Possibility Determination of Using Saponite in Agriculture

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Abstract. The article analyzed the possibility of using saponite as an ameliorant. In a model experiment, the effect of saponite on soil acidity, the content of biogenic elements (nitrogen, phosphorus, potassium), and productivity were studied. We found that introducing various doses of saponite does not affect the accumulation of water in the soil. It does not play the role of a deoxidizer and does not saturate the soil with nutrients, but prevents the removal of mobile nitrogen and potassium from the soil. Saponite does not increase soil productivity, but can affect the green mass productivity.

1. Introduction

The Arkhangelsk Region is rich in forest and water resources. It has mineral resources for hydrocarbons and the diamond mining industry. The Arkhangelsk diamond deposit, in contrast to others, contains kimberlite rocks of smectite category minerals, such as saponite. In the enrichment kimberlite ores up to 1 million tons of waste (empty sandy-clayey rocks) are accumulated in the tailing dump annually [1]. Large-scale saponitization is a feature of the deposits in the Arkhangelsk diamond province [2-3]. Because of such a large accumulation of waste, the area of tailings is constantly increasing. This entails a significant increase in anthropogenic pressure on the ecosystem.

The problem solution of recycling waste from the diamond mining industry is to use waste, especially saponites in various fields of industry and agriculture. Many authors [4-8] describe that saponites have a lot of chance of being used as mineral additives to feed and fertilizers for soil detoxification. Therefore, research on the selection doses of saponite-containing materials is needed.

This can lead to an increase in economic efficiency, a reduction in costs, and to decrease in the negative impact on the environment [9-10].

The purpose of this study is to determine the effect of saponite on the physical and chemical soil properties and soil productivity. Thus, it will be possible to evaluate the use saponite as ameliorant and fertilizer.

2. Materials and methods

To test the use of saponite as an ameliorant, we set up 2 model experiments: 1 - to determine the effect of saponite on the content of nutrients (N, P, K) with soil fertilizing; 2 – on the influence of saponite on plant cultivation using oats as the example.

Saponite from the Arkhangelsk kimberlite province contains 5.09% Al₂O₃, 3.14% Fe₂O₃ and 2.56% FeO. Silicon (53.48%) and magnesium (25.94%) predominate in samples of saponite-containing
materials. It also includes iron (7.04%), calcium (4.27%), aluminum (3.87%), sodium (1.065%), potassium (0.992%), hydrogen (0.875%), titanium (0.82%), phosphorus (0.52%), carbon (0.43%) [4]. For the study, we used the soil of the meadow ecosystem, which was not influenced by anthropogenic factors. The soil was sieved through the hole diameter of 2 mm, placed in containers with a volume of 0.0016 m\(^3\) (0.08 * 0.1 * 0.2). Then in the amount of 5 g / 1 kg fertilizer (N : P\(_2\)O\(_5\) : K\(_2\)O = 11 : 10 : 11) was applied. It added water to 20% humidity of the total moisture capacity. We introduced saponite at the concentrations of 12 t / ha, 9 t / ha, 7 t / ha, 4 t / ha into the 2 kg soil. We used a liquid suspension of saponite, which came from the pond zone of the tailing dump of Public Joint Stock Company Severalmaz.

The experiment was carried out in 4 replicates. As a control, it used 4 samples without saponite, but with the addition of fertilizer, and 2 soil samples without saponite and fertilizer. To maintain optimal soil moisture, watering was carried out once a week.

Sampling for chemical analysis was performed at 2, 4, 6, 8, 12 and 16 weeks of the experiment. 80 g samples were taken from each container. To study the effect of saponite on the nutrients, the content of nitrates (standard), mobile compounds of potassium and phosphates have been defined with GOST R 54650-2011. The effect of adding saponite on soil acidity was monitored by pH measuring according to GOST 26483-85.

We also hypothesized that saponite can retain water in the soil. To confirm this hypothesis, the amount of evaporated water was measured weekly.

We investigated the influence of saponite on productivity in a model experiment with oats growing. First, the germination of oat seeds was determined according to GOST 12038-84. Based on this, the seeding rate was determined - 16 seeds per soil weighing 2 kg and an area of 0.02 m\(^2\). We carried watering and loosening of the soil out 2 times a week. Samples for the plant biomass analysis were carried out on the 3rd week of the experiment.

The results were processed by methods using MS Excel and SPSS Statistics. Significant statistical differences were determinate using the Kruskal-Wallis and Mann-Whitney tests. Differences for all analyzes were significant at p <0.05.

3. Results
To determine the effect of saponite on the fixation of water, the mass of evaporated water in the containers was determined weekly. Statistical analysis of the data showed no significant differences in volumes. Thus, the hypothesis that saponite, because of its layered structure, can keep water in the soil, was not confirmed in this model experiment.

The pH values of soil extracts were in the range of 5.10–6.00, which corresponds to this type of soil. There was no statistical difference between the samples with different applied doses of saponite. However, a significant difference in pH values was determined in samples with saponite and fertilizer and control samples without them (figure 1). Apparently, fertilizer influences on the pH value.

![Figure 1. pH of soil solutions in a model experiment.](image-url)
Some authors show that introducing clay material into soils, in particular, saponites, increases the amount of dust and silt particles. This increases the proportion of physical clay and water-resistant aggregates and also helps to stabilize the phosphorus and nitrogen state of the soil nutrient regime.

We have estimated the content of nitrogen, potassium and phosphorus in soil samples. It shows the results in figure 2.

![Graph showing N, P, K content in soil samples](image)

**Figure 2.** N, P, K content in soil samples

In a long-term exposure, the addition of saponite did not lead to the accumulation of mobile compounds of potassium and phosphorus in the soil. We found no statistically significant differences in the samples with the addition of different doses of saponite and fertilizer. We can associate the constant increase in the content of nitrogen from the 4th week of the experiment with the course of nitrification processes in the soil.

According to the research results, it can be concluded that saponite does not enrich the soil with nutrients. We can also note that the saponite adjunction in concentrations from 4 to 12 t/ha with fertilizer does not reduce the content of phosphorus, potassium and nitrogen in the soil and does not neutralize fertilizer. Thus, an increase in the dose of fertilizers when applying saponite is not required.

To test the hypothesis that the saponite introduction has a beneficial effect on plant growth, we set up a model experiment using growing oats as an example. We have determined the oat biomass and the degree of N, P, K removal after 3 weeks of cultivation. The plants were preliminarily removed from the pods and washed from residual soil.

Statistical analysis of the data showed no significant differences in the weight of oat samples grown with the addition of saponite and fertilizer, and one fertilizer (figure 3).
The addition of saponite does not affect the increase or decrease in biomass. However, statistically significant differences were found between the samples biomass grown in soil containing fertilizer and saponite and in soil without treatment, which is apparently because of the effect of fertilization in each box. With an increase in the dose of saponite, an increase in the mass of the aboveground part of plants is observed. Although a statistically significant difference cannot be calculated because of the small number of samples, this hypothesis can be tested in field cultivation experiments. Perhaps the use of saponite will have a positive result and increase the yield of green mass with prolonged exposure.

Since at present there is such an environmental problem as the lack of replacement of nutrients taken out with the harvest and, as a result, land degradation. Therefore, the content of nutrients in the soil samples was determined to study the effect of the introduced saponite before and after the model experiment.

The data analysis showed that the content of potassium and nitrogen in the soil decreased after the model experiment (figure 4). There was no statistical difference in the mobile phosphorus content in the samples before and after the model experiment with the addition of different doses of saponite and fertilizer.

In the experiment with saponite, this decrease averaged 8-12% for potassium, and 35-48% for nitrogen. In samples without saponite, the removal of elements is more significant: for potassium 20-70%, and for nitrogen - 47-50%. We can assume that saponite prevents the removal of nutrients from the soil, especially for mobile potassium.

4. Discussion

As a result of our experiments, we got the following results:

- Our hypothesis that saponite, because of its layered structure, can keep moisture in the soil, has not been confirmed;
- In this model experiment, the hypothesis about the effect of saponite on soil pH was not confirmed because of its properties to act as a deoxidizer;
- Model experience showed the absence of the effect of saponite on the content of mobile compounds of potassium and phosphorus coming from fertilizer, and the addition of saponite during long-term exposure did not lead to the enrichment of the soil with these nutrients;
- There was a constant increase in the concentration of nitrogen throughout the entire duration of the experiment, including in samples without introducing doses of saponite, which is possibly associated with internal processes in the soil (nitrification);
• No statistical difference was found in the mass of oat samples grown with the addition of saponite and fertilizer, and one fertilizer. The addition of saponite did not affect the increase or decrease in plant biomass;

• Statistically significant differences were found in the weight of stems grown in soil containing fertilizer and saponite and in soil without treatment, which may because of the effect of fertilization; it revealed no influence of saponite on the root mass;

• We found an increase in the mass of the aboveground part of plants with an increase in the dose of saponite in the soil. Perhaps the use of saponite will have a positive result and increase the yield of green mass with prolonged exposure in field cultivation experiments;

• The content of potassium and nitrogen in the soil after the model experiment on growing oats decreased. In the experiment with saponite, this decrease averaged 8-12% for potassium, and 35-48% for nitrogen. In samples without saponite, the removal of elements is more significant - 20-70% for potassium and 47-50% for nitrogen; we found no statistical difference in the content of mobile phosphorus in the samples before and after the model experiment with the addition of different doses of saponite and fertilizer was found.

![Graphs showing nitrogen, potassium, and phosphorus content](image)

**Figure 4.** Nitrogen, potassium and phosphorus content in plant samples.

**5. Conclusion**

Thus, according to the results of the study, it can be concluded that saponite does not enrich the soil with nutrients. It does not affect the increase in the biomass of the grown oats. We can note that introducing saponite in concentrations from 4 to 12 t / ha with fertilizer does not reduce the content of phosphorus, potassium and nitrogen in the soil and does not neutralize fertilizer. Thus, an increase in the dose of fertilizers when applying saponite is not required. However, saponite in doses of 12 - 4 t / ha prevents the removal of mobile forms of nitrogen and especially potassium from the soil when growing oats. In the results with phosphorus, the addition of saponite did not affect the removal of substances.
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