Use of Gamma Spectrometry Method for Environmental Monitoring in the area of NPP

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Abstract. It is generally not possible to correctly determine the long and short term impact of human activity upon the environment, without thorough processing of data, obtained through monitoring. It was confirmed that such impact on the environment must be monitored over a long time period. The data obtained must be of high quality, an attribute assured by present state of scientific knowledge. One of the well established methods for monitoring atmospheric deposition of radionuclides in the environment is laboratory and in situ gamma spectrometry. With the aim to monitor an occurrence of a one-time escape or persistent release of fission products into the air, resulting from an operation of a nuclear plant, two types of monitoring are performed: i/ measurement of samples from the environment (Schreber moss, forest humus, pine bark, mushrooms and forest berries) using laboratory gamma spectrometry method in the range up to 3 MeV (those data are used for the trend analysis and for the construction of the contamination-maps); ii/ in situ gamma spectrometry for assessment dosimetry and spectrometry characteristic of photon-fields (those data are used for the dose rate calculation).

Keywords: gamma spectrometry, biomonitoring, trend analysis, nuclear power plant, dosimetry

1. Introduction

It is generally not possible to correctly determine the long and short term impact of human activity upon the environment, without thorough processing of data, obtained through monitoring. It was confirmed that such impact on the environment must be monitored over a long time period. The data obtained must be of high quality, an attribute assured by present state of scientific knowledge. One of the well established methods for monitoring atmospheric deposition of radionuclides in the environment is laboratory and in situ gamma spectrometry. With the aim to monitor an occurrence of a one-time escape or persistent release of fission products into the air, resulting from an operation of a nuclear plant, two types of monitoring are performed: i/ measurement of samples from the environment (Schreber moss, forest humus, pine bark, mushrooms and forest berries) using laboratory gamma spectrometry method in the range up to 3 MeV, ii/ in situ gamma spectrometry for assessment dosimetry and spectrometry characteristic of photon-fields. After processing of the measured spectra we obtain mass activity of individual primordial radionuclides or even of manmade radionuclides that enable us to prepare distribution maps for individual radionuclides within the monitored area in each year of monitoring.
With a sufficient amount of measurement samples collected, it will be feasible to compare the potential radionuclide accumulation, against the “zero level” reference obtained in the year 2000 (before the start of the NPP operation), using trend analysis [3]. The area of interest contained 29 sampled location along eight radial profiles intersecting the area up to distance from 2 to 20 km around the NPP [3].

2. Measurements and methods in laboratory
The gamma spectrometric method (with very good range of detection) was chosen to determine the presence of natural and manmade radionuclides. The gamma laboratory measuring equipment consists of HPGe detector with built-in preamplifier (mfg. by EG&G Ortec), amplifiers 2022 Canberra, Source VN31060 Canberra, ADC built-in analyser, analyser model 4202 Canberra and a PC, Marinelli geometry 0.5 l. Processing of measured spectra in the range up to 3 MeV provided mass related activity of naturally radioactive elements (40K, 226Ra, and 232Th) and contaminant 137Cs (resulting from nuclear weapon tests in the fifties of last century and from Cernobyl accident fallout) using program SP DEMOS.

After drying, the samples were enclosed in Marinelli containers with a volume of 0.5 l, surrounding during the measurements a coaxial HPGe detector [1, 2].

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Figure 1a showes one example of the “contaminations” maps of the 137Cs mass activities (Bq/kg) in the years 2001 - 2004. Very interesting is comparison with the year 2003, which was extremely “dry” (without rainfall). Despite claims that the moss grows independently on contact with forest humus, contents of 137Cs went down (see Fig 1b).

Figure 1a: One of the laboratory gamma spectrometry method application: the maps of the 137Cs mass activity (Bq/kg) (autumn sampling of the Schreber moss) [axis x: the west-east distance from NPP (km); axis y: the south-north distance from NPP (km)]

Figure 1b: The maps of the 137Cs mass activity (Bq/kg) (autumn sampling of the Schreber moss) in the “dry” year 2003 [axis x: the west-east distance from NPP (km); axis y: the south-north distance from NPP (km)]

With a sufficient amount of measurement samples collected, it will be feasible to compare the potential radionuclide accumulation, against the “zero level” reference obtained in the year 2000 (before the start of the NPP operation), using trend analysis [3]. The main tasks of this project is to describe the influence of NPP Temelin on radiation increase in its neighbourhood. Two model situations have to be studied:

- the accident with extensive radionuclide escape
- the long-term continuous escape

The first results of the trend analysis do not confirm any marked increase in the checked radionuclides. Although the assessment of the radiation increase is complicated due the fluctuations, that are typical for most environmental measurements, this method seems to be appropriate for such investigation.

3. Measurements and methods in situ
The measurements of photon-spectra (using scintillation spectrometer MCA μ NOMAD EG &G Ortec with scintillation detector NaI(Tl) diameter 3” by 3” in the energy range up to 3 MeV), the
determination of air kerma rate (1. by direct measurements with device TESLA NB 3201 using plastic scintillator and 2. through calculations based on spectrometry data), is performed.

In order to appraise human irradiation, measured kerma rates to air were converted to absorbed dose rates to water. The conversion arises from general dose-kerma correlation summarized in Eq.1.

\[
D_w = D_{\text{air}} \frac{\mu_{\text{en}}/\rho}{\mu_{\text{en}}/\rho}_{\text{air}} = K_{\text{air}} \frac{\mu_{\text{en}}/\rho}{\mu_{\text{en}}/\rho}_{\text{air}} (1 - G)_{\text{air}}
\]

\( (\mu_{\text{en}}/\rho) \) and \( (\mu_{\text{en}}/\rho)_{\text{air}} \) represent mass energy-absorption coefficients for water and air respectively. Emission of bremsstrahlung is taken into account in G factor. Although mass energy-absorption coefficients depend on photon energy, their ratio is almost constant for photons in the energy range from 100 keV to 3 MeV [4]. The results of the dose rate calculation are summarised in Table 1 and Figure 2.

Table 1: Dose rates to water derived from in-situ measurements of kerma rate to air

| locality code | total dose rate to water | total dose rate to water | st.dev. |
|---------------|-------------------------|-------------------------|---------|
|               | [nGy/h]                 | [mGy/year]              | [%]     |
| 1             | 115                     | 1,01                    | 2,1     |
| 3             | 79                      | 0,93                    | 3,9     |
| 4             | 134                     | 1,17                    | 3,9     |
| 6             | 110                     | 0,96                    | 1,8     |
| 8             | 121                     | 1,06                    | 3,7     |
| 12            | 106                     | 0,93                    | 2,3     |
| 14            | 147                     | 1,29                    | 3,0     |
| 16            | 117                     | 1,03                    | 3,1     |
| 17            | 153                     | 1,34                    | 1,9     |
| 20            | 106                     | 0,93                    | 3,6     |
| 22            | 157                     | 1,38                    | 2,1     |
| 23            | 123                     | 1,08                    | 2,5     |
| 25            | 124                     | 1,09                    | 3,0     |
| 29            | 110                     | 0,96                    | 2,8     |
| average       | 121                     | 1,06                    | 2,8     |

Figure 2: Total dose rate to water from in situ gamma spectrometry measurement

Table 1 contains the typical values of the natural background in Czech Republic, which is formed by radionuclides present in rocks and \(^{137}\)Cs from nuclear weapon tests in the fifties of the last century and from Chernobyl accident fallout in 1986.

It is necessary to note how miniscule will be the share from the NPP operation (0.04% from average annual dose in CR) – it will be fully masked by the fluctuations of irradiation from the natural sources.

4. Conclusion

Cross-comparison of results obtained in individual years enables the determination of possible contamination. With the exception of the identified \(^{137}\)Cs (resulting from nuclear weapon tests in the fifties of the last century and from Chernobyl accident fallout) it was not possible to identify among the measured spectra any significant contribution of any other manmade radionuclides in the years 2000-2004.

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