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CHANGES OF NATURAL IONIZING RADIATION IN ANTHROPOGENIC OBJECTS

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Abstract. Dosimetric investigations that were performed in various geographic places, mostly connected to anthropogenic activities, are observed in this work. Equivalent dose rate was measured with a radiometer SRP-68, 0,3 m above the point of investigation.
It is determined that equivalent dose rate changes from 97 nSv/h measured above a non-arable field soil to 219 nSv/h measured in a tunnel. The hignest values of equivalent dose rate are in closed buildings with a bad ventilation system. It is noticed that the specific activity of ^{40}K and ^{226}Ra changes depending on the depth of a trench. The specific activity of ^{40}K is the highest at the deepest point (441 Bq/kg) of a trench; the highest specific activity of ^{226}Ra is at the ground level (37 Bq/kg).

Keywords: ionizing radiation, natural radionuclides, dosimetry, equivalent dose rate, specific activity.

1. Introduction

In the last years there has been an increasing interest in artificial and natural radionuclides present in the environment and their possible effects on human health. Radionuclides can be transported at long distances from their source of emission, removed from the atmosphere, deposited in the biosphere and hydrosphere and enter the human population by several pathways [1–2]. The widely spread natural radionuclides are from uranium (^{238}U), thorium (^{232}Th), actinium (^{235}Ac) and potassium (^{40}K) [3].

All building materials contain various amounts of natural radioactive nuclides. Materials derived from rock and soil contain mainly natural radionuclides of the uranium and thorium series, and the radioactive isotope of potassium. In the uranium series, the decay chain segment starting from radium is radiologically the most important and, therefore, reference is often made to radium instead of uranium. The worldwide average concentration of radium, thorium and potassium in the Earth's crust is about 40 Bq/kg, 40 Bq/kg and 400 Bq/kg, respectively [4]. Radiation exposure due to building materials can be divided into external and internal exposure. The internal exposure is caused by the inhalation of radon, thoron and their short-lived decay products. Radon is part of the radioactive decay series of uranium which is present in building materials. Because radon is an inert gas, it can move rather freely through porous media, such as building materials, although usually only a fraction of that produced in the material reaches the surface and enters the indoor air. The most important source of indoor radon is the underlying soil.

The purpose of setting controls on the radioactivity of building materials is to limit the radiation exposure due to materials with enhanced or elevated levels of natural radionuclides. The doses to the members of the public should be kept as low as reasonably achievable [5]. It is very important to evaluate natural radionuclide spread in the environment.

In Lithuania and other countries radionuclide specific activity in building materials is different. The specific activity of ^{226}Ra in cement in India (151 Bq/kg) is almost four times bigger than that in Lithuania (42 Bq/kg). The specific activity of ^{226}Ra in cement in Algeria (41 Bq/kg) and in Israel (48 Bq/kg) is similar to that in Lithuania (42 Bq/kg). The measured value of ^{226}Ra in a sample of gravel in Lithuania (12,2 Bq/kg) differs not very much from Israel's gravel (15 Bq/kg), and in Algeria the specific activity of ^{226}Ra (24 Bq/kg) is twice bigger than in Lithuania. The specific activity of ^{226}Ra in bricks made of clay in Algeria and Germany (65 Bq/kg) is twice bigger than in Lithuania (32,5 Bq/kg). The specific activity of ^{40}K in cement in Israel is almost the same as in Lithuania but three times smaller than in Algeria (420 Bq/kg), in Lithuania – 157 Bq/kg. The specific activity of ^{40}K in gravel in Israel is six times less than in Lithuania, but in Algeria (260 Bq/kg) it is similar to that in Lithuania – 300 Bq/kg. The specific activity of ^{40}K in clay in Germany and Lithuania is the same (550 Bq/kg). The specific activity of ^{40}K in sand in Lithuania (238 Bq/kg) is four times bigger than in Israel, in India, Germany and Algeria the specific activity of ^{40}K in the sand is three times less (70 Bq/kg) than Lithuania [6].

The main goal of the work was to evaluate natural radionuclides in anthropogenic objects ant to compare the results with the natural environment.

2. Investigation methodology

There are numbers of methods and variations for the detection and measurement of radioactivity: ionization chamber, Geiger tube, semiconductor detector, scintillation detector, Cerenkov detector. All of them are based on the ionizing power of radiation.

The choice of a particular detector type for application depends upon the X-ray or gamma energy range of interest and the application resolution and efficiency requirements [7].

In this work dosimetric investigations were performed in various geographic places, mostly connected to anthropogenic activities. Equivalent dose rate was measured with a radiometer SRP – 68, 0,3 m above the point of investigation. The temperature of the air was 2 °C.

The device SRP-68 was used for investigating land radioactivity, ores with radioactive additives and for other geological works. The device SRP-68 is a portable radiometer. It consists of a detecting block which changes gamma quants to electrical impulses and controls.

One experiment took place at points in a tunnel and above it. There were eighty-five points where measurements of equivalent dose rate were made with a dosimeter. At each point equivalent dose rate was measured three times and its average value was calculated. The distance from the points where measurements were made was 0,5 m. The points were situated in a straight line. This place was in the center of Vilnius city near the same building. The scheme of points where equivalent dose rate was measured is shown in Fig 1.

Another experiment took place at points in a garage. There was twenty-one point where measurements of equivalent dose rate were made with a dosimeter. The first, the second and the third points were outside the garage, the rest of the points were inside it. At each point equivalent dose rate was measured three times. After processing measurement data calculations of equivalent dose rate at each measuring point were made. The distance from the points where measurements of equivalent dose rate were made was 0,5 m. This garage was in Vilnius city on Žirmūnai street. The scheme of the points where equivalent dose rate was measured is shown in Fig 2.

Another experiment took place in an arable field and non-arable one with grass. The field with grass was compared with the arable soil. There were two points where equivalent dose rate was measured in the field with grass. The third point was at the border between the field with grass and arable soil field. Other points were in the arable soil field. The distance between the points was 0,5 m. This field is near a road. The scheme of measurements is shown in Fig 3. Thirteen points were measured for this experiment. Thirteen measurements were made at one point. An average value of equivalent dose rate was calculated. Time between each measurement at one point was about ten seconds.

Equivalent dose rate was measured at the points that were situated in a trench. The ground in which a trench was dug was mostly from sand, gravel and clay. This trench was dug for laying pipes. There were five points where measurements of equivalent dose rate were made with a dosimeter. The first point was at the bottom of the trench, the last one was at the ground level. At each point equivalent dose rate was measured four times. After processing the measurement data, calculation of equivalent dose rate at each measuring point was made. This place was in Vilnius city on Žirmūnai street. The

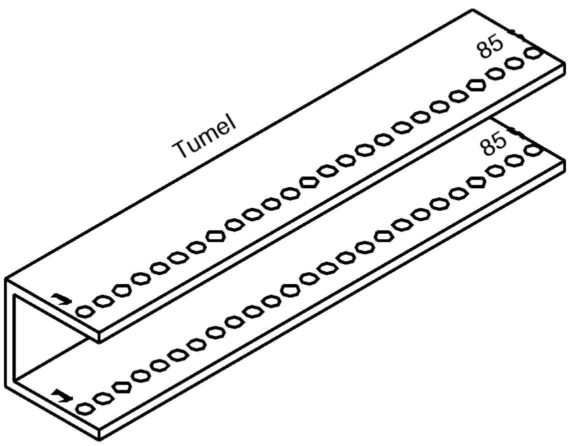

Fig 1. Scheme of measuring points in a tunnel

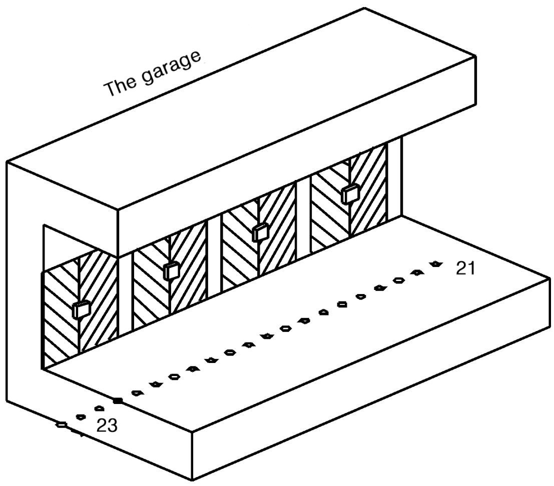

Fig 2. Scheme of measuring points in a garage

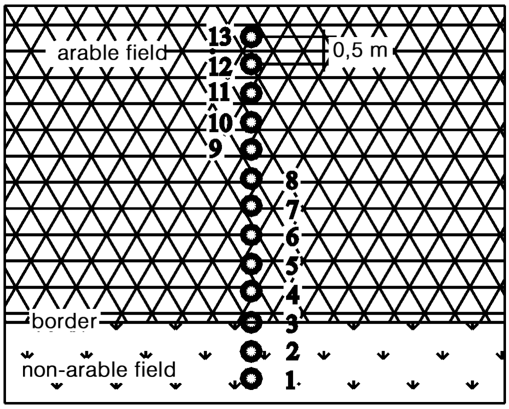

Fig 3. Scheme of measuring points in an arable and non-arable fields

distance from the points where measurements of equivalent dose rate were made was 0,5 m.

The main gamma radioactivity sources ^{40}K and ^{226}Ra and their concentration in the soil of equivalent dose rate measurement places were evaluated. Radionuclide concentrations for gamma-active radionuclides were determined with gamma spectrometry. This method can be used for different types of samples including soil and sediment samples, ground waters, bottled waters, effluent wastes, etc. The samples of the soil were taken from the trench every 0,5 m going upwards. Pipes were put in that trench. The samples of the soil were brought to the laboratory in polyethylene bags, dried, weighed, the density was determined and the specific activity was measured in a standard vessel. Gamma radiation activity was determined with a semiconductor scintillation NaI(Tl) spectrometer Canberra [7]. The samples were measured in 200 ml bulbs.

The efficiency of a spectrometer of gamma registration Ge(Li) was 0,26 %, but for scintillation spectrometer Canberra – 0,79 %. Radionuclides were identified according to the following energetic lines: ^{226}Ra – 186 keV, ^{40}K – 1460 keV. The measured activity of a sample was calculated for the unit of mass.

3. Measurement results

After the investigation was performed, all the data were statistically processed and charts were drawn. These charts show the dependence of the equivalent dose rate of natural radionuclides on the location of a point.

As a result of an experiment in a tunnel (Fig 4), a chaotic dispersion of the values of measured equivalent dose rate in the tunnel and above it is seen. The equivalent dose rate, which is measured in a tunnel, has higher values (176–219 nSv/h) in comparison with the equivalent dose rate, which is measured above a tunnel (120–147 nSv/h). Higher equivalent dose rate values in a tunnel are due to building materials used to build this tunnel. In the chart it is shown that in the middle of a tunnel the equivalent dose rate values are higher than those at its end and beginning. This is because of a bad ventilation in the middle part of the tunnel. It is very important to continue radioactivity measurements in a tunnel in order to obtain sufficient data for statistical processing.

From measurements in a garage (Fig 5), it is seen that equivalent dose rate outside the garage (151 nSv/h) is lower than inside it (169–209 nSv/h). The splitting of radon products causes it. It was noticed that equivalent dose rate got higher going to the end of the garage. It was getting higher by the dependence $y = 1,5 + 162$. This is because of a bad ventilation at the end of the garage.

In Fig 6 equivalent dose rate distribution in an arable part of a field and non-arable part of the same field was drawn. Points 1 and 2 are in a non-arable field with grass. Point 3 is above the border of an arable and non-

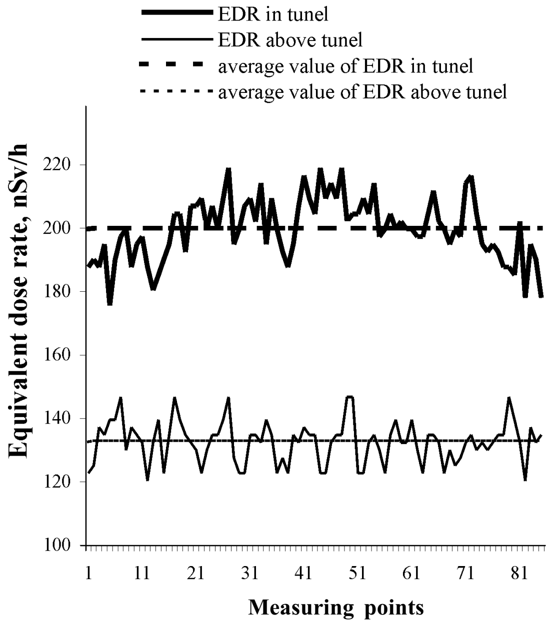

Fig 4. Distribution values of equivalent dose rate in a tunnel and above it

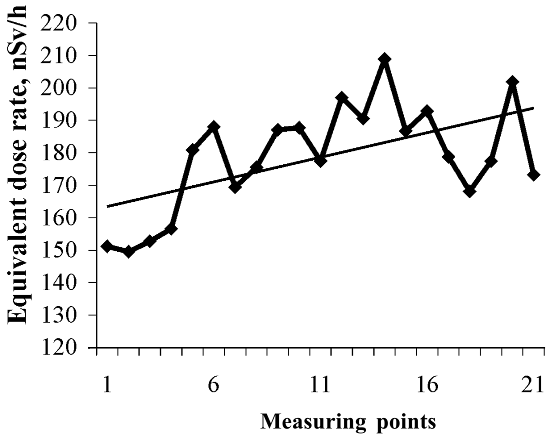

Fig 5. Distribution values of equivalent dose rate inside a garage and outside it

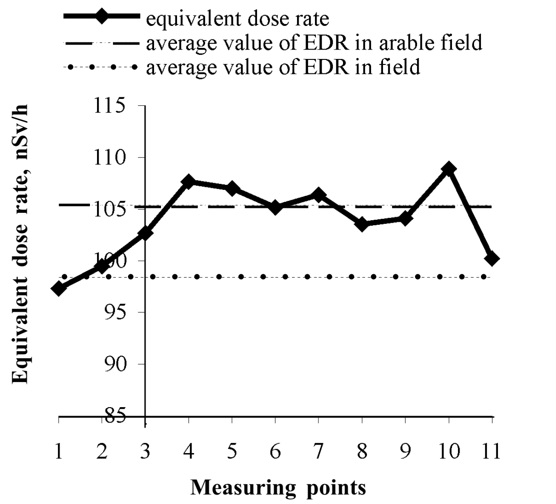

Fig 6. Distribution values of equivalent dose rate in an arable and non-arable fields

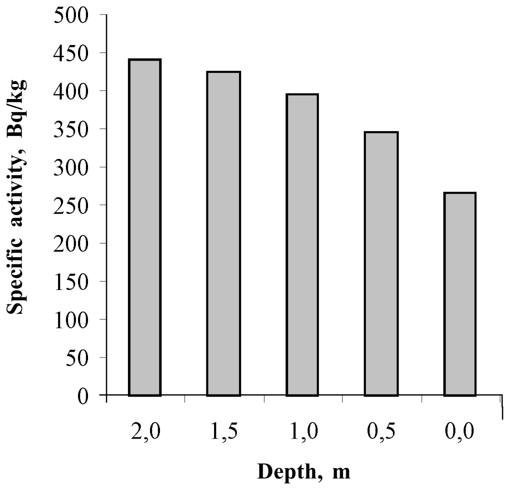

Fig 8. ^{40}K distribution of specific activity in the soil

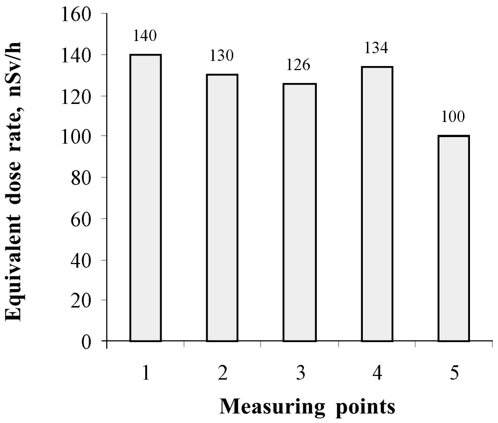

Fig 7. Distribution values of equivalent dose rate in a trench

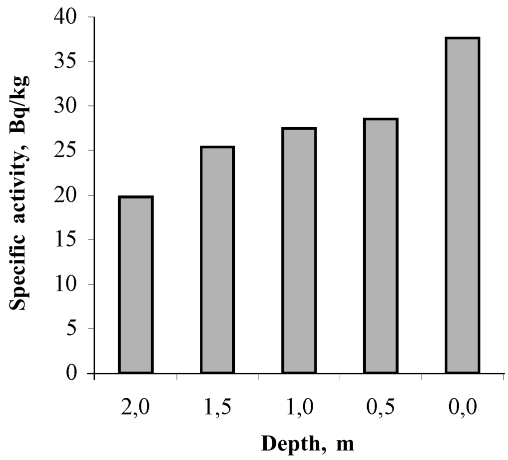

Fig 9. ^{226}Ra distribution of specific activity in the soil

arable fields. The rest points are situated in the arable part of a field. The lower line shows an average value of equivalent dose rate in a field with grass. The upper line shows an average value of equivalent dose rate in an arable field. As a result of this measurement, it is seen that equivalent dose rate in a field with grass has a lower value (97 nSv/h) than in an arable soil (104 nSv/h). The differences are very small. This can be explained in one way: it is because of radon in the ground. But it can also be that the soil constitution in different parts of this field is different. In an arable part of the field there can be the same clay impurity. For a particular analysis of this situation, a spectrometric analysis must be made.

As a result of an experiment in a trench (Fig 7), dependence on the height for values of measured equivalent dose rate in the trench is seen. It is seen that the highest value of equivalent dose rate (140 nSv/h) was at point 1, that is at the bottom of the trench. The lowest value of equivalent dose rate (100 nSv/h) was at point 5, that is at the ground level. This is because of the splitting of radon and its decay products in the ground. A spectrometric analysis will be made for this experiment in order to determine the value of specific activity.

After a spectrometric analysis of the ground that was freshly dug from a trench dependence on the height for values of the measured specific activity of ^{40}K and ^{226}Ra is seen (Figs 8, 9). It was determined that the specific activity of ^{40}K was higher than that of ^{226}Ra. It is seen that the highest value of specific activity of ^{40}K (441 Bq/kg) was at point 1, that is at the bottom of a trench. The lowest value of the specific activity of ^{40}K (267 Bq/kg) was at point 5, that is at the ground level. This is because of the splitting of radon in the ground. The highest value of the specific activity of ^{226}Ra (37 Bq/kg) was at point 5, that is at the ground level of a trench. The lowest value of the specific activity of ^{226}Ra (19 Bq/kg) was at point 1, that is at the bottom of a trench.

4. Conclusions

After dosimetric investigations in various geographic places it is determined that:

1. Equivalent dose rate above an arable field (108 nSv/h) is higher than that above a non-arable field (97 nSv/h). It is because of radioactive elements in deeper layers of the soil.

2. The equivalent dose rate of ionizing radiation in a tunnel (176–219 nSv/h) is higher than that above a tunnel (120–147 nSv/h). Higher values of the equivalent dose rate of ionizing radiation in a tunnel are caused by the ionized radiation of radionuclides in the building material of a tunnel.

3. Equivalent dose rate in an underground garage (169–209 nSv/h) is higher than that outside the garage (151 nSv/h). The splitting of radon products causes it.

4. After a spectrometric analysis of the ground that was freshly dug from a trench, it is determined that the highest specific activity of ^{40}K is at the deepest point (441 Bq/kg), the highest value of the specific activity of ^{226}Ra is at the highest point (37 Bq/kg).

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GAMTINĖS JONIZUOJANČIOSIOS SPINDULIUOTĖS POKYČIAI ŽMOGAUS VEIKLOS OBJEKTUOSE

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Santrauka

Atlikti dozimetriniai bei spektrometriniai tyrimai įvairiose geofizinėse vietose, labiausiai susijusiose su antropogenine veikla. Lygiavertės dozės galia išmatuota radiometru SRP-68 0,3 m aukštyje virš tiriamo taško. Nustatyta, kad lygiavertės dozės galia kinta nuo 97 nSv/h dirvoje iki 219 nSv/h tunelyje. Didžiausios gamtinės kilmės radionuklidų sukeltos lygiavertės dozės galios reikšmės yra uždarose, blogai vėdinamose patalpose. Pastebėta, kad ^{40}K ir ^{226}Ra savitasis aktyvumas priklauso nuo gylio. ^{40}K savitasis aktyvumas didžiausias giliausiame taške (441 Bq/kg), o ^{226}Ra – atvirkščiai – aukščiausiame taške (37 Bq/kg).

Raktažodžiai: jonizuojančioji spinduliuotė, gamtinės kilmės radionuklidai, dozimetrija, lygiavertės dozės galia, savitasis aktyvumas.

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