RADIOECOLOGICAL INVESTIGATION AT THE CONSTRUCTION OF «BELENE» NPP

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INTRODUCTION

Normally, when nuclear power plants (NPP) are in ordinary mode of operation, the exhausts of the radioactive elements into the environment are insignificant and, in particular, consist of radioactive iodine and cesium. Therefore, it is important to conduct preliminary measurements of soils on the territories with possible radioactive pollution, in order to find out whether there are such radioactive elements as cesium, uranium, thorium and radium. Also it is necessary to define the radioactive background in such areas in order to obtain the database for comparing data after the launching of the NPP.

For this purpose the soil samples taken from the regions of NPP «Belene»,the towns of Svishtov and Belene, as well as the villages of Oresh, Dekov, Bulgaria were investigated (Fig. 1).

Fig. 1. The Region of NPP "Belene" and place of sampling

EXPERIMENTAL METHODS AND RESULTS

To determine the concentration of natural radioactive elements: U-238, Ra-226, Pb-210, Th-232, K-40 and anthropogenic radionuclide Cs-137 (Table 1), the semiconductor gamma-spectrometer with Ge(Li)-detector with 2,0 keV resolution for 1332 keV gamma-line of ^{60}Co was used.

Table 1. The concentration of radioactive elements in soil

Place of sampling	U-238 Bq/kg	Ra-226 Bq/kg	Pb-210 Bq/kg	Th-232 Bq/kg	K-40 Bq/kg	Cs-137 Bq/kg
Svishtov	21±9	28±3	<46	28±1	439±14	3,2±0,2
Oresh	20±7	16±2	52±25	15±1	336±11	2,0±0,1
Dekov	48±10	45±7	<62	50±1	546±18	7,9±0,3
Belene	34±11	38±3	<65	40±1	539±17	1,9±0,1

In the Table 2 the results of measurement of the natural radiation background in the places of sampling are presented.

Table 2. The natural radiation background in the places of sampling.

Place of sampling	Power of the equivalent dose, μSv/h
Svishtov	0,16
Oresh	0,13
Dekov	0,14
Belene	0,11
Average value	0,13

Another important problem occurring at the NPP construction site is the activation of concrete by the neutron irradiation during reactor operation. One of the important tasks in this area is to choose such a concrete that activates less, so as to decrease the irradiation of the personnel and the pollution of the environment with radioactive wastes on terminating the exploitation of reactors.

The calculation of the concrete activation is complicated because there is insufficient data on the concentration of elements forming long-living nuclides, in particular, Eu, Co, Cs, Fe [1] (Table 3).

Table 3. Nuclear characteristics of the radionuclides.

Element	Reactions with thermal neutrons	Activation cross-section, barn	Radioactive half-life
Fe	$^{58}Fe(n,g)^{59}Fe$	1,28	44,6 days
Co	$^{59}Co(n,g)^{60}Co$	37,45	5,3 years
Cs	$^{133}Cs(n,g)^{134}Cs$	29,0	2,06 years
Eu	$^{151}Eu(n,g)^{152}Eu$	5939	13,3 years
Eu	$^{153}Eu(n,g)^{154}Eu$	603	8,8 years

The purpose of the present work is to experimentally determine the concentration of these and other elements in concrete samples from NPP «Belene».

Four samples of concrete from different locations of the NPP «Belene» were chosen as an investigation material. These are as follows: sample 1 — reactor building; sample 2 — location near reactor; sample 3 — diesel-generator station; sample 4 — communication channels of special enclosure.

The concentration of elements is determined by means of the RFA-analyzer with the semiconductor Si-detector in the Laboratory of nuclear reactions, JINR, Dubna. The results for 28 elements in concrete samples are presented in Table 4.

Table 4. The concentration of elements in concrete samples.

Element	The concentration in samples from concrete

	Sample 1	Sample 2	Sample 3	Sample 4
K ,%	1.6±0.4	1.6±0.4	1.6±0.4	0.8±0.2
Ca, %	11±2	2.4±0.4	14±2	5.2±0.5%
Ti, %	0.10±0.05	0.12±0.05	0.2±0.05	0.09±0.05
Mn, %	0.06±0.01	0.06±0.01	0.07±0.01	0.04±0.01
Fe, %	1.4±0.2	1.2±0.2	1.1±0.2	0.6±0.2
Co, ppm	≤10	≤10	≤10	≤11
Ni, ppm	30.0±3.0	<24.3	<23.8	40.0±3.0
Cu, ppm	70±5	70±4	60±4	80±5
Zn, %	0.20±0.01	0.04±0.01	0.05±0.01	0.19±0.01
As, ppm	<21.0	<20.3	<10	<10
Se, ppm	2.3±0.6	<1.2	1.7±0.6	2.0±0.6
Rb, ppm	55±6	60±6	60±6	36±6
Sr, ppm	220±40	200±40	380±40	170±40
Y, ppm	<27.1	<29.2	<27.9	<28.8
Zr, ppm	600±60	1400±60	360±60	450±60
Nb, ppm	6±2	9±2	<5.7	<5.7
Pb, ppm	110±30	40±10	40±10	80±30
Th, ppm	17±5	21±5	17±5	17±5
Cd ppm	3.9±1.0	2.1±0.5	2.2±0.5	5.0±1.0
Sn, ppm	13± 7	8±3	5±3	7±3
Sb, ppm	≤2.0	<1.9	<2.0	<1.8
Cs, ppm	10±5	9±5	20±5	9±5
Ba, ppm	800±50	700±50	1900±100	700±50
La, ppm	33±5	27±5	24±5	25±5
Ce, ppm	54±5	54±5	47±5	42±5
Nd, ppm	40±5	30±5	40±5	40±5
Eu, ppm	≤0.5	≤0.5	≤0.5	1.0±0.5
Ag, ppm	1.6±0.5	1.4±0.5	1.4±0.5	1.7±0.5

In works [2, 3] in portland cements the average concentration of Eu, Co, Cs, Fe is measured to be 2,4 ppm, 6,3 ppm, 1,2 ppm and 1,6 ppm, respectively. The obtained results for the NPP «Belene» concretes show that Eu and Fe values are lower, and Cs values are higher than in portland cements. In order to define the Co value more precisely it is necessary to carry out new investigations applying another method, for example — gamma- and/or neutron-activation analysis.

CONCLUSIONS

The obtained values of the concentration of the natural radionuclides of U-238, Ra-226, Th-232, Pb-210 and K-40 in soil from the NPP «Belene» region appear to be in the frames of average values for Bulgaria, and the value of anthropogenic radionuclide of Cs-137 is lower than an average for Bulgaria — 25 Bq/kg [4].

The measured level of the radiation background (0,13 μSv/h) is in the frames of average values for Bulgaria [4].

The obtained results indicate the present radiation state and may serve as a basis for future comparisons at estimating the changes of ecological state of the NPP «Belene» region.

The novel results were obtained on the element composition of the concretes used at NPP «Belene» construction. These results present a possibility to estimate the induced activation of concretes and the personnel and environment irradiation dose.

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