ACTIVE BIOMONITORING OF AIR RADIOACTIVITY IN URBAN AREAS

by

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To assess the validity of the moss bag monitoring technique in the radioactivity control of ground level urban air, a study on radionuclide contents in moss was performed in the city of Belgrade, Serbia. From May 2006 to May 2007, moss (*Sphagnum girgensohni*, Dubna, Russia) was exposed to the aero pollution in a location in the central area of the city. The activity of ^{40}K, ^{210}Pb, and ^{137}Cs was measured on an HPGe detector (Canberra, relative efficiency 23%) by standard gamma spectrometry. The activities 245 ± 25 Bq/kg for ^{40}K, 315 ± 34 Bq/kg for ^{210}Pb, and 28 4 Bq/kg for ^{137}Cs are in the range of values reported for the region; the differences are due to the moss species, local climate and measuring technique. Taking into consideration the time of the exposure and appropriate calibration procedure, moss bag biomonitoring could be used as a complementary method for determination of radionuclides in urban air.

Key words: radionuclides, air, urban area, moss monitoring, gamma spectrometry

INTRODUCTION

Due to their morphology, physiology, and aerial spacing, mosses have comparatively higher efficiency in accumulating elements and heavy metals than other plant species. Therefore, in the late 1960s, moss biomonitoring was used as a complementary technique to classic instrumental methods in air pollution detection and control. Since then, mosses have been utilized as bioindicators of radioactive contamination of the environment, global distribution of radionuclides following nuclear weapon atmospheric tests, assessment of radioactive contamination of the environment after the nuclear plant accident in Chernobyl in 1986, and in radioactivity monitoring in the vicinity of nuclear power plants [1-4]. Moreover, moss and lichen proved to be reliable indicators of environmental contamination caused by the military use of depleted uranium (DU) in Bosnia and Herzegovina and Serbia, in the late 1990s [4-7].

Since the moss biomonitoring indicates antropogenic sources of pollution in urban areas, it is included in the standard control procedures in heavy metals pollution in urban areas [1, 7]. Mosses accumulate elements continuously and thus provide data about pollution sources even long after the pollution episode took place [8]. In urban areas, however, mosses are not often found in sufficient quantities. To overcome this drawback, a method in which moss transplants are utilized, the so called bag technique, has been frequently used. The method has a number of advantages, such as: the exposure time can be precisely recorded, concentrations of different elements in the sample are known prior to the exposure, and depending on the specific needs an adequate location can be chosen. The main disadvantage of the method is the unknown efficiency of accumulation for different pollutants [1, 2].

The paper presents the results of determination of radionuclide contents in moss by moss bag monitoring technique, performed in the city of Belgrade, Serbia. The aim of this study was to assess the validity of

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the method for radioactivity monitoring and control in ground level air.

EXPERIMENTAL

During one year (May 2006 to May 2007), the samples of moss packed in bags of nylon net (*Sphagnum girgensohnii*, Dubna, Russia, total mass 254.6 g) were exposed in Belgrade central city area. The chosen location is in the vicinity of a highway, and is one of the pollution "black spots" in the city. Moreover, that site is a sampling point for air radioactivity control by filter paper method [9]. Prior to the transport and exposure, the mosses were dried and cleared of soil and other material. After being exposed in the native state, the sample was divided into eight subsamples of 25-36 g (geometry Marinelli) to examine whether the radionuclides' distribution was uniform within the sample.

The activity of three radionuclides, ^{40}K, ^{210}Pb, and ^{137}Cs, was determined with an HPGe detector (Canberra, relative efficiency 23%) by standard gamma spectrometry. The reference radioactive material IAEA-373 (grass, with ^{134}Cs, ^{137}Cs, ^{40}K, and ^{90}Sr, total activity of 15 kBq dry weight on December 31, 1991) was used for geometric calibration. The counting time was 58000 s, and the total standard uncertainty of the method for the detected radionuclide was 16% for ^{40}K, 20% for ^{210}Pb, and 10% for ^{137}Cs.

RESULTS AND DISCUSSION

Fission product ^{137}Cs and naturally occurring ^{40}K and ^{210}Pb were detected in all eight subsamples, while ^{7}Be was detected only in one, with the activity of 60 Bq/kg. The absence of ^{7}Be in the subsamples could be explained by its decay, since the period between the sample arrival in the laboratory and the analysis was nearly 60 days. The mean activities A (Bq/kg) of ^{40}K, ^{210}Pb, and ^{137}Cs in moss, along with their standard deviations, are presented in tab. 1, while the radioactivity distributions in the divided subsamples of moss (subsamples 1–8) are given in figs. 1, 2, and 3.

The distributions of the radionuclides' content in the divided samples differ within 30%. Considering the standard uncertainty of the method and the volume of the composite sample, the activity distribution could be considered as rather uniform. The obtained annual activities imply that the exposure time could be reduced to a month, thus enabling a monitoring of seasonal variations in the content of radionuclides in air.

Table 1. Activity of radionuclides in moss [Bq/kg]

^{40}K	^{210}Pb	^{137}Cs
245 25	315 34	28 4

Furthermore, as can be concluded from figs. 1, 2, and 3, the activity ratio ^{210}Pb/^{40}K is within the range of 1.16-1.56, with the mean value of 1.30. A constant activity ratio ^{210}Pb/^{40}K could provide a sound basis for the ^{210}Pb activity estimation by solely measuring the activity of ^{40}K (which is more easily detected, and with a lesser uncertainty than ^{210}Pb). In future, this activity ratio will be more closely examined.

The mean activities of the detected radionuclides in moss were in the range of the values reported for the local moss species in the region [10, 11], with some differences. For comparison, the activities of radionuclides in the local moss species in the area of Borovac, Southern Serbia [11], are given in tab. 2. In that study, the moss was sampled in the immediate vicinity of a site hit by DU ammunition (Site 1) and 5 km away (Site 2). The differences in activities given in tabs. 1 and 2 could be explained by

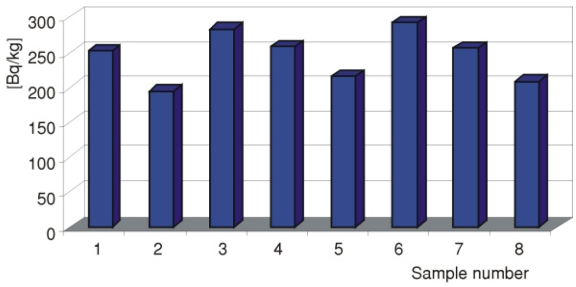

Figure 1. Distribution of ^{40}K activity in moss (subsamples 1–8)

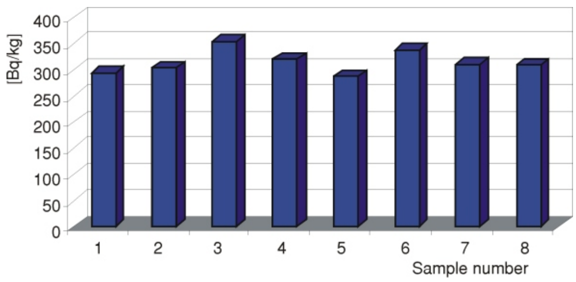

Figure 2. Distribution of ^{210}Pb activity in moss (subsamples 1–8)

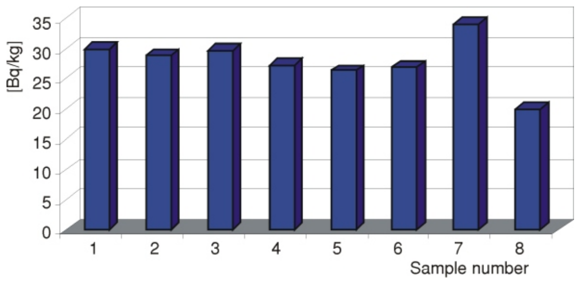

Figure 3. Distribution of ^{137}Cs activity in moss (subsamples 1–8)

Table 2. Radionuclides in moss, Borovac, South Serbia (Bq/kg dry weight) [11]

Site	^{40}K		^{210}Pb		^{137}Cs		^{7}Be	
1	178	25	552	55	149	14	199	30
2	298	42	210	52	226	22	228	34

the differences in moss species, measuring techniques, local climate, and soil characteristics. The soil in Southern Serbia is uncultivated and poor in potassium and although the local moss species, which are different from those used in the Belgrade study, absorb radionuclides mainly from air, a small amount of radionuclides' content is due to the soil uptake too. On the other hand, the exposure period, precisely defined in the Belgrade study, was undefined for the moss sampled in Southern Serbia. All these factors should be taken into consideration when comparing the results of moss radioactivity monitoring in different studies.

CONCLUSIONS

The annual (May 2006 – May 2007) mean activities of ^{40}K, ^{210}Pb, and ^{137}Cs obtained at a site in the central city area of Belgrade, Serbia, by the moss bag monitoring technique were 245 ± 25 Bq/kg, 315 ± 34 Bq/kg, and 28 ± 4 Bq/kg, respectively. The results are in good agreement with the results reported previously. Our study showed that the exposure time in the technique could be a month; thus, the moss bag monitoring could be used to follow seasonal variations in the content of radionuclides in air. Therefore, along with the other advantages of the method, the moss bag monitoring technique is adequate as a complementary method for determination of radionuclides in urban air.

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АКТИВНИ БИОМОНИТОРИНГ РАДИОАКТИВНОСТИ ВАЗДУХА У УРБАНИМ СРЕДИНАМА

У циљу утврђивања ваљаности технике активног мониторинга помоћу маховина у контроли радиоактивности приземног слоја атмосфере, на територији града Београда спроведена је студија садржаја радионуклида у маховинама. Од маја 2006. до маја 2007. године, маховина (*Sphagnum girgensohni,* Дубна, Русија) излагана је ваздушном загађењу на локацији у центру града. Концентрација активности ^{40}K, ^{210}Pb и ^{137}Cs мерена је HPGe детектором (Canberra, релативне ефикасности 23%) методом стандардне гама спектрометрије. Концентрације активности од 245 25 Bq/kg за ^{40}K, 315 34 Bq/kg за ^{210}Pb и 28 4 Bq/kg за ^{137}Cs спадају у опсег вредности измерених у региону; разлике у резултатима потичу од врсте маховине, локалне климе и технике мерења. Узимајући у обзир време излагања и правилну процедуру калибрације, активни мониторинг маховинама може да се примени као комплементарни метод за одређивање концентрације радионуклида у ваздуху у урбаном подручју.

Кључне речи: радионуклиди, ваздух, градска средина, активни биомониторинг, маховине, гама спектрометрија