



Radon concentration and physicochemical properties measurement and internal exposure assessment in different brands of commercial soft drinks consumed in Türkiye

Dalal A.O. Sultan^a, Şeref Turhan^{b,*}, Ergin Murat Altuner^c, Temel Kan Bakır^d

^a Department of Physics, Science Institute, Kastamonu University, 37150, Kastamonu, Türkiye

^b Department of Physics, Faculty of Science, Kastamonu University, 37150, Kastamonu, Türkiye

^c Department of Biology, Faculty of Science, Kastamonu University, 37150, Kastamonu, Türkiye

^d Department of Chemistry, Faculty of Science, Kastamonu University, 37150, Kastamonu, Türkiye

ARTICLE INFO

Handling editor: Dr. Daniele Wikoff

Keywords:

Energy drinks
Radon
pH
Brix
Internal exposure
Annual effective dose

ABSTRACT

Energy drinks (EDs) are soft drinks with energy-boosting ingredients such as caffeine, taurine, vitamin B, and herbal extracts. In this study, the first-ever radon activity concentrations of thirty-five canned ED samples from mostly preferred sixteen assorted brands consumed in Türkiye were analyzed by using a monitoring system. Also, radiological risk resulting from internal exposure due to the ionizing radiation emitted from radon, and its short-lived decay daughters were assessed for adults. Additionally, some physicochemical parameters of ED samples were determined by well-known instruments. Radon activity concentrations analyzed in ED samples ranged from 21.3 ± 0.8 to 37.5 ± 1.8 mBq/L and these values are significantly below the limits recommended for drinking water by the US Environmental Protection Agency and the European Union directive. The values of physicochemical parameters determined for ED samples ranged 2.56 to 4.30 (pH), 593 to 3030 $\mu\text{S}/\text{cm}$ (electrical conductivity), 525–2680 mg/L (total dissolved solids) and 1.30–13.20 % (Brix values). Since the annual effective doses estimated based on the annual consumption of soft drinks and EDs per capita in Türkiye are well below the individual dose criterion of 100 μSv , the radiological risk is at a negligible level.

1. Introduction

Continuous exposure of human beings to ionizing radiations (alpha-, beta-, and gamma-rays) from natural cosmogenic and terrestrial (or primordial) radionuclides is an inevitable fact of life (UNSCEAR, 2008). An individual is annually exposed to an average effective dose of 2.4 mSv due to natural radioactivity (UNSCEAR, 2008). There are two types of exposure to ionizing radiation: external and internal. External exposure is essentially the whole-body irradiation of gamma-rays from radionuclides in the uranium (^{238}U), actinium (^{235}U), and thorium (^{232}Th) decay series, and potassium (^{40}K) found in environmental samples (soil, rock, etc.). Internal exposure results from ingestion and inhalation of terrestrial radionuclides. Ingestion exposure dose is mainly due to the terrestrial radionuclides present in drinking waters and foods. Therefore, it depends on water and food consumption rates and the concentrations of radionuclides (UNSCEAR, 2008). Inhalation exposure dose arises from the existence of dust particles contained radionuclides in the

air. The predominant components of inhalation exposure are radon (^{222}Rn) and its short-lived daughters (^{218}Po , ^{214}Pb , ^{214}Bi , and ^{214}Po). ^{222}Rn is the largest source of natural radiation contributing to general public exposure because an annual effective internal dose of 1.15 mSv, corresponding to approximately half of the total exposure dose from natural radioactive sources, is due to ^{222}Rn and its progenies (UNSCEAR, 2008). ^{222}Rn ($T_{1/2} = 3.82$ days), generated by the alpha decay of radium (^{226}Ra) in the ^{238}U series can be found in soil, rock, groundwater, and food (UNSCEAR, 2008). ^{222}Rn is a tasteless, colorless, and odorless noble gas. As a consequence of the ingestion and inhalation of ^{222}Rn dissolved in beverages, its daughters settle in the lungs and stomach and undergo alpha and beta decay. Ionizing radiations (alpha- and beta-rays) emitted by these radionuclides can damage tissues and induce lung cancer (WHO, 2022; Nayak et al., 2022).

Recently, functional complementary drinks and foods are generally preferred instead of those with high vitamin and protein content due to rapid technological developments in the food industry, changing eating

* Corresponding author.

E-mail addresses: serefturhan63@gmail.com, sturhan@kastamonu.edu.tr (Ş. Turhan).

<https://doi.org/10.1016/j.yrtph.2025.105880>

Received 13 March 2025; Received in revised form 6 May 2025; Accepted 4 June 2025

Available online 6 June 2025

0273-2300/© 2025 Elsevier Inc. All rights reserved, including those for text and data mining, AI training, and similar technologies.