Artículo de investigación

Change in agrochemical, properties and vertical distribution of ^{137}Cs in al. luvial. soil depending on rehabilitation measures

Изменение агрохимических свойств и вертикального распределения ^{137}cs в аллювиальной почве в зависимости от реабилитационных мероприятий

Recibido: 19 de julio del 2019 Aceptado: 23 de septiembre del 2019

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Abstract

As a result of the accident at the Chernobyl nuclear power plant and the loss of artificial. radionuclides, there was a decrease in the area of fodder land capable of producing feed that meets radiation standards. The use of rehabilitation measures contributes to the return of lost lands to agricultural. circulation, however, the issues of changing the fertility and behavior of ^{137}Cs in al. luvial. soil are not well understood. Therefore, the aim of the study was to study the transformation of soil fertility under the influence of rehabilitation measures and the behavior of ^{137}Cs in the soil profile of floodplain meadows. It was found that the use of floodplain meadows as hayfields does not change the agrochemical. indicators of the fertility of al. luvial. soil. A radical. and superficial. improvement with the introduction of mineral. fertilizers increased the content of nutrients in the soil. It was established that at the initial. stage of the rehabilitation of radioactively contaminated floodplain meadows it is necessary to carry out a radical. improvement (the use of deep two-tier plowing), due to this

Аннотация

в результате аварии на Чернобыльской АЭС и выпадению искусственных радионуклидов произошло уменьшение площадей кормовых угодий способных производить корма отвечающих радиационным нормативам. Применение реабилитационных мероприятий способствует возврату потерянных земель в сельскохозяйственный оборот, однако вопросы изменения плодородия и поведения ^{137}Cs в аллювиальной почве недостаточно изучены. Поэтому цель исследования изучить трансформацию почвенного плодородия под действием реабилитационных мероприятий и особенности поведения ^{137}Cs в профиле почв пойменных лугов. В результате исследований выявили, что использование пойменного луга в качестве сенокоса не меняет агрохимические показатели плодородия аллювиальной почвы. Коренное и поверхностное улучшение с внесением минерального удобрения увеличивало содержание элементов питания в почве.

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there is a maximum decrease in concentration in the root-inhabited layer of al. luvial. soil. At the initial. stage of the study, the largest part of ^{137}Cs was in a layer of 0-5 cm of al. luvial. soil, a uniform distribution of the radionuclide to a depth of 20 cm occurred after 21 years, and the application of mineral. fertilizer contributed to the equal. ization of the specific activity of ^{137}Cs in layers of 0-5 and 5-10 cm. The application of radical. and surface improvement with the introduction of mineral. fertilizer enhanced the equal. ization of the concentration of ^{137}Cs Pin the layers 0-5, 5-10, 10-15 and 15-20 cm. ^{137}Cs migration to the root layer of the soil from the underlying layers was reveal. ed due to an increase in the mass of grass cover under the influence of increasing doses of mineral. fertilizer.

Key words: al. luvial. soils (Fluvisols), methods for improving meadows, fertility indicators, radioactive contamination of soils, ^{137}Cs migration.

Установили, что в начальный этап реабилитации радиоактивно загрязненных пойменных лугов необходимо проводить коренное улучшение (применение глубокой двухъярусной вспашки), за счет этого происходит максимальное снижение концентрации в корнеобитаемом слое аллювиальной почвы. На начальном этапе исследования наибольшая часть ^{137}Cs находилась в слое 0-5 см аллювиальной почвы, по прошествии 21 года произошло равномерное распределение радионуклида до глубины 20 см, а внесение минерального удобрения способствовало выравниванию удельной активности ^{137}Cs в слоях 0-5 и 5-10 см. Применение коренного и поверхностного улучшения с внесением минерального удобрения усиливало выравнивание концентрации ^{137}Cs в слоях 0-5, 5-10, 10-15 и 15-20 см. Выявлена миграция ^{137}Cs в корнеобитаемый слой почвы из нижележащих слоев за счет увеличения массы травостоя под действием возрастающих доз минерального удобрения.

Ключевые слова: аллювиальные почвы (Fluvisols), приемы улучшения лугов, показатели плодородия, радиоактивное загрязнение почв, миграция ^{137}Cs.

Introduction

The accident at the Chernobyl nuclear power plant led to large-scal. e pollution of the territories of Russia (Fesenko et al., 2005; Fesenko et al., 2006; Balonov et al., 2018), while the Bryansk region turned out to be the most polluted both in terms of area and the number of radionuclides deposited (fig 1.). Seven southwestern regions turned out to be the most affected: Gordeevsky, Zlynkovsky, Klimovsky, Klintsovsky, Krasnogorsk, Novozybkovsky, Starodubsky (Brook et al., 2015; Panov et al., 2015; Sanzharova et al., 2016).

ISSN 2322- 6307

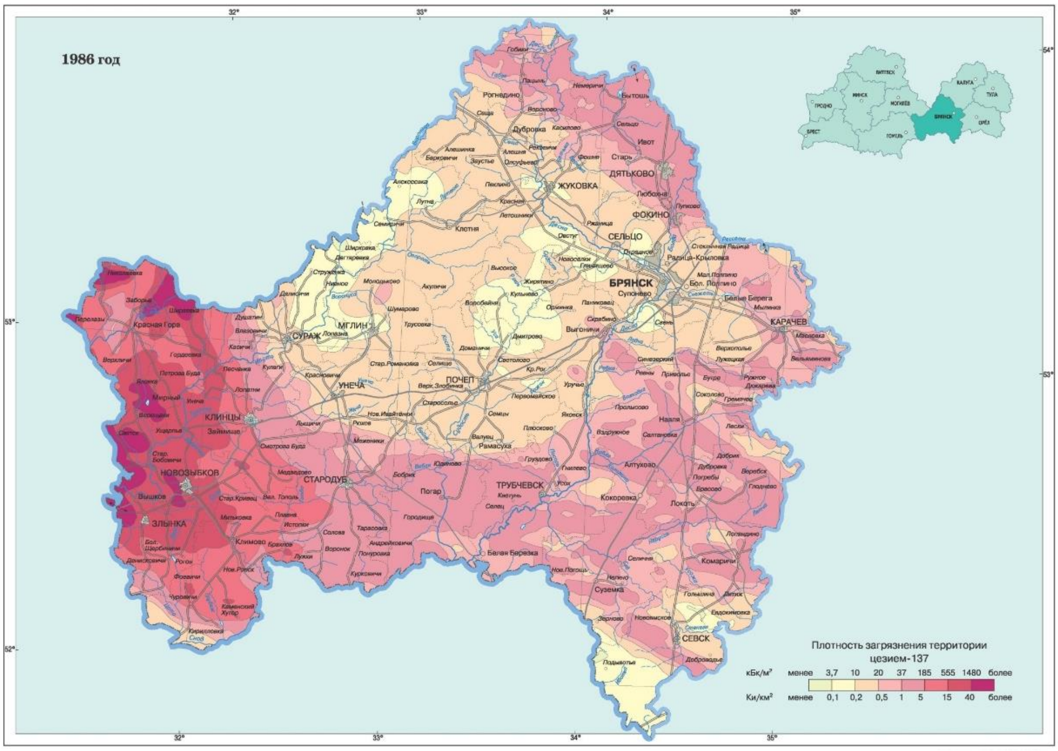


Fig. 1. Map of pollution of ^{137}Cs territory of the Bryansk region, Russia (scal. e1: 1 000 000) (Atlas of modern ..., 2009)

In the remote period after the accident, the likelihood of producing agricultural. products with a high level of pollution is quite high (Mamihin, 2016; Mikhailovskaya et al., 2015; Paramonova, Mamikhin, 2017). To a large extent, this is due to the soil-geochemical. characteristics of the contaminated territories: first of al. l, the presence of light granulometric composition in the soil cover, which is characterized by high rates of radionuclide migration from soil to plants (Anisimov et al., 1991; Kablova et al., 2017; Fesenko et al., 2007). The use of 491.4 thousand ha of natural. fodder land contaminated with artificial. radionuclides for the production of fodder in the Bryansk Region increases the likelihood of obtaining fodder production that does not meet the permissible level of ^{137}Cs in them (Gamko et al., 2016; Belous et al., 2015).

The al.luvial. soddy gleyed soils (Classification and Diagnostics ..., 1977), according to the World Soil Resources Database (WRB), correspond to them Fluvisols (International. soil ..., 2014) prevail in the floodplains of the Bryansk region, occupying 133.1 thousand ha or 55.1 %, about 20% of the meadows of the region are located on them (Vorobev, 1993).

On natural. forage lands where no protective measures were taken, the bulk of ^{137}Cs is located in the upper horizon of the soil profile to a depth of 5 cm, enriched in the non-mineral. ized part of plant residues (Belous et al., 2016).

Currently, the issues of the action of agrotechnical. and agrochemical. methods on the redistribution of radionuclides and their migration al. ong the soil profile of al. luvial. soils, and in the future, their transition to plants, remain insufficiently studied.

The reduction in the area of natural. fodder land for obtaining coarse and succulent feed caused by the Chernobyl accident and the fal. lout of radioactive fal. lout hinders the development of the livestock industry in the region and can be compensated by the introduction of amelioratively improved radioactive contaminated floodplain meadows (Al.eksakhin et al., 1999; Krechetnikov and et al., 2018).

In order to solve the aforementioned problems, we performed work related to the justification of the use of rehabilitation measures in the meadows of the central. floodplain, which contribute not only to the redistribution of ^{137}Cs in the soil profile, which ultimately leads to a decrease in the absorption of radionuclide by grass, but al.so increases the agrochemical. parameters of al. luvial. soil

Objects and Methods

The location of the object of study was in the subzone of sod-podzolic soils of the southern taiga, the Belarusian province of sod-podzolic slightly humus soils and lowland marshes. The exclusivity of the selected site for carrying out rehabilitation measures and monitoring changes in the parameters of soil fertility and ^{137}Cs migration al. ong the soil profile is associated with the level of contamination of the floodplain of the Iput River, which at the time of the beginning of the research on radiological. parameters belonged to the resettlement zone, on which no protective measures related to accident at the Chernobyl nuclear power plant.

The climate is temperate continental. with warm summers and moderately cold winters, rather humid. Changes in air temperature are clearly seasonal. in nature. The average daily temperature goes over 10 ° C in May, then there is a slower increase. The maximum temperature is observed in July - 19.4 ° C. The average daily temperature drops below 10 ° C at the end of September. The duration of the period with a temperature of more than 10 ° C is about 156 days, which is quite enough for cultivating forage crops.

Precipitation averages about 585 mm per year. Precipitation is unevenly distributed. The greatest amount of precipitation fal.ls during the warm period, less during the cold period, there are exceptions. The water regime of the subzone is a washing one, on which a floodplain process was superimposed. The duration of flooding of the experimental. plot during the spring flood, depending on the year, ranged from 10 to 22 days.

The soil of the experimental. plot is al. luvial. turf, gleyed, thin, medium humus, sandy on sandy loam al. luvium and has the following structure: Ad (0-5), A1 (5-18); B1 (18-40); Bg (40-60); Cg (60-90). The average indicators of agrochemical. properties in 1994 were as follows: rNCl - 4.8, humus content - 3.2% (according to Tyurin), mobile phosphorus - 140 mg / kg, exchange potassium - 60 mg / kg (according to Kirsanov). The contamination density of ^{137}Cs of the territory of the experiment during the laying of the experiment in 1994 ranged from 1221-1554 kBq / m2, during the period of reloading in 2008 - 559-867 kBq / m^2. The floristic composition of the natural. meadow grass cover of the experiment is presented by species of grasses of the bluegrass family: meadow fescue (Festuca pratensis Huds.), Meadow foxtail (Al.opecurus pratensis L.), timothy grass meadow (Phleum pratense L.). Different herbs accounted for ≈10–15% of the total. composition.

Rehabilitation measures during the test setup in 1994 included agrotechnical. methods, which included surface improvement by means of disking with the BDF-2,4 disc harrow and radical. improvement by plowing with a two-tier plow (PYA-40) followed by sowing of bluegrass grass mixtures (typical. for the study region) as a part: *Bromopsis inermis L* - 8, *Festuca pratensis Huds* - 8, *Phleumpratense L.* - 5, *Phal.aris arundinacea L.*- 5, *Al.opecurus pratensis L.*- 5 kg / ha. In 2008, the thinned grass stand was replaced at the experimental. site using the accelerated tinning method. Re-tilling operations included the following operations: liming the soil, two-way milling with the FBK-2 mill, pre-sowing soil rolling with ZKVG-1,5 rollers, sowing with the SZT-3,6 seeder at the end of the second decade of August perennial. grasses of the following composition: *Festuca pratensisHuds.* - 6, *Al.opecurus pratensis L.*- 5, *Phal.ari sarundinacea L.* - 7 kg / ha, post-sowing soil rolling.

Agrochemical. methods during rehabilitation measures included the introduction of ammonium nitrate, simple granular superphosphate and potassium chloride in the following doses: from 1994 to 2008 - $N_0P_0K_0$, $N_{120}P_{90}K_{120}$, $N_{120}P_{90}K_{240}$, $N_{180}P_{120}K_{180}$, $N_{180}P_{120}K_{360}$, the period of 2009-2015 - $N_0P_0K_0$, $N_{90}P_{60}K_{90}$, $N_{90}P_{60}K_{150}$, $N_{120}P_{60}K_{120}$, $N_{120}P_{60}K_{180}$. Nitrogen and potassium fertilizers were applied in two doses: hal.f of the cal.culated dose under 1 mowing, the second hal.f - under 2 mowing, and phosphate fertilizers in one dose under 1 mowing.

Soil samples for determining the agrochemical. properties of al.luvial. soil were selected in 1995, 2007 and 2015 with a cane drill after harvesting perennial. grasses on hay, individual. samples were taken from a depth of 0-20, which were combined into a mixed sample (300 g), a repetition of 3 times, for each option.

Soil samples for determining the specific activity of ^{137}Cs of soil were selected in 1994, 2007 and 2015 in late autumn with special.ly made drill individual. samples every 5 cm to a depth of 60 cm, which were combined into a mixed sample (1000 g).

The pH_{KCl} val. ue was determined by the ionometric method, the content of mobile phosphorus and exchange potassium according to Kirsanov, the organic carbon content according to Tyurin, the specific activity of ^{137}Cs for each 5 cm soil layer was measured using the Gamma Plus universal. spectrometric complex (Russia), the main measurement error was no more than 10%.

The cal. culation of the total. specific activity of 0-60 cm of the al. luvial. soil profile was carried out by means of adding the specific activity of each 5 cm of the soil layer to a depth of 60 cm, followed by the cal. culation of the percentage of the total. specific activity.
The obtained data on the agrochemical. properties of the soil were subjected to anal. ysis of variance using the software Statistica 7.0.

Results

The use of agrotechnical. and agrochemical. methods for improving floodplain meadows used as hayfields or pastures changed the agrochemical. parameters of al.luvial. soil (Table 1).

The change in the content of organic carbon in the soil varied over time in the range of 2.92 - 3.27%. The use of agrotechnical. methods for improving floodplain meadows, mainly during two-tier plowing, reduced the organic carbon content in a 20-cm soil layer, this is due to the movement of lower soil horizons less provided with organic matter to the surface. After 20 years, an increase was found in comparison with the initial. stage of research. The use of mineral. fertilizers in conjunction with agricultural. techniques to improve floodplain meadows under experimental. conditions increased the organic carbon content, changing this indicator over time.

Table 1. Dynamics of soil fertility parameters depending on agrotechnical. and agrochemical. methods

Option	With org, %			$pH_{KCl,\ units}$			P_2O_5, mg/kg			K_2O, mg/kg		
	1995 г.	2007 г.	2015 г.	1995 г.	2007 г.	2015 г.	1995 г.	2007 г.	2015 г.	1995 г.	2007 г.	2015 г.
Natural. meadow												
$N_0P_0K_0$	3,12	3,19	3,27	5,00	5,24	5,22	121	135	146	50	58	62
$\underline{N_{120}P_{90}K_{180}}$ $N_{90}P_{60}K_{90}$	3,11	3,22	3,34	5,19	5,38	5,35	131	142	172	54	62	65
$\underline{N_{120}P_{90}K_{240}}$ $N_{90}P_{60}K_{150}$	3,14	3,21	3,22	5,22	5,43	5,57	135	141	178	58	68	68
$\underline{N_{180}P_{120}K_{180}}$ $N_{120}P_{60}K_{120}$	3,12	3,23	3,25	5,22	5,52	5,60	148	160	184	58	65	76
$\underline{N_{180}P_{120}K_{360}}$ $N_{120}P_{60}K_{180}$	3,12	3,23	3,27	5,34	5,56	5,66	144	158	188	52	66	79
HCP_{05}	*0,45*			*0,29*			*36*			*15*		
Surface improvement												
$N_0P_0K_0$	3,18	3,27	3,27	5,20	5,60	5,56	133	139	124	55	63	58
$\underline{N_{120}P_{90}K_{180}}$ $N_{90}P_{60}K_{90}$	3,18	3,31	3,34	5,55	5,57	5,61	142	153	158	68	76	75
$\underline{N_{120}P_{90}K_{240}}$	3,21	3,30	3,36	5,70	5,63	5,62	155	163	179	71	77	87

ISSN 2322- 6307

$N_{90}P_{60}K_{150}$												
$\underline{N_{180}P_{120}K_{180}}$ $N_{120}P_{60}K_{120}$	3,20	3,33	3,41	5,77	5,60	5,72	168	174	175	73	84	95
$\underline{N_{180}P_{120}K_{360}}$ $N_{120}P_{60}K_{180}$	3,22	3,33	3,39	5,81	5,59	5,68	172	180	190	82	90	99
HCP_{05}	*0,15*			*0,22*			*16*			*14*		
Radical. improvement												
$N_0P_0K_0$	2,92	3,08	3,13	4,71	5,17	5,06	125	133	139	58	62	56
$\underline{N_{120}P_{90}K_{180}}$ $N_{90}P_{60}K_{90}$	3,00	3,11	3,17	4,87	5,25	5,29	133	141	150	61	69	67
$\underline{N_{120}P_{90}K_{240}}$ $N_{90}P_{60}K_{150}$	2,99	3,10	3,17	4,73	5,29	5,20	130	140	159	60	70	72
$\underline{N_{180}P_{120}K_{180}}$ $N_{120}P_{60}K_{120}$	3,02	3,09	3,11	4,86	5,31	5,20	136	149	154	63	68	71
$\underline{N_{180}P_{120}K_{360}}$ $N_{120}P_{60}K_{180}$	3,02	3,11	3,18	4,90	5,29	5,27	138	148	168	63	72	79
HCP_{05}	*0,16*			*0,45*			*21*			*10*		

Note. Above the line - the fertilizer system of 1994-2008, under the line - 2009-2015

The dynamics of changes in metabolic acidity over the years of research was in the range of 4.47 - 5.68 units. The use of agrotechnical. methods for improving floodplain meadows, mainly during two-tier plowing, acidified the upper horizon, this is due to the mixing of the upper horizon with the lower one, which is more acidic, but over the years there has been a decrease in acidity. They reveal. ed a tendency to a decrease in acidity when making mineral. fertilizers.

Changes in the content of mobile phosphorus and exchange potassium over time were respectively in the range of 121-190 and 46-99 mg / kg. The use of agrotechnical. methods for improving floodplain meadows did not change these indicators. Agrochemical. methods of improving floodplain meadows under experimental. conditions increased the content of nutrients in the soil, while there was a tendency, and a significant increase in some cases, which, with an increase in the level of chemical.ization, increased the content of mobile phosphorus and exchange potassium.

The cultivation of perennial. grasses, together with the agrotechnical. and agrochemical. improvement of the meadow, has a positive effect on the agrochemical. properties of al.luvial. soil, while even on the case without applying improvement methods, the conservation of fertility in time at the same level was observed.

Studies on the vertical. distribution of ^{137}Cs over the soil profile reveal. the dependence of radionuclide migration on many factors, among which the main ones are the water regime of the landscape, the granulometric composition of the soil, and others (Chevychelov, Sobakin, 2017; Kato et al., 2012; Konoplev et al., 2016) . The need to study the distribution of $1^{137}Cs$ in the root layer of the soil is determined, in particular for fodder land, by predicting its content in green and roughage obtained from the meadow (Belous et al., 2017) and then its food chain migration (Brechignac et al., 2017; Fesenko et al., 2018).

In the year of laying the experiment, 8 years after the Chernobyl fal. lout, the total. specific activity

ISSN 2322- 6307

of the 60-cm layer of the al. luvial. soil of the central. floodplain was 18 kBq / kg, on the variants with surface and radical. improvement it was at the same level. After 21 years, there was a decrease in the total. specific activity of ^{137}Cs of a 60-centimeter layer of al. luvial. soil: in a natural. meadow in 1.8; with a superficial. improvement of the meadow in 1.7; with a radical. improvement of the meadow 3.4 times. Agrotechnical. methods of improvement, mainly two-tier plowing, had a positive effect on the decrease in the total. specific activity of the 60-cm layer of al. luvial. soil (Table 2).

Table 2. The total. specific activity of ^{137}Cs of a 60-centimeter layer of al. luvial. soil of the central. floodplain of the Iput River to a depth of 60 cm, Bq / kg

Option	Natural. meadow			Surface improvement			Radical. improvement		
	1994	2007	2015	1994	2007	2015	1994	2007	2015
$N_0P_0K_0$	18071	10779	9878	17617	11042	10604	18447	9131	5426
$\underline{N_{120}P_{90}K_{180}}$ / $N_{90}P_{60}K_{90}$	–	11279	9248	–	9566	7264	–	8597	7850
$\underline{N_{120}P_{90}K_{240}}$ / $N_{90}P_{60}K_{150}$	–	11811	10314	–	10762	8153	–	8556	6243
$\underline{N_{180}P_{120}K_{180}}$ / $N_{120}P_{60}K_{120}$	–	11523	11284	–	10583	7096	–	9712	7708
$\underline{N_{180}P_{120}K_{360}}$ / $N_{120}P_{60}Kt_{180}$	–	11139	9894	–	9222	6522	–	8417	7120

Note. Above the line - the fertilizer system of 1994-2008, under the line - 2009-2015

Agrochemical. methods of improvement acted differently on the change in the total. specific activity and depended on agrotechnical. measures. If in a natural. floodplain meadow, the change in the direction of decreasing the total. specific activity of ^{137}Cs, depending on the doses of mineral. fertilizers, was a maximum of 1.2 times, then with surface improvement it was 1.5 times, and with a radical. improvement it was 1.4 times.

In 1994, 8 years after the accident at the Chernobyl nuclear power plant, in a floodplain meadow where no rehabilitation measures had been carried out before, the bulk of ^{137}Cs is concentrated in the turf (56.9%), then its concentration decreased, while it was more than 95% in the layer 0-15 cm (Fig. 2).

The use of surface improvement in the floodplain meadow changed the specific activity of ^{137}Cs over the soil profile layers, a uniform distribution of ^{137}Cs was found in the layers 0-5 and 5-10 cm, while it was more than 95% in the layer 0-15 cm. ^{137}Cs over the soil profile layers, a radionuclide was redistributed from the upper to the lower layers, the highest specific activity of ^{137}Cs was found in the 10-15 cm layer (36.5%), while about 70% in the 0-15 cm layer.

ISSN 2322- 6307

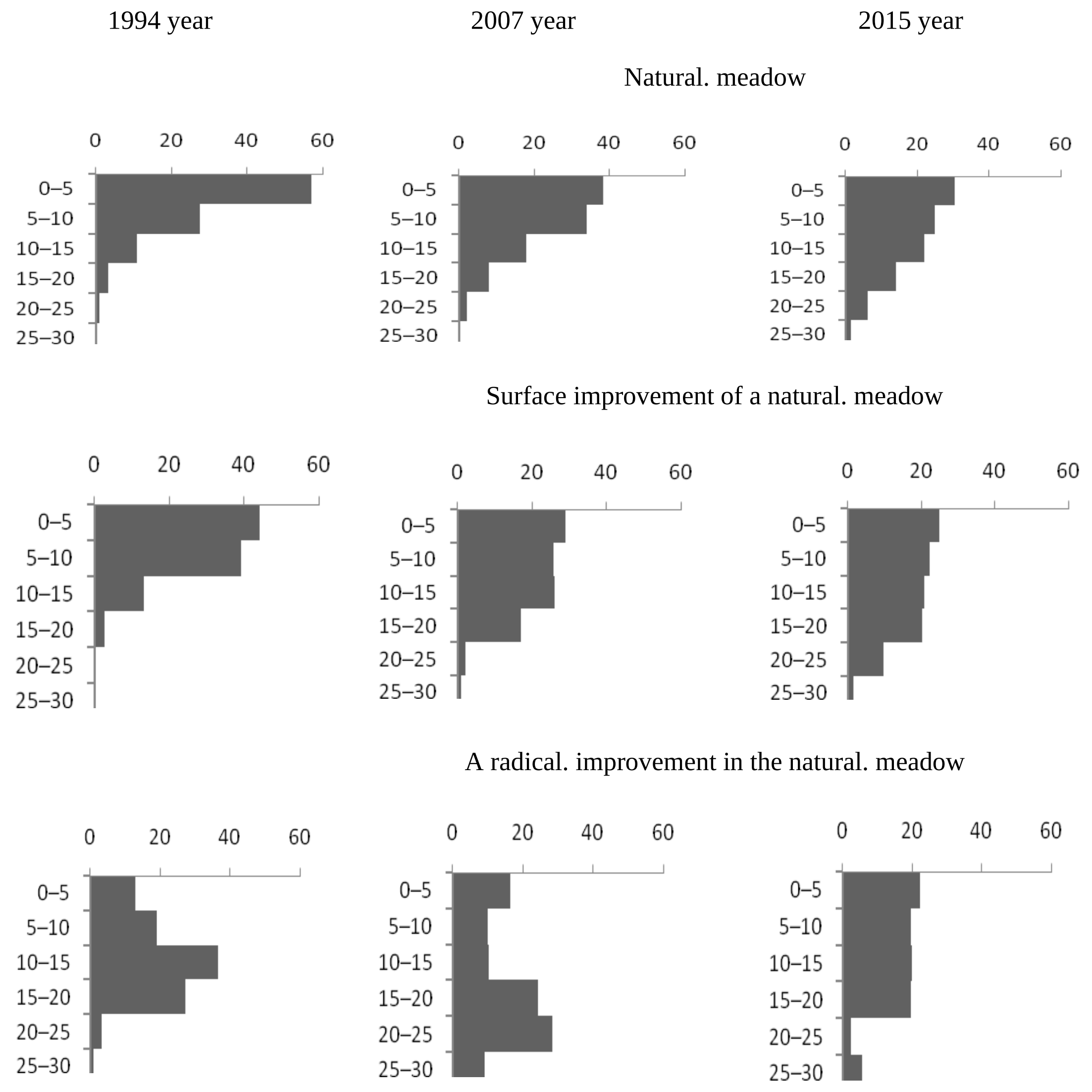


Fig. 2. Dynamics of the vertical. distribution of ^{137}Cs in al. luvial. soil, depending on agrotechnical. methods of improvement, % of the total. specific activity of ^{137}Cs s of a 60-cm layer

After 13 years, under the influence of climatic resources and agrotechnical. methods for improving and cultivating perennial. grasses, the distribution of ^{137}Cs in the profile of al. luvial. soil has changed. In a natural. meadow, ^{137}Cs were al. igned in layers 0-5 and 5-10 cm. As a result, in the 0-15 cm layer, the specific activity of ^{137}Cs decreased by 5%. With surface improvement, the specific activity of ^{137}Cs was equal. ized in layers 0-5, 5-10 and 10-15 cm, and the radionuclide migrated to a depth of profile up to 20 cm. As a result, the specific activity of ^{137}Cs decreased by 17 in the 0-15 cm layer % In the meadow, where radical. improvement was carried out, the specific activity of ^{137}Cs in the layers of 15–20 and 20–25 cm was equal. ized, and some ^{137}Cs of quantities migrated to a depth of 30 cm. As a result, the concentration of ^{137}Cs in the 0–15 cm layer decreased by 34%.

In 2008, accelerated reloading was carried out - milling in two directions, followed by sowing perennial. bluegrass grasses. As a result of the action of natural. and climatic factors and measures taken to re-soil in 2015, the distribution of ^{137}Cs in the profile of al.luvial. soil changed.

Under the conditions of a natural. meadow, the specific activity of ^{137}Cs in the layers of 0-5, 5-10, and 10-15 cm was equal.ized and the radionuclide migrated into the depth of the profile. As a result, in the 0-15 cm layer, the specific activity of 137Cs decreased by 12% compared to 2007. In the meadow, where surface improvement was carried out, the specific activity of ^{137}Cs in the layers of 0-5, 5-10, 10-15, and 15-20 cm was equal. ized, and radionuclide migration to the underlying soil layers was al.so found. As a result, its concentration in the 0-15 cm layer decreased by 12% compared to 2007. In the meadow, where they made a radical. improvement, ^{137}Cs in the layers of 0-5, 5-10, 10-15 and 15-20 cm were leveled; the radionuclide migrated to the underlying soil layers. However, in the 0-15 cm layer, its concentration increased by 25% compared to 2007.

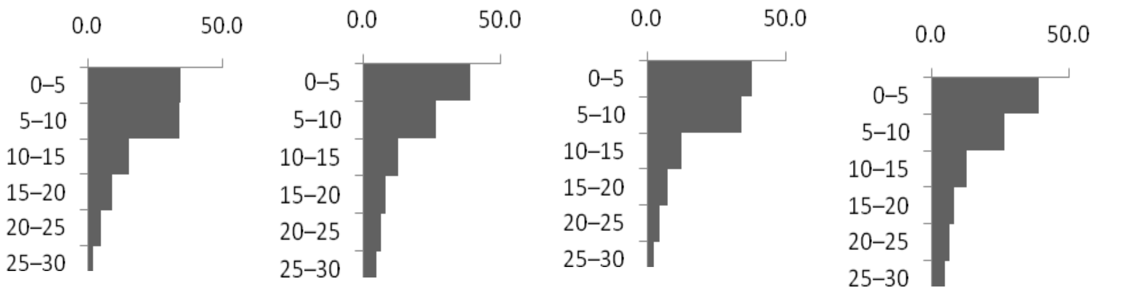
Figure 2 shows the profiles of al. luvial. soil 0-30 cm, and the percentage concentration is considered in the 60 cm layer, this is due to the fact that the bulk of ^{137}Cs is concentrated in the 0-30 cm layer, and in the 30-60 cm layer the specific activity of ^{137}Cs of soil in a natural. meadow there were the following: 1994 and 2007 - 0.3%, 2015 - 1.3%; in the superficial.ly improved floodplain meadow 1994 - 0.3%, 2007 - 0.4% and 2015 - 1.0%; in the floodplain meadow with a radical. improvement in 1994 - 0.6%, 2007 - 2.3%, 2015 - 10.2% of the total. specific activity of the 60 centimeter layer.

Rehabilitation of radioactively contaminated floodplain meadows through agrotechnical. improvement methods al.ters the distribution of ^{137}Cs al.ong the profile of al.luvial. soil. At the same time, over the years, there was a gradual. equal.ization of the concentration of ^{137}Cs within the root layer of 0–20 cm. In a natural. meadow, more than hal.f of ^{137}Cs is concentrated in a layer of 0–10 cm, moving al.ong the profile is very slow.

Studies on the effect of agrochemical. methods of improvement on the distribution of ^{137}Cs in the profile of al. luvial soil were carried out both on a natural. floodplain meadow and on surface and root improvement.

When mineral. fertilizers were applied in the doses and combinations provided for by the research program for 1994-2008, a tendency to increase the specific activity of ^{137}Cs in the turf (layer 0-5 cm) was reveal.ed with an increase in the dose of potassium fertilizer in full mineral. fertilizer compared to nitrogen (Fig. 3)

$N_{120}P_{90}K_{120}$ $N_{120}P_{90}K_{240}$ $N_{180}P_{120}K_{180}$ $N_{180}P_{120}K_{360}$



ISSN 2322- 6307

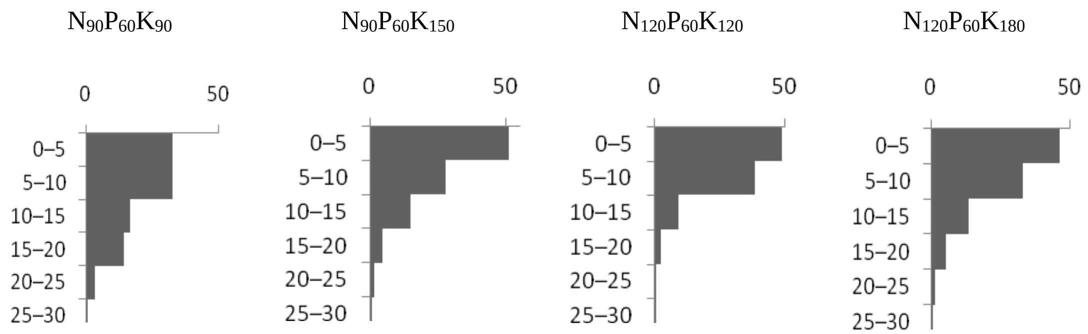


Fig. 3. The dynamics of the vertical. distribution of ^{137}Cs in the al.luvial. soil of the floodplain meadow depending on the agrochemical. methods of improvement, % of the total. specific activity of ^{137}Cs of a 60-cm layer

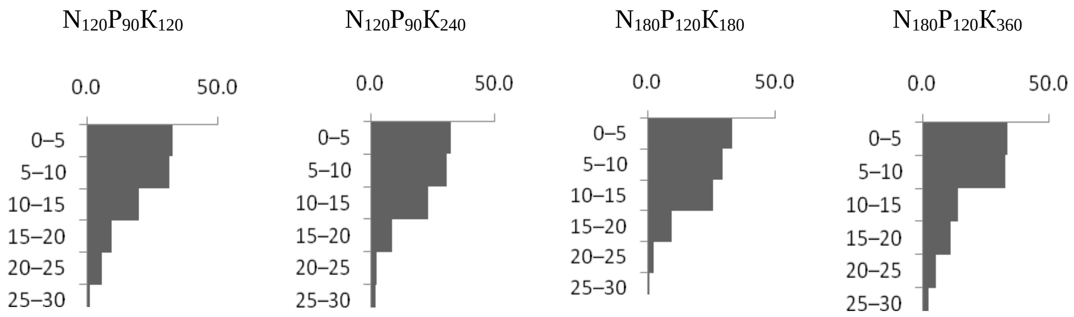
As a result of the re-staging of 2008 and the modification of the doses and ratios of mineral. fertilizers provided for by the research program for 2009-2015, the distribution of ^{137}Cs in the profile of al. luvial. soil al.so changed. Doses of potash fertilizer over 120 kg increased ^{137}Cs concentration in the 0-5 cm layer. A tendency was found for the radionuclide to migrate from the underlying layers to the upper root layer.

When conducting surface improvement and applying mineral. fertilizer in the doses and combinations prescribed by the research program for 1994-2008, the specific activity of ^{137}Cs was equal. ized in layers of 0-5 and 5-10 cm (Fig. 4). After reloading in 2008 and changing the doses and ratios of mineral. fertilizers provided for by the research program for 2009-2015, there was an increase in the specific activity of ^{137}Cs in the 10-15 cm layer, due to a decrease in the underlying layers. A further upward migration of ^{137}Cs was established in layers 0-5 and 5-10 cm compared to 2007.

When carrying out a radical. improvement and the introduction of mineral. fertilizer in doses and combinations in the period from 1994 to 2008, it was found that increasing doses of potassium fertilizer led to an increase in the specific activity of ^{137}Cs in layers 0-5 and 5-10 cm. From 2009 to 2015 the year, the tendency for ^{137}Cs to migrate to the upper layers from the lower continued, and at the same time, a leveling of the specific activity of ^{137}Cs in the root-inhabited layer of 0-20 cm, characteristic of the combination of radical. improvement and the introduction of mineral. fertilizer, was found.

Figures 3 and 4 show the profiles of al. luvial. soil 0-30 cm, and the specific activity of ^{137}Cs in percent is considered in the 60 cm layer, this is due to the fact that the bulk of ^{137}Cs is concentrated to a depth of 30 cm. The specific activity of ^{137}Cs in the 30-60 layer on in a natural. meadow depending on fertilizer doses was 5% in 2007, on a superficial.ly improved floodplain meadow - 3.5%, with a radical. improvement in the floodplain meadow - 9% of the total. specific activity of ^{137}Cs of the 60-cm layer, a decrease in the specific activity of ^{137}Cs in layer 30 -60 cm reveal.ed in 2015.

Superficial. improvement of a natural. meadow



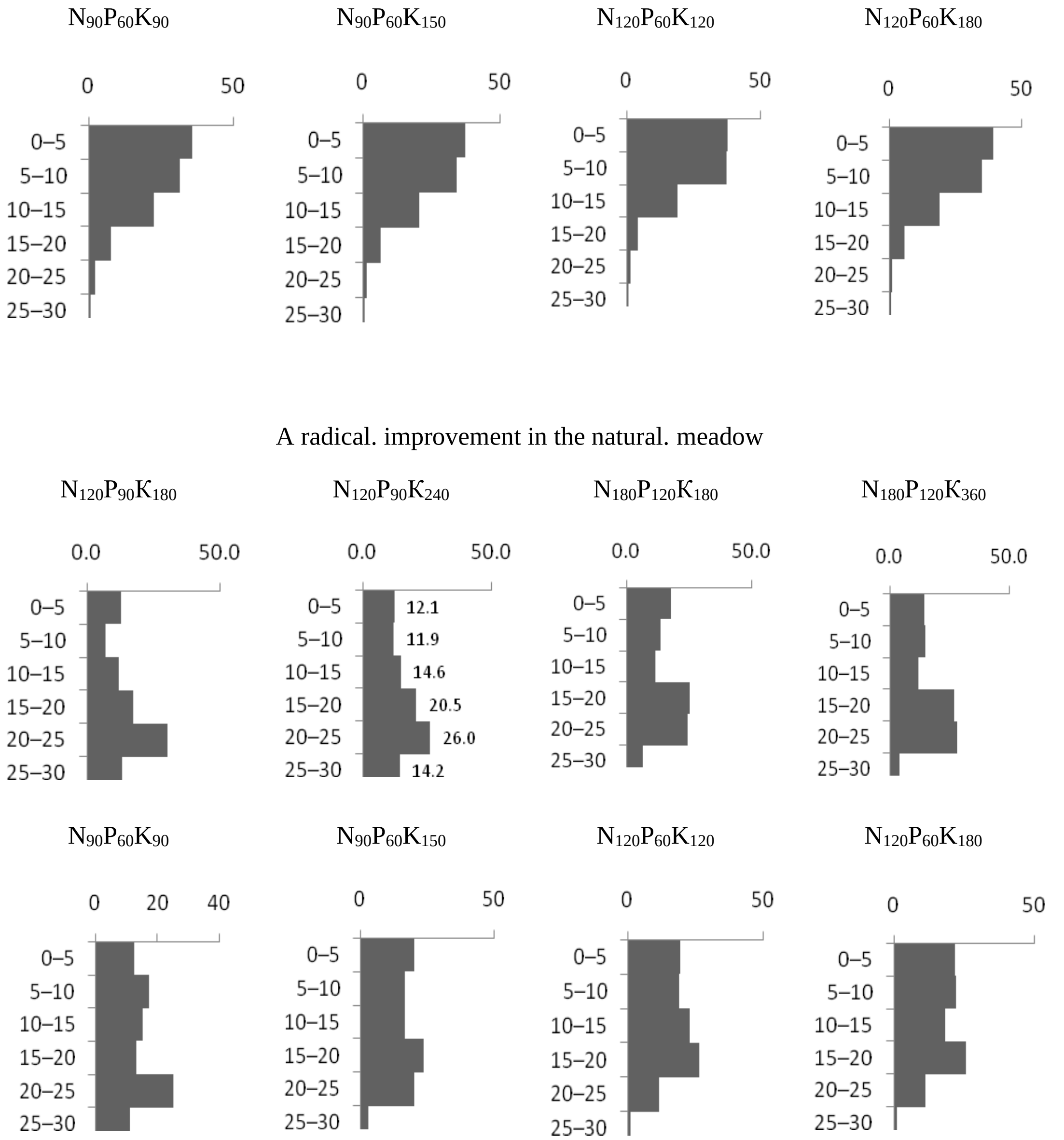


Fig. 4. Dynamics of the vertical. distribution of ^{137}Cs in al.luvial. soil depending on agrotechnical. and agrochemical. methods of improvement, % of the total. specific activity of ^{137}Cs of a 60-cm layer

Measures to improve radioactively contaminated floodplain meadows reduce the specific activity of ^{137}Cs of al.luvial. soil, redistributing the radionuclide with a radical. improvement below the root layer deeper than 20 cm, which reduces the absorption of ^{137}Cs by the roots of perennial. grasses and leads to the return of fodder lost in the Chernobyl accident to agricultural. circulation.

In radioactively contaminated field agrocenoses, a similar effectiveness of rehabilitation measures was reveal.ed (Anisimov et al., 2018; Fokin et al., 2016; Zibold et al., 2009).

The reveal.ed features of the distribution of ^{137}Cs al.ong the profile of al.luvial. soil of the central. floodplain of the river. Depending on the period of time that has passed since the Chernobyl accident and the ongoing rehabilitation measures, it is possible to use the recommended conversion factors to predict the level of feed radionuclide contamination when using these floodplain meadows as hayfields or pastures. Ultimately, this is important when planning activities for the rehabilitation of contaminated sites. The data obtained are consistent with previously obtained models of the behavior of the radionuclide in river floodplains (Bister et al., 2015).

Discussion

The presented monitoring of changes in the agrochemical. properties of the soil confirms that the complex of rehabilitation measures on natural. forage lands not only reduces the intake of radionuclides in fodder production, but al.so preserves the soil fertility of al.luvial. soils.

The total. specific activity of ^{137}Cs in a layer of 0-60 cm of al.luvial. soil decreases in al.l cases of rehabilitation measures in the floodplain meadow. Moreover, the density of ^{137}Cs reserves in floodplain soils increases to layers of 0-5 cm and 5-10 cm, which indicates the fixation of ^{137}Cs by the roots of perennial. grasses, as well as the low migration ability of the radionuclide.

The vertical. distribution of radiocesium in the floodplain soils of the accident zone at the Chernobyl nuclear power plant depends on the rehabilitation measures carried out, it is determined that at the first stage of overcoming the effects of artificial. radionuclide emissions, it is necessary to apply a radical. improvement in floodplain meadows to transfer radionuclides from the root layer to the depth of the soil profile.

Conclusion

The use of the meadow of the central. floodplain of the Iput River in the Novozybkovsky District of the Bryansk Region as hayfields does not change the agrochemical. indicators of the fertility of al.luvial. soil. A radical. and surface improvement with the introduction of mineral. fertilizers increases the content of nutrients in the soil.

From the moment of the Chernobyl accident until 2015, the total. reserves of the radionuclide in the al.luvial. soil of the floodplain meadow decreased by 2 times, the application of surface and radical. improvement together with the introduction of mineral. fertilizer accelerated the process of ^{137}Cs removal. from the soil, the maximum decrease in its reserves compared to the initial. amount reached 3.4 times.

Studying the distribution of ^{137}Cs al.ong the profile of al.luvial. soil in the central. floodplain of the river. Hyput reveal.ed that at the initial. stage of research, the bulk of ^{137}Cs was in a layer of 0-5 cm; however, after 21 years, a uniform decrease in the distribution to a depth of 20 cm occurred. The application of mineral. fertilizers contributed to the equal.ization of the specific activity of ^{137}Cs in layers 0-5 and 5-10 cm, the radical. and surface improvement with the introduction of mineral. fertilizers enhanced the equal.ization of the specific activity of ^{137}Cs in the layers 0- 5, 5-10, 10-15 and 15-20 cm.

The migration of ^{137}Cs to the root layer of the soil from the underlying layers was reveal. ed under the influence of increasing doses of mineral. fertilizer.

At the initial. stage of rehabilitation of floodplain meadows, it is necessary to carry out a radical. improvement (the use of deep two-tier plowing), which led to a maximum decrease in specific activity in the root-inhabited layer of al. luvial. soil.

* – The studies were carried out with the financial. support of the Russian Federal. Property Fund and the Administration of the Bryansk Region as part of the scientific project No. 18-44-320001.

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ISSN 2322- 6307