MAPPING OF TERRAIN CONTAMINATION ON AIR-GAMMA-SPECTRUM SURVEY DATA

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Abstract

The principles of preparation European maps on terrain contamination density by long-lived radionuclides resulted from the Chernobyl nuclear power plant accident are stated. The main method of the mapping is combination of air-gamma-spectrum survey of the territory and ground-based soil sampling to determine the levels of soil contamination by caesium-137, strontium-90, plutonium-238,239,240, and americium-241. Synthesized maps on caesium-137 contamination over the European parts of the former USSR and Russia compiled in that way were published on scales 1:500,000 and 1:2,500,000, these maps having status of the national ones.

Natural radionuclides (mainly the family of uranium and thorium, as well as radioactive isotopes of potassium) and artificial ones (e.g., fission products resulted from nuclear tests or by action of nuclear reactors, activation products by irradiation of non-active materials by neutrons) are presented in all parts of the earth's surface. Many of them emit gamma-radiation. Investigating gamma-radiation, one can detect nature and quantity of the radionuclides. In this study it is reported about airborne survey of soil contamination over the European part of the former USSR undertaken to estimate the Chernobyl accident consequences.

Now, the radioactive contamination of soils is presented mainly by caesium-137 and strontium-90 (the latter being beta emitting radionuclide) resulted from nuclear test products global fallout and accidents accompanied with radionuclides release to the environment. Soil global Cs-137 contamination density is equal to about 0.05 Ci/km^2 (1.85 kBq/m^2) on the planes of moderate latitudes, mean deepening into natural soils being around 1 cm. On cultivated areas, the isotope is distributed practically evenly within the ploughed layer, what decreases intensity of radiation by 2-5 times. An indicator of the Chernobyl contamination is caesium-134 (occurring parallel with caesium-137). Soil contamination by caesium-137 above 1 Ci/km^2 is a reason to make special arrangements to provide radiation monitoring and social protection of population.

Air-gamma-spectrum survey method makes it possible to estimate soil surface contamination density by gamma-radiating nuclides (e.g., in kBq/m^2, or Ci/km^2), and fraction of total mass of natural radionuclides in soils (in per cent, or its shares). An airplane or a helicopter intended for the survey is equipped with a gamma-spectrometer with scintillation detector, computer technique, radio-altimeter, navigation apparatus. The gamma-spectrometer enables to measure energetic spectra of emissions in the surface atmosphere forming the base for calculation the contamination density and natural radionuclide content (taking into account corrections for flight altitude and degree of deepening of the radionuclides into the soil). To carry out such processing, calibration of the spectrometer is required on some routes recommended as standard ones on the base of ground-based measurements of caesium contamination density and mass percentage of potassium, uranium, and thorium. Sampling of typical soils is also required to detect the deepening of the artificial isotopes into the soil by laboratory way. Soil sampling was

carried out on the areas under the survey to detect contamination density, radionuclide composition, and the degree of deepening into the soil; the results of the airborne measurements were corrected depending on the latter factor. The ground-based data can not be used to control remote data within individual sections of the routes because of their low representativeness, but they can display biased errors of the mean values within rather vast areas.

An individual measurement of the radioactivity was conducted over a route pass by the aircraft for a period not less than 1-3 sec. This requirement is necessary to compile data to decrease specific errors of this method. Peculiarities of distribution and registration of radiation enable to average individual measurements within a belt 5-6 times wider than the flight altitude. So, the techniques of measuring include automated smoothing of small-length contamination irregularities. Degree of the smoothing is so that, on the base of deviation from the mean values of the storage within a square with a side length equal to the length of the route, one airborne measurement is equivalent to data of nearly 100 soil samples analyzed within the same square. The flights were conducted at an altitude of 25-100 m. An error of individual measurement of the contamination density was 10-20 per cent. The main errors were caused by variations in the degree of deepening of the radionuclide into the soil, by topography, and, in some cases, by changes in background radiation.

In 1988-1993 high precise survey was conducted to estimate caesium-137 and caesium-134 soil contamination resulted from the Chernobyl accident and nuclear test products global fallout over the European territory of the former USSR. Regions characterized by contamination density above 1 Ci/km^2 were covered by the survey at a scale of 1:200,000, the other regions - at a scale of 1:1,000,000. (Flight over parallel routes every 2 and 10 km providing individual measurements over every 0.4 and 2.0 sq km accordingly). As a rule, soil radioactivity was also registered within different landscape sections of the routes, such as forests, meadows and arable lands differing from each other as to the degree of caesium deepening. Large settlements and highlands were not covered by such survey. Making inventory the contamination, it is necessary to bear in mind that fallout on water areas and the radionuclides washed down there, also are not considered by the survey. Since the survey was carried out by some airplanes, and parameters of their equipment were slightly different, numerous arrangements were provided for the control such as measuring on the standard routes, repeated measurements, ground-based control soil sampling, etc.

The maps compiled on the base of airborne measuring data on soil contamination, are synthesized ones, because these data are essentially supplemented with the results of ground-based measuring, data on typical landscapes distribution (taken into consideration when errors for deepening are calculating). Comparison of the results obtained by some aircrafts on overlapped areas was also used. The results of measuring radioacivity and co-ordinates of the route section's centers were interpreted by computer as vector reflection of cartographic load correlated with topographic map.

On the maps published the load is shown by color and isolines of caesium-137 contamination density [1-3]. Uncertainty of the isolines' location on the map estimated as a quotient of division measuring error by gradient of measured value, reaches 1-2 km (without smoothing) in contaminated regions. In the regions not subjected to contamination where contamination gradients are insignificant, more pronounced deviations of the isolines (from their real location) may take place.

The maps compiled on the base of the survey results are used to determine social and economic status of the contaminated regions, because the isolines of 40, 15, 5, and 1 Ci/km^2 are the boundaries of the following zones: zone of estrangement, one of eviction, one of strict control with the right of eviction and one of social privileges. Correlation between quantities of caesium and the other radionuclides (beta radiating strontium-90, alpha radiating plutonium isotopes) enables to estimate the density of terrain contamination by these radionuclides for certain. Caesium-134 is an indicator of the Chernobyl fallouts what gives a possibility to make distinctions between them and explosion products. The isoline of 0.2 Ci/km^2 can be considered as a boundary of the regions practically free of the Chrenobyl contamination, because the caesium global fallouts level is below this value over East European Plain. The total amount of the caesium-137 fallouts on the soils resulted from the Chernobyl accident is estimated on the map as equal to 2 MCi (with the error up to 20 per cent). Dimensions of predominating irregularities in the contamination density estimated by autocorrelation functions are equal to 50-80 km, and around 500 km.

Taking into account the data on the deepening, the map on contamination density was converted into a map on dose rates from certain radionuclides. It enables to calculate exposure dose rates (at an altitude of 1 m) separately for non-arable and ploughed plots within this area. Calculation of collective doses was carried out on the base of such maps. On such a base, it is possible to plan medical control and to conduct some kinds of medical statistics, radio ecological calculations, division of the area into districts, as well as to plan economic activities. Besides, the map is used for the purposes of adequate informing the general public about the real state of the contamination in the suffered regions. It favors development of the right method of approach to the danger of radiation. The radioactive contamination is investigated much better than other negative anthropogenic influences upon the environment. All these provide a possibility to spread the application of the contamination distribution regularities to chemical pollutions which can not be investigated with the same operativeness and detailing because of technical difficulties.

References

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