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Investigation of Building Materials and the Street's Surface Radioactive Emission

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Abstract

Protection of the environment is becoming more important role as pollution and magnetic loads from electronic devices are growing as never before. The radioactive background radiation does not explore explicit increase nevertheless more and more attention is paid to this. An increasing number of countries are paying more attention to measurements of the levels of background radiation from various radioactive sources and to the values of their exposure limits.

It is known that the vast majority of background radiation in the enviroment comes from radioactive construction (buildings, roads, etc.) built by humans. It is important to understand its sources, evolution, determining parameters, etc. Radioactivity of the human-built environment is assessed on the basis of building materials, construction techniques, and dose-loading related to building technologies.

The Department of General and Environmental Physics in the Juhász Gyula Teacher Training College at the University of Szeged (Hungary) out radioactive measurements related to background radiation, especially the absorbed dose load from full gamma radiation. Among a wide range of measurements, the most important are:

The power of radiation from walls and other parts of buildings.

The field, such as radioactivity mapping of the environment. Using maps, we not only have actual data for the radioactivity, but we can follow the impact of the human-built environment (buildings, streets, etc.) on whole background radiation (Köteles, 1994).

Key words: Building materials; Total gamma activity; Radon; Porosity

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INTRODUCTION

The sources of natural radiation can be divided into two categories: external and internal. The former is connected to the Earth' crust, building materials and natural radioactivity in the air, as well as cosmic radiation, and internal radioactive sources are in the human body as natural radioisotopes. The major sources of external radiation are the so-called ancient radioisotopes: some members of the thorium and uranium decay series and ^{40}K. Throughout the soil there are small amounts of thorium, uran and radium. Upon their decay, we get radon which, through the cracks in the soil, is released into the air. One also finds the isotopes ^{40}K and ^{87}Rb; potassium is rock-forming mineral, and while rubidium does not form a mineral, it is present in potassium minerals.

The average annual dose of natural radiation is about 1.4 millisievert (mSv). The main sources are ^{40}K (0.3 mSv), members of the thorium family (0.15 mSv), members of the uranium family (0.5 mSv), radon caused by decay of uranium (0.4 mSv), cosmic rays (0.4 mSv), and ^{14}C (0.05 mSv). We must consider the building materials and our surrounding objects, keeping in mind that most of us spend the majority of our time indoors. From the building, our average annual dose is 1 mSv, with most of it coming from radon (0.6 mSv). The dose of our radioactive building materials mostly depends on their uranium content. This is ~ 2.4 mSv for Earth, although for Hungary it is higher at ~ 4.1 mSv, where the difference is due primarily to the building load factor and the amount of time spent indoors. More numerical information is available in Table 1.

Table 1
Effective Dose of Natural Origin Radiation for the Adult Population

	Source	Annual effective dose (μSv/year)
Secondary cosmic radiation	Ionizing radiation component	300
	Neutron component	80
	Cosmic radionuclide	12
Crustal origin radiation	Building	392
	Outdoors	70
	^{40}K-incorporation	173
	^{238}U-, ^{232}Th-incorporation	62
Radon (based on a pulmonary model)	Inhalation within building	1009
	Aspiration outdoors	126
	Dissolved in blood	56
Toron	Aspiration	70
Total (mSv/year)		**2.4**

The role of radon therefore is extremely high as an environmental load, so that more and more countries have radon monitoring. Radon appears as the radioactive noble gas isotopes ^{222}Rn (daughter element of ^{238}U), ^{220}Rn (toron, daughter element of ^{232}Th) and ^{219}Rn (actinon, daughter element of ^{235}U). It very easily diffuses out of a building, releasing into the atmosphere, so in the immediate vicinity of people, it can enter the human body when breathing, causing internal radiation exposure. ^{222}Rn has the most important role of the three isotopes since it has a maximum half-life of 3.8 days and is thus present for the longest period of time as a noble gas, with the most time to diffuse out from the walls to the soil. The radon diffusion is largely determined by the amount of soil relative to a wall, or at what dose the rate is measured. If radon is easily released into the soil, the dose measured on the surface is reduced, but if it is trapped inside, other remaining major components of the surface dose come into play. The soil porosity, permeability, coverage – through the radon motion – largely determines the surface dose. Higher porosity and permeability of the soil with the same radioactive substance content of radioactivity have smaller surface radioactivity than the more compact soils. This is also true in the case of building materials. Compared to radon flux, trees represent the most commonly used building material with the maximum value added for the porous loam. This is less than brick with much lower porosity, and the smallest is concrete, which has a very low porosity (and also low radioactive element content).

If there is an insulating layer on the top of the soil, like snow, ice or thick mud after a heavy rainfall, radon is trapped in the soil, increasing the surface activity. In such a case, the sealed-off radon searches for a new path to reach the surface. Therefore, it may flow into because there is no possible way to move directly into the atmosphere.

Gamma-emitting isotopes are found in all natural decay processes of radioactive elements, which are well studied and characterized because of the high penetration and easy detectability. The gamma dose rate can help determine the effective dose for residents due to the small effective distances of other radiation on the human body.

Area radiometric mapping is the most common method for full gamma radiation measurements. One reason is the high penetrating distance of gamma radiation, and another is the alpha-emitting (and beta-emitting) radioisotopes themselves emitting gamma photons, so that they are also counted into radioactivity measurement results. The saturation thicknesses of various rocks are about 50-60 cm, whereby gamma radiation doe not go deeper from the surface. In the case of the deeper soil layers, radon can easily get out, with its subsidiaries increasing the upper layer activity.

Measuring the full gamma radiation with a scintillation detector is very appropriate, because the energies of the gamma photons from the soil fit well with the sensitiviy range of the detector. A higher resolution is possible with semiconductor detectors, but their operation is less dependent on external parameters; we are focused on outdoor measurements, which is a very important aspect (Nagy, 1983).

The full gamma radiation of the soil originates from ^{40}K, radium and thorium, where the isotope count for each one depends on the detector type, size and level of energy resolution. The energy range of the measurements must be adjusted so that the scattered radiation is very low, with the range distribution from 0.4 to 3 MeV.

Radioactivity measurements of surface soil usually give the total number of counts where 88% is terrestrial radiation, 2.5% cosmic radiation, 8% radon decay products in the air, and 1.5% radioactivity in the detector material. The whole measurement process should be done at same time, if carried out under the same weather conditions as the soil radiation influenced by meteorological conditions, such in regard to wind flowing out of by the suction effect of radon from the soil, the rain washing radioactive isotopes from the air, and due to snow and water the radon remains in the soil (Szederkényi et al., 1994).

In 1996 the Radiometric Laboratory of the Eötvös Loránd Geophysical Institute launched a project called

Radiometric Basemap Hungary, where U, Ra, Th, ^{40}K isotopes, ^{137}Cs radiation intensity and dose full gamma radiation are mapped. The project also aims to follow the movement of gamma-emitting isotopes and Th detection of their migration determinants. Their measurements are carried out at a height of 1 meter by semiconductor gamma spectroscopy in the 0-1500 keV energy range. For the analysis of a soil sample, the U, Ra, Th, ^{40}K content and dose rate derived from ^{137}Cs is measured in the upper and lower layers of the sample, with the bottom of the upper layer data recorded separately on radiometric maps[1].

Similar studies have been carried out for decades at the Fodor József National Center for Public Health within the Frédéric Joliot-Curie National Research Institute for Radiobiology and Radiohygiene (NRIRR). Measurements for Hungary show 87 nGy/h in an open space and 116 nGy/h indoors at the average gamma dose rate.

The Polish national radiometric map, originally constructed in 1992, has been edited based on 20000 measurements points at distance points per 1000 m for U, Th, ^{40}K, Tc, ^{137}Cs content and full gamma radiation. It is seen that, in addition to geological factors, there is a significant impact on the impurity of the radioactive background radiation. The average rate of high full gamma radiation in the country is doubled due to volcanic rocks. On the other hand, high rates measured in the Opole region are due to Chernobyl-originated Cs decay (Lis et al., 1997).

The measurements done above the soil should take into account the effect of self-absorption. It has been seen that 90% of the radiation originates from a depth of 20 cm in the soil layer. The actual state of the soil also impacts the results of the measurements, e.g., the water in porous voids or snow shadows (partly) the gamma radiation. In the case of snow. At 10 cm within the water layer, we have a 50% decrease of the emitted gamma radiation (Akerblom et al., 2000).

1. METHOD

For our measurements, we have used a ND-497-type portable scintillation detector with a NaI(TI) head of 50×50 mm sizes. This equipment is available for measurements in temperature range from –10 ℃ to 50 ℃ using a 7 V adapter (stabilized). The counting element was a NC-483-type portable nuclear analyzer. This equipment allows for a wide scale of measurements and thus is used widely in studies associated with nuclear energy and environmental technology. It may be adaptable to scintillation heads. We have monitored the dosage at the soil surface, making measurements at 3, 5 and 10 s at given position points. We have completed a 10m×10m grid system at 3,640 positions) for the full gamma dose rate.

We have tried to choose for our measurements of different environments, such as green belts, housing estates and highly-built city parts, in order to get realistic values for soil and environmental impacts. These include:

- Szeged-Low city: With garden-like buildings – 718 points.
- Szeged-Downtown (center): highly built area – 845 points
- Szeged-Mora city: Garden-type houses with huge parks – 657 points.
- Szeged-Tarjan city: Very dense with habitants, living blocs – 1442 points.

All of the measurements were carried out with similar meteorological conditions and in houses in the afternoon with the same temperature and soil humidity.

2. RESULT

Table 2
The Resulting Dose Rate Statistics of the City

	Low city	Downtown	Mora city	Tarjan city city
Expected value (nGy/h)	56.0	51.8	59. 3	59.2
Median (nGy/h)	55.6	50.2	58.4	57.8
Mode (nGy/h)	52.8	53.1	51.3	55.0
Deviation (nGy/h)	7.2	11.3	11.9	11.6
Range (nGy/h)	33.0.82,6	30.1-99.6	34.2-105.1	34.7-117.4
Peaks	0.15	1. 74	1.80	1.20
Skew	0.32	1.15	1.01	0.77
Number	718	845	657	1442

The resulting dose rate statistics of the city are provided in Table 2. These values remain well below average as measured by the NRIRR (Hungary) in open air as 87 nGy/h.(It should be noted that the NRIRR teasurements were performed at 1 m at the highest. However, by increasing the distance from the ground, lower dose levels can be measured. The situation in Szeged was in line with low background radiation due to the fact that within the city and in the surrounding sandy soils, the chernozem and alluvial soils along with saline are the main types of soils, which have low radioactivity by reason of their composition. Soil is the primary determinant of radiation as compared to buildings and pavements. Specifically:

- The building walls increase the background radiation coming from 4π directions.
- Road and building foundations shield the soil radiation, and their radioactivity may increase the measured dose rate.

[1] ELGI Beszámoló (2000, 2001).

- Built-in changes in the outflow of radon emission, due to the radon insulating compact enclosures of the trapped elements, increase the dose rate.

In some neighborhoods, the dose rates as measured by the Cohen's impact rate assay, the Mann-Whitney *U*-test and χ^2-test were compared. The Cohen's effect-scale study compares the average value of the samples (Vargha, 2000). This method can be used if the measured values are compatible with the average, i.e., the distribution is not too skewed. The effective rate (Δ) specifies the average value of the two samples (X_1 and X_2) and the variances, i.e., standard deviations (σ_1 and σ_2) squared, are required:

$$\Delta = \frac{X_1 - X_2}{\sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}}} .$$

We designate a power measurement of 0.5 as the medium.

As a size comparison of the two samples, let us invoke the random position indicator A_{12} and designate R_1 as the ranking of the first sample. Then through a probabilistic model with (N_1, N_2) as the numbers of samples analyzed, we can write

$$A_{12} = \frac{R_1}{N_1 N_2} - \frac{N_1 + 1}{2N_2} .$$

If $A_{12} > 0.5$, the values of sample 1 are greater, that is, its probability is greater than sample 2. The so-called visual meaning stochastic variations (a), $a = 2A-1$. This is shown that the higher the percentage chance that a random sample of the first component of the larger sample to sample 2. Through the distribution analysis, we assess the cause of the difference of the two distributions.

The Mann-Whitney *U*-test is a type of non-parametric method, also known as a distribution-free test, and does not require that the variables show a normal distribution. In our cases, the skew and peak coefficients differ strongly from zero, which does not reflect normal probability distributions. The in situ measurements of radioactivity in a general show a normal log distribution, i.e., the logarithm of the measured data given a normal distribution. For the resulting dose rate distribution logarithms, only the peak coefficients strictly follow the assumptions of normality.

The Mann-Whitney *U*–test with statistical procedures uses a sequence of data called ranks (Dinya, 2001), where coupled ranks (R_1, R_2) are related to average values of the same data. For the evaluation of the test, one must give the *U*-statistics in terms of the number of elements in each sample, N_1 and N_1:

$$U = N_1 \cdot N_2 + \frac{N_1(N_1+1)}{2} - R_1 .$$

The distribution average (x) and standard deviation (s) are

$$x = \frac{N_1 \cdot N_2}{2} \quad s = \sqrt{\frac{N_1 \cdot N_2 (N_1 + N_2 + 1)}{12}} ,$$

with so-called normalized z-values:

$$z = \frac{U - x}{s} .$$

In the case of a large number of elements, if the absolute value of z is greater than 1.96, the two distributions have a 5% significance level difference. The larger the absolute value of z, the lower is the significant level difference in the two distributions. It has been suggested that in order for the Mann-Whitney *U*-test to be applicable, there must be homogeneous variance distributions, i.e., the variances should not significantly deviate from each other. Our distribution is compatible with this condition, based on the so-called Levene test (Ibid.).

The χ^2-test can be applied to any probability distribution and any type of data (Ibid.). This entails comparing two or more samples with some type of variance. There is a contingency table for each variable of the dose rate intervals. The value of the expected frequency of a specific contingency cell (v_{ij}) for given row and column sums (g_i and g_j) of the cell can be determined for the specific number of elements (N) as

$$v_{ij} = \frac{g_i \cdot g_j}{N} .$$

The χ^2-value can be determined by

$$\chi^2 = \sum_{i=1}^{n} \sum_{j=1}^{k} \frac{(m_{ij} - v_{ij})^2}{v_{ij}} .$$

The test is based on the degrees of freedom (f) and the contingency table row number (k) and column number (n):

$$f = (k\text{-}1)(n\text{-}1) .$$

Knowing χ^2 and f, we can determine how two distributions differ and which cation level test is suitable for testing the normality of the distributions.

A comparison of the results from the Mann-Whitney *U*-test and χ^2-test is provided in Table 3 below for six parts of the city region. We see that the dose rate distribution for five of the cases is below the 0.1% level of significance (α), so in these cases it is not the fault of the measurement due to the difference in distributions. While the Mann-Whitney *U*-test and χ^2-test are somewhat contradictory, we must bear in mind that not all of the information can be taken into account with either test.

Table 3
Comparison of the Performance of Various City Districts

City districts	*Δ*	*A*	Mann-Whitney *U*-test		χ^2-test		
			z	*α* (%)	χ^2	*f*	*α* (%)
Tarjan city-downtown	0.65	0.39	15.6	< 0.1	298.6	12	< 0.1
Mora city-downtown	0.64	0.40	−13.3	< 0.1	201.6	12	< 0.1
Low city-downtown	0.44	0.34	-11.7	< 0.1	237.6	10	< 0.1
Mora city-low city	0.34	0.15	−4.8	< 0.1	72.0	10	< 01
Tarjan city-low city	0.33	0.14	5.3	< 0.1	121.7	9	< 0.1
Tarjan city-mora city	0.006	0.038	−1.42	16	35.2	12	< 0.1

Within in a typical part of the city, there are different types of spatial average dose rates:

- The uploading thickness significantly determines the thickness of the soil surface, where higher dose rates are found mostly where there is high-filling thickness.
- Above the lower dose, we find looser soils. This is partly explained by the lower content of radioactive material from the lower density and a decrease in the escape of radon.
- For areas around bus stations, close to the same dose rate is, which is used when designing the building uploading sites consequence.
- In the case of pavements, the shielding effect of the coating composition depends on the housing activity, which jointly modify the original soil radioactivity. Based on the main constituents of concrete pavements, their radioactivity for low asphalt coverings is somewhat higher, due to the accumulation of radioactive materials in bitumen crude oil, such as U and Th. Additives can significantly increase the activity of the naturally cover, such as boiler slag, but sand using thorium is also crucial. For a tight, low-porosity, high-bituminous asphalt, a slightly higher dose is measured, which can be explained by the large bituminous radon isolation.
- Characteristics of the surrounding buildings also determine the size of the radiation dose rate. For closed basement windows, we have 74-86 nGy/h, whereas it is 95-110 nGy/h for open windows. When the street is part of the basement, we see an average of average of 55 nGy/h dose rate, where the difference is explained by the movement of radon gathered in the basement.
- The zone radiation is significantly influenced by the original foreign soil material.

In a given area, respectively the extent of a measurement point of radiation is determined by several factors together on this basis at the basic ground cover and soil physical and chemical properties of the original activity; the filling material and the thickness applied; roads of the earthwork and pavement type and thickness; the surrounding buildings, especially in respect of the funds and the caves.

CONCLUSION

Based on the results of the measurements, the Szeged radioactive background radiation is well below the average value of other populated areas in Hungary. This is mainly due to the city's ground makeup. The study involves four districts (two suburbs, one downtown and one housing area), with the following observations:

- Unpaved ground shows a lower dose performance, which is consistent with the low dose performance for downtown.
- At the measuring point, the dose rate of the building, the building cave system, the type of pavement thickness, compression, and the uploads used largely determine the subsoil.

For many parameters *in situ* measurements, it is very difficult to draw definite conclusions, because the impact of the parameters cannot be investigaged independently. Since each parameter has a significant role, even a seemingly minor change can have a significant effect on the results. Further studies in this direction should be of interest because they can be used to define the limits for radioactive exposure of building materials, which is important to the future of smaller buildings and the effects of radiation. The area map for the measurements is shown in Figure 1.

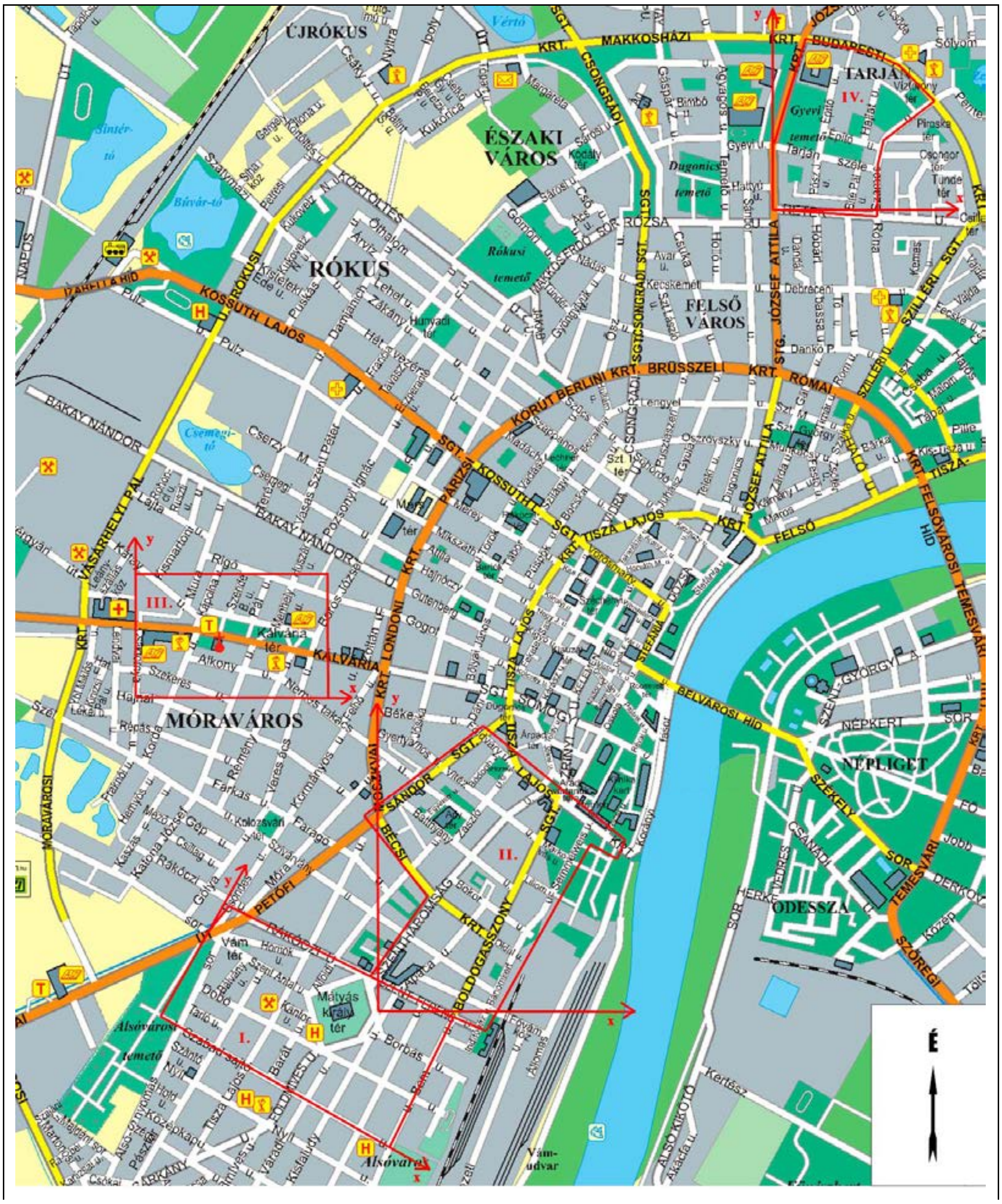

Figure 1
Area Mapping of Measurements
Note. Alsóváros (Low City), Belváros (Downtown), Móraváros (Mora City), Tarján (Tarjan City).

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