Journal of Environmental Radioactivity 144 (2015) 32–40

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Nature of radioactive contamination of components of ecosystems of streamflows from tunnels of Degelen massif

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ARTICLE INFO

Article history:
Received 20 December 2014
Received in revised form
13 February 2015
Accepted 17 February 2015
Available online 17 March 2015

Keywords:
Nuclear tests
Radioactive contamination
Radionuclides
Tunnels
Meadow soils
Radionuclides' distribution

ABSTRACT

The paper provides data on environmental contamination due to radionuclides' migration with water. As a result of investigations there was obtained data on character of contamination of soil cover, surface water and underflow from tunnels of Degelen massif. Character of radionuclides' spatial distribution in environment was also shown. Mobility ranges of radionuclides' vertical and horizontal movements have been established in soils both across and along the stream flow. There was also shown a possibility to forecast radionuclides' concentration in soil by specific activity of these radionuclides in water. Different concentrations of radionuclides in associated components of the ecosystem (surface waters – ground waters – soils) have shown disequilibrium of their condition in this system. Generalization of investigation results for tunnel water streams' with water inflows, chosen as investigation objects in this work, allows to forecast radionuclides' behavior in meadow soils and other ecosystems of water streams from tunnels of Degelen test site. Based on analysis of curves, describing radionuclides' behavior in horizontal direction, we can forecast, that at this stage ^{137}Cs and $^{239+240}$Pu would not be distributed more than 1.5 km from the access to the daylight surface, ^{90}Sr – not more than 2 km.

1. Introduction

The underground nuclear explosions made in 1961–1989 in tunnels of the Degelen massif caused radioactive contamination not only of cavities but also on the surface. In spite of demilitarizing measures on the territory, radioactive substances continue to migrate by water flows from tunnels. As a result, a large amount of radioactivity has accumulated in soil.

After stopping nuclear tests on the Degelen test ground, radioecological investigations were carried out in the framework of national and international contracts (DSWA, ISTC, INTAS, HDTRA ect.). The first radioecological investigations were performed within the frame of DSWA 0027/5 contract of 1 June1997. These investigations included a field gamma-survey of investigated near-portal areas of various tunnels, in-vitro gamma-spectrometric analysis of soil samples, and also determination of $^{239+240}$Pu, ^{137}Cs and ^{90}Sr concentrations. Investigations revealed the most contaminated areas with concentrations of $^{239+240}$Pu, ^{90}Sr and ^{137}Cs up to 9.0×10^6, 4.5×10^5 and 6.9×10^6 Bq/kg, respectively. Observations detected migration of artificial radionuclides along creekbed sediments from water coming from the tunnels, with migration rates ordered as: ^{90}Sr > $^{239+240}$Pu > ^{137}Cs.

As a result of tunnel stream flow monitoring, the quantities of radionuclides carried out with tunnel water from the from test cavities could be estimated (Ptitskaya, 2003, 2004).

The above projects gave a certain amount of information on the radioecological situation on the "Degelen" test ground. However, information was lacking about the distribution in creek valleys' soils and subsoils and also beyond them of ^{137}Cs, ^{90}Sr and especially $^{239+240}$Pu, whose distribution was not revealed before. The investigations were carried out in valleys of Baytles creek (tunnel № 176) and Uzynbulak creek tributary (tunnel № 177).

2. Methods

2.1. Background information about the sites

The choice to study the valleys of the Baytles (tunnel № 176) and Uzynbulak (tunnel № 177) creeks was made from reconnaissance studies on discharges from tunnels of the "Degelen" test ground, radionuclide characteristics of tunnel waters and contamination of outlet areas around the tunnels. An important

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http://dx.doi.org/10.1016/j.jenvrad.2015.02.021
0265-931X/

factor for choosing the above tunnels was their different conditions. Firstly, the Baytles stream runoff goes beyond the Degelen region whereas the Uzynbulak stream remains in the valley. Secondly, the water from tunnel № 176 carries away large amounts of ^{137}Cs and ^{90}Sr, whereas the water from tunnel № 177, in addition to above radionuclides, contains $^{239+240}$Pu – up to 12 Bq/L and ^{241}Am – up to 2.6 Bq/L. A feature of the two steams investigated is that their locations exclude impact of other tunnels.

According to previous investigations (Ptitskaya, 2003, the average annual flow rate of the stream from tunnel № 176 exceeds 500 L/min. The average annual activity concentration of radionuclides at the tunnel outflow was 89 Bq/L for ^{137}Cs, for ^{90}Sr – 275 Bq/L, and for ^{3}H – 341 kBq/L. Radiation monitoring results showed that the flux of artificial radionuclides to the surface with the tunnel water was not constant and depended first of all on amount of precipitation. However, the concentration of ^{90}Sr was always 2–3 times higher than concentration of ^{137}Cs (Ptitskaya, 2003). The activity concentration of $^{239+240}$Pu was below the detection limit of 0.02 Bq/L. From results of field radiometry performed at the moment of closure at the near-discharge point site, equivalent dose rate (EDR) did not exceed 0.50 μSv/h, α- and β-particles fluence rates were below detection limit (<0.5 and <10 parts/(min × cm^2), respectively) (Ptitskaya, 2003).

The sampling area was the left bank of Baytles creek characterized by small elevations with exposed rock. The width of the channel generally does not exceed 1 m. Lumps and slabs of rock can be observed in the water stream. At the distance of ≈750 m from the dam in the flat channel, formed by granite slabs, no constant water runoff can be observed. At this point the channel drops of 3 m, and in of high water this is a waterfall.

In the Uzynbulak tributary, the samples were taken on the right-bank of the creek downstream from tunnel No. 177. The stream width is mainly <1 m. The stream bed includes heaps of debris where the flow disappears or it is diverted. Besides the main waterflow, at the foot of the ridge, where the crater of the tunnel is located, there appear small springs forming a common stream. The distance from the source of the stream of tunnel No. 177 to the main creekbed of the stream Uzynbulak is about 650 m. Tunnel № 177 is characterized by a constant water flow (in first years of observations water appeared seasonally). During the observation period 2001–2005, the average annual water discharge was estimated as 4.4 × 10^8 L (over 500 L/min) (Ptitskaya, 2003. Average annual concentrations of radionuclides in the tunnel water for that period was ^{137}Cs – from 2 to 6 Bq/L. ^{90}Sr – from 630 to 1100 Bq/L, ^{3}H – from 550 to 630 kBq/L. Previous analysis of water samples were almost 12-fold above intervention levels for $^{239+240}$Pu (0.56 and 6.6 Bq/L).

2.2. Sampling

Field work included measurement of radiation parameters, sampling of environmental components, walking γ-survey and geographical coordinate determination (GOST 17.4.3.01-83, GOST 17.4.4.02.-84, GOST 24481-80, GOST 27262-87. Detailed measurements of equivalent dose rates (EDR) and beta β flux density on the soil surface was done, with a 25 × 25 m grid and in the area of tunnel № 176 and with a 10 × 10 m grid in the area of tunnel № 177.

Thirty soil profiles along 9 transect lines (Fig. 1) were sampled. Soil samples were collected at depth intervals of 5 cm. The transect lines were perpendicular to the water stream flow and consisted of 3 trial pits in the area of detailed investigations and 4–5 trial pits (transect lines VI-IX) in the lower part of the right tributary of the Baytles stream. In surface horizons of soils in 5 central trial pits of tunnel № 176 soil samples were taken in the intervals: 0–5, 5–10, 10–15 cm. In the Uzynbulak stream (tunnel № 177), 14 soil profiles were sampled in first years of investigations, 10 as part of 3 transect lines perpendicular to the creekbed (Fig. 2) and 4 profiles continue the row in the dry creekbed.

In tunnel № 176 daily measurements of streamflow discharge were made. For this purpose a sheet-iron chute with length 2 m, width 15 cm and height-20 cm was installed at the outlet from the tunnel. The speed of the water discharge in the chute was measured using a float, and from this data streamflow discharge was computed. To determine water budget for tunnel № 177, different parts of it (Fig. 2) were monitored daily with stage gauges, and at each position channel geometry was leveled for accuracy of measurements. Due to insignificant water flow (<6 L/min) from the tunnel discharge point, flow stage gauge № 1 was not measured.

Water from tunnel №176 was sampled every 3 days for measurement of ^{137}Cs and ^{90}Sr and every 12 days for $^{239+240}$Pu. To study downstream movement of radionuclides with the water from tunnel № 176, samples were taken at the tunnel outlet, mainstream and dam positions (points1/1–1/9) (Fig. 1). At each position, samples were collected twice 2 months apart for γ-spectrometry and radiochemical analysis. Samples of the tunnel № 177 stream were collected at the gauging stations on a weekly basis. All water samples were filtered by « Blue ribbon » filter.

2.3. Radionuclide analysis

Activity of radionuclides in environmental samples was measured according to standardized practices using calibrated equipment. Measurements of ^{137}Cs and ^{241}Am were performed using a Canberra GX-2020γ-spectrometer (M I and 2143-91), ^{90}Sr and $^{239+240}$Pu – by radiochemical extraction with further measurement with TRI-CARB 2900 TR β-spectrometer and Canberra α-spectrometer (model 7401) respectively (Instruction and

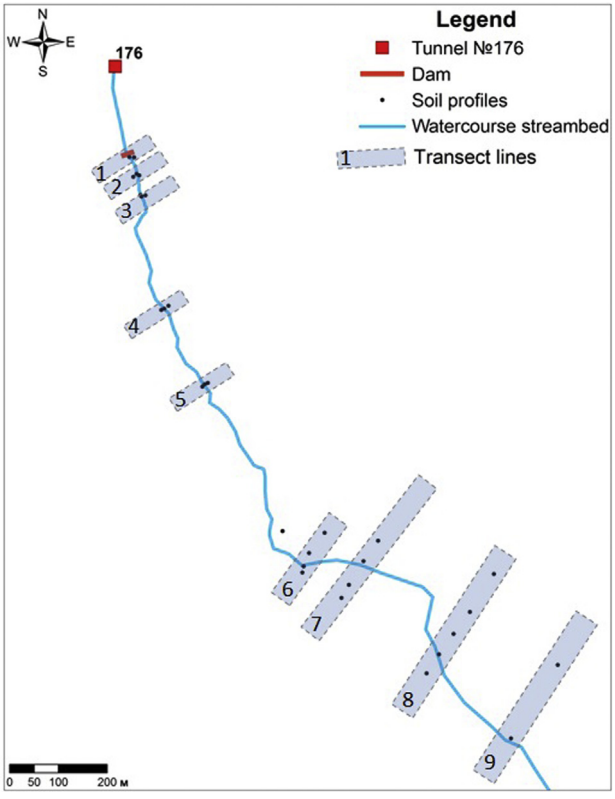

Fig. 1. Scheme of soil sections in the environment of tunnel № 176.