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Current Level of Tritium Concentrations in the River Techa and in Drinking Water Sources in Coastal Areas

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ABSTRACT *The paper gives presents data on the current levels of tritium concentrations in the water of the Techariver and in the drinking water in the settlements located in the coastal zone. It is shown that the delivery water entering water pumps from deep wells contains more radionuclide than the water from less shallower personal wells, boreholes and springs. The observed increased tritium content in the delivery water from deep wells is obviously due to the fact that the bed of the Techa is located in the earth crust break zone along which the contaminated water penetrates from the industrial reservoirs of the enterprise "Mayak", located in the upper part of the regulated river bed.*

KEYWORDS : boreholes, delivery water, river Techa, settlements, tritium concentration

INTRODUCTION

Tritium is one of the most widespread radioactive contaminants of the world ocean and of water ecosystems in continental areas. Its concentrations in natural waters are several orders of magnitude higher compared with those of ^{90}Sr and ^{137}Cs. Since water is the main accumulator of tritium in nature it easily moves at large distances with water streams and vapor from initial locations of pollution and contaminates water and air in concentrations exceeding the background [1, 2].According to the available literature, the global background level of tritium on the planet is ~ 1 Bq / l. The contemporary technological background level in the surface waters in various areas of Russia depends on the presence of nuclear enterprises in the vicinity. According to the results of our research, the technological background level of tritium is ~ 5 Bq /l in the Urals (the settlement of Kytliym, north of Sverdlovsk region) [1].

This paper concerns considers the present tritium concentrations in the river Techa water ecosystem in the southern Urals, in the zone affected by the enterprise "Mayak". The river rises has its origin in the lake Irtyash in the Chelyabinsk region, it is 243 km long, the drain area is area 7600 km^2, the average drain height is ~211 m. The Techa crosses the border between the Cheliabinsk and Kurgan regions at a distance of 144 km from its source. In the Kurgan region it flows over 99 km. The main tributaries are the Misheliak, the Zyuzelga and the Baskazyk[3].

In its upper part the river flows through a broad valley with many swamps. A large area is occupied by Asanovsky marches ~ 10 km long and ~ 2 km wide. The river bed in this area is not distinct, and the river flows in small channels. In the middle and lower parts (near Muslyumovo settlement and below) it becomes wider and deeper, with a distinct moderately twisting bed with reaches, shallows and spits. The banks are asymmetric: a steep bank on the one side and a low sloping one on the opposite side. The bottom is mostly sandy and sandy-rocky, rocky, rocky in some places. In deeper places, where the flow is slow, silty and sandy-silty sediments occur. A more detailed description of the morphological and hydrological characteristics of the Techa is given in the work of Mokrov[4].

During the construction and operation of "Mayak," the discharges into the upper part of the Techa was regulated by the system of waterworks, including a cascade of industrial reservoirs (R-3, R-4, R-10, R-11), a dam and bypass channels. These reservoirs were designed for the storage of non-technological low-level radioactive liquid wastes, and they are well drained. On the left bank of the reservoirs the left bank channel (LBC) is present, through which the "clean" water from the lake Irtyash enters the Techa, passing the cascade of reservoirs. To its right there is the right bank channel (RBC), receiving the water of the Mishelyak, the right tributary of the Techa (Fig. 1).

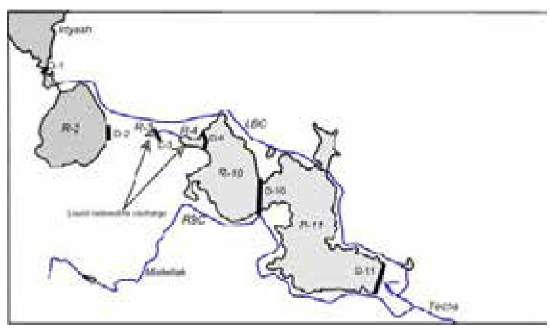

Fig. 1. Layout of the industrial reservoirs of "Mayak" in the Techa upper part

According to the results of the studies, made in 2007–2009, the tritium concentration in the water of the industrial reservoirs varied in the following range (Bq/l): R-2 – 3200–10 000 (on the average 6730±830), R-3 – 2400–8100 (4970±1000), R-4 – 2400–6300 (4000±690), R-10 – 1900–3800 (2910±300), R-11 – 700–1800 (850±270). During this observation period the average radionuclide concentration in the water of the industrial reservoirs according to the distance of sampling sites from the Techa origin. This regularity suggested that the industrial reservoirs formed a single hydrogeological system in which tritium concentrations in the reservoirs were diluted by the water flowing through them [5]. The liquid waste waters of "Mayak" containing tritium and other radionuclides passed through the industrial pond, entering the Techa and migrating downstream to the Iset and the Tobol rivers.

To assess the levels of tritium concentrations in the water of the river and in the drinking water sources, the water samples were taken from the Techa in the middle and lower parts from Muslyumovo settlement to Zatechenskoe settlement, as well as the drinking water in the settlements located in the river area and in the control area which is remote from the river (along the transect from Barabanovskoe settlement to Lobanovo settlement).

2. Material and methods

Samples of the river water and drinking water were taken in 2005-2011 in the vicinity of the following settlements: Muslyumovo (residents transplanted), Brodokalmak, RusskayaTecha, Lobanovo, Anchugovo, Upper Techa, Bugaevo, Shutikha, Pershinskoye, Zatechevskoe, Dolmatovo (Fig. 2).

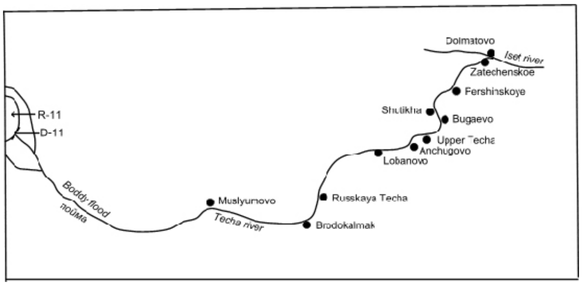

Fig. 2. Location of observation points along the river Techa.

The water was collected in glass bottles, which were subsequently sealed with rubber stoppers and transported to the Department of Continental Radioecology of the Institute of Plant and Animal Ecology (Zarechny). During the analysis, the water was filtered through a paper filter, distilled and stored in a refrigerator. For the quantitative determination of tritium in the water samples, preliminary enrichment was made by single-stage electrolysis. The method is based on significantly different rates of release of the light (protium) and heavy (deuterium and tritium) isotopes of hydrogen ions during the discharge at the cathode during the electrolytic decomposition of water. The enrichment was made using a specially designed electrolytic installation. The detailed information on the device, method and calculation of the tritium concentrations is presented in the monograph [1] produce a 'greener' concrete for construction. An innovative supplementary Construction Material is formed through this study.

3. Results and discussion

3.1. *Water of the river Techa.* **Figure 3 shows the tritium concentrations in the water of the Techa at various distances from the dam D-11, located at the outlet of the reservoir R-11.**

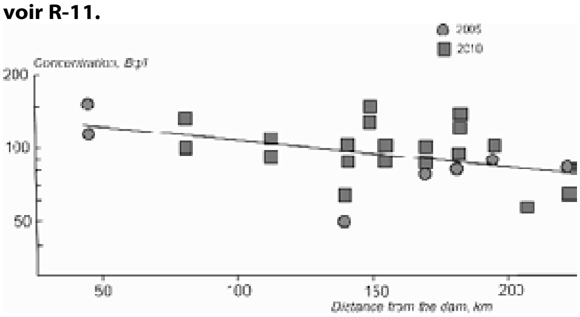

Fig. 3. Tritium concentrations in the Techa water in various years of observations

The radionuclide content in the river water was about the same in 2005 and 2010, it and would decrease in the investigated section of the river from 70 to 130 Bq/l. The highest values of the tritium concentrations were observed near the settlement Muslumovo. Radionuclide monitoring in this part of the river showed that in various years of observation, the tritium content in the water varied in a wide range – 30 to 600 Bq/l with an average index of 250 Bq/l. Considering the fact that the global ba–ckground level for tritium is 1 Bq/l, and the technogenic background level in the Ural region is 5 Bq/l [1], 2005), it is worth noting that the water of the Techa contains at present increased radionuclide concentrations, exceeding the technogenic background level by approximately 10–30 times. However, in some years of observation the technogenic background level was exceeded by 100 or more times.

3.2. *Drinking water*. To reduce the risk of population overexposure to the increased concentrations of radionuclides discharged into the Techa, the Governments of the Russian Federation and the Chelyabinsk region have issued several statements since 1951 and developed a number of programs aimed at improving the radioecological situation in the contaminated area [6]. Protective measures have been implemented. In particular, to reduce the entry of radionuclides in the drinking water in the riverside area of the contaminated river, deep boreholes were drilled (up to 100–180 m), from which the water entered the water pumps located in the residential areas (delivery water). It was assumed that the water from the deep boreholes should be radiologically cleaner than that from shallower water sources. As the population uses both the delivery water and the water from shallower personal wells, springs and boreholes we examined tritium concentrations in all the above kinds of water sources.

Figure 4 shows tritium concentrations in the drinking water in the settlements, depending on their distance from the dam D-11.

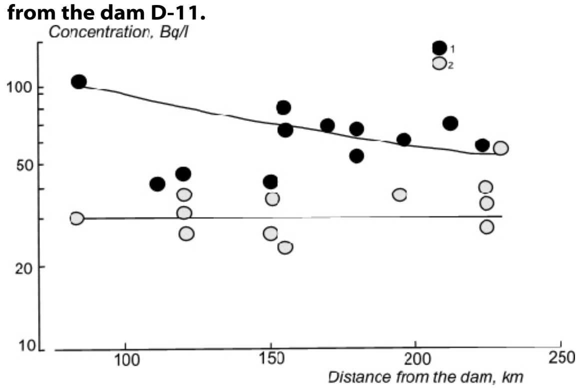

Fig. 4.Tritium concentrations in the drinking water in settlements located along the Techa. 1 – delivery water; 2 – water from wells, springs, private boreholes.

The analysis of the data showed that the delivery water entering the water pumps from the deep boreholes had a radionuclide concentration two or three times higher a radionuclide concentrations than the shallower personal wells, springs and boreholes. Tritium concentrations in the delivery water decreased with the distance from the dam, while in the wells, springs and boreholes they were the remained constant. Statistical processing of the data using the computer program Statistika (Fig. 5) showed a great difference in the tritium concentrations between the delivery water from the shallower boreholes and the water from the shallower water sources used by the settlement residents of the settlements ($p = 0.0016$).

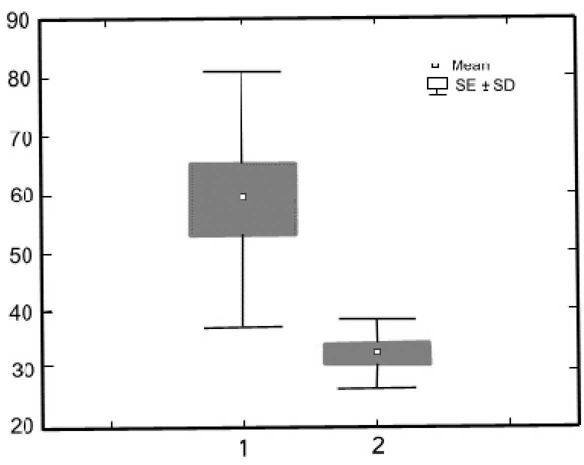

Fig. 5. Results of statistical treatment data on the drinking water in settlements along the Techa (using the Mann-Whitney test): 1 – delivery water; 2 – water from wells, springs and boreholes.

The observed increased tritium content in the water from the deep boreholes is obviously due to the fact that the bed of the Techa is located in the earth crust break zone along which the polluted water penetrated from the industrial reservoirs located in the upper part of the regulated river bed [7]. A direct exponential dependence between the tritium concentrations in the industrial reservoirs and their distance from the Techa origin on the one hand [5], and a similar dependence from the dam of the reservoir D-11, on the other hand, confirms the fact that the industrial reservoirs and the Techa are a single water system through which, as the surface water flows downstream, the polluted water discharged by "Mayak" penetrates from the deep underground. From deep aquiferous strata near the watercourse (100 m and more) the contaminated water enters the deep boreholes from which it is then distributed into the water pumps in settlements.

Unlike distinct from the deep water connected with the industrial ponds, the water in personal boreholes, wells and springs is supplied by mainly atmospheric and surface sources, perhaps it is only partly connected with the Techa.

To determine if the observed difference in tritium levels in the deep and surface drinking water sources existed only in the riverside part or in the remote areas as well, we examined various types of drinking water in the control area on the left bank between the Iset and the Techa (along the transect Barabanovskoye – Kirda settlements (Fig. 6).

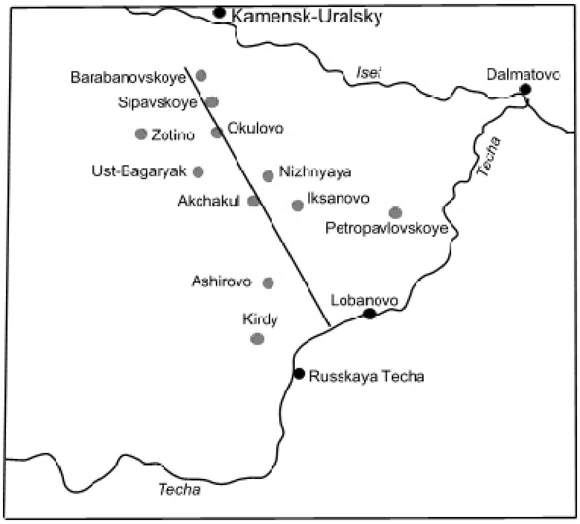

Fig. 6. Location of sampling points in the control territory between the theTecha and the Iset

Figure 7 shows the tritium concentrations in various types of the drinking water sources in the control area depending on the distance from the Techa bed. Boreholes 100–200 m deep are absent in the control area.

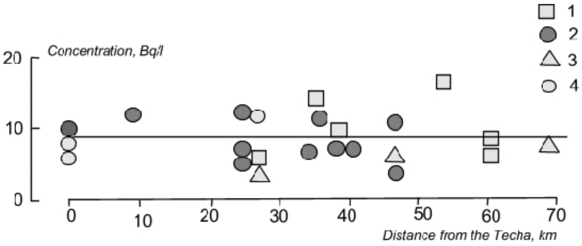

Fig. 7. Concentrations of tritium in the drinking water sources located along the transect at various distances from the Techa bed, Bq/l: 1 – wells; 2 – private boreholes up to 20 m; 3 – springs; 4 – delivery water and private boreholes over 30 m deep

There are 4 less deep boreholes (Petropavlovsk – 60–80 m; Kinda – 90 m; Iksanovo – 68 m; Nizhnyaya – 33 m), which are marked in the figure. The study showed that beside the main river bed, the tritium concentrations in all the drinking water sources, including relatively deep wells (30-90 m) were similar (5 to 15 Bq/l) and did not differ statistically ($p > 0.05$). Therefore, higher concentrations in the deep water sources were only downstream the river.

4. Conclusion

The assessment of the current tritium concentrations in the Techa water system, including the river itself, wells, boreholes and springs, showed that the investigated reservoirs contained higher radionuclide concentrations compared to the global and technogenic background levels. In particular, all along the Techa the radionuclide concentrations exceeded the global background level up to 600 times, and the technogenic background level – up to 6 times. The delivery water entering the water pumps in the riverside settlements from the deep boreholes (> 100 m) had radionuclide concentrations two or three times higher than the shallower personal wells, boreholes and springs. This is obviously due to the fact that the Techa is located in the earth crust break zone, along which the contaminated water penetrated from the industrial reservoirs located in the upper part of the regulated river bed. Beside the river bed (along the transect between the Techa and Iset) the tritium concentrations in all the types of water were similar and varied around the level of the technogenic background or were slightly higher. In all the types of the investigated waters the average tritium concentrations did not exceed the level established for the drinking water standards [8]. Our conclusion is that in order: to reduce the entry of tritium into an organism with the drinking water, the residents of the riverside part of the Techa should make use of wells, springs and shallow personal boreholes rather than the delivery water from water pumps.

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The authors declare that they have no conflict of interest.

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