (232Th), radium-226 (226Ra), and polonium-210 (210Po)] and beta emitters [228Ra and lead-210 (210Pb)]. Radionuclide-specific concentrations should be brought into compliance with WHO guidance levels: 0.1Bq/L for 228Ra; 1Bq/L for 223–226Ra, 234U, and 235U; 10Bq/L for 238U; 100Bq/L for radon-222 (222Rn), and 15µg/L for total uranium (WHO 2004).

When ingested, radionuclides are absorbed into the blood leading to accumulation in specific tissues with potential damage [19]. Of absorbed uranium, 66% is rapidly eliminated via urine, while the rest is distributed and stored in the kidney (12-25%), bone (10-15%), and soft tissue [20]. Radium is deposited mostly in the bone [20]. Ingested radon gas diffuses into the stomach wall, thus making the stomach wall the tissue most irradiated by ingested radon due to its short half-life (3.8 days) [21].

Natural uranium induces chemical toxicity, especially nephrotoxicity, and this is believed to be more harmful than radiotoxicity solely induced by radium and radon [20,22]. However, there is scant information on the possible health effects following ingestion of naturally occurring radionuclides via drinking water [23-25].

Prevention and control

Methods suggested to reduce radiation exposure have been targeted at increasing the distance between the operator and the source, and these include.

A. Avoidance of direct handling of sources of penetrating radiation and unshielded multi-millicurie sources.

B. Ensuring the use of forceps, tongs, custom-designed holders and spacers to maintain distance between your hand and the source.

C. Designing simple tools for securely handling sources.

D. Avoidance of placing potentially-contaminated objects in the mouth.

E. Securing radioactive materials in sealed containers to avoid inhalation intakes.

F. Using splash guards and wearing gloves, a lab coat and other protective clothing.

Conflict of Interest

The authors declare no potential conflict of interest.

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