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Recultivation of soils contaminated with radionuclides by phytomelioration

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Abstract. The use of aqueous solutions of ammonium nitrate and microorganisms in the proposed method will intensify the transition of radionuclides into soluble forms for assimilation by the root system of plants, obtaining maximum biomass of plants accumulating radionuclides, and significantly reducing the growing season. The process of obtaining biomass using the above technology makes it possible to repeat this method of purification many times, including within one seasonal period, until the content of radionuclides in the soil reaches acceptable values, after which the soil becomes suitable for agricultural use. The purpose of the study. Consider the transition of radionuclides into soluble forms for assimilation by the root system of plants. Material and Methods. To substantiate the possible directions of soil reclamation, we propose a conceptual model of radionuclide transport in the agrocenosis, on the basis of which a functional scheme for recultivation of soils contaminated with radionuclides has been developed. The collected biomass and the root system of plants must be disposed of. Due to the fact that large volumes of mass are subject to disposal, it is subjected to heat treatment - drying. Keywords: phytomelioration, soil reclamation, contamination radionuclides, azotobacterin

1 Introduction

The urgency of the problem of recultivation of soils contaminated with radionuclides is now more acute than ever. As a result of the escalating geopolitical conflict around the world, there is a possibility of a threat of a nuclear explosion, the consequences of which will be catastrophic.

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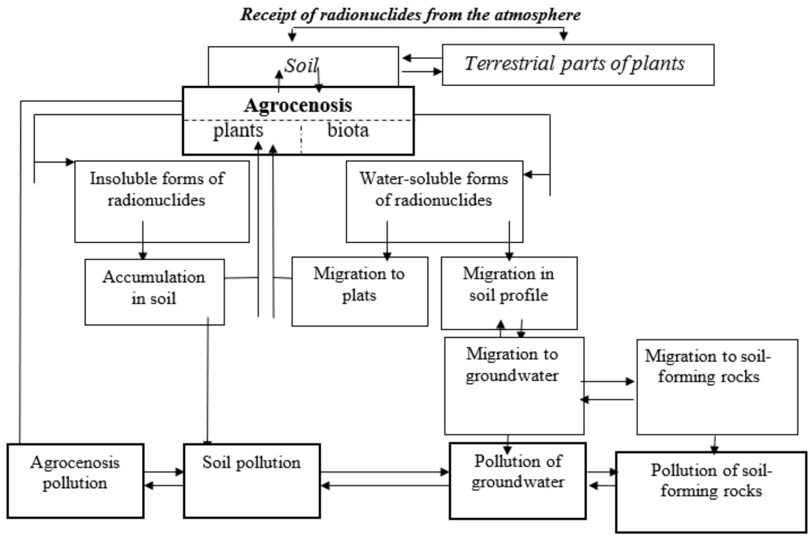

Fig. 1. Conceptual model of radionuclide transport in agroecosystems.

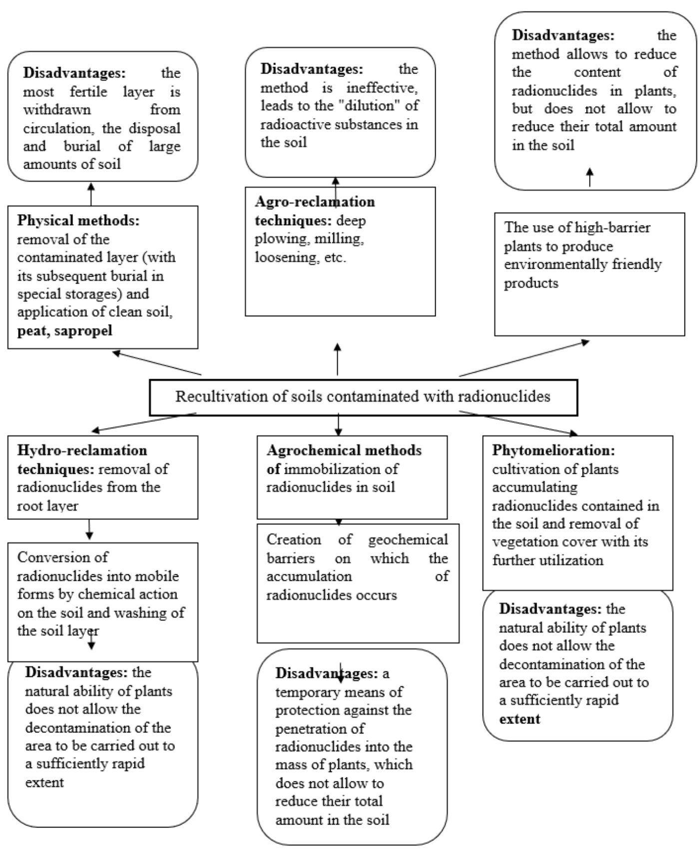

Fig. 2. Methods of recultivation of soils contaminated with radionuclides.

2 Material and Methods

To substantiate the possible directions of soil reclamation, we propose a conceptual model of radionuclide transport in the agrocenosis (Fig. 1), on the basis of which a functional scheme for recultivation of soils contaminated with radionuclides has been developed (Fig. 2).

There are several systems of measures to eliminate pollution of agricultural land. The analysis of the literature does not provide any universal methodology for the reclamation of soils contaminated with radionuclides. When evaluating various methods of reclamation of soils contaminated with radionuclides, three criteria must be taken into account: environmental safety, technological efficiency, and economic profitability.

Phytomelioration technology is aimed at restoring the soil and eliminating contamination with radioactive elements. This technology is large-scale, it can be successfully used as an active means of purification from radionuclides in vast areas that have been contaminated, without the need to remove, transfer and recycle the soil and mechanical impact on it. Since phytomelioration is implemented on the principle of soil purification without excavation, it requires much less costs in comparison with engineering technologies with excavation. Phytomelioration is much more economical than physico-chemical and chemical reclamation, at the same time it requires more costs than natural cleaning of polluted soil. However, for the natural cleaning of soil contaminated with radionuclides, very long recovery periods to the level of environmental safety are required.

The essence of the technology is to use the method of phytomelioration, in combination of chemical and microbiological factors affecting the soil and plants. The technology of soil purification from radionuclides consists of the following stages: 1. determination of the type and physico-chemical properties of the soil in the contaminated area; 2. depending on the type of soil, a group of sorbent plants is selected with the maximum intensity of accumulation of cesium-137 and strontium-90 radionuclides characteristic of this type of soil. To select sorbent plants, we use data on the intensity of accumulation of cesium-137 and strontium-90 radionuclides by plants. Before direct transfer to the soil, the seeds of sorbent plants are treated with an aqueous suspension of Azotobacter chroococum; 3. soil treatment with an aqueous solution of ammonium nitrate salts followed by planting of sorbent plant seeds; 4. during the active maturation and development of cultivated plants, repeated soil treatment with an aqueous solution of ammonium nitrate salts is carried out; 5. collection of root and ground parts of plants with subsequent drying; 6. disposal.

Plants that are used to extract radionuclides from contaminated soils must meet a number of requirements: be tolerant to high concentrations of radionuclides, capable of absorbing and accumulating the maximum amount of radionuclides, efficiently transport them from the root system to the ground-pressed mass, have a deeply expanding root system, high resistance to diseases and pests, convenient for harvesting and unattractive for domestic and wild animals.

3 Results and discussion

The technology provides for the treatment of a mixture of sorbent plant seeds with an aqueous suspension of Azotobacter chroococum before transferring them to the soil for final cultivation, which spread from seeds to young roots, continuing their activities. The use of active microorganisms in the proposed method, such as Azotobacter chroococum (azotobacterin), belonging to the class of aerobic bacteria capable of fixing nitrogen and improving nitrogen nutrition of plants, stimulating the germination of plant seeds, accelerating their growth and significantly reducing the growing season. Azotobacterin improves the growth of biomass and the root system of plants, increasing the germination rate, lengthening the stem, increases the size of the leaves, leads to early flowering and fruiting. Its positive effect on plants is associated with the entry into plants of biologically

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active compounds produced by the microorganism – vitamins and growth stimulants. Azotobacterin produces a fungistatic substance – an antibiotic active against a significant number of phytopathogenic fungi that delay plant growth [1].

To intensify the process of soil purification, the proposed method of soil purification from radionuclides includes the introduction of inorganic compounds into it. Before planting sorbent plants, the infected soil layer must be treated with an aqueous solution of ammonium nitrate salts. During the period of active maturation and development of cultivated plants, the soils are re-treated with the above solution, and upon reaching the maximum seasonal biomass, the vegetation cover and the root system of plants are removed. The collection of biomass and the root system of plants should be carried out at the end of the seed ripening period.

Radionuclides on polluted soils are mainly concentrated mainly in the 0 – 30 cm layer, as evidenced by numerous sources [2]. Up to 90-95% of radionuclides are in a fixed, strongly bound to humic acids form and only about 1-3% in a water–soluble form. It is known that nitrogen fertilizers, especially physiologically acidic ones, contribute to the accumulation of caesium-137, strontium-90 and most of the studied radionuclides twice or more [3]. Soil treatment with solutions of inorganic compounds not only contributes to the transfer of radionuclides into soluble forms, keeping them in this state for a long time, but also contributes to an increase in the content of humic acids in the soil, due to the presence of - groups [4]. This creates conditions for intensive assimilation by plants of radionuclides in a soluble form, and the amount and concentration of an aqueous solution of ammonium nitrate salts are selected from the condition that prevents the suppression of cultivated plants.

The choice of the time of re-treatment is due to the period of active vital activity of plant growth and maturation, which allows for the process of intensive accumulation of radionuclides by them [5].

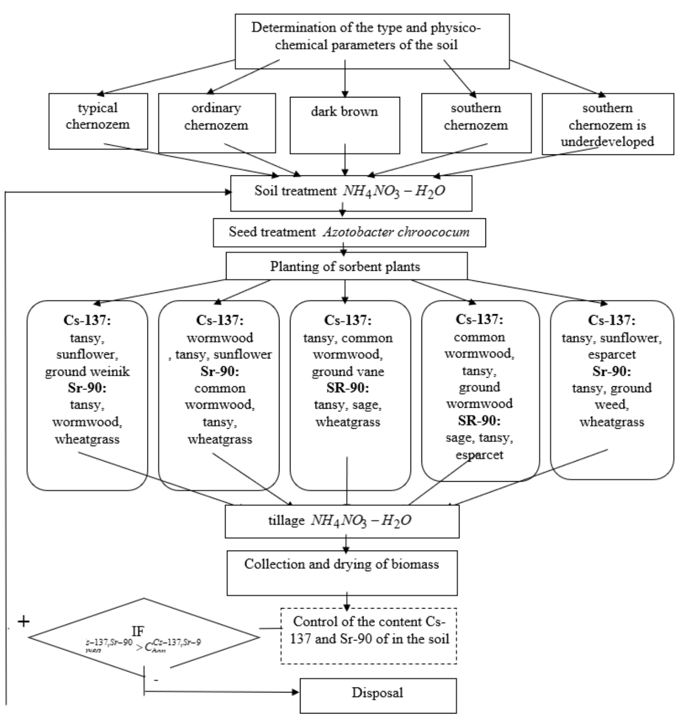

Fig. 3. Algorithm of phytomelioration technology of steppe zone soils contaminated with radionuclides caesium-137 and strontium-90.

The use of aqueous solutions of ammonium nitrate and microorganisms in the proposed method will intensify the transition of radionuclides into soluble forms for assimilation by the root system of plants, obtaining maximum biomass of plants accumulating radionuclides, and significantly reducing the growing season [6].

The process of obtaining biomass using the above technology makes it possible to repeat this method of purification many times, including within one seasonal period, until the content of radionuclides in the soil reaches acceptable values, after which the soil becomes suitable for agricultural use.

4 Conclusion

The collected biomass and the root system of plants must be disposed of. Due to the fact that large volumes of mass are subject to disposal, it is subjected to heat treatment - drying. Heat treatment of biomass is carried out by drying it in conditions of natural convection at an air temperature not exceeding 90-95 0C. Heating of the air to the drying temperature of biomass is carried out by gradually increasing the air temperature at a rate not exceeding 2 0C / min (Pat. 2028678, 1995). These drying conditions make it possible to prevent local overheating and local boiling of raw biomass, which does not lead to the release of activity into the environment during this treatment. Dried, concentrated in small volumes, plant biomass containing sorbed radionuclides is subjected to burial.

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