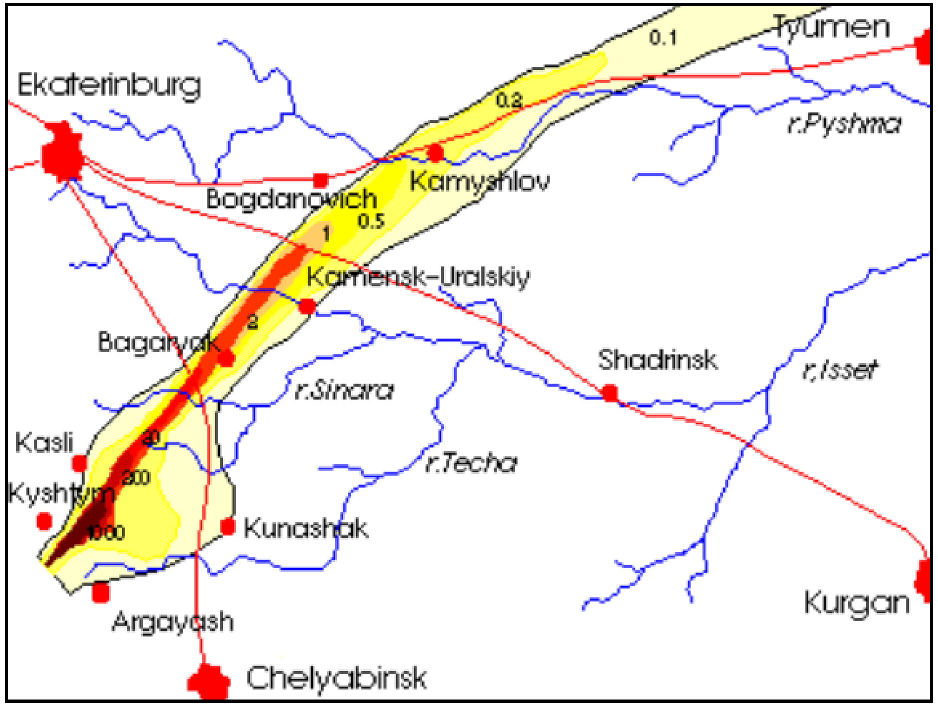
About the character of variation of ^{90}Sr concentration in plants within elementary landscape geochemical system

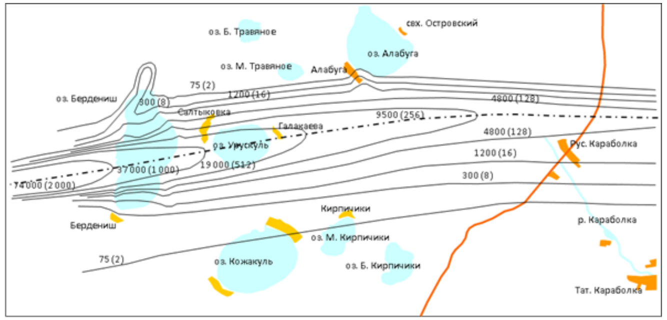
Elena Korobova[1], Vladimir Baranchukov[1], Denis Dolgushin[1],
Oleg Tarasov[2], Lyudmila Mikhailovskaya[3]
[1]Vernadsky Institute of Geochemistry and Analytical Chmistry, Rus. Ac. of Sci.
[2]SPA “Mayak“
[3]Institute of Ecology of Plants and Animals, Ural Branch of Rus. Ac. of Sci.

Study site

A detailed study of ^{90}Sr distribution in the overground vegetation cover within an elementary landscape geochemical system (top-slope-closing depression, ELGS) was performed in several forested and meadow test sites located in the Eastern Urals Radioactive Trace highly contaminated with this technogenic radionuclide during its release in the Kyshtym accident in 1957 (INES level 6).

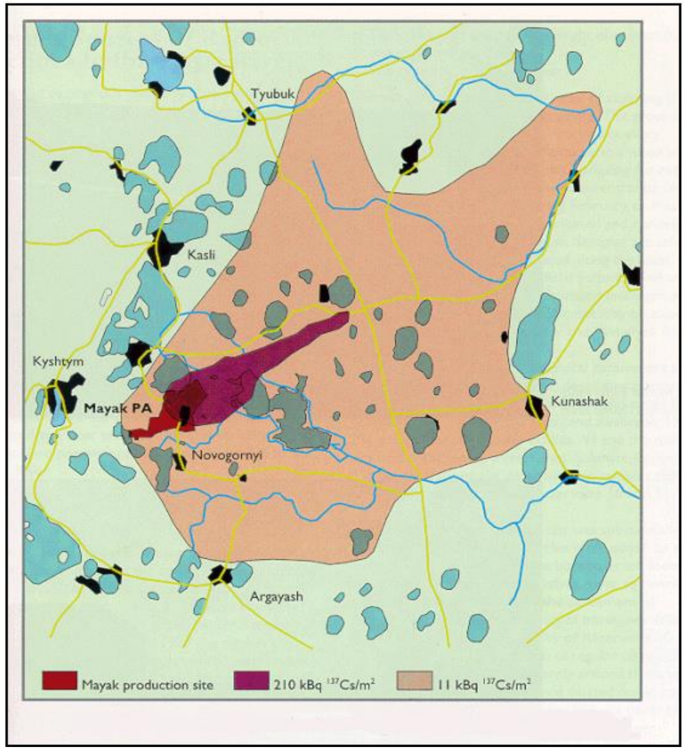


The East Urals Radioactive Trace (EURT).
Initial contamination densities of ^{90}Sr (Ci/km^2)



^{90}Sr kBq/m^2 (Ci/km^2) (Archive SPA "Mayak", 2005)

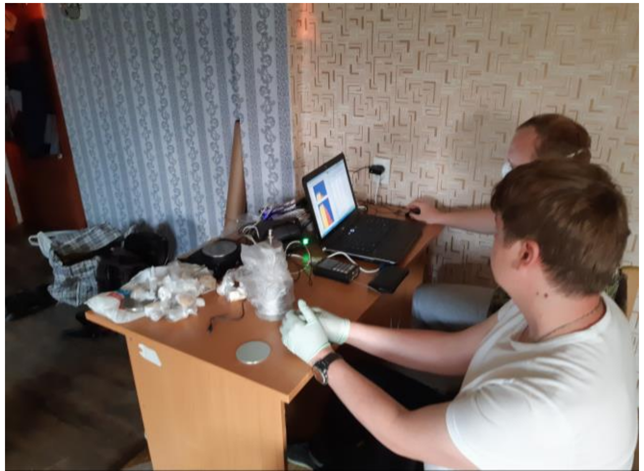
Risø-R-1243(EN)
Radiological Assessment of Past, Present and Potential Sources to Environmental Contamination in the Southern Urals and Strategies for Remedial Measures (SUCON) by A. Aarkrog, J. Simmonds, P. Strand, G. Christensen, B. Salbu (2000)



Cs-137 contamination from the dispersion of wind-borne contamination from Lake Karachai (kBq/m^2, 1967)

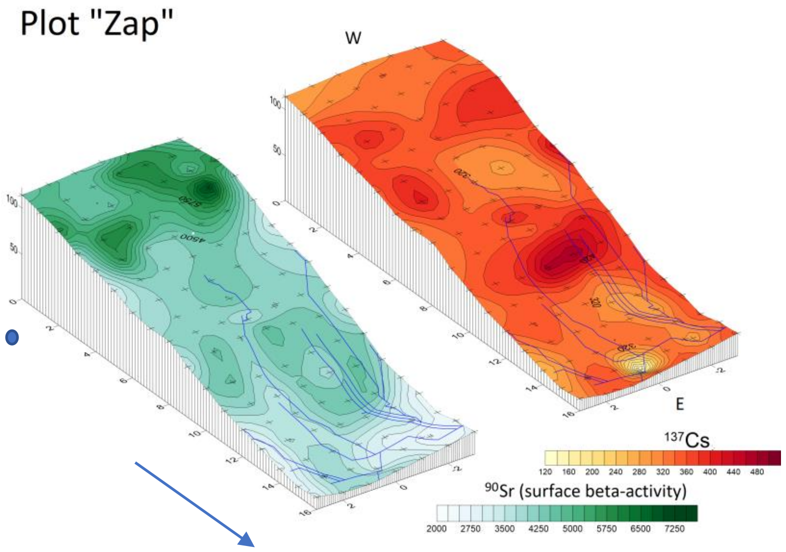
1. Contamination densities in the range: 11-210 kBq/m^2.
2. Contamination densities in the range: 210-765 kBq/m^2.

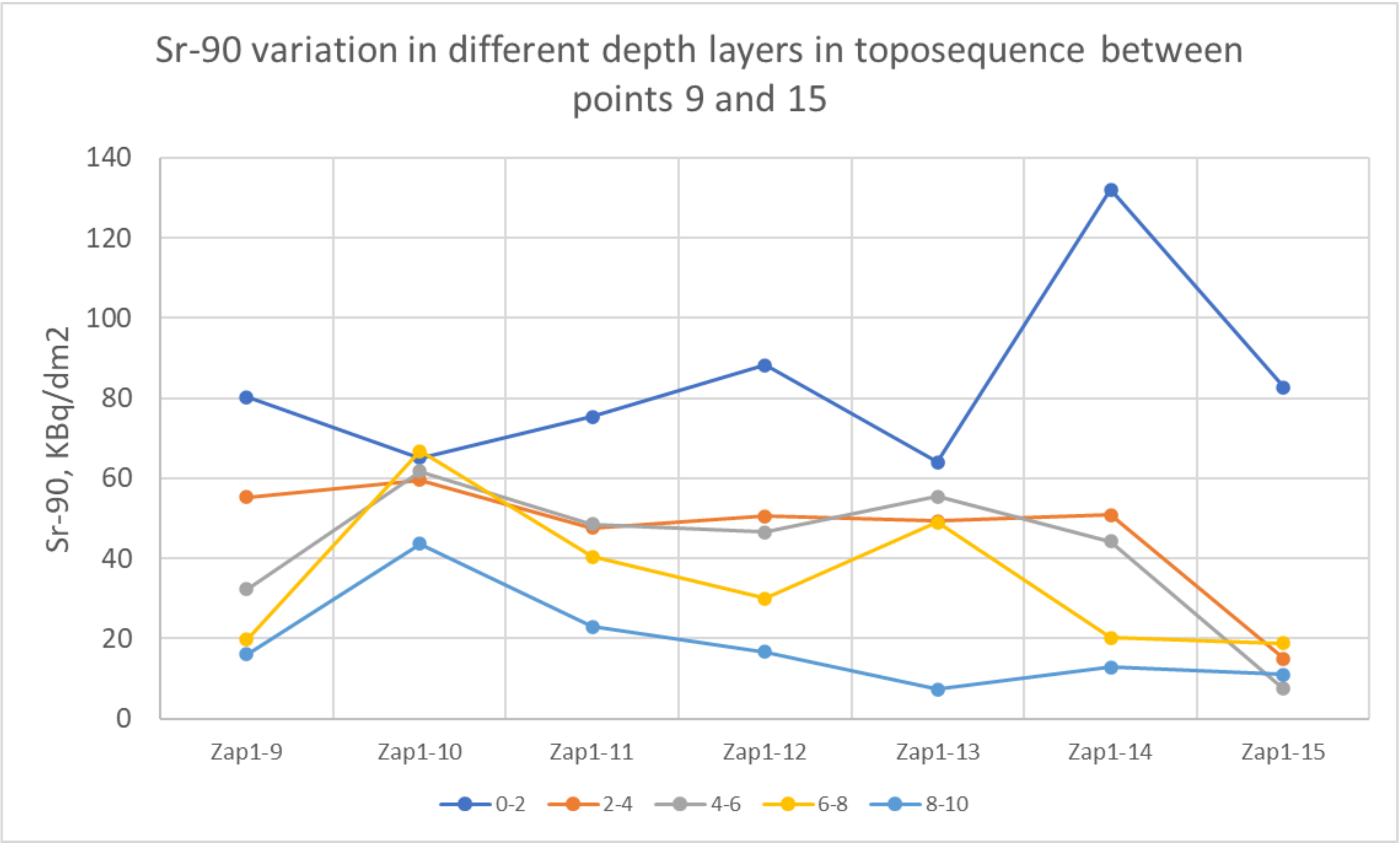
Methods

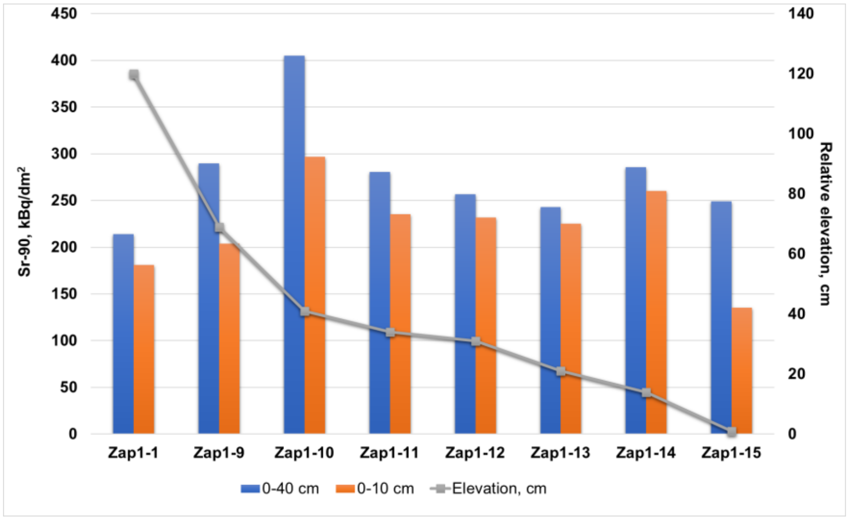


- After selecting the suitable test sites, they were crossed by several lateral profiles along which relative altitude with a step of 1 m and precision of 1 cm was measured using theodolite Boif-DJD10.
- Soil cores were taken to study the radionuclide depth distribution in ELGS.
- Averaged plant samples were taken at each point within a standard steel ring (14 cm diameter) later separated into the groups of grasses, legumes and other different herbs.
- Particular species were also collected if present at no less than seven consequent points.
- Strontium-90 activity was measured by the portable complex ”Colibri” (SKS-08P) developed in the Kurchatov Institute (Potapov et al., 2021). It allowed the measurement of radionuclide activity in field conditions. The determination error did not exceed 15%.
- Cesium-137 was measured by a portable gamma-spectrometer “Violinist” (USA)

Sr-90 and ^{137}Cs surface contamination and Sr-90 lateral distribution in different soil layers (plot “Zap1”)







Sr-90 inventories in soil cores located along ELGS

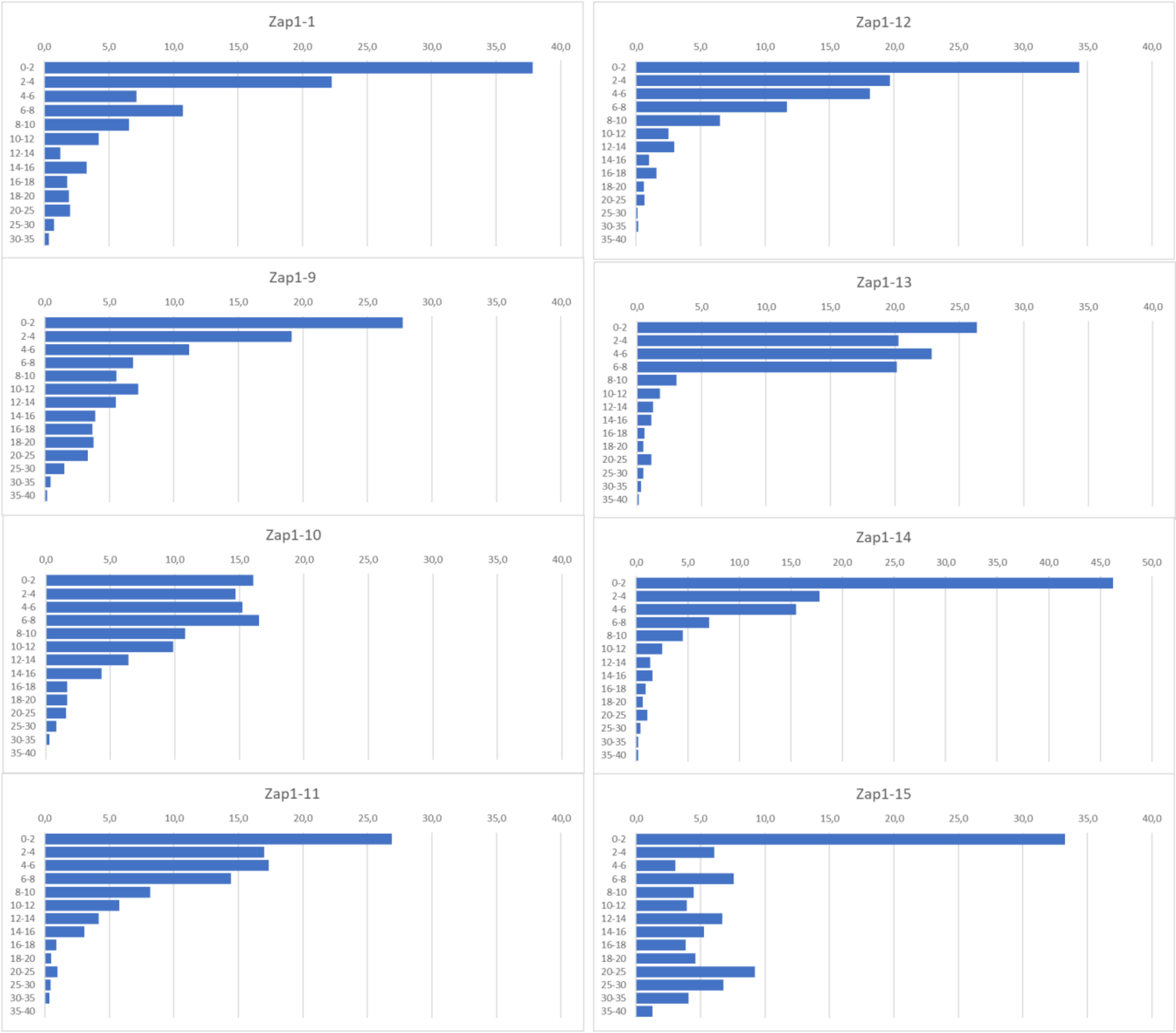
Plot “Zap1” was located close to the head of the EURT zone in a secondary birch forest. Sr-90 and ^{137}Cs surface contamination had polycentric structure. Lateral distribution of ^{90}Sr in the top 10-cm layers showed clear variation with a step 1-2 m.

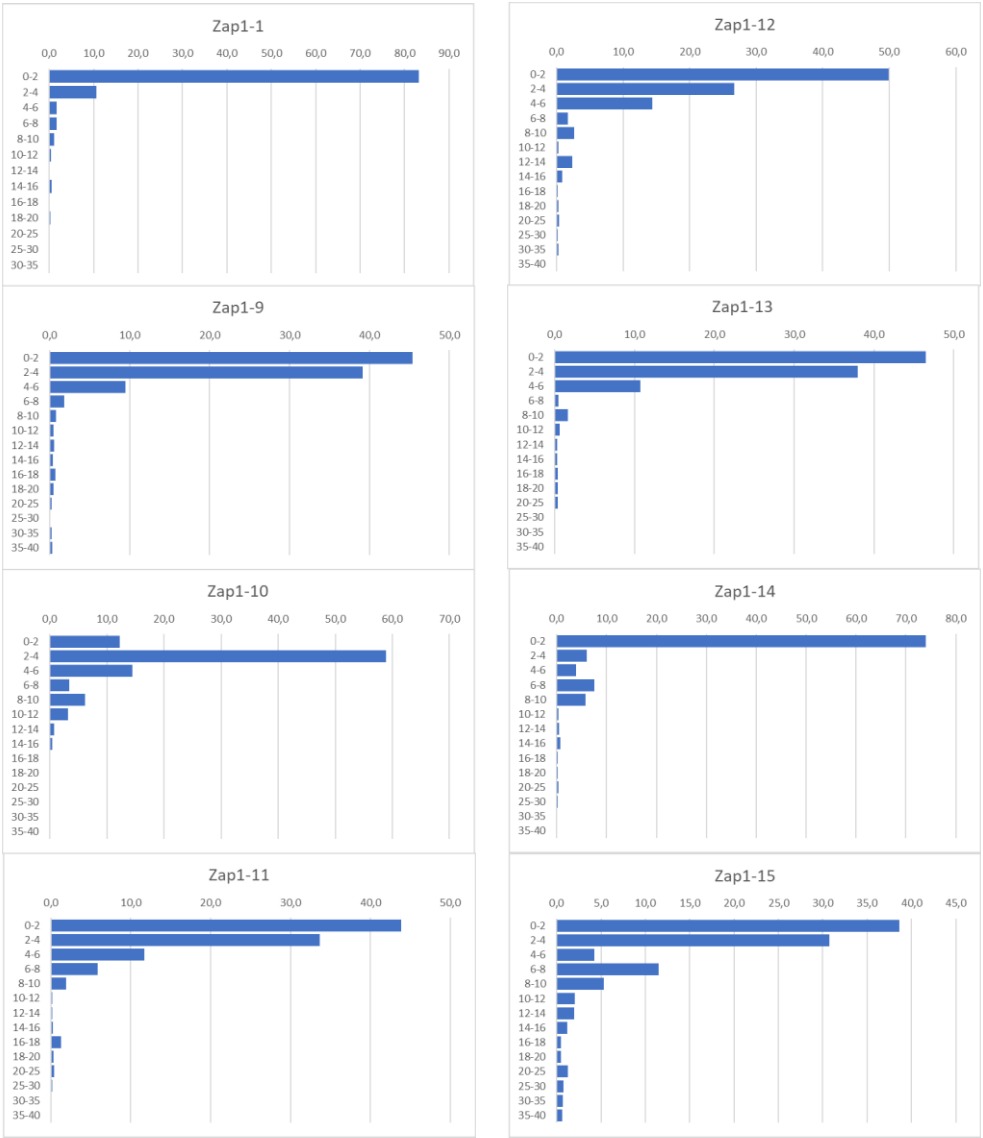
Sr-90 and ^{137}Cs depth distribution in soil cores (test site “Zap” in the head of Eastern Urals Radioactive trace)

^{90}Sr

More mobile ^{90}Sr penetrated deeper than ^{137}Cs (54-93% in the top 0-10 cm layer against 90,5-98,2%)

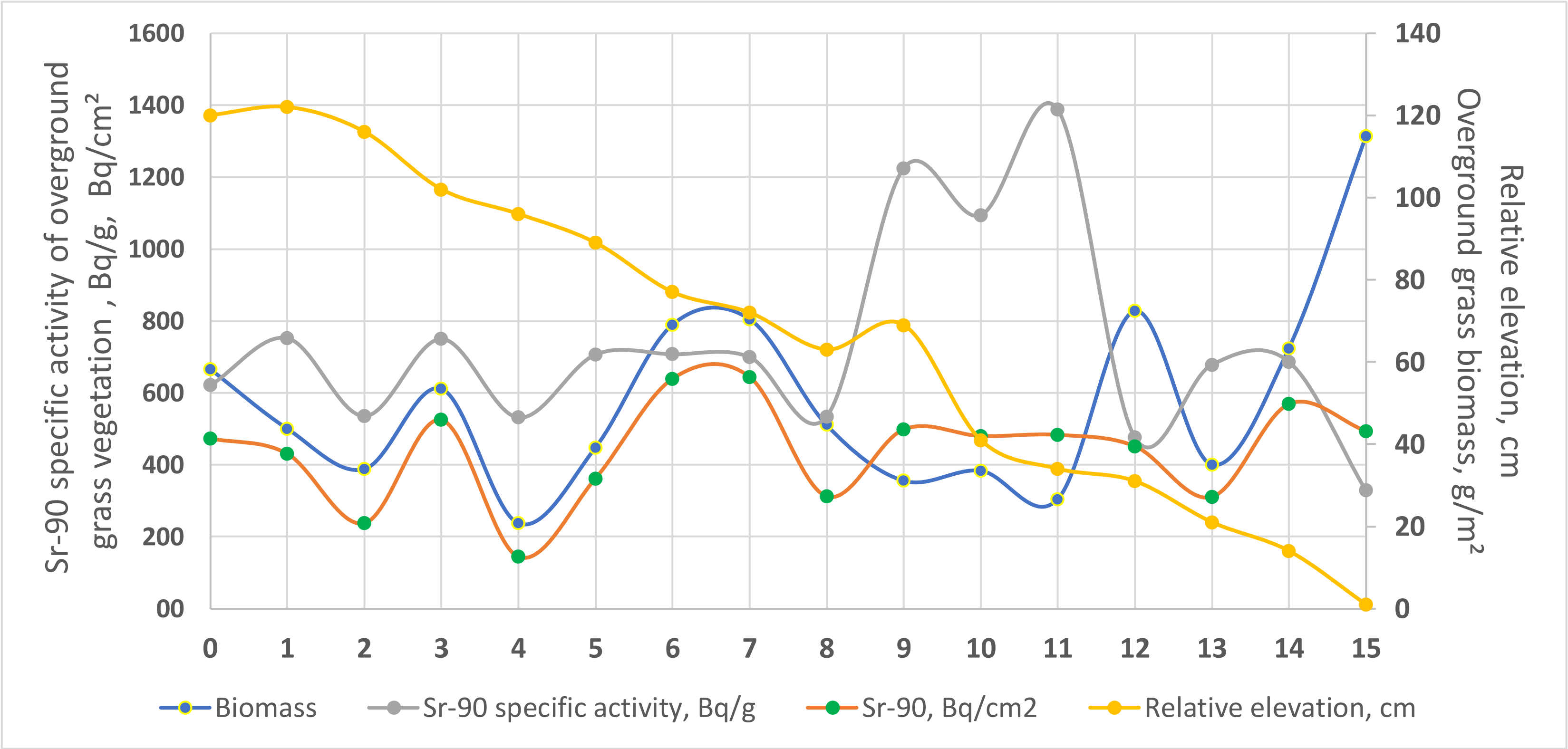
^{137}Cs

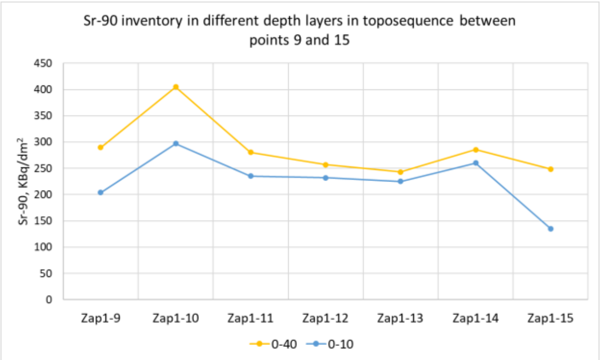


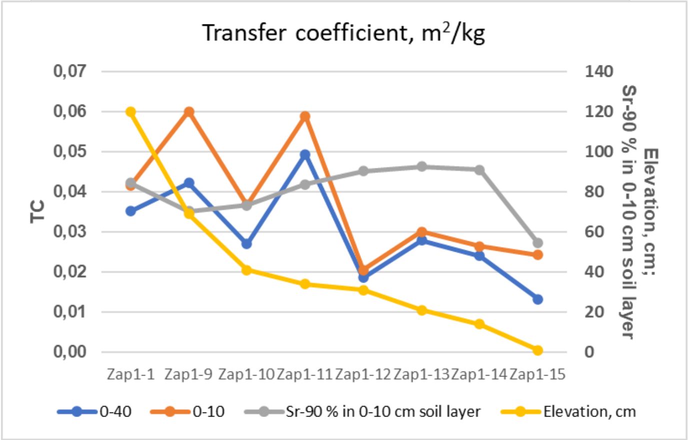


Cores were located at the indicated points, field measurement step - 1 m

Variation of Sr-90 surface contamination, grassy biomass Sr-90 activity in grass vegetation cover along woodland ELGS "Zap1-1"



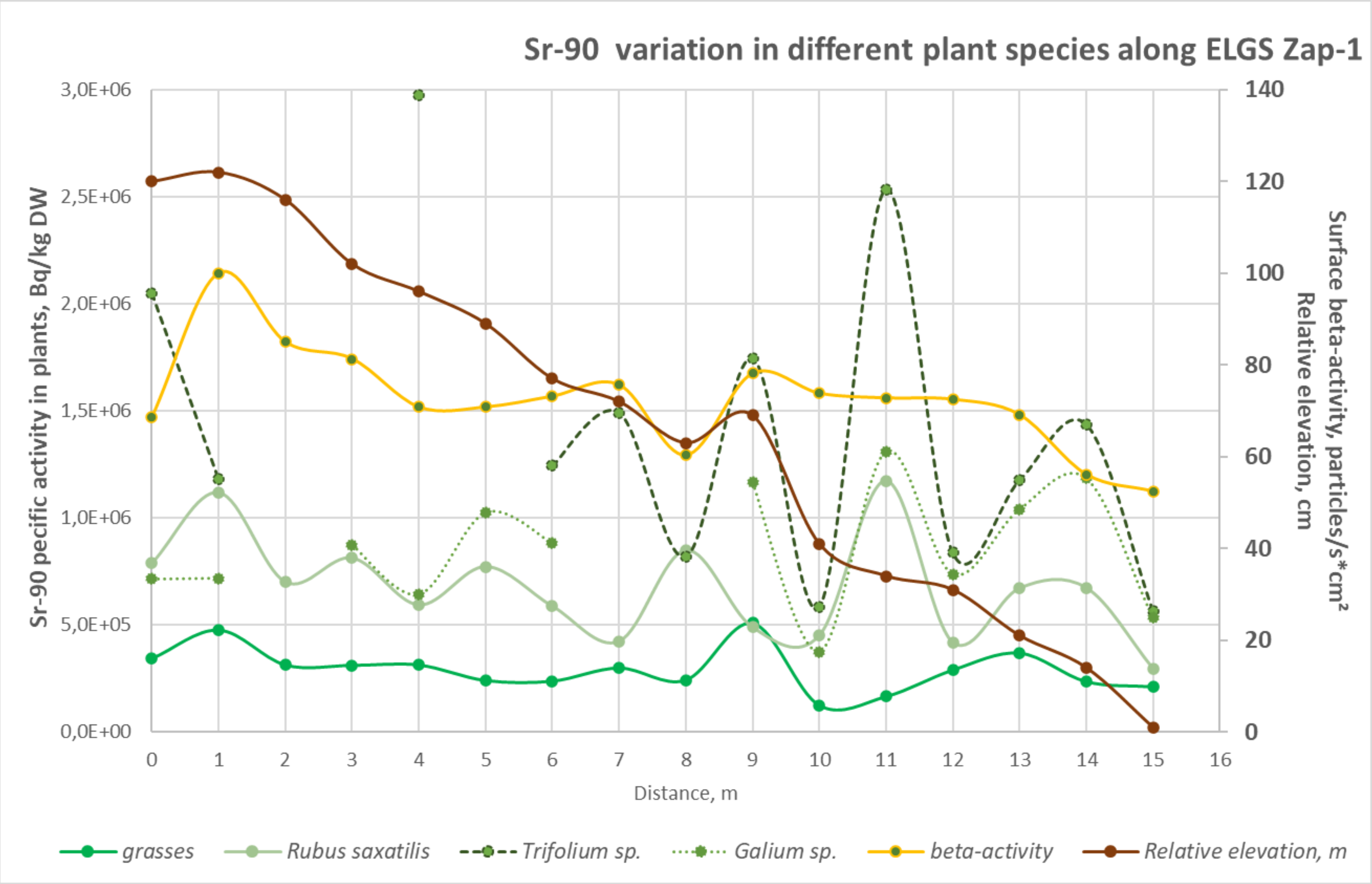




Analysis of data obtained revealed the ordered variation of ^{90}Sr in all groups of plants. This order was presented by the cyclic (periodic) change of ^{90}Sr activity downslope without definite radionuclide accumulation at the foot of the slope and in depression as usually expected.

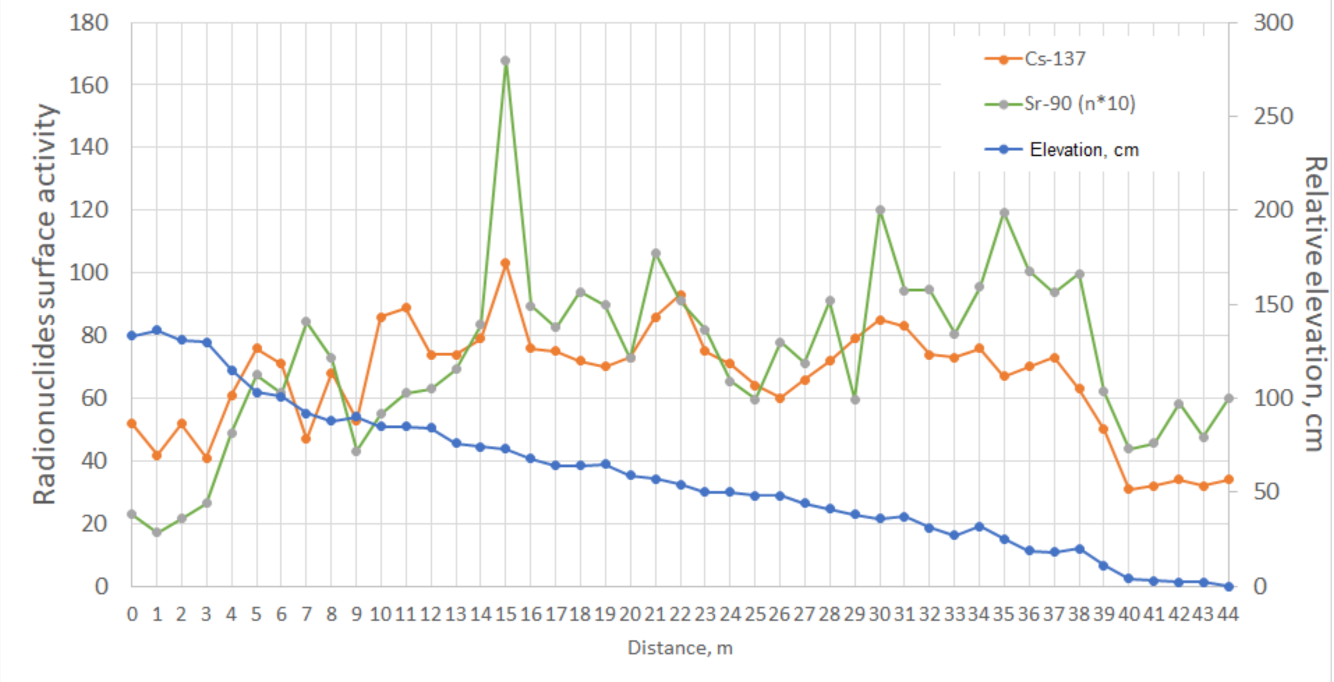
Specific ^{90}Sr activity in forest overground grass vegetation correlated negatively with its biomass volume (r=-0,544) and positively with ^{90}Sr surface activity (r=0,543) and its content in the top 0-2 cm soil layer (r=0,680). Transfer coefficient to vegetation decreased with deeper Sr-90 depth migration or its major concentration in the surface thin layer.

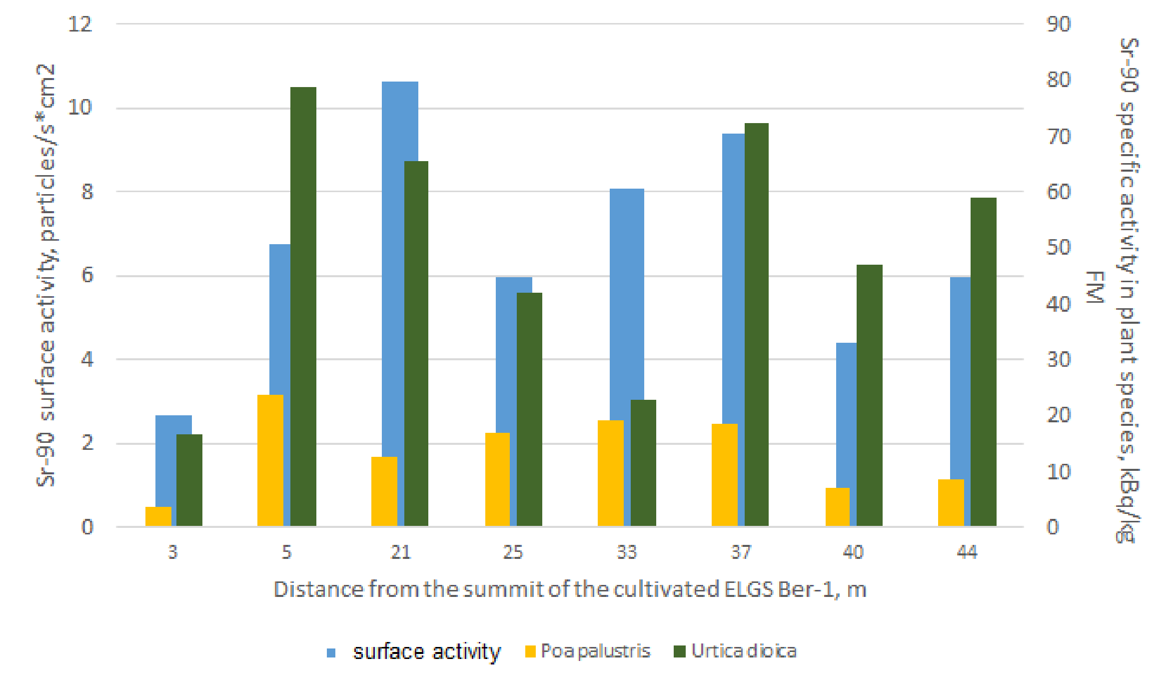
Variation of Sr-90 in grasses and other plant species typical for vegetation cover along ELGS “Zap1-1”



Plant groups and species significantly differed in ^{90}Sr variation amplitude. However, in general the radionuclide concentration increased in a row: grasses <*Rubus saxatilis* <*Galium sp*. <*Trifolium sp.*

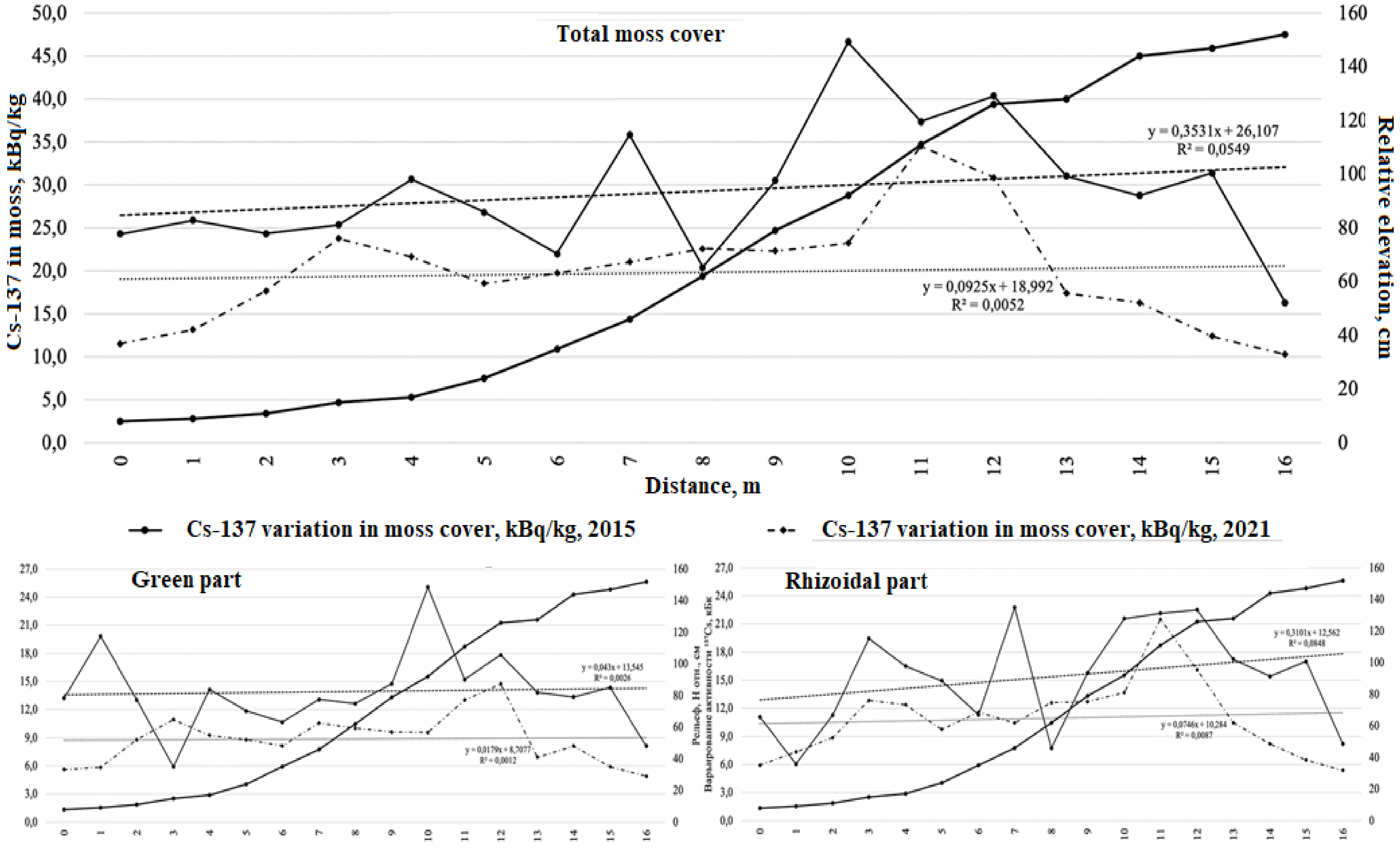
Variation of ^{90}Sr and ^{137}Cs along the cultivated ELGS “Ber1-1” and ^{90}Sr in grass and herb species typical for ruderal vegetation cover





Notable cyclic variation of ^{90}Sr and ^{137}Cs surface activity (field measurements) and a considerable difference in ^{90}Sr concentration and amplitude of its variation in two typical ruderal plant species (*Poa palustris and Urtica dioica*) was also registered along the ELGS “Ber1-1” deeply cultivated after the Kyshtym accident of 1957.

^{137}Cs variation in moss cover along ELGS D-21 studied in the Chernobyl zone (test site "Vyshkov-2")



A similar cyclic pattern of variation and its dynamics in both the photosynthetic and rhizoidal parts of the moss was found for ^{137}Cs in the moss cover studied in the Chernobyl abandoned zone at the pine forest polygon along ELGS D-21 in 2015 and 2021 (Dolgushin and Korobova, 2021).

CONCLUSIONS

1. Technogenic radioisotopes are a useful tool to study and reveal patterns of chemical elements distribution and migration in the environment and the soil-plant system, in particular.

2. Given a uniform character of the primary anthropogenic aerial contamination of the elementary landscape-geochemical systems (summit-slope-closing depression ≤ 100 m long) allows following secondary pathways chemical elements in topo-sequence under natural climatic and weather conditions at any detailed scale.

3. Both ^{137}Cs and ^{90}Sr tracers showed that secondary redistribution of elements in ELGS does not lead to a simple accumulation in the closing depression but has the ordered cyclic character which is revealed for elements with different rates of water migration in both the undisturbed and cultivated conditions.

4. We suggest that the revealed features of ^{90}Sr and ^{137}Cs variation in both the soil and vegetation cover of ELGS reflect the peculiarities of water migration in soils, the structure of root system, and the plants' ecological demands, in water and nutrients.

5. The ordered character of variation can be evaluated mathematically. We suggest that periodicity of variation depends upon the soil water regime and plants hydrophilicity and nutrition status.

6. The finding can be helpful for improvement of environmental monitoring and decision making in the areas subjected to contamination as well as for optimum application of fertilizers.

Many thanks for your attention!

The study was partly supported by the Russian foundation for basic research #19-05-00816.