Assessment and rehabilitation of radioactively contaminated soils in residential and agricultural areas

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Abstract. Our goal is to reduce internal and external radiation exposure to the value established by the standards of safety of life and health of the population of 1 mSv/year (millisievert/) and increase life expectancy. The article touches upon the problems related to the radioecological situation in the territory of settlements of the Bryansk region, plots of private farms (private farms) and country houses that were contaminated with cesium-137 radionuclide after the Chernobyl accident. The experience of rehabilitation works of previous years from 1986-2012 is considered. Their insufficient effectiveness has been revealed. Forecasts and prospects of water management rehabilitation measures at the present stage are also given. The urgent need to combat foci of radioactive contamination with a small area of 0.4 hectares (cesium spots), which are common on the territory of private farms and in the residential area of settlements in the Bryansk region, is emphasized. Annenkov B.N. and Yudintseva E.V. recommend washing the soil using solutions of various salts and acids (hydrochloric acid, iron salts, sodium, calcium and others), but this method of soil purification is well suited for use in small areas of suburban areas, private farms and lawns of settlements. At the Bryansk State University, at the Department of Environmental Management and Water Use, experiments were conducted to investigate the identification of the most intensive and effective methods of washing soils from cesium pollution. Periodic watering with the use of chemmeliorants and intensifiers has shown good results. Drip irrigation is slightly worse. But of particular interest is the flooding of closed depressions, at the bottom of which there are spots of cesium contamination. With proper organization of surface runoff, deep loosening, application of chemical fertilizers, taking into account the temperature regime of frost, very good results can be achieved here.

1 Introduction

As a result of the accident at the Chernobyl nuclear power plant (Chernobyl NPP), the Bryansk region turned out to be the most contaminated territory in the Russian Federation with caesium-137 radionuclide [1]. This could not but affect the ecological situation in the region, the health of the population, life expectancy, psychological comfort, further

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development of various spheres of life. The territory of the region was transferred to the category of ecologically dangerous zones, in which rehabilitation and protective measures became necessary to reduce the level of external and internal exposure to caesium-137 radionuclide to the value corresponding to the norms of radiation safety of the population. In the radioactively contaminated region there are more than 1300 settlements with a population of about 500 thousand people (see Table 1).

Table 1. The change in the number of settlements and the population in the Bryansk region in the years before and after the Chernobyl accident at the nuclear power plant.

Indicator	26.04. 1986	01.01. 1998	01.01. 2020	01.01. 2008	01.01. 2010	01.01. 2012
The territory of the Bryansk region, thousand km^2	34.9	34.9	34.9	34.9	34.9	34.9
Population, thousand people	1470.1	1448.3	1410.3	1308.5	1292.1	1264.4
The number of settlements in the zones of radioactive contamination	1393	974	974	978	978	706
Including: - exclusion zone (over 1,480 kBq/m^2)	17	4	4	4	4	4
- settlement area (over 555 kBq/m^2)	266	194	194	202	202	124
- living area with the right to move out (185-555 kBq/m^2)	282	237	237	237	237	183
- living area with preferential socio-economic status (37-185 kBq/m^2)	828	539	539	535	535	395
The population in the zones of radioactive contamination, thousand people:	484.5	379.1	378.8	337.8	334.3	310.3
- the settlement area	90.4	78.2	77.4	75.6	75.0	72.0
-a living area with the right to move out	154.6	134.5	134.8	120.0	118.5	113.6
-a zone of residence with a preferential socio-economic status	239.4	166.4	166.6	142.2	140.8	124.3

The most contaminated area is currently the south-western part of the Bryansk region (districts of Gordeevsky, Zlynkovsky, Klimovsky, Klintsovsky, Krasnogorsky, Novozybkovsky, Starodubsky and others), where there are more than 700 settlements with a total population of about 300 thousand people, which is about 24% of the total number of residents of the Bryansk region. Including the zone of resettlement is occupied by 5.2% of the population, the zone with the right to resettlement 8.8% and the zone with a favorable socio-economic status 10%.

Almost immediately after the Chernobyl catastrophe at the NPP, measures on protection from radioactive exposure were carried out for liquidators of the accident and further for residents in settlements, workers of collective farms and PSF. The primary objective of such measures was to reduce the impact of internal doses on people in radioactive zones, but the danger from external doses was not taken into account. These measures have decreased year by year and are now of little use (see Table 2).

Table 2. Decrease in the volume of cultural and agrochemical work performed over the years in the radioactively contaminated territory of the Bryansk region

Types of work	1986-1990	1991-1995	1996-2000	2001-2005		2006-2012	
	thousand hectares	thousand hectares	million rubles	thousand hectares	million rubles	thousand hectares	million rubles
Cultural and technical works	97.60	3080	12.80	36.4	65.0	83.6	241.4
Liming	335.80	145.00	24.50	50.6	75.7	14	66.8
Phosphorization	183.80	130.60	23.00	22.2	36.7	8.8	27.6
Application of potash fertilizers	1359.60	630.20	164.10	29.8	19.4	16.4	75.4
Bacterial fertilizers	0.00	0.00	0.00	0.00	0.00	6.5	5.8
Total	1976.80	936.60	224.40	139.0	196.8	129.3	416.8

During the first years after the Chernobyl accident there was a stabilization and decrease of radionuclide intake in agricultural products. Such slowdown made the problem of internal exposure not so noticeable as in the beginning, so according to the data of recent years and at present, only legumes, peas, vetch, lupine and green mass are especially dangerous, and some crops, for instance potatoes are practically clean (see Table 3). But despite this, the problem of external exposure due to soil, dust, and silt contamination remains high and continues to worsen over time.

Table 3. The amount exceeding ^{137}Cs in the samples of tested crop production in the south-western regions of the Bryansk region in 2005-2012 years.

Product Type	Total checked		Including above the standard		
	tons	sample	tons	sample	%
Seed	176787	3893	5769	91	2.3
Potato	23629	189	0	0	0.0
Hay	211415	4975	11095	431	8.7
Haylage	199874	1944	1074	9	0.5
Silo	416840	1243	900	2	0.2
Green mass	164134	7261	24462	1299	17.9
Straw	23689	743	464	8	1.1
Lupin	4814	242	3576	211	87.2
Vika	5	1	5	1	100.0
Peas	1665	78	1048	46	59.0

Radioactively contaminated products of animal origin are particularly dangerous, as they have the ability to accumulate radionuclides in themselves over time in the process of life, living in a contaminated zone, and then with food enter the human body.

The diet of people living in rural areas consists of 70% of food produced in the PSF, both of plant and animal origin.

The problem of providing livestock with cultivated pastures and improving forage lands has become acute. The first attempts to solve it were carried out from 1989 to 1995 for collective and subsidiary farms, which had a good effect and contributed to reduction of internal exposure doses up to 2-3 times. It was found out that the contamination of milk with cesium-137 is mainly affected by the density of contamination of hayfields and pastures.

Measures to reduce the contamination of agricultural products began to be carried out since 1986. Further in the agro-industrial complex, were carried out at the expense of the state budget in the period from 1992 to 2012. Considering the outcome of this period and the present moment, we see that rehabilitation has not been achieved. In the territories, which were subjected to radioactive contamination with cesium-137, none of the rehabilitation programs has been implemented even by 25% of the planned, due to the reduction of funding.

According to the data of 2000-2006. [1] in the southwestern districts of Bryansk Oblast, the factor of economy was added to the unfavorable circumstances associated with the highest mobility of radiocaesium and its high content in soil. In addition to the reduction of labor and money costs, the amount of fertilizer application to agricultural land decreased. In average for Bryansk region the reduction of fertilizers was 7 times. This led to an increase of caesium content in crop production [1]. During the first years after the Chernobyl accident, measurements repeatedly showed stabilization, and in some cases increased caesium content in foodstuffs and organisms of people living in these territories. The vegetables and fruits grown in the PSF, which are not a small part of the diet of the inhabitants of the settlements of the Bryansk region, showed an increase in the dose of radioactive contamination. Over time, the internal dose of people and animals increases, as in their organisms and organs there is a gradual increase of radionuclides coming with food and aerially, as well as with increasing radioactivity of consumed food.

In recent years, the role of land reclamation and water management measures in reducing radiation contamination of the territory has increased, and they have been successfully applied under the state program “Overcoming the consequences of the radiation accident for the period up to 2015”. Within the framework of this program, research was conducted at Bryansk Agrarian University to reduce radiation contamination of soils when washing them using chemical ameliorants and intensifiers. Numerous ways of influencing the effectiveness and intensity of caesium-137 leaching from soil samples and silt were identified. Positive results helped to consider possible perspectives in rehabilitation of radioactive territories of Bryansk region and not only.

It should be noted that on PSF lands and dacha plots chemical ameliorants and intensifiers were practically not used in the required volume.

There is also an opinion about possibility to clean soils from radionuclides by biological method. For this purpose, a large amount of Cs-137 should be taken out with the harvest of crops that accumulate increased caesium content in their biomass. But this is actually not the case. Very small amounts of radionuclides are carried out by the crops of these plants; during the growing season it is only a small fraction of a percent of what is present in the soil.

2 Aims and objectives

The research was conducted with the aim to reduce the internal and mainly external dose of people living on the territories contaminated with radionuclides to the value of 1 mSv/year established by the norms of safety of life activity and public health, and as a consequence to increase life expectancy, with special attention paid to effectiveness and intensity of cleaning of soils contaminated with cesium, reduction of monetary costs, water consumption and labor use.

Washing of contaminated soils ^{137}Cs, as well as solonetz soils with clean water is hampered by the ability of soil to swell when wetting, which leads to a decrease in its filtration capacity. Improvement of filtration properties, increase of deactivation and desorption ability of radioactive soils should be carried out by washing with application of chemical ameliorants and intensifiers of leaching. The most common ones, which were used for washing of solonets, are salts of calcium chloride, calcium nitrate, gypsum and other salts of nitric, sulfuric, hydrochloric ... acid. We have investigated innovations: the impact on pollution ultrasound and compressor air injection, as well as the application of potassium and nitrogen fertilizers under irrigation. Owners of private subsidiary farms, often use manure from private farms, so the application of manure to improve the filtration properties of soil and increase the effectiveness of leaching of cesium-137 was studied.

Quite acute is the problem of maintenance of private subsidiary farms on the territories contaminated with caesium-137 radionuclide. One of the most important objectives arises - provision of livestock and dairy cows with clean fodder and pastures. Research has shown that meat and dairy products produced in private farms are more contaminated than in the industrial sector [2]. In order to reduce caesium-137 intake into fodder crops it is necessary to use irrigation with chemical ameliorants. To improve the radioecological condition in vegetable gardens and garden plots it is necessary to try to use “clean” manure for fertilization, periodically apply liming and maintain neutral or slightly acidic environment in the soil. Annual application of 2-3 kg of double superphosphate and 3-4 kg of potassium chloride or sulfuric acid per 100 m^2 of the vegetable garden plot is also well suited for this purpose [2], the use of artificial irrigation is naturally desirable.

3 Research methodology and methods

The accident at the Chernobyl nuclear power plant resulted in contamination of the territory with caesium-137 radionuclide, where agriculture is still intensively practiced. The soils here are represented by a variety of sod-podzolic, swamp-gley and gray forest soils and mechanical composition of sandy, sandy loam, loamy soils, widespread in the Bryansk region.

After 40 years since the Chernobyl nuclear accident, the redistribution of radionuclides in the area has undergone major changes. This has been affected by horizontal and vertical movement of water flow, soil type and mechanical composition, agricultural use, topography, wind erosion and others.

How cesium-137 is subject to migration, its redistribution in the places of contamination was studied by us on special samples taken in the areas of the greatest radioactive contamination in the Bryansk region, on the objects of land reclamation and hydraulic structures (dams, spillways, canals, reservoirs), which were built before the accident at the Chernobyl station.

The influence of already performed rehabilitation measures and the state of radioecological situation at present was studied by us at the same objects.

Radioactive radiation was determined in the field at the sampling site using dosimetric devices (DKG-03D-Grach, RKSB-104-Belvar, SRP-68-01 and others).

Samples of soil, water, soil, muddy sediments and plants were taken in the field conditions according to the existing standards. On these samples the processes of vertical migration of radionuclides from water and their control by intensifiers were studied. Vertical migration was determined on a Darcy apparatus, in which soil or silt samples taken by us were placed in the upper part of the filtration column, water supply was also carried out from above in portions or continuously. The values of specific activity in Bq/kg obtained as a result of washing the samples were recorded by us with the help of radiometer RUB-01P6 in the Radiology Laboratory of BSAU and were the average value of measurements with 15-fold repetition.

In more than 16 years of continuous laboratory-field experiments we have accumulated rich material on the peculiarities of caesium radionuclide migration with water, which was reflected in the description of more than 100 laboratory works, the duration of experiments was several hours, days, months, years.

All this was planned to be applied to radiological problems in this region. Water management and reclamation measures will have to solve them.

4 Results and discussion

Considering the experience of remediation works of the past years and their prospects at the present stage, it can be noted that washing of cesium-137 contamination of soils of homestead plots by flooding is not acceptable, as it requires large water consumption [3].

Such leaching technology can be used in the catchment area of closed depressions, where, as a rule, a large amount of radionuclides accumulates, forming "caesium spots" at the bottom of these depressions. Such a spot is a hotspot of contamination in the area used. If we assume that an irrigated area of 25 hectares is required to grow agricultural products to support a settlement of 500 people, then there may be about 5-7 such contamination spots. Water also tends to accumulate in depressions, forming temporary lakes that stand for two weeks to a month, both in spring and summer-autumn periods. Covering more than 1% of the Bryansk Oblast, these water-filled depressions create difficulties in agricultural operations.

Before the Chernobyl accident, measures were taken in the region to control waterlogging of closed depressions. Stationary drainage with absorption funnels and absorption columns on drains was constructed, also selective drainage, which found wide application on cesium contaminated territories, proved itself well. Shortcomings of drainage operation not seldom led to the fact that water drainage from the bottom of depression was stopped because of its colmatization. The projects planned to carry out deep loosening of the bottom of depressions regularly, but it was not implemented. A frequent phenomenon in spring was standing water in the saucers of closed depressions after snow cover melt and the same in the summer-autumn rainy season.

The precipitation layer for the average annual winter period in the Bryansk region is 210 mm [3, 4]. When snow is blown by the wind from elevated areas of relief, it accumulates in closed depressions in a thick layer. When melting, a large amount of water is obtained, which should be used for washing of "cesium spots". This amount can be supplemented by transferring melt water flow from nearby catchments. For this purpose, water flow collectors are laid in the snow strata, using tractor wheel tracks or any compactors as collectors. After the ground thaws, the snow runoff seeps into the soil and continues to move along the plow bed.

By timely organizing spring melt water flow and deep loosening of the bottom of closed depressions, under favorable climate conditions, it is possible to create an abundant washing norm for washing of "cesium spot" on the area of 0.04 ha. According to preliminary calculations it will be about 525000 m^3/ha. If to take only half of the area of "cesium spot", the flushing norm will be doubled and will amount to 1050000m^3/ha. Deep loosening at realization of such washing will become obligatory and regular measure.

We have made laboratory experiments simulating flushing with large flushing rates. As a result, it was revealed that caesium leaching during irrigation, applied in 0.5-5 days, slightly depends on the set value of leaching rate, but strong dependence occurs on the filtration rate and rate of water absorption by the soil [5].

Table 4. Washing of soil contaminated with cesium-137 by flooding the surface on the Darcy device after freezing the soil

The cycle	C Bq/kg	t day	$Q_{average}$ cm^3/s	W liter	Σ W liter	E effectiveness swashing out %
Beginning	9166					
16	8870	4	1.358	469.3	469.3	3.2
17	8638	4	1.322	456.9	926.2	5.8
18	8508	4	1.182	408.5	1334.7	7.2
19	8140	5	1.135	490.3	1825	11.2
20	8123	1	1.089	94.1	1919.1	11.4

21	8069	1	0.980	84.7	2003.8	12.0
22	7926	1	1.0896	94.1	2097.9	13.5
23	7919	0.5	1.247	53.7	2151.6	13.6
24	7803	0.5	0.893	38.6	2190.2	14.9
25	7465	0.5	1.204	52.0	2242.2	18.6

Note: In cycles 22, 23 and 25 – pre-soaking

Leaching rates obtained by us in preliminary calculations may seem too large or overestimated, but they are formed in real natural conditions. We need to come to the point that by regulating the process of filtration and water absorption by soil to achieve maximum caesium leaching. To increase the rate of filtration and water absorption it is suggested to use chemical ameliorants and intensifiers, which influence the change of physical and chemical properties of the soil layer. They also contribute to increase the rate of caesium desorption from colloids of soil particles and plant roots, thus increasing the mobility of caesium, thus contributing to the effectiveness of radionuclide leaching.

The possibility of radionuclide leaching is illustrated in the description of uranium mining from ore-bearing rocks. Here aqueous chemical solutions were successfully used: sulfuric acid solutions with a concentration of H_2SO_4 – 10 g/l of water; sodas with concentration of Na_2CO_3 - 10 g/l; water saturation with carbon dioxide (CO_2+H_2O). Thus, in two months about 90% of uranium from its original amount in the rock could be extracted [6].

It is often judged what amount of contaminating elements can be leached by how the soil-absorbing complex interacts with salt extracts or other solutions, but this is not quite correct, because the soil solution contains a very large number of different competing ions.

In radioactively contaminated land, potassium should predominate over nitrogen in the soil solution, because if nitrogen predominates over potassium, this leads to increased uptake of caesium by plants from the soil, resulting in an increase in the radioactivity of the product [3].

Washing of radioactive soils in the territories of Bryansk region should be carried out by effective methods with the use of chemical ameliorants and intensifiers of leaching, maximizing the use of rain and snow water flow.

The influence of chemical ameliorants in periodic sprinkling irrigations gave the best results. It was found that specific water consumption for leaching of 1 Bq/kg, under irrigation with clean water amounted to 35-40 m^3/ha, and with chemameliorants water consumption decreased to the lowest in all experiments value of 6-16 m^3/ha [5].

Checking the method of flooding or creating a layer of water on the soil surface showed that clean water required a very large amount, specific costs amounted to about 2800 m^3/ha, and with chemameliorants and intensifiers decreased more than 2 times [5].

The application of drip irrigation gave relatively average results; specific water consumption was 170 m^3/ha when leaching with pure water, and with chemameliorants it decreased to 36 m^3/ha for 12 cycles of washing [5].

In order to assess the effectiveness and intensity of leaching of caesium-137 radionuclide from soil, we have carefully studied the timing and rate of extraction of this radionuclide from soils with different degrees of contamination, which depend mainly on:

- on a nearby water source with water of appropriate quality and volume;
- on the correct choice of leaching method and type of irrigation water supply and on the organization of leaching technology using short leaching cycles;
- organization of full use of natural surface water flow during flushing in spring, summer-autumn and autumn-winter periods of the year with obligatory use of deep selective soil loosening in places of closed relief depressions, microfalls and saucers, where the highest concentration of radionuclides is detected;
- availability in sufficient quantity and possibility of observing the regime of application of intensifiers and chemical ameliorants under irrigation;

Let us compare the rates of caesium-137 leaching from soils with different levels of contamination. In one of the experiments the loam was washed with tap water [5], the initial soil activity was not high 2303 Bq/kg. In cycles 8 and 14, ammonium nitrate was applied as a chemical ameliorant before irrigation. The effectiveness of leaching for 17 cycles was appreciable and amounted to 23.8% (Figure 1), specific activity of soil decreased by 547 Bq/kg during leaching. Leaching effectiveness for the first 7 cycles, when water without nitrate was applied, was 8.38%, and specific activity of soil decreased only by 193 Bq/kg. The maximum effectiveness of cesium removal for 23 cycles was close to the highest and amounted to 30.4% (Figure 1).

The effectiveness of caesium-137 leaching was calculated by the formula:

$$E = \frac{C_{in} - C_t}{C_{in}} \cdot 100\ \%$$

where C_{in} – initial specific activity of soil before washing, Bq/kg;

C_t – current specific activity of soil after the washing cycle, Bq/kg.

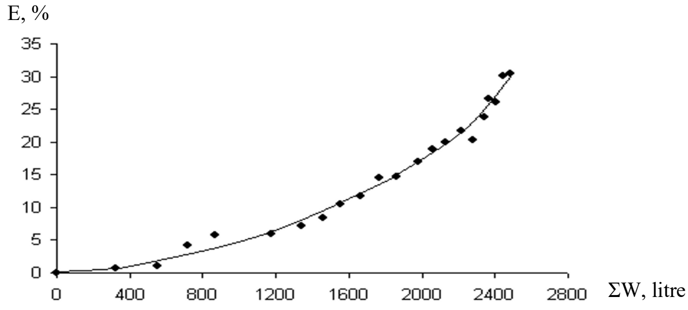


Fig. 1. Dependence of the flushing effect on the amount of water supplied

In another experiment sandy soil was washed with tap water [5], with a high level of initial specific activity 11916 Bq/kg. After 15 cycles, the effectiveness of cesium leaching was 23.07% (Figure 2), i.e., almost the same as in the previous experiment, but here in 4 cycles intensifiers were applied (ultrasound, air compressor injection) and in 3 cycles potassium chloride was applied. Specific activity of soil for 15 cycles decreased by much higher absolute value 2750 Bq/kg. After the first 6 cycles without intensifiers and chemical ameliorants the effectiveness of washing was not great and amounted to 10.4%.

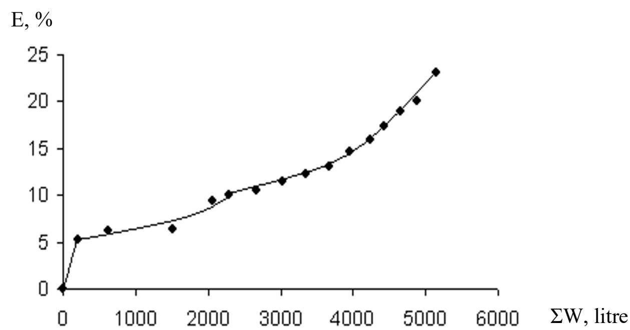


Fig. 2. Dependence of the flushing effect on the amount of water supplied

In the new experiment, a light loamy soil [5] with an initial specific activity of 4159 Bq/kg was washed for 17 cycles, the effectiveness of radionuclide washing was the highest value of 36.4% (Figure 3). Ammonium nitrate was applied in cycles 12 and 15, and manure effluent was applied in the last cycle. Rain and snow water was used for irrigation. The specific activity decreased by an average absolute value of 1513 Bq/kg.

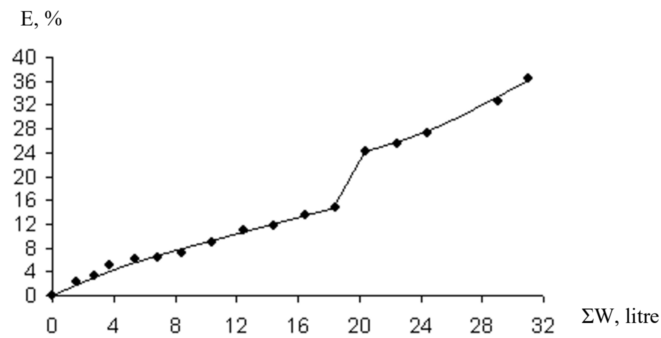


Fig. 3. The efficiency of cesium leaching from light loamy soil, underlain by a layer of zeolite, during periodic watering

In one of the experiments light loamy soil was washed with rain and snow water [5] for 16 cycles, but in cycle 14 water from the main canal was used, initial soil activity was average 4234 Bq/kg. The effectiveness of washing in cycle 9 after using snow and rain water was 10.8%, potassium chloride was applied in cycle 10 and the effectiveness increased to 15.1%. In cycles 11, 12 and 16, ammonium nitrate was applied and the combined action with MC water resulted in a total washing effectiveness of 28.8% (Figure 4). The specific activity decreased by an average absolute value of 1221 Bq/kg.

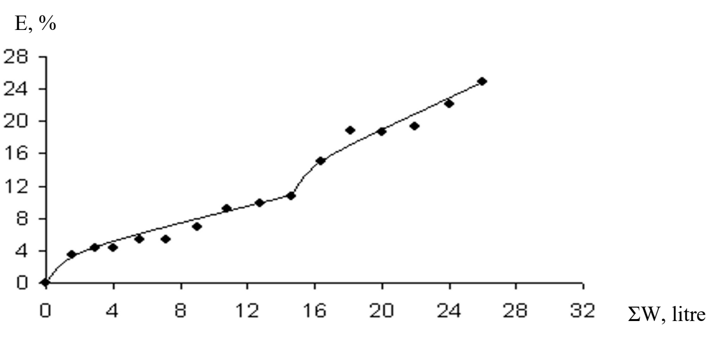
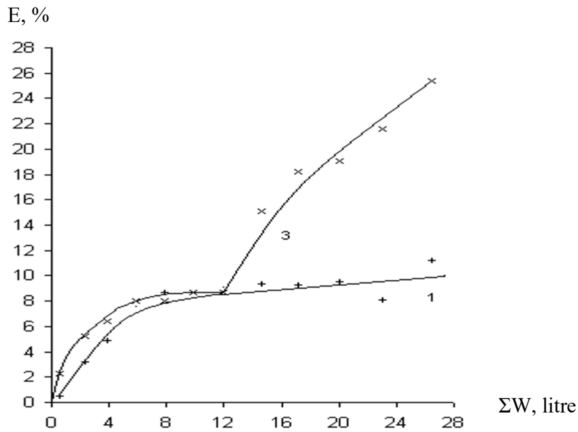


Fig. 4. The efficiency of cesium leaching from light loamy soil (0-3 cm layer), underlain by sand, with periodic watering.

In another experiment [5], washing of loam with high value of initial specific activity 11258 Bq/kg was carried out. Rain and snow water was used for 11 cycles, and in the 12th cycle irrigation was carried out with water flowing from manure. Chemical ameliorants were not used here, but soil freezing was applied 5 times. So, after three times soil freezing in cycles 1, 2, 3, leaching effectiveness in the 3rd cycle was 5.75% on average from two layers, specific water consumption during leaching was 7.57 m3/ha, and the next cycle 4 was without freezing, but leaching effectiveness increased to 7.9% and specific water consumption also increased to 8.17 m^3/ha. Cycle 5 was also without freezing, where the effectiveness again increased to 8.35%, but specific water inputs also increased to 9.89 m^3/ha. As a result, the specific activity of soil for 12 cycles decreased for the first layer by an average absolute value

 https://doi.org/10.1051/bioconf/202414102006

of 1261 Bq/kg, and for the second lower layer by a higher value of 2476 Bq/kg. The maximum average effectiveness of washing for the two layers was 18.3% (Figure 5). Soil freezing increased the effectiveness of caesium leaching and reduced specific water consumption compared to other washing methods.



+ 1 layer; x – 3 layer.

Fig. 5. The efficiency of leaching caesium -137 from sandy loam soil during periodic watering and freezing.

It became evident from the experiments that intensifiers and chemameliorants appreciably influence the degree of caesium-137 leaching from soil. Application of such influence should contribute to increase of effectiveness and intensity of soil leaching, decrease of specific water consumption for leaching of 1 Bq/kg, which significantly facilitates application and development of such technologies. Highly contaminated soils have shown that the effectiveness of caesium leaching is lower than on soils with not high contamination, but the absolute value of caesium removal with leaching irrigation is much higher from more contaminated soils. The purification of highly contaminated soils is slow, so the period until the normative purification is prolonged, but the payback of chemical ameliorants on soils with higher radioactivity becomes higher.

A similar feature of less intensive uranium mining from richer ores was established by Markelov S.V. et al. [6].

5 Findings

It should be noted that the Bryansk Oblast is well provided with water resources, but there may not be enough flushing water for household plots, settlements and dacha settlements, as the distribution of water bodies across the Oblast is not uniform. Settlements are often located far from large rivers and lakes and it is impossible to bring them closer. In small settlements it is not rare that village wells are the only source of water supply. Using such water for irrigation or flushing will not only be difficult, but will also create a deficit of water use. The urgency of water saving in this region is especially visible, the use of chemical ameliorants to normalize the radioecological situation for people living in such areas becomes important, and the development of technology for soil purification from radionuclides comes to the fore [7-12]. It is reasonable to find an alternative to abundant water sources, for this purpose it is supposed to use mine and shallow tube wells (boreholes). Water consumption from the upper, non-pressurized groundwater horizon should become widespread in Bryansk region, because the construction of shallow wells up to 30 m with a low flow rate of 0.5 l/s does not require large costs.

6 Conclusion

1. It is obvious that remediation activities in radioactively contaminated territories of Bryansk Oblast are necessary. This issue is especially acute for dacha plots and private subsidiary farms, where centers of radioactive contamination in the form of "cesium spots" are widespread, which continue to have a negative impact on human health.
2. In our research, experiments have established numerous options of impact on such foci of contamination. Periodic irrigations with the use of chemical ameliorants and leaching intensifiers, as well as the use of manure, drip irrigation and snow melt water, which can easily accumulate over the area of cesium contamination, have proved to be especially good.
3. The experience of private subsidiary farms, quite applicable for collective farms and farms on regional and municipal care in our country.
4. Implementation of targeted state rehabilitation programs aimed at reducing the external and internal radiation dose to the value of 1 m^3/year, health protection, increasing the life expectancy of the population, it is necessary to renew, create and apply new.

7 Acknowledgements

The author expresses gratitude and appreciation to the scientific supervisor – Professor, Doctor of Technical Sciences Valery F. Vasilenkov; members of his family; the staff of the Department of Environmental Management and Water Management for their contribution to the implementation of this work.

A statement of a conflict of interest. The author declares that there is no conflict of interest.

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