Journal of Environmental Radioactivity 171 (2017) 148–159

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Experiences of radiological examinations of buildings in Hungary

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ARTICLE INFO

Article history:
Received 8 August 2016
Received in revised form
23 January 2017
Accepted 4 February 2017

ABSTRACT

Natural radioisotopes occur everywhere in the environment, being a source of exposure to the general population. Everyone is continuously exposed to terrestrial and cosmic radiations both indoors and outdoors, which are the main contributors to external exposure of individuals. There were made many ambient dose rate and indoor gamma radiation and radon concentration measurements in Hungarian by different laboratories. The main goal of the present work is the summarisation and evaluation of the latest results of the Laboratory of National Public Health Center National Research Directorate for Radiobiology and Radiohygiene. The reviewed examinations were made between 1995 and 2016. The average ambient dose rate was 103 ± 17 nSv/h and the average indoor gamma dose rate was 155 ± 47 nSv/h based on the data of 382 and 581 sampling points, respectively. The average indoor radon concentration was 108 Bq/m^3 with the median value of 75 Bq/m^3 based on the data of 415 sampling points. We performed an additional analysis of the results of 233 personal surveyed buildings where sophisticated gamma radiation and/or indoor radon concentration measurements were made. We were also interested in has got any affect the presence of slag to the radiation levels of the buildings? We found that usually elevated radiation can be detected in houses which contain slag compared to buildings without slag. In addition we conclude that the recommended minimum duration of short-term radon measurement shall be at least three days even if it does by closed conditions.

1. Introduction

(1) Natural radioisotopes occur everywhere in the environment, being a source of exposure to the general population. Everyone is continuously exposed to terrestrial and cosmic radiations both indoors and outdoors, which are the main contributors to external exposure of individuals. The intensity of cosmic radiation depends mainly on the altitude and shows smaller variability with time and the latitude. Its value in Hungary is about 32 nSv/h (UNSCEAR, 2000). The most important components of the terrestrial radiation are provided by the elements of ^{238}U and ^{232}Th series as well as ^{40}K. These isotopes occur in all environmental media, but their activity concentrations are generally higher in soils and rocks. Since these materials are used for production of building materials, the above mentioned isotopes and their decay products occur also in building materials by different extent of concentration. Buildings do not only contribute to our external exposure but shield the exterior sources (mainly the terrestrial and slightly the cosmic radiation).

(2) The main contributors to our internal exposure are the alpha-ray emitter radon daughter elements. Radon (^{222}Rn), which is the element of the ^{238}U decay chain has a bigger importance than thoron (^{220}Rn), which is the element of the ^{232}Th decay chain. The concentration of thoron is usually much lower in buildings and its distribution within a room is uneven. About ten times smaller dose could be received from inhalation of thoron than from the inhalation of radon (UNSCEAR, 2000). Radon can enter the air after the emanation from the soil, rocks and building materials. The radon concentration in air is expected to reach higher levels only in confined spaces due to its quick dilution in open air and by reinforced ventilation. Its activity concentration does not exceed a few Bq/m^3 in the outdoor air under normal circumstances (Köteles, 2002; UNSCEAR, 2000).

(3) Several surveys have been conducted to assess the radiation exposure of the Hungarian population to natural sources, especially from indoor dose rate and radon concentration (Nikl, 1996; Hámori

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http://dx.doi.org/10.1016/j.jenvrad.2017.02.004
0265-931X/

et al., 2004). Other radon studies deal with radon concentration at specific workplaces where increased radon levels may occur, such as spas, wine cellars and caves open to the public to visit (Szerbin, 1994; Szeiler, 2012; Csige et al., 2004).

(4) The main goal of the present work is the summarisation and evaluation of the latest results of the Laboratory of National Public Health Center National Research Directorate for Radiobiology and Radiohygiene (NPHC NRDRR)[1] regarding the ambient gamma and indoor gamma radiation as well as radon concentration and to make a dose assessment for the Hungarian population based on our current results. The collected data originate from routine and occasional environmental radiological monitoring activities and radiological surveys of dwellings and other measurements made upon public request. The timeframe of this study is the period of 1995 and July 2016.

2. Material and methods

2.1. Measurement techniques and methods

(5) Several methods were applied to determine the gamma dose rate and radon concentration depending on the circumstances and objects of the surveys. These methods can be separated into two groups based on the principles of the detection: active and passive. Passive detectors were used for long-term (typically for monthly or quarterly) measurements, while active detectors were used to obtain prompt results when time was crucial and long-term measurements were deemed unnecessary or could not be carried out. The possibilities, circumstances and the scope of the survey were considered case by case to choose the appropriate method.

(6) The following types of passive detectors were used for long-term gamma dose rate measurements:

- $CaSO_4$:Tm thermoluminescence (TL) detectors in sealed containersTL powder was placed in a cylindrical copper holder containing a Teflon insert and sealed with a Teflon cap. Each container had a unique identification number and was filled with about 15 mg of TL powder. The detectors were put into a dual layer plastic bag to protect them from harsh weather effects. The exposure time was normally a quarter or one year, but at least one month. After their exposure, the detectors were collected and the doses were read out by TL readers (type HARSHAW, 2000 A-B or A-C) and eventually divided by the exposure time to obtain dose rate values. Some detectors were irradiated tri-annually with predetermined doses by the national metrology institute (Hungarian Trade Licensing Office (HTLO), operating a Secondary Standard Dosimetry Laboratory) for calibration purposes.

(7) The below listed equipment were used for short-term gamma dose rate measurements:

- pressurized ionisation chamber, type: RSS-112 (Reuter-Stokes, USA)
- scintillation detectors, types: AUTOMESS 6150 AD 6 and 6/H (Automess, Germany)
- proportional counter, type: Berthold Umo LB 123 (EG&G Berthold, Germany)

Using these instruments, the gamma dose rate values can be easily read from the display after a few minutes and the results were recorded by hand. The instruments were calibrated by the HTLO on annual or bi-annual basis.

(8) The following types of detectors were used for long-term radon measurements:

- CR-39 alpha track detectors having different housings, types: RSKS (Radosys Ltd. Hungary) and Radamon (Institute of Nuclear Research, Debrecen, Hungary)CR-39 track detectors are commonly used to measure radon concentration in air. The detector is a small polymer sheet, placed in a plastic chamber. The chamber cap is not airtight, so radon can enter the chamber by diffusion through small gaps between the cap and the chamber wall. Subsequent decays of radon inside the chamber emit alpha-particles, which may cause small defects (tracks) on the surface of the detector. After the sampling, the detectors were etched in 6.25 M sodium-hydroxide solution at a temperature of 90 °C for 6 h to enlarge the tracks. The number of tracks was counted by Radosys (2000) system. Their density is proportional to the original radon concentration in the sampled air. The calibration factors for the detectors were determined by the manufacturer and they were also checked by the Laboratory of NPHC NRDRR using active detectors. The exposure time was typically between 3 months and one year for one detector. The sampling sites were usually the most frequently used ground floor rooms of dwellings.
- electret detectors, type: E-Perm (Rad Elec Inc. USA)The electret detector contains an electrostatically charged Teflon disk. It has two distinct functions: serves as an electrode for ion collection and as an integrated sensor. Negative ions are produced inside the chamber during the decay of radon, and they are collected on the positively charged electret disc. This process causes the reduction of its charge. The depletion of charge during the total exposure period is proportional to the ionization caused by alpha particles and consequently to the sampled radon concentration. The detectors were read out with a special reader unit (Rad Elec Inc.). The exposition time was the same than in case of CR-39 detectors.

(9) The below listed equipment was used for short-term radon measurements:

- pulse-counting ionisation chamber, type: AlphaGUARD PQ 2000 Pro (Genitorn Inc, Germany)
- ion-implanted silicon alpha detector, type: RAD7 (Durridge Co. USA)
- pulse-counting ionisation chamber, type: Atmos12DPX (Gammadata Mätteknik, Sweden)The duration of the sampling was usually between 1 day and 2 weeks at one sampling point. The radon concentration results were recorded once or twice per hour in the memory of the sampler and read out in the Laboratory. These monitors were calibrated by the manufacturer and their validity was checked by an intercomparison among them.

(10) In case of passive methods and detectors, the uncertainty of the individual measurements was determined from the deviation of results of repeated measurements. The active detectors calculate and display the one or two sigma error of the measurements. The square-root law was applied to assess the uncertainty of a group of data using the individual uncertainties.

2.2. Sources of data

(11) Radiological surveys were made in 233 buildings upon public request between 2012 and July 2016. These surveys included gamma dose rate and/or radon concentration measurements

[1] The name of the institute was 'Frédéric Joliot-Curie' National Research Institute for Radiobiology and Radiohygiene (NRIRR) before 2015.