



Radiological quality of packaged natural spring waters sold in Türkiye and radiological health risk assessment

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ABSTRACT

The quality of drinking water is related to the physical, chemical, microbial, and radiological aspects of the water. It is of great importance for human health and plays an important role in tap and packaged water preferences. Groundwater obtained from aquifers by drilling wells constitutes the main source of packaged natural spring water (PNSW) consumed in Türkiye. The radiological quality of these waters is determined by the concentration of natural radionuclides dissolved in water from the aquifer rocks. This study presents the first detailed radiological data on PNSW brands commercially sold in Türkiye. The activity concentrations of ²²⁸Ra, ²²⁶Ra, and ⁴⁰K in eighty-two PNSW brands were measured by gamma-ray spectroscopy. Radiological risk caused by the intake of these radionuclides in PNSW samples was assessed for adults by estimating the annual effective dose and excess lifetime cancer risk. The activity concentrations of ²²⁸Ra are above the guidance level (GL) of 0.1 Bq/L recommended by the World Health Organization of the United Nations (WHO), while the activity concentrations of ²²⁶Ra are below the GL of 1 Bq/L. However, risk assessment estimations for radium isotope ingestion reveal that the annual consumption of 130 L/y of PNSW water does not pose a risk for radiological human health.

1. Introduction

Drinking water (DW), which is indispensable for human life, plays a fundamental role in the fulfillment of many functions in the human body, such as regulating body temperature, helping to dissolve vitamins and minerals, transporting nutrients and oxygen to cells, removing toxins and transporting waste products (Daniele et al., 2019). However, it is a well-known fact that the rapid increase in population, urbanization, technological, commercial, industrial, and agricultural activities, and natural events in recent years have caused the pollution, decrease, and deterioration of water resources (surface and groundwater) (Salam and Sultana, 2022; Lin et al., 2022). Diseases related to pollution and deterioration of DW quality pose a major burden on human health (World Health Organization (WHO), 2022). Therefore, the right of access to clean, safe, and quality DW (packaged water, tap or public-piped water, etc.) is a fundamental human right and is one of the main components of an effective policy for the protection of human health (World Health Organization (WHO), 2022). Therefore, the purpose of regulations or standards regarding DW quality is to ensure that consumers

have access to safe, sufficient, and sustainable DW (World Health Organization (WHO), 2022). DW quality, which is related to the physico-chemical, microbiological, and radiological properties of water, is the most important characteristic in terms of the safety of water intended for human consumption and is also an important factor affecting people's DW consumption preferences (Ćirić et al., 2018; World Health Organization (WHO), 2022).

In recent years, there has been a trend among people to replace tap water with commercially packaged DW (PDW) or bottled DW (BDW) in their daily diets because of its higher quality, safer, healthier, tastier, and awareness of water-related diseases (Asaduzzaman et al., 2016; Semerjian et al., 2020; Pourfadakari et al., 2022; Altıkulaç et al., 2022; Turhan et al., 2023). Therefore, the PDW industry has become a rapidly developing market worldwide today, an important part of daily life, and a key commodity even in the most remote corners of the world. PDW, in its simplest terms, is water that has been purified, processed, and packaged to be consumed immediately or in a short time. It is possible to talk about different packages of water. These include single-use packages such as bottles and glasses of various sizes and shapes and larger

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