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# Monitoring Background Radiation in Belgrade - Kumodraž Location from 1999 to 2009

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**The article presents the results of monitoring the gamma radiation dose rate as an indicator of background radiation at the location of Belgrade - Kumodraž. The dose rate of gamma radiation in the air has been followed in the period from May 1999 to May 2009 by a PC-RM gamma radiation monitor. The obtained results show that the average annual effective doses range from 1.01 to 1.19 mSv/y and are lower than the worldwide average.**

*Key words*: **background radiation, radiation, exposure dose, gamma ray.**

## Introduction

THE man is exposed to various types of naturally occurring radiation. This is commonly referred to as a background radiation. Investigations and measurements of background radiation are of great importance and interest in health physics not only for many practical, but also for more fundamental scientific reasons [1]. Human beings are exposed to natural background radiation every day from the ground, building materials, air, food, the universe, and even elements in their own bodies. Fig.1 shows the relative contribution of radiation sources to total exposure.

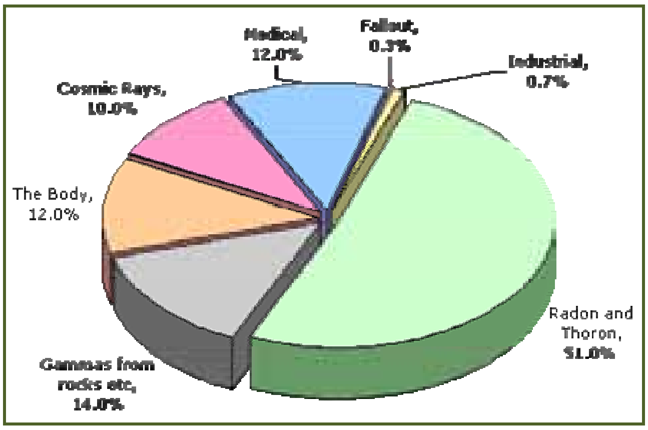


**Figure 1.** Relative contribution of individual radiation sources to total exposure

After radon, the next highest percentage of natural ionizing radiation exposure comes from cosmic rays, followed by terrestrial sources, and "internal" emission. Cosmic radiation including secondary highly energetic particles produced by spallation reactions with primary cosmic rays and atmospheric nuclei.

Terrestrial radiation originates mostly from radiations of thorium ($^{232}$Th) and uranium ($^{238}$U) series radionuclides and potassium ($^{40}$K). There are many naturally occurring radionuclides results that have half-lives of at least the same order of magnitude as the estimated age of the Earth, and that have been present since their formation. They include isotopes of potassium, thorium and uranium [2]. The amount of terrestrial radiation from rocks and soils varies geographically.

"Internal" emissions come from radioactive isotopes in food and water and from the human body itself. Exposures from eating and drinking are due in part to the uranium and thorium series of radioisotopes present in food and drinking water [3].

Average annual exposures worldwide to natural radiation sources would generally be expected to be in the range of 1-10 mSv, with 2.4 mSv being the present estimated of the central value [4]. In this article, exposure is used most often in its general sense, meaning to be irradiated. When used as the specifically defined radiation quantity, exposure is a measure of the ionization produced in air by X or gamma radiation. The unit of exposure, $X$, is coulomb per kilogram (C kg$^{-1}$). The radiation level is characterized with quantities of absorbed, equivalent and effective dose and measured in units called Gray (Gy) for absorbed and Sievert (Sv) for equivalent and effective dose. When assessing health effects due to radiation, the unit Sievert (abbreviated Sv) is used rather than the unit Gray. The number of Sievert units is $Q$ times the number of the dose units in Gray. $Q$ is called a quality factor. $Q$ = 1 for gamma rays, $X$ rays, and fast electrons. For simplicity, all dose units in the article are reported in Sieverts (Sv) which is the measure of energy deposited in living tissue. Fig.2 shows average annual doses from natural radiation sources in different countries [5].

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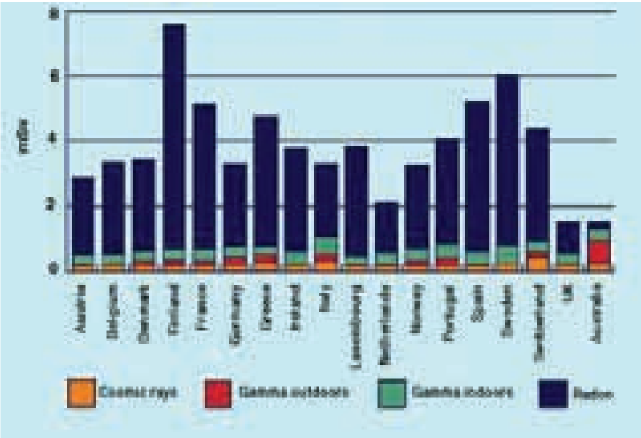


**Figure 2.** Average annual doses from natural radiation sources

Recommended dose limits [5, 6] are shown in Table 1.

**Table 1.** Recommended dose limits

| Category | | Effective Dose, annual |
|---|---|---|
| Radiation workers | | 50 mSv/y |
| Pregnant workers | | 0.5 mSv/y |
| General public | Infrequent exposure | 5 mSv/y |
| | Continuous exposure | 1 mSv/y |

For timely actions in case of radiation accidents, prevention and reduction of harmful consequences of radiation effects on the health and lives of people and the environment, a continuous automated system of early warning of radiation accidents[1] was established in Serbia in 2008 for the first time.

## Methodologies and measuring techniques

Background radiation was monitored by daily measurements of gamma dose rates in the air. Gamma dose rate measurements were performed using a radiation monitor on the basis of personal computers PC-RM, which was designed at the Laboratories of Electronics Institute of Nuclear Science "Vinča" [7].

Gamma radiation was detected using a Geiger-Müller counter (Philips ZP1400 type). The sensitivity of the detector is 2.7 $s^{-1}/\mu Gyh^{-1}$ at $^{60}Co$. As a consequence of radiation passing through the detector, an electric signal occurs at the output of the detector. The counting number is proportional to the level of radiation in the specific area. Electrical impulses are transmitted from the transducer cable to the acquisition card and the computer. The computer calculates the dose rate. The registration pulse from the probe is done by the data acquisition card. This card is installed in a free 62-pin ISA slot on the motherboard of personal computers. Pulse counting is done by an Intel 8254 which contains three 16-bit timers. In this context, two related to the row count is used for pulse counting, while the third timer is used to detect the probe. The maximum counting rate which may be registered by this counter is $10^7 s^{-1}$.

The software package that provides the user through an interface (Fig.3), directs the functioning of the monitor and gets information about the measurement results. The program provides a range of additional functions, which is not the case with the classical radiation monitors. User has a choice to set measurements with the limit of statistical errors or measurements with the definite time. Measurements of exposure dose rate are displayed on the computer monitor in both analog and digital form. The values of measurements can be displayed in $Gyh^{-1}$ units. The interface is realized using the LabWindovs/CVI software package for virtual instrumentation [8] which works under the Windows operating system and is a visual software package in which the programming is done in ANSI C language.


**Figure 3.** Interface for radiation monitoring

Measurements were performed at the location of Kumorаž (coordinates $X$ = 460050, $Y$ = 4954400 - UTM transformation, World Geodetic System - WGS 84). During measurements, the probe was located 1 m above the ground in the open air.

## Results and discussion

The results of measuring exposure dose rates of gamma radiation in the air are memorized for each day individually. Based on the results of daily measurements, the monthly value was calculated as average of all daily values for that month.

The relation between the adsorbed dose rate and the exposure rate is given by the following equation [9]

$$D_{air} = 8.69 \times 10^{-3} \cdot X \left[ Gy \right] \quad (1)$$

where $8.69 \times 10^{-3}$ is a conversion factor obtained using the 34 eV ionization energy required to produce an ion pair, multiplied by $1.6 \times 10^{12}$ ions produced for each Roentgen.

The equivalent dose ($H_T$) is calculated by multiplying the absorbed dose to the organ or tissue ($D_T$) with the radiation weighting factor, $w_R$. This factor is selected for the type and energy of the radiation incident on the body, or in the case of sources within the body, emitted by the source. The value of $w_R$ is 1 for x-rays, gamma rays and beta particles, but higher for protons, neutrons, alpha particles, etc. [5].

$$H_{T,R} = w_R \cdot D_{T,R} \quad (2)$$

where $H_{T,R}$ = equivalent dose to the tissue $T$ from the radiation $R$, $D_{T,R}$ = absorbed dose $D$ (in Grays) to the tissue $T$ from the radiation $R$.

The effective dose, $E$, is the sum of the weighted equivalent doses in all the tissues and organs of the body. It is given by the expression

$$E = \sum_T w_T \cdot H_T \quad (3)$$

[1] http://www.ekoplan.gov.rs/en/dodaci/radijacija/index.php

where $H_T$ is the equivalent dose in the tissue or the organ $T$ and $w_T$ is the weighting factor for the tissue $T$. The sum of value of $w_T$ is 1 for the whole body. For gamma or $X$ radiation quantitatively is valid

$$E \approx H \approx D \tag{4}$$

Table 2 gives the values of effective dose rates, determined from Eqs. (1-4), for the period from 1999 to 2009. The organizationl changes in the Military Technical Institute caused that the monitoring of background radiation was not in operation from May 2005 to December 2006.

**Table 2.** Monthly average, minimum and maximum effective dose rates for each year [μSv/h]

| In 1999 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| May | 0.1255 | 0.1202 | 0.1286 | 0.0020 |
| Jun | 0.1224 | 0.1135 | 0.1285 | 0.0083 |
| Jul | 0.1177 | 0.0972 | 0.1537 | 0.0167 |
| Aug | 0.1330 | 0.1302 | 0.1369 | 0.0022 |
| Sep | 0.1329 | 0.1296 | 0.1423 | 0.0029 |
| Oct | 0.1315 | 0.1252 | 0.1413 | 0.0046 |
| Nov | 0.1306 | 0.1240 | 0.1368 | 0.0040 |
| Dec | 0.1253 | 0.1161 | 0.1397 | 0.0037 |

| In 2000 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1268 | 0.1178 | 0.1337 | 0.0049 |
| Feb | 0.1216 | 0.1104 | 0.1334 | 0.0063 |
| Mar | 0.1213 | 0.1134 | 0.1333 | 0.0038 |
| Apr | 0.1226 | 0.1174 | 0.1272 | 0.0031 |
| May | 0.1248 | 0.1181 | 0.1308 | 0.004 |
| Jun | 0.1267 | 0.1222 | 0.1342 | 0.0035 |
| Jul | 0.1288 | 0.1243 | 0.1336 | 0.0026 |
| Aug | 0.1302 | 0.1255 | 0.1352 | 0.0026 |
| Sep | 0.1278 | 0.1215 | 0.133 | 0.0032 |
| Oct | 0.1277 | 0.1229 | 0.1324 | 0.0028 |
| Nov | 0.1253 | 0.1183 | 0.1317 | 0.0034 |
| Dec | 0.1274 | 0.1220 | 0.1386 | 0.0044 |

| In 2001 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1251 | 0.1196 | 0.1320 | 0.0030 |
| Feb | 0.1217 | 0.1166 | 0.1254 | 0.0025 |
| Mar | 0.1198 | 0.1104 | 0.1243 | 0.0048 |
| Apr | 0.1243 | 0.1116 | 0.1308 | 0.0052 |
| May | 0.1357 | 0.1325 | 0.1434 | 0.0036 |
| Jun | 0.1354 | 0.1260 | 0.1429 | 0.0058 |
| Jul | 0.1323 | 0.1224 | 0.1385 | 0.0037 |
| Aug | 0.1293 | 0.1189 | 0.1360 | 0.0033 |
| Sep | 0.1267 | 0.1174 | 0.1311 | 0.0033 |
| Oct | 0.1122 | 0.1083 | 0.1144 | 0.0027 |
| Nov | 0.1156 | 0.1116 | 0.1278 | 0.0036 |
| Dec | 0.1139 | 0.1176 | 0.1404 | 0.0022 |

| In 2002 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1142 | 0.1101 | 0.1178 | 0.0020 |
| Feb | 0.1138 | 0.1103 | 0.1165 | 0.0020 |
| Mar | 0.1148 | 0.1119 | 0.1184 | 0.0016 |
| Apr | 0.1163 | 0.1128 | 0.1222 | 0.0023 |
| May | 0.1137 | 0.1093 | 0.1167 | 0.0020 |
| Jun | 0.1144 | 0.1102 | 0.1183 | 0.0022 |
| Jul | 0.1136 | 0.1065 | 0.1198 | 0.0030 |
| Aug | 0.1151 | 0.1112 | 0.1229 | 0.0030 |
| Sep | 0.1150 | 0.1123 | 0.1207 | 0.0021 |
| Oct | 0.1158 | 0.1121 | 0.1239 | 0.0035 |
| Nov | 0.1159 | 0.1123 | 0.1198 | 0.0020 |
| Dec | 0.1160 | 0.1127 | 0.1208 | 0.0023 |

| In 2003 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1198 | 0.1137 | 0.1444 | 0.0100 |
| Feb | 0.1161 | 0.1123 | 0.1210 | 0.0022 |
| Mar | 0.1136 | 0.1107 | 0.1191 | 0.0021 |
| Apr | 0.1167 | 0.1127 | 0.1237 | 0.0038 |
| May | 0.1156 | 0.1118 | 0.1339 | 0.0047 |
| Jun | 0.1303 | 0.1094 | 0.1361 | 0.0087 |
| Jul | 0.1339 | 0.1293 | 0.1428 | 0.0034 |
| Aug | 0.1371 | 0.1332 | 0.1641 | 0.0067 |
| Sep | 0.1332 | 0.1295 | 0.1364 | 0.0020 |
| Oct | 0.1329 | 0.1262 | 0.1410 | 0.0036 |
| Nov | 0.1275 | 0.1232 | 0.1354 | 0.0028 |
| Dec | 0.1324 | 0.1230 | 0.1598 | 0.0101 |

| In 2004 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1428 | 0.1208 | 0.1760 | 0.0169 |
| Feb | 0.1359 | 0.1192 | 0.1561 | 0.0090 |
| Mar | 0.1341 | 0.1264 | 0.1540 | 0.0072 |
| Apr | 0.1376 | 0.1248 | 0.1552 | 0.0094 |
| May | 0.1355 | 0.1253 | 0.1473 | 0.0069 |
| Jun | 0.1300 | 0.1110 | 0.1537 | 0.0115 |
| Jul | 0.1323 | 0.1284 | 0.1430 | 0.0070 |
| Aug | 0.1323 | 0.1224 | 0.1424 | 0.0070 |
| Sep | 0.1372 | 0.1324 | 0.1601 | 0.0086 |
| Oct | 0.1328 | 0.1231 | 0.1479 | 0.0053 |
| Nov | 0.1335 | 0.1244 | 0.1500 | 0.0058 |
| Dec | 0.1368 | 0.1255 | 0.1627 | 0.0124 |

| In 2 0 0 5 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1420 | 0.1316 | 0.1437 | 0.0017 |
| Feb | 0.1295 | 0.1160 | 0.1440 | 0.0111 |
| Mar | 0.1338 | 0.1169 | 0.1538 | 0.0106 |
| Apr | 0.1346 | 0.1284 | 0.1397 | 0.0068 |

| In 2007 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1248 | 0.1178 | 0.1311 | 0.0039 |
| Feb | 0.1252 | 0.1212 | 0.1280 | 0.0022 |
| Mar | 0.1250 | 0.1200 | 0.1452 | 0.0034 |
| Apr | 0.1259 | 0.1291 | 0.1233 | 0.0015 |
| May | 0.1261 | 0.1227 | 0.1321 | 0.0032 |
| Jun | 0.1235 | 0.1174 | 0.1269 | 0.0027 |
| Jul | 0.1265 | 0.1199 | 0.1321 | 0.0021 |
| Aug | 0.1267 | 0.1227 | 0.1321 | 0.0032 |
| Sep | 0.1257 | 0.1174 | 0.1321 | 0.0027 |
| Oct | 0.1263 | 0.1205 | 0.1306 | 0.0036 |
| Nov | 0.1231 | 0.1132 | 0.1313 | 0.0047 |
| Dec | 0.1242 | 0.1199 | 0.1282 | 0.0033 |

| In 2008 | | | | |
|---|---|---|---|---|
| **Month** | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1231 | 0.1163 | 0.1301 | 0.0036 |
| Feb | 0.1229 | 0.1198 | 0.1268 | 0.0021 |
| Mar | 0.1243 | 0.1252 | 0.1265 | 0.0022 |
| Apr | 0.1241 | 0.1199 | 0.1280 | 0.0022 |
| May | 0.1257 | 0.1203 | 0.1301 | 0.0023 |
| Jun | 0.1275 | 0.1247 | 0.1305 | 0.0017 |
| Jul | 0.1282 | 0.1233 | 0.1329 | 0.0026 |
| Aug | 0.1279 | 0.1239 | 0.1327 | 0.0026 |
| Sep | 0.1279 | 0.1239 | 0.1321 | 0.0025 |
| Oct | 0.1252 | 0.1203 | 0.1284 | 0.0022 |
| Nov | 0.1254 | 0.1197 | 0.1339 | 0.0035 |
| Dec | 0.1243 | 0.1187 | 0.1299 | 0.0027 |

| In 2009 | | | | |
|---|---|---|---|---|
| Month | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1272 | 0.1176 | 0.1399 | 0.0055 |
| Feb | 0.1203 | 0.1114 | 0.1294 | 0.0070 |
| Mar | 0.1241 | 0.1207 | 0.1275 | 0.0019 |
| Apr | 0.1258 | 0.1231 | 0.1282 | 0.0014 |
| May | 0.1262 | 0.1213 | 0.1313 | 0.0024 |

Table 3 shows monthly average, minimum and maximum effective dose rates for the whole period of 10 years.

**Table 3.** Monthly average, minimum and maximum effective dose rates for the whole period from 1999 to 2009 [μSv/h]

| From 1999 to 2009 | | | | |
|---|---|---|---|---|
| Month | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| Jan | 0.1273 | 0.1142 | 0.1428 | 0.0094 |
| Feb | 0.1230 | 0.1138 | 0.1359 | 0.0067 |
| Mar | 0.1234 | 0.1136 | 0.1341 | 0.0072 |
| Apr | 0.1253 | 0.1163 | 0.1376 | 0.0071 |
| May | 0.1254 | 0.1137 | 0.1357 | 0.0074 |
| Jun | 0.1263 | 0.1144 | 0.1354 | 0.0063 |
| Jul | 0.1267 | 0.1136 | 0.1339 | 0.0073 |
| Aug | 0.1290 | 0.1151 | 0.1371 | 0.0065 |
| Sep | 0.1283 | 0.1150 | 0.1372 | 0.0067 |
| Oct | 0.1256 | 0.1122 | 0.1329 | 0.0078 |
| Nov | 0.1246 | 0.1156 | 0.1335 | 0.0064 |
| Dec | 0.1250 | 0.1139 | 0.1368 | 0.0076 |

Table 3 shows that the monthly average of effective dose rates for the period from 1999 to 2009 range from 0.1230 μSv/h in February to 0.1290 μSv/h in August. This can be explained by the weather conditions at the location.

Table 4 shows the average, minimum and maximum annual effective dose rates for the period from 1999 to 2009.

**Table 4.** Average, minimum and maximum effective dose rates from 1999 to 2009.godine [μSv/h]

| From 1999 to 2009 | | | | |
|---|---|---|---|---|
| Year | $\bar{E}$ | $E_{min}$ | $E_{max}$ | $\sigma$ |
| 1999 | 0.1274 | 0.0972 | 0.1537 | 0.0056 |
| 2000 | 0.1259 | 0.1104 | 0.1386 | 0.0029 |
| 2001 | 0.1243 | 0.1083 | 0.1434 | 0.0080 |
| 2002 | 0.1149 | 0.1065 | 0.1239 | 0.0010 |
| 2003 | 0.1258 | 0.1094 | 0.1641 | 0.0087 |
| 2004 | 0.1351 | 0.1110 | 0.1760 | 0.0034 |
| 2005 | 0.1350 | 0.1160 | 0.1538 | 0.0052 |
| 2007 | 0.1253 | 0.1132 | 0.1452 | 0.0012 |
| 2008 | 0.1255 | 0.1163 | 0.1339 | 0.0019 |
| 2009 | 0.1247 | 0.1114 | 0.1399 | 0.0027 |

The average annual effective dose can be calculated from the average annual effective dose rates by equation

$$E(y) = \bar{E}(y) \cdot t \qquad (5)$$

The effective dose rates were expressed in Sv/h. The value $t$ from eq. (5) can be replaced with 8760 hours (or 8784 hours for the leap years 2000, 2004 and 2008).

Average annual effective doses are given in Fig.4.

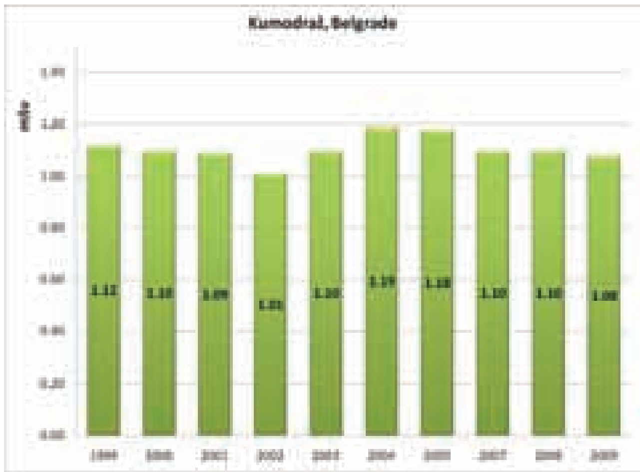


**Figure 4.** Determined average annual doses from natural radiation sources from 1999 to 2009 at Kumodraž [mSv]

Average annual effective doses are in the range from 1.01 mSv/y to 1.19 mSv/y.

## Conclusion

The method of daily monitoring of exposure rates in the air using the radiation monitor RM-PC, described in this paper, proved to be successful for the control of background radiation. The determined annual and montly doses in the period from 1999 to 2009 are below to allowable limits. The average annual doses are lower than the worldwide average.

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# Praćenje prirodnog fona jonizujućeg zračenja na lokaciji Beograd - Kumodraž od 1999. do 2009. godine

**Rad prikazuje rezultate praćenja jačine doze gama zračenja kao indikatora prirodnog fona na lokaciji Beograd - Kumodraž. Jačina doze gama zračenja u vazduhu praćena u periodu od maja 1999. do maja 2009, pomoću monitora gama zračenja PC-RM. Dobijeni rezultati pokazuju da je prosečna godišnja efektivna doza u granicama od 1.01 do 1.19 mSv/y i da je niža od svetskog proseka.**

*Ključne reči*: **prirodna radioaktivnost, jonizaciono zračenje, doza zračenja, gama zračenje.**

# Наблюдение над естественным фоном ионизационного излучения в районе Белград - Кумодраж с 1999-ого по 2009-ый год

**В настоящей работе представлены результаты наблюдения предела прочности экспозиционной дозы гамма-излучения в роли индикатора естественного фона в районе Белград - Кумодраж. За пределами прочности экспозиционной дозы гамма-излучения во воздухе наблюдали в периоде с мая 1999-ого по май 2009-ого года, при помощи монитора гамма-излучения PC-RM. Полученые результаты доказывают, что средняя эффективная доза в течении одного года бывает с 1.01 по 1.19 mSv/y и что она является ниже мирового среднего значения.**

*Ключевые слова*: **естественная радиоактивность, ионизационное излучение, доза излучения (облучения), гамма-излучение.**

# Le contrôle du fond naturel des rayons gamma sur la localité Belgrade - Kumodraž, de 1999 jusqu'à 2009

**Ce papier présente les résultats des contrôles de l'intensité de la dose d'exposition aux rayons gamma comme l'indicateur du fond naturel sur la localité de Belgrade – Kumodraž. L'intensité de la dose d'exposition des rayons gamma en l'air a été contrôlé dans la période entre le mois de mai 1999 et le mois de mai 2009, au moyen du moniteur pour ces rayons gamma PC-RM. Les résultats obtenus démontrent que la moyenne dose annuelle est située entre 1.01 et 1.19 m Sv/y et qu'elle est inférieure à la moyenne mondiale.**

*Mots clés*: **radioactivité naturelle, radiation ionique, dose de radiation, rayons gamma.**