

RISK ASSESSMENT DUE TO TRITIUM INGESTION THROUGH DRINKING WATER

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Abstract: The population is exposed to ionizing radiation from both naturally occurring and anthropogenic sources. The main pathways of exposure are ingestion, inhalation, or absorption through the skin. Dose estimation of ionizing radiation due to ingestion of water or food, or due to inhalation is a key step in assessing the risk to the health of the population. Drinking water contains naturally occurring radionuclides potassium-40, and those of the thorium and uranium decay series. In addition, drinking water may contain artificial radionuclides as a consequence of accidental or regular discharges from nuclear facilities, the medicine industry, military activities. One of them, tritium, radionuclide which occurs in the environment both naturally and artificially can be present in drinking water. In order to estimate dose from drinking water for individual radionuclides, concentration of radionuclide must be known. Effective dose than can be estimated for different age groups. Research results provide important information for risk assessment and implementation of appropriate measures to protect public health. This manuscript evaluates the risk associated with tritium ingestion through drinking water, focusing on its sources, pathways, and regulatory standards.

Key words: tritium, drinking water, LSC, risk assessment, dose

1. INTRODUCTION

Drinking water contains naturally or artificially occurred radionuclides, that contribute to the dose of ionizing radiation ingested. Assessment of the effective dose introduced through drinking water is crucial for identifying potential health risks and complying with international recommendations. The ingestion of water is one of the pathways of incorporation of radioactive substances into the human body. The contribution to the exposure of the general public as a whole from practices which involve a risk from ionizing radiation must be kept as low as reasonably achievable [1].

Naturally occurring radionuclides in drinking water usually give radiation doses higher than those provided by artificially produced radionuclides and are therefore of greater concern. Radiological risks are best controlled through a preventive risk management approach following the framework for safe drinking water, and the water safety plan approach. The Drinking Water Directive (Council Directive 2013/51/ Euratom; European Union, 2013a) [1] stipulates requirements for protecting public health from radioactive substances in water intended for human consumption, and specifies parametric values for radon, tritium and indicative dose. Natural radionuclides, including potassium-40, and those of the thorium and uranium decay series, in particular radium-226, radium-228, uranium-234, uranium-238 and lead-210, can be found in water as a result of either natural processes or technological processes involving naturally occurring radioactive materials (e.g. the mining and processing of mineral sands or phosphate fertilizer production) [2].

Tritium is a very important nuclide for detecting potential radioactive contamination of waters, especially as its origin in water is mostly anthropogenic and not natural. Tritium is a radioactive form of hydrogen with a half-life of 12.3 years [3]. Tritium predominantly exists as tritiated water (HTO), making it readily integrated into hydrological cycles. Consequently, tritium contamination in drinking water is a growing concern, particularly near nuclear facilities. Although tritium is a low-energy beta emitter, its ingestion poses potential health risks due to internal radiation exposure.

This study aims to assess the potential health risks associated with tritium ingestion through drinking water. By analyzing exposure pathways, dose-response relationships, and existing regulatory

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limits, the manuscript provides a comprehensive framework for understanding and mitigating tritium-related risks.

2. SOURCES OF TRITIUM

Naturally

Tritium is generated naturally through the interaction of cosmic rays with atmospheric gases in the upper atmosphere. Tritium exists in the following forms: in water molecules as tritiated water (HTO), in organic molecules as organically bound tritium (OBT), and in air as tritiated gas (HT) [4]. The average natural (cosmogenic) concentration of tritium in environmental waters has been estimated to range from 0.12 to 0.9 Bq/l [5].

Artificial

Anthropogenic sources of tritium include nuclear fission reactors and decommissioning, past nuclear weapons testing (until the early 1960s) which significantly increased global tritium levels, nuclear accident such as Fukushima and Chernobyl, tritium production facilities, and medical and research facilities [6]. Tritium is abundantly released from nuclear industries. It is extremely mobile in the environment and in all biological systems. Tritium releases from nuclear facilities only contribute a small amount to the overall exposure to radiation. The tritium dose from nuclear power plants is much lower than exposures to natural background radiation and medical exposure.

2.1. Pathways of Exposure

Tritium reaches to the atmosphere, as mentioned, either naturally by creation in the upper layers of the atmosphere or artificially, from where it enters in the natural watercourses through precipitation. Tritium enters the human body in the following ways: inhalation (of any atmospheric form), absorption through the skin, and through ingestion of water or consumption of food irrigated with tritiated water. Once ingested, tritium is distributed uniformly in body fluids and tissues, where it behaves chemically similar to hydrogen. Most tritium leaves the body as tritiated water in urine, in breath as moisture and through perspiration. Half of the tritium is excreted within approximately 10 days after exposure. Most inhaled tritiated hydrogen gas is exhaled immediately. For this reason, it is necessary to obtain ecological data which would enable the estimation of public exposure to tritium released in the atmosphere.

3. METHOD

Natural levels of tritium in environmental water are low, so the water samples (composite monthly samples) have to be purified by distillation, followed by an isotopic enrichment procedure using electrolysis through a direct current [3,7]. Each sample was removed from the organic materials by distillation process to prevent the interference of organic compounds. The enriched samples are mixed with 12 ml scintillation cocktail ULTIMA GOLD LLT in polyethylene vials. Samples were measured using ultra-low-level liquid scintillation counter Quantulus 1220 [3,7,8]. Liquid scintillation counting (LSC) is based on the conversion of the energy of a particle emitted by a radioactive nucleus to light energy by means of a scintillating chemical. The scintillations are detected by a photomultiplier (PM) tube. The electrical signals from the PM tube are amplified and sent through a simple multichannel analyzer (three or four channels at most) where sorting into energy takes place.

Measuring time of each sample is 300 min. Beside the samples, *dead water DW* (tritium free water) is also measured for background, as well as water of known tritium activity (*BEFORE BE*). *BEFORE*, after enrichment calls *SPIKE SW* water. Their ratio determines cell enrichment factor. For determination of efficiency, standard tritium solution ^3H 9031-OL-548/13 Czech Metrology Institute Type: ERX with activity 5.060 MBq on day 1.10.2013 is used. The tritium measurement uncertainty is expressed as the expanded measurement uncertainty for the factor $k=2$, which corresponds to a normal distribution with a confidence level of 95 %.

For effective dose calculation, conversion factors for different age groups (Table 1), as well as average annual intake of drinking water for different age groups must be known, implying knowledge of the tritium concentration in water. Although infants and children consume a lower mean volume of drinking water, the age-dependent dose coefficients for children are higher than those for adults, accounting for higher uptake or metabolic rates.

Table 1 – Conversion factors $h(g)_{3H,ing}$ [Sv/ Bq] [9] for different age groups [years]

$h(g)_{3H,ing}$	0-1	1-2	2-7	7-12	12-17	> 17
	6.4×10^{-11}	4.8×10^{-11}	3.1×10^{-11}	2.3×10^{-11}	1.8×10^{-11}	1.8×10^{-11}

4. RESULTS AND DISCUSSION

Based on the tritium concentration in drinking (tap) water from Belgrade (April+May+June 2024), calculated effective dose for different age groups were in the range 0.027 μ Sv/y for age 7-12 to 0.055 μ Sv/y for age 1-2 (Table 2). The individual dose criterion of 0.1 mSv/y represents a very low level of risk that is not expected to give rise to any detectable adverse health effect. The obtained value for tritium in investigated water was 3.30 ± 0.41 Bq/l which is below the permissible value of 100 Bq/l given in the Rulebook [10]. Regulatory limits for tritium in drinking water vary globally: Canada 7000 Bq/l, USA 740 Bq/l, EU 100 Bq/l, Finland 30000 Bq/l, Russia 7700 Bq/l, Switzerland 10000 Bq/l [11].

Given the fact that tritium is beta emitter, it cannot be detected by gamma spectrometry. For that reason if in drinking water some parameters are above the permissible value for natural radionuclides such as ^{226}Ra , ^{232}Th , ^{238}U , specific method must be performed such as determination of tritium. Its presents in the environment at an elevated level, may indicate the presence of other artificial radionuclides [10].

Table 2 – Calculated Effective dose E_{ing} [μ Sv] for different age groups

E_{ing}	0-1	1-2	2-7	7-12	12-17	> 17
	0.053	0.055	0.036	0.027	0.033	0.043

5. CONCLUSION

Tritium ingestion through drinking water poses potential health risks, particularly for populations near nuclear facilities. For that reason, knowledge of tritium concentration in natural watercourses (tap water, underground water, precipitation, surface water) is of great importance. Comprehensive risk assessments, stringent regulatory standards, and proactive mitigation measures are essential to safeguard public health. In this paper is just one example of dose calculation that different age groups receive from tritium ingestion in drinking water. A database is required for understanding long-term health effects.

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