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Use of Local Natural Resources to Reduce the Chernobyl Radiocesium Trace in Agriculture

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Abstract

The search for ways to reduce the Chernobyl radiocesium trace in agriculture has been a relevant task in Kaluga Region for many decades. This problem particularly concerns personal subsidiary farms that did not take any centralized protective measures on rehabilitation of polluted soils. In this regard the purpose of the study was to develop measures of safe economic use of personal subsidiary garden soils and natural meadows as hayfields and pastures. The study utilizes comparative and analytical, instrumental and statistical methods. Based on the study of dynamics of natural change of specific activity of meadow plant formation, alluvial soil and cattle milk the half-reduction period for the level of bioproduct pollution within 7--8 years caused by stronger binding and physical disintegration of radiocesium is defined. Seasonal dynamics of radiocesium reduction in hay of a meadow ecosystem and milk of cows of personal subsidiary plots from April to July of the vegetative period is established. The radio reclamative ability of activated sludge and ground tripolite when receiving products in personal subsidiary plots is proved.

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1. Introduction

The Chernobyl accident led to radionuclide contamination of huge territories, including 10 areas of Kaluga Region and, in particular Hvastovichsky, Zhizdrinsky and Ulyanovsk districts that require continuous monitoring. The main land pollutant in the region is caesium-137 of the Chernobyl trace, which represents a certain biodanger to the region. According to the law of ten physical half-life periods, full rehabilitation of ^{137}Cs polluted lands will require 250--300 years. Therefore, the problem of receiving ``clean'' agricultural products satisfying radio environmental standards established by SANPIN-2.3.2.1078-01, as well as reducing radiation doses of public exposure is still particularly acute for this region [1--3].

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2. Problem Statement

Special protective measures subsidized from the federal budget made it possible to stabilize the radiation situation in polluted territories. In this regard personal subsidiary farms (PSF) remained ``unprotected'' due to the lack of organized counter-measures at personal plots and small pastures for cattle grazing [4--6]. Hence, there is a need to search for cheap protective measures available to the population of polluted territories aimed to reduce the content of radiocesium in PSF products, to increase environmental safety and economic attractiveness in the market [7--9].

The purpose of the study was to analyze the dynamics of natural change of specific activity in herbage, alluvial soil, cattle milk and to develop measures to reduce the content of radiocesium in PSF products in radioactively contaminated territories of Kaluga Region due to the use of local resources.

3. Materials and Methods

The research work regarding this problem was carried out during 1997--2016 at APC Lesnye Polyany (Ukolitsa village) of Ulyanovsk district, Kaluga Region. Three personal subsidiary plots 25 hundred meters each used for cattle pasture in the flood plain of the Sorochka River were chosen for experiments. No protective measures in these farms were earlier held. The soil cover of these personal subsidiary plots is presented by derno-average podzolic middle loamy soil with humus content of about 2 %; labile phosphorus -- 90--105; exchangeable potassium -- 80--85 mg/kg; pHsalt -- 4.7--5.1 and radiocesium pollution density -- 7.5 Cu/km^2. The inundation plot is presented by alluvial meadow loamy soils with humus content of 2.6 %, labile phosphorus -- 115--120, exchangeable potassium -- 90 mg/kg, pHsalt -- 5.0-5.2 and ^{137}Cs pollution density -- 6.8 Cu/km^2. Potatoes are continuously cultivated in gardens at systematic introduction of manure, and cattle of personal subsidiary plots is freely grazed on a flood plain. In particular years the flood plain is flooded with spring waters, and alluvial deposits of up to 1 cm are accumulated there.

Activated sludge from a biological pond located 15 km from Ulyanovo village and ground tripolite from CJSC Sorbent on the production of bleaching earth (Zikeevsky plant of Zhizdrinsky district) located 30 km from of Ukolitsa village were used in experiments. Activated sludge and tripolite have all necessary positive sanitary and hygienic conclusions of the Kaluga Center of Sanitary and Epidemiological Inspectorate. Activated sludge (AS) has the following characteristics: humidity -- 60 %; pHsalt -- 6.8;

content of organic matter -- 50 %; N_{tot} -- 3.3 %, P_2O_5-- 5.4 %, K_2O -- 1.5 % in dry matter and very low concentration of Pb, Cd, Ni, Cu, Cr, Zn. Ground tripolite (GT) is a complex mixture of minerals consisting of calcite, zeolite, quartz, feldspar, mica, clay and others. Zeolite, a natural adsorbent, defines the main value of tripolite. Activated sludge in a dose of 10 t/ha in dry matter and ground tripolite in a dose of 8 t/ha were introduced in autumn under plowing in gardens and in a superficial manner on inundated meadows according to the following scheme: 1) control; 2) AS, 10; 3) GT, 8; 4) AS, 10 + GT, 8.

The areas of experimental plots made 50 m^2 (10×5 m). The experiments were carried out in three replications on personal plots and in a flood plain. The accounting of potato tuber yield was made in September during harvesting, and the biomass of pasturable grass was carried out three times: in the middle of May, July and September. Radiocesium content in yield was defined by express method according to γ-radiation using RUB-6 gamma spectrometric radiometer.

4. Results and Discussion

Features of radionuclide localization in soil of grassy ecosystems and feature of root nutrition of grassy plants lead to the fact that plants of natural meadows are much more polluted in comparison with artificial grass of agroecosystems and other agricultural crops. At the same time natural meadows are characterized by the accumulation dynamics of radionuclides as part of plants: maximum intake is noted during the first weeks of vegetation, then, in the process of biomass accumulation and shift of root absorption in the underlying horizons of soil, as well as partial washing out of radionuclides from vegetative plants, their content is reduced by unit of plant biomass. Fig. 1 shows that the main part of ^{137}Cs got to meadow plants during the period until May 20. During this time plants formed about 30 % of the maximum above-surface phytomass. Later the phytomass gain was almost not followed by the total removal of radionuclides, and at final stages of vegetation there was even some reduction of their content due to loss of dried parts of plants, lifelong washing out of ^{137}Cs from elevated bodies or outflow of radionuclides to plant roots.

Earlier studies illustrate significant influence of specific activity of herbage on the level of milk contamination (Fig. 2 and 3).

According to obtained data, there is an increase of radionuclide binding by soil through time intervals of 5 years and, respectively the reduction of the contamination level of hay from a natural meadow and milk. The period of half reduction of the contamination level of primary bioproducts of this natural meadow is about 7--8 years.

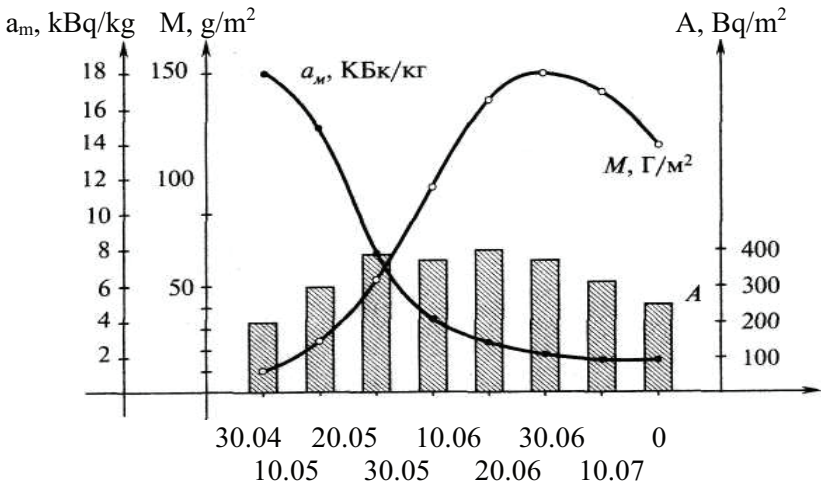

Figure 1: Dynamics of specific activity of plants (a_m), land biomass (M) and total content of ^{137}Cs as a part of land biomass, A (histograms) in the conditions of a damp meadow (flood plain of the Sorochka River, sandy loam alluvial meadow soil).

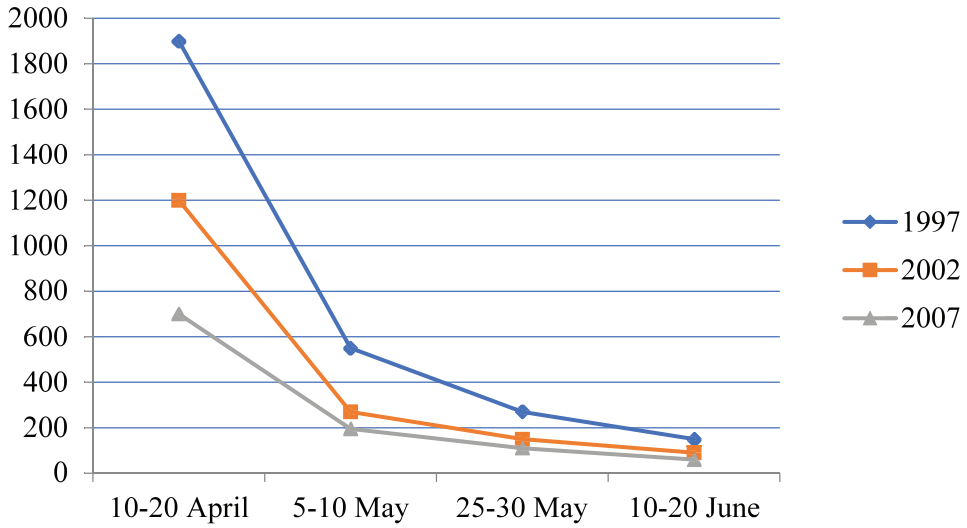

Figure 2: Dynamics of the Chernobyl radiocesium trace in herbage of a natural meadow (APC Lesnye Polyany, 1997--2007).

In this case the reduction is mainly caused by the strength of radionuclide binding by soil and (to a lesser extent) by physical disintegration of ^{137}Cs. The calculations showed lack of radionuclide removal from top horizons during the study [10].

The given examples justify the search for safe economic use of natural meadows as hayfields and pastures, as well as personal subsidiary garden soils. While solving the problems of net production from personal subsidiary plots and agricultural industry in general we conducted long-term study of the influence of tripolite and activated sludge on radionuclide intake by potatoes crops and gramma grass.

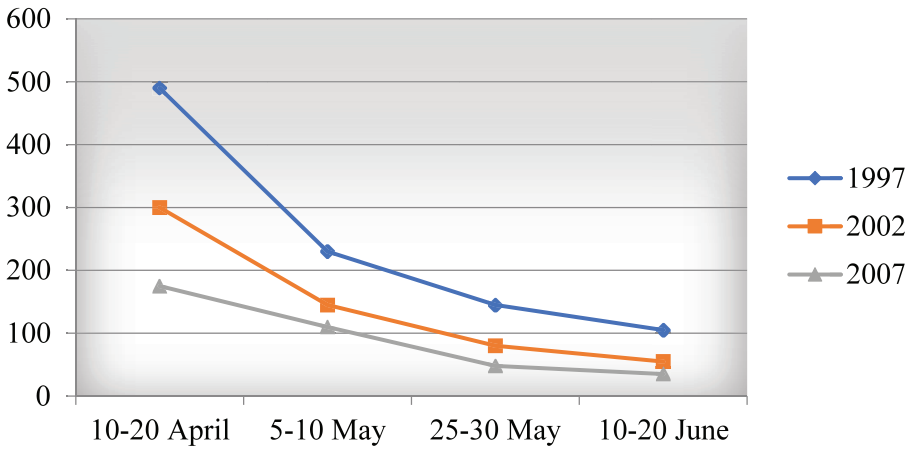

Figure 3: Dynamics of the Chernobyl radiocesium trace in cow milk (APC Lesnye Polyany, 1997--2007).

The results of the study are presented in Tabl. 2 and 3. The introduction of activated sludge and ground tripolite increases productivity of potato tubers in personal subsidiary plots from 110 to 155 and 136 c/ha respectively. Their joint introduction increases the productivity of potato tubers to 172 c/ha. The greatest reliable increase of potato tubers is reached at joint introduction of activated sludge and ground tripolite -- 62 c/ha (Tabl. 2).

TABLE 1: Productivity and specific activity of potato tubers (average data for 1997--2016) in experiments on personal plots.

Option (AS and GT, t/ha)	Yield, c/ha	Specific activity, Bq/kg
Control	110	105
AS, 10	155	48
GT, 8	136	55
AS, 10 + GT, 8	172	38
	HCP_{05} = 15.0 c/ha	SanPiN -- 01 = 120 Bq/kg

The studied local resources (AS and GT) have radio meliorative properties and reduce the content of radiocesium in potato tubers. Thus, with the introduction of AS the specific activity of potato tubers decreases from 105 Bq/kg to 48 Bq/kg, GT -- to 55 Bq/kg, AS + GT -- to 38 Bq/kg. The greatest effect is reached at joint introduction of AS + GT, the difference in comparison with the control option reaches 67 Bq/kg. The frequency rate of radiocesium reduction in potato tubers in experimental plots makes 1.9--2.8 times.

In experiences on a flood plain with the introduction of AS and GT the biomass of gramma grass also increases from 26 to 41 and 36 c/ha (Tabl. 3). At their joint introduction the biomass of gramma grass increases to 52 c/ha. AS and GT reduce specific activity of gramma grass at separate introduction from 625 Bq/kg to 310 and

350 Bq/kg respectively, and at joint introduction up to 290 Bq/kg. The content of ^{137}Cs in hay in the control area exceeds the admissible level 1.7 times. The introduction of AS and GT separately or jointly leads to 1.8--2.2 multiple decrease of ^{137}Cs concentration in biomass of gramma grass.

Table 2: Total biomass and specific activity of gramma grass (average data for 1997--2016).

Option	Biomass, c/ha	Specific activity, q/kg
Control	26	625
AS, 10	41	310
GT, 8	36	350
AS, 10 + GT, 8	52	290
HCP_{05}= 4.0 c/ha	MAL = 370 Bq/kg	

According to us, the radio meliorative effect of AS and GT in products of personal subsidiary plots is reached due to such processes as effect of ``dilution'', increase in ^{137}Cs sorption by soils and ameliorants, as well as partial blocking of the absorption mechanism of this radionuclide by the root systems of plants due to available chemical analogs in these complex ameliorants.

5. Conclusion

The study of the dynamics of natural change of specific activity of meadow grass, alluvial soil and cattle milk made it possible to establish a half reduction period of bioproducts contamination within 7--8 years caused by stronger binding and physical disintegration of radiocesium. Seasonal dynamics of radiocesium reduciton in hay of a meadow ecosystem and cow milk of personal subsidiary plots from April to July of the vegetative period is established.

Long-term field studies made it possible to establish that local resources such as activated sludge and ground tripolite are key in increasing the productivity of potatoes and hay of gramma grass in personal subsidiary plots and reducing radiocesium content by 1.8--2.8 times. Therefore, AS and GT can be recommended as an available method of increasing radio environmental safety of farm products in radioactively contaminated territory of Kaluga Region after the Chernobyl accident.

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