# Distribution and Biological Effects of Radionuclides in Terrestrial Ecosystems Affected by Nuclear Enterprises in the Southern Urals

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In the southern Urals there are several sources of radioactive contamination of terrestrial ecosystems:

a) global fallout from nuclear weapons testing,
b) accident at the MAYAK Production Association in 1957 (Kyshtym accident), when about 74 PBq of radionuclides were released into the atmosphere, which formed the East-Ural Radioactive Trace (EURT),
c) transfer of radionuclides in 1967 (about 222 TBq) from the shore of Lake Karachay, where liquid radwasts were discharged,
d) releases from routine operations of the MAYAK,
e) Chernobyl accident in 1986.

In this paper we present the results of a study on concentrations of radionuclides in soils of some ecosystems and radiation effect on the plants in the zone of the East-Ural Radioactive Trace (EURT).

In September 1957, a chemical explosion occurred in a tank containing radioactive waste in Kyshtym. About 74 PBq of radioactive substances were released into the atmosphere, which resulted in the contamination of a vast area (about 20.000 km$^2$), i.e. formed East-Ural Radioactive Trace. The most of the activity consisted of short-lived products, in particular $^{95}$Zr and $^{144}$Ce. At present they have decayed completely. Of the long-lived products, the main pollutant was $^{90}$Sr of which about 2 PBq was released. Ten years later Lake Karachay dried out during drought, and 20 TBq of radioactive dust was spread with wind and formed a contamination of the same area as the EURT [3].

Samples of the soil and plant seeds were taken along the centreline of the contaminated zone at a distance of 45-100 km from the epicentre of the accident (Fig. 1). The control plot was chosen in a birch/pine forest outside the contamined zone. The layers of soil (5 cm thick) were cut horizontally to a depth of 30 cm taking into account the area of the soil layers. The $^{90}$Sr content of the samples was estimated radiochemically by its daughter $^{90}$Y. The concentrations of $^{137}$Cs were measured by means of a multichannel gammacounter.

Biological effects on the dandelion (Taraxacum officinale Wigg.) seed progeny were estimated using a complex of morphological and cytological features.

It was shown, that the concentrations of long-lived radionuclides at all investigated locations are increased (Tab. 1). The maximum concentrations of $^{90}$Sr and 137Cs in the soils were observed at a depth of 0-5 cm. The differences with a control at some locations for the $^{90}$Sr concentrations in the upper layer were by a factor of 2-8. The radionuclide content decreased with the distance from the source of contamination. The main contribution to the level of contamination by $^{90}$Sr is from the Kyshtym accident. It was shown before [1], that 70-95% of $^{90}$Sr in the samples collected was got from this source. A considerable source of $^{137}Cs$ was Lake Karachay, which is an open storage area for radioactive wastes. In 1967 drought led to the evaporation of water from this Lake, the dust with radionuclides was spread by winds and formed a patchy contamination of the region. Contributions from other sources from Chernobyl accident and from routine operations of the MAYAK were smaller.

It is necessary to take into account that, from the moment of the explosion in 1957, more than half of the dose was absorbed by living organisms during the first 120 days, about 90% during the first two years [3]. Today, the gamma-radiation background on the EURT territory is not different from the control (7-11 µR/h). The main contaminant in the EURT area is $^{90}Sr$. The most sensitive tissues of dandelion, meristems, are located in the upper 0-5 layer of soil, where the $^{90}Sr$ concentrations were 600-200 Bq/kg (see Fig. 1., plots 1,2,3). The seeds of plants were collected at these plots. Assessment of doses from the $^{90}Sr$ show, that presently meristemal tissues of these plants get in addition to natural background of doses about 1-3 mSv per year.

The study of plants from contaminated zone in 1991 (plot 1, see Fig. 1) showed that, for dandelions increased rates of growth were characteristic. While typical monthly sproutings have one leaf, the plants from EURT, with rare exceptions, had two. There were chlorophyll disturbance in the leaves and seed-lobes of these plants (with frequency 0.42%). The high level of cytogenetic damages in the meristematic cells of the plants from contaminated area was discovered. The variability of the absolute values of the number of chromosome aberrations was great (Tab. 2). We suppose that, it is a result of sprouting time, effect of the biological rhythms.

Additional irradiation of the seeds showed the seeds that were formed on the plot with a higher content of $^{90}Sr$ in soil had a greater level of radioresistance (Fig. 2). It can be supposed that the higher radioresistence of the seeds from contaminated area is an adaptive response to the chronic influence of small doses of radiation. A similar phenomenon was previously described for other plants [2]. However, it is not clear whether the process of developing the adaptation had finished.

To answer this question, we gathered dandelion seeds again two years later in the previously studied and nearby ecotopes. The germination power and viability of the seedlings practically do not differ from the control ones. No greater rates of growth and development were observed in this population two years earlier. The only significant difference concerned the frequence of chromosome aberrations in the meristematic cells (Tab. 2).

Test on the resistance to the provocative additional irradiation for these seeds was made. It was revealed that there is no significant difference of radioresistance of plants from contaminated and control areas (Fig. 2).

## Conclusion

Thus, the concentrations of long-lived radionuclides in the terrestrial ecosystems around MAYAK are increased. The contribution of the Kyshtym accident to the activity of the samples of soil was 70-95% for Sr. The most part of Cs came from Lake Karachay, which is an open storage area for radioactive wastes.

Such phenomena as a higher frequency of chromosome aberrations in meristematic tissues, higher radioresistance to subsequent irradiation and modified rates of growth and development in organisms under chronic irradiation are observed, but they are not stable. An increase in the variability and lability of the cytomorphological features and physiological properties is the real result of the long-term influence of small doses of radiation on a biota.

**References**

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**Table 1: Contents of Cs-137 and Sr-90 in Soils of East-Urals Radioactive Trace**

| No location (see Fig. 1) | Distance from explosion place | Sr-90, kBq/m$^2$ | Cs-137, kBq/m$^2$ |
|---|---|---|---|
| 1 | 95 | 85.5 | 10.1 |
| 2 | 92 | 31.0 | 12.0 |
| 3 | 95 | 22.7 | 10.8 |
| 4 | 88.5 | 78.1 | 8.8 |
| 5 | 87.5 | 3.8 | 6.8 |
| 6 | 85 | 126.9 | 9.5 |
| 7 | 77.5 | 103.0 | 10.2 |
| 8 | 63 | 142.7 | 16.7 |
| 9 | 55 | 5.5 | 17.3 |
| 10 | 50 | 3.7 | 8.6 |
| 11 | 47 | 6.4 | 9.5 |
| 12 | 45 | 222.5 | 18.7 |
| control | outside of EURT | 1.7 | 11.1 |

**Table 2: Characteristic of the dandelion seeds from the East-Urals Radioactive Trace area**

| Year | Location | Survival, % | Anaphase with chromosome aberrations, %, sprouting | |
|---|---|---|---|---|
| | | | in February | in July |
| 1991 | control | 60.3+3.4 | 5.2+2.2 | 1.6+0.5 |
| | plot 1 | 80.7+3.8 | 19.8+3.1 | 7.5+0.9 |
| 1993 | control | 77.6+13.0 | - | 2.9+1.1 |
| | plot 1 | 70.6+8.8 | - | 4.6+1.1 |
| | plot 2 | 74.2+3.4 | - | 2.0+0.8 |
| | plot 3 | 61.0+5.2 | - | 6.1+0.7 |

**Figure 1:** **Map-scheme of investigated area**
**The sampling locations are indicated "1, 2, ..."**

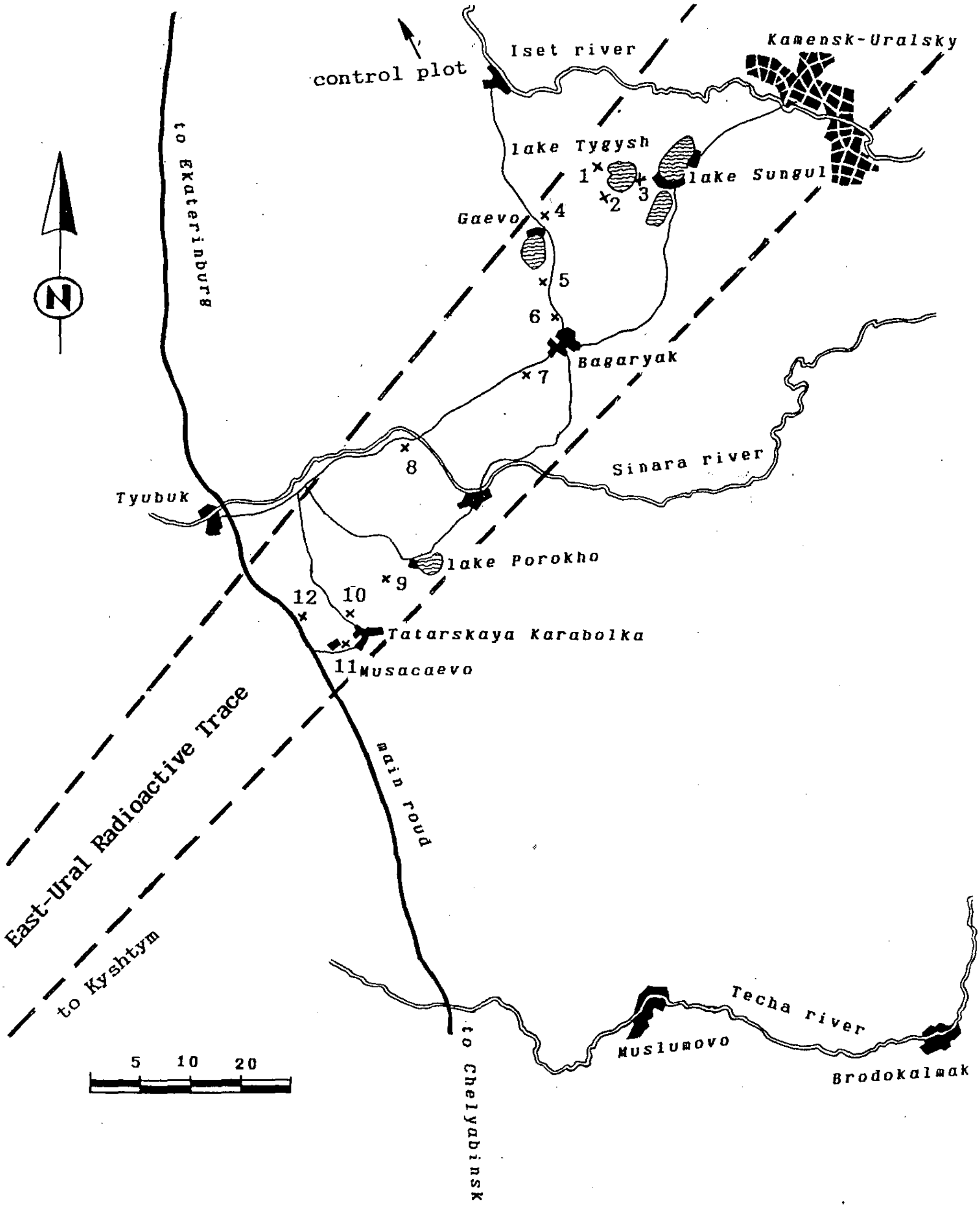

**Figure 2:** **Radioresistance of dandelion seeds, formed in the East-Ural Radioactive Trace area c - control, 1, 2, 3, - numbers of plots, see Figure 1**