RADIATION EXPOSURE OF POPULATION DUE TO CARELESS USE OF RADIOACTIVE RAW MATERIALS IN THE URALS

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HISTORY and BACKGROUND

In the middle of the forties a deposit of thorium monacyte sand was found in the Urals. Thorium monacyte is a physically and chemically resistant mineral, practically insoluble in water. The formula for monacyte is $(Ce,La,Y,Th)P_2O_5$. The monacyte sand contains high concentrations of long-live natural nuclide ^{232}Th. Characteristic ThO_2 concentration in sand is about 3-9%.

During 1949-64 in village Ozerny located in 70 km to the north-east from Ekaterinburg a concentrating mill processing thorium containing monacyte sand for the purposes of nuclear and military industry was functioning. In summer the mill processed local staff and in winter the staff brought from another places. The territory of railway station Kostousovo was used for loading and storage of staff and as a result of this the territory of temporary monacyte sand storage was subjected to technogenic radioactive contamination.

After the concentration mill has ceased its operation the careless use of thorium monacyte sand for private and public construction, for paving the roads along with natural dispersion of sand took place. Thus in the village and at the railway station some centres of technogenic radioactive contamination by natural radionuclides has been formed.

One of the reasons of careless use of radioactive raw materials was the absence of objective information on the character of the staff.

OBJECTIVES

Our main objective was to single out all cases of radioactive contamination for planning the rehabilitation and deactivation measures and for calculating the accumulated exposure dose for population of village Kostousovo. It was assumed besides, that the main ways of population exposure beyond the natural radioactive background was the external gamma-irradiation and inhalation receipt of ^{220}Rn (thoron) along with its daughter products in houses built with the use of thorium-containing materials. It was also necessary to ascertain the level of natural radioactive background for comparing it with the additional irradiation.

METHODOLOGY

For revealing the centres of radioactive contamination the method of continuous pedestrian sampling point by point with distance 5 m (scale 1:5000) at the territories of common use (streets, vacant lots, railway station), in private gardens, along the external fronts of buildings and indoors - ceilings, walls, stoves was conducted. Scintillation radiometers were used.

The measuring of equivalent equilibrium concentration (EEC) of thoron was conducted by aspiration method implying aerosol adsorbtion on filter with further measuring of alpha-activity on the filter. Besides the equivalent volume activity of ^{222}Rn (radon) is revealed, being an important share in population exposure. The obtained results of seasonal samplings were converted to mean annual activity by the methodology tested and applied in the Urals. This methodology accounts for typical value of equilibrium factor and relation between seasonal and annual concentrations. For the purposes of evaluating the ^{232}Th supplies the samples of soil were taken in the areas with elevated gamma-irradiation. To estimate the specific activity of long-live radionuclides in air and water we conducted air- and water- sampling.

RESULTS

The whole territory of village and 235 private and public buildings were tested for radiation exposure dose rate. 16 places of concentration of radiologically contaminated staff were found along with 25 cases of using thorium-containing materials for building purposes.

Total contaminated territory is about 10200 m^2 The most extensively contaminated spot is at the former loading site of the concentration mill (8000 m^2), now it is a vacant lot. Other contaminated centres are located in the vicinity of, or directly in residence zone; their square is from 1 up to 1.300 m^2. Total Th concentration at the contaminated territory is about 1.6 Ci. Such Th concentration was formed as a result of spreading of about 300 tons monacyte sand (5% concentration) by a thin layer of 1 sm.

The range of radiation exposure dose rate in the middle of the most contaminated site was from 0.8 up to 1.0 mR/h, and Th specific activity in ground samples reaches 600 kBq/kg.

In all 25 tested houses the elevated rate of exposure dose (up to 150 μR/h) is caused by non-controlled use of monacyte sand as building material. As a result such parts of buildings as the fundamentations, wall plasterer, stove grout and garret fillings were radioactively contaminated. The total Th content in building materials do not exceed 0.15 Ci.

These materials also served the source of thoron emanation . The volume activity of thoron in contaminated buildings was 2.5-15 Bq/m^3, whereas the mean value for the village in non-contaminated buildings equals to 1.7 Bq/m^3 and doesn't exceed 2.5 Bq/m^3. The mean value of indoor volume radon activity in the village is 77 Bq/m^3. There was no difference in radon concentrations in "clean" and contaminated houses in the village.

The air and ground-water samplings don't show the elevated level of contamination (exceeding the background).

DISCUSSION, DOSES

It was estimated that the natural background radiation is rather high at this territory. Mean outdoor exposure dose at the territory of the village is equal to 20 μR/h, and indoors - 23 μR/h. Indoor radon concentrations are also rather high.

Basing on the results of estimating the external dose of gamma-irradiation in private houses in village Kostousovo the collective exposure dose was calculated. Population of the village is 430 people. Taking into consideration that population spends indoors about 7000 hours per year this dose equals to 56 cSv/year. Besides, 77% (43 cSv) of this dose is formed by the sources of natural gamma-irradiation, whereas 23% (13 cSv) - by technogenic concentrations of natural radionuclides (addition). Maximum individual effective dose by gamma-irradiation is a private house is 16.2 mSv/year.

The collective exposure dose formed as the result of inhalation penetration of thoron and daughter products is equal to 32 cSv/year. Besides, 81% of this dose (26 cSv) is caused by exhalation of thoron from the building materials and soil with natural concentration of ^{232}Th, and 19% (6.0 cSv) - by Th exhalation from building materials with elevated concentration of natural radionuclides (addition). Maximum individual effective dose in a private house constitutes 3.8 mSv/year. In the result of penetration of radon and daughter products the annual collective dose (59 cSv) is formed.

The structure of collective exposure dose H for population of village Kostousovo is shown in table 1.

Table 1.

The structure of collective exposure dose H for population of village Kostousovo

	H_{Tn}	H_{Rn}	H_{γ}	$H_{Tn}+H_{Rn}+H_{\gamma}$
Total, cSv/year	32	59	56	147
Excess, cSv/year	6,0	-	13	18
Excess, %	19	-	23	12

In the most contaminated private house there are living 7 persons. The structure of annual individual effective dose E is shown in table 2. This house was built in 1970. The accumulated for 25 years over-background individual exposure dose constituted almost 0.5 Sv.

Table 2.

The structure of annual individual exposure dose E for inhabitants of most contaminated house in village Kostousovo

	E_{Tn}	E_{Rn}	E_{γ}	$E_{Tn}+E_{Rn}+E_{\gamma}$
Total , cSv/year	5.3	1.4	16.2	22.9
Excess, cSv/year	4.7	-	15.2	19.9
Excess,%	89	-	94	87

CONCLUSION

Careless storage of radioactive staff at the railway station Kostousovo has led to its non-controlled use in building construction and thus to contamination of the territory by long-live natural radionuclides and daughter products. About 10200 m^2 of the territory and more than 10% of houses were subjected to contamination. As a result the external gamma-irradiation and indoor ^{222}Rn concentrations have increased.

Annual collective dose has increased by 19% through inhalation of thoron and daughter products, by 23% through external gamma-irradiation , an increase of 12% is registered in cumulative exposure dose. In case of extreme radioactive contamination of private house there was registered an 11-fold increase of the individual effective exposure dose.

Basing on the results of investigations some rehabilitation measures were proposed.