The diffraction peaks are identified, the corresponding structure of montomorillonite, illite and quartz. The remaining mineral phases (biotite, K-feldspar, sericite) are subordinate. Main CSS components are calcium and magnesium compounds, sulfates, carbonates, chlors, nitrates and other electrolytes. Clay-salt slimes have several important properties such as hydrophilicity, swelling, high dispersion (the slimes contain 60-70% of particles smaller than 0.05 mm). Clay-salt slimes are characterized by high specific surface area (40-45 m²/g) and a significant degree of defectiveness of the crystal structure that stimulates their high sorption capacity. Cation exchange capacity CSS is 7-12 meq/100g and is determined only by the content of aluminosilicates in them. The use of clay-salt slimes as sorbents of radionuclides is reasonable because of their content of KCl up to 15%, biologically active trace elements (Mn, Cu, Mg) and the presence of aluminosilicates. CSS are characterized by highly selective sorption with regard to 137Cs:

![Sample](image)

Use of CSS as a mineral additive to sapropels will increase their sorption properties and significantly increase fixation of radionuclides during the rehabilitation of the contaminated soils. For this means, clay-salt slimes are applied as perspective inorganic additives to the amendments, intended for carrying out rehabilitation of radioactive contaminated soils. The results of the laboratory experiments on 137Cs sorption by the CSS samples can be displayed via sorption isotherm:

As can be seen from the sorption isotherm, the curve can be divided into two parts, described by the linear form of the Langmuir equation. The first part describes sorption on the Frayed Edge Sites (FES), the second – on the Highly Affinitive Sites (HAS). Availability of these specified sorption sites explains the high capacity for selective sorption in relation to 137Cs, observed in the CSS samples.

4. Results and discussion

In the course of the long-term research that was carried out by the Laboratory staff within the framework of the national programs for rehabilitation of the radioactive contaminated soils in Belarus, as well as the results of the ISTC projects №859 and №3189, the following results were obtained:

1) Analysis of physicochemical, agrochemical and sorption properties of soils, sapropels (organic; silicon; carbonate), hydrolyzed lignin (acid, neutralized), clay-salt slimes and organomineral amendments (OMA) on their basis was carried out.

2) Sorption-desorption kinetics of 137Cs and 90Sr was determined by soils, sapropel, hydrolyzed lignin, clay-salt slimes.

3) The effect of the OMA application on the soils contaminated by radionuclides was studied:

a) physicochemical properties of soils and amendments; b) essential dependence on the quantitative parameters which describe behavior of radionuclides in soils and amendments. Amendments containing CSS are the most perspective for protection of 137Cs and 90Sr migration from soils into plants.

4) A methodology of purposeful search of substances and materials as a sorbent of radionuclides of 137Cs and 90Sr was developed with use of the following parameters: a) the content of exchange forms of radionuclides; b) cation exchange capacity (CEC); c) Radicaesium Interception Potential (RIP).

5) A technical specification draft on amendments composition was prepared.

6) The Technology Implementation Plan for amendments production, based on the natural raw material and industrial waste and their testing on the radioactive contaminated soils in Belarus and other countries was developed, two patents of the Republic of Belarus have been received.

5. Conclusions and Acknowledgements

- The obtained results indicate high sorption properties of the amendments based on sapropels and clay-salt slimes and the prospects of their use for rehabilitation of radioactively contaminated soils.

- The given approach could be used in Japan for rehabilitation of radioactively contaminated as a result of the nuclear accident at Fukushima soils, and in other countries for minimization of the consequences of a possible radiation accident.

- The authors gratefully acknowledge the ISTC management which as a result of the project №3189 has made a significant contribution to the presented results.

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**Sapropel:**
- The phase composition of the CSS samples was determined.
- **Chemical analysis:**
  - Sodium-podzol soils
  - Sapropel (silica)
  - Clay-salt slimes

**Theoretical aspects of 137Cs behavior in soils**

One of the main factors governing the redistribution of 137Cs and 90Sr in ecosystems is the mobility of radionuclides in soil on the contaminated areas. The physicochemical conditions and migration properties of the radionuclides impact seriously the radioecological situation of an ecosystem as a whole. The most important role in the process of migration of the radionuclides through a soil profile plays the soil solution, composition and physicochemical characteristics on which the level of the radionuclides depends. The mobility of 137Cs strongly depends on the concentration of cations K⁺ and NH₄⁺, competing for sorption centers.

In general the triply charged cations are adsorbed by soils more efficiently than the singly charged cations, and the doubly charged cations occupied the intermediate position. However, this rule is not true for the singly charged cations such as K⁺, Ca²⁺, Mg²⁺, which exhibit ability to be specifically adsorbed on a particular type of kaolinite clay minerals, fully occupying the negative surface charge of kaolinite particles. The properties of kaolinite particles are directly related with the availability of minerals of certain groups in the soil, primarily the clay and mica minerals, and energy heterogeneous of the binding sites which can be unique among the cations.

Three types of binding sites in increasing order of the selective sorption of the singly charged cations are usually distinguished:

1. **The Regular Edge Sites (RES),** located on the flat outer faces on the surface of mineral and micaceous substances.
2. **The Frayed Edge Sites (FES),** which are located on the edges and the extended boundary (edge) zone of the layered structure of minerals.
3. **The Highly Affinitive Sites (HAS),** which are located deep in the interlayer-space of the clay lattice of minerals.

Energetic heterogeneity of binding sites explains the specificity of 137Cs sorption. Only 137Cs which was sorbed at RES retains the ability to exchange easily for other cations in soil solution. The sites (FES and HAS) are referred to as a specific sorption sites and are responsible for selective sorption and fixation of 137Cs. Exchange of 137Cs in the cations Ca²⁺, Mg²⁺ and Na⁺ is hampered when placed on FES.

It can be concluded from the above that the specific sorption of 137Cs in different types of soils is driven by clay minerals with the specific surface of 2.1 m², which are present in a particular soil type in different quantity. Thus, features of the 137Cs behavior in each soil will be determined by the special characteristics of its mineralogical composition.

3. Objects of investigation and obtained results

Within the framework of the ISTC project №3189 the complex of research on the properties and characteristics of natural raw materials, industrial wastes, and different types of soils in Belarus has been executed. As a result of its implementation, amendments on the basis of sapropels and industrial waste (clay-salt slimes) have been developed intended for the rehabilitation of radioactively contaminated soils.

3.1. Sapropels

Sapropels are the substances of biogenic origin, which are formed by animal and vegetable remains at the bottom of freshwater lakes where there is a lack of oxygen. There are four types of sapropels in the Republic of Belarus:

1) Organic sapropels
2) Silicon-sapropels
3) Carbonate-sapropels
4) Silicate-sapropels

Theoretical and applied research carried out during 1988-2010 (Belgium, Belarus) has shown that sapropels have high sorption properties both in terms of radionuclides, and radionuclides show one type of sorption depending on the extent of sorption of radionuclides differs significantly. It is indicated that organic sapropels, which are characterized by high values of cation exchange capacity (CEC), are more effective for the sorption of radionuclides. While the silica, which have the highest Radicaesium Interception Potential (RIP) values will be the most effective for the sorption of radionuclamps.