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Radon concentration of waters in Greece and Cyprus

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Radon (^{222}Rn) is a radioactive gas generated by the decay of the naturally occurring ^{238}U series. It is considered very important from radiological point of view, since it is the most significant natural source of human radiation exposure (approximately 50% from all natural sources). Radon is present in soil, rocks, building materials and waters. Through diffusion and convection, radon migrates and emanates to the atmosphere. Outdoors, radon concentrates at low levels (in the order of 10 Bq/m^3). However indoors, radon accumulates significantly. It is trivial to observe indoor environments with high radon levels (in the order of 400 Bq/m^3 or higher). Radon accumulation indoors, depends on the composition of the underlying soil and rock formation, on building materials, meteorological parameters, ventilation, heating and water use. Although soil and building materials are the most significant radon sources, there have been reported elevated radon concentrations in building structures due to entering water. It is the radon concentrations in the entering water, the volume and the way of water usage, separated or in combination, that result in large amounts of radon in indoor air. Moreover, radon is a factor of stomach radiation burden due to water consumption. This burden is estimated by measurements of radon concentrations in waters. Due to the health impact of radon exposure, the reporting team continuously measures radon. This work focused on the radon concentrations exposure due to water consumption and use in Greece and Cyprus. Various locations in Greece and Cyprus were accessed taking into consideration existing natural radioactivity data (mainly radon in water), however under the restriction of the capability of movement.

Radon in water was measured by Alpha Guard (Genitron Ltd) via a special unit (Aqua Kit). This unit consists of a vessel used for forced degassing of radon diluted in water samples, a security vessel used for water drop deposition. Vessels and Alpha Guard are connected via plastic radon proof tubes. Forced degassing of radon gas is performed by circulating the air in the set up with the use of a pump. Water sampling (to avoid radon escape) was driven by a strict protocol. Water taps were opened for 10 minutes before drawing the sample. Glass storage vessels of 200 to 1000 ml, with adjustment glass stoppers with standard NS 29/32 grounding, as well as sealing rings and granted security clamps for taper grounding, were completely filled slowly and immediately closed (to avoid the formation of air bubbles). Similar procedure (except tap opening) was followed for underground and surface waters. Laboratory measurements were performed at least one hour after drawing the sample in order to assure the full decay of any thoron content and to the minimum achievable time interval, so as the radon content to be the highest possible to allow higher precision. For the measurement the glass stopper was removed and immediately exchanged with the degassing cap. Afterwards water quantity was reduced to about half and measured. From the measurements, the mean annual equivalent dose rate (aEDr) delivered to stomach due to ingestion and the contribution to aEDr due to inhalation of radon in drinking water were calculated as using the EURATOM 2001 dose conversion factor (0.00144 mSv/Bq).

Radon concentrations in drinking waters ranged between (1.1+/-0.5) Bq/L and (15+/4) Bq/L. Only three samples collected from the radon prone area of Arnea Chalkidikis presented high radon concentrations (120+/20 Bq/L, 320+/-40 Bq/L, 410+/-50 Bq/L). Radon concentrations in underground waters ranged between (1.2+/-0.7) Bq/L and (14.7+/-1.1) Bq/L. The corresponding concentration range in surface waters was (2.7+/-0.8) Bq/L and (24+/-6) Bq/L. The radon concentrations in thermal waters (some of which are used for drinking) were quite higher (in the range of (220+/-20) to (340+/-40) Bq/L). In both countries, no correlation of radon in underground waters

with depth was observed. In Cyprus, the highest water radon concentrations were found in Protaras region. The average value of radon in water resulted to an average contribution of 0.3% in respect to the average indoor radon concentration and mean annual effective dose. The corresponding values for Greece resulted to a 0.1% contribution. This contribution is considered quite low both for Cyprus and Greece (0.1%) and hence this part of effective dose may be considered of slighter significance compared to inhalation of total radon. Yet this contribution is comparable to the effective dose values delivered through medical uses of radiation. On the other hand, significant doses are delivered to stomach of the Cypriot and Greek population due to ingested radon following water consumption. The corresponding average annual dose rates were found equal to 0.085 mSv/y (S.D of 0.080 mSv/y) for Cyprus and 0.081 mSv/y (S.D of 0.081 mSv/y) for Greece.