Improvement of environmental indicators of coal energy and agricultural production due to the integration and diversification of these industries

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Abstract. At present, there is extensive experience in the use of sulfuric acid ameliorant for soils with soda type of salinity. The authors found that as a result of using a weak solution of sulfuric acid on soils containing sodium and hydrocarbonates in their salt composition, their agrochemical characteristics are significantly improved. The article presents the results that show that the production of fertilizers and ameliorants from the waste of energy enterprises will increase their environmental safety. The use of sulfur oxides captured from the flue gases of coal-fired energy enterprises as a raw material for the production of sulfuric ameliorant will allow solving a double task: to reduce pollution of the zone of influence of enterprises and improve the condition of lands with soda salinization.

1 Introduction

National security is implemented by a number of indicators that are closely integrated with each other, for example, such as food security, energy security, environmental security, etc. The steady trend of recent years is a reduction the strategic stock of food products not only in Russia, but also in most of other countries. According to statistics, as of December 1, 2018, grain reserves in our country amounted to 29.7 million tons, which is 30.2% less than the 2017/2018 season and 20.4% less compared to the 2016/2017 season [1-3]. This state of affairs destabilizes the national security of the country.

The «Concept of Enhancing Food Security of the CIS Member States» indicates that the most important criteria for food security in the world are the level of self-sufficiency of the main types of food and the level of their carryover stocks, which should be 15 - 20% of annual food consumption in the country.

In order to ensure food security of the Russian Federation, it is necessary to develop comprehensive, scientifically based methods for restoring and maintaining arable land, since the level of food production is directly dependent on the fertility of these soils.

Non-depleting agricultural production technologies in such high volumes do not currently exist. Soil fertility can only be maintained and preserved for a longer period,

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which is achieved by introducing various kinds of organic and chemical fertilizers, carrying 
out recultivations and reclamation of disturbed and unfavorable land, scientifically-based 
irrigation and sowing of agricultural and other crops.

However, the production of mineral fertilizers in large volumes, ameliorants, 
mechanized processes of irrigation, sowing, care and harvesting of agricultural products are 
accompanied by large energy consumption. Yes, and the production of necessary 
equipment, ensuring the needs of workers in this industry and much more are tied to energy 
consumption.

The possibility of generating sufficient energy for consumption of the economy and 
other spheres is the basis of the state’s energy security.

According to the approximate estimates given in the «Energy Strategy of Russia for the 
period until 2030», in the current period the share of different sources in the global energy 
production are [4-8]: fossil fuels - 80%; waste and biomass incineration - 10%; nuclear 
power plants - 5%; hydroelectric stations - 5%; other sources (wind, solar panels, 
geothermal and marine installations, etc.) - 0.5%.

As can be seen from the above data, the most energy-intensive resource of the planet is 
fossil fuels, namely, natural gas, oil and coal.

However, the use of these resources for the production of electricity is accompanied by 
the formation of large amounts of waste.

2 Materials and method

To ensure the environmental safety of both individual sectors of the economy and the state 
as a whole, it is necessary to develop an integrated approach to the above-mentioned 
branches of the national economy. The possibility of giving the energy industry more 
environmentally attractive indicators has been repeatedly considered. In this direction, 
agriculture can become a very promising symbiote of the energy-producing industry.

Considering the chemical potential of the waste of the energy industry, the conclusion 
suggests itself that it is possible to attract this potential for the needs of agricultural 
production, which is both environmentally and economically justified [9-11].

For instance, emissions from energy producing enterprises using coal fuels contain a 
significant amount of sulfur, carbon and nitrogen oxides, which, using traditional capture 
technologies, can be converted into marketable products demanded in agriculture as 
fertilizers and ameliorants, which improve soil structure and its salt composition.

For example, technologies have been developed that derive from emissions of sulfuric 
acid by means of catalytic gas cleaning from SO₂ formed during coal combustion. In turn, 
sulfuric acid is a very successful ameliorative for lands that have soda salinization. At 
present, soil salinization is a scourge of the main agricultural producing regions, especially 
when used in crop cultivation of irrigation systems. Thus, in the most irrigated region - the 
Southern Federal District, about 50% of saline soils of their total number in the Federation 
(total ≈ 79 mln. Ha) are noted [5, 11, 12].

In our country and abroad there is a wide experience of using sulfuric acid improver for 
soils having soda type salinity. Soda salinization during irrigation dramatically reduces the 
productivity of agricultural crops, causes deep negative transformations of the entire soil 
mass, both organic and mineral.

3 Results and discussion

As a result of the use of a weak solution of sulfuric acid (0.8-1.0%) on soils having sodium 
and bicarbonate in the salt composition, their agrochemical characteristics are significantly
improved. The results are shown in tables 1 - 4.

To maintain agricultural biomass production at an appropriate level, and, above all, in crop production, it is necessary to constantly saturate the soil with essential nutrients. The main sources of nutrients and trace elements are currently mineral fertilizers. Of the above-mentioned components of the exhaust gases of energy enterprises, it is possible to obtain various types of macro-fertilizers, such as ammonium nitrate — NH₄NO₃ and ammonium sulfate — (NH₄)₂SO₄.

This technology was developed by VTI specialists for the simultaneous purification of flue gases from NOₓ and SO₂ to produce a mixture of NH₄NO₃ and (NH₄)₂SO₄ fertilizers and was tested on a pilot plant of the Moldavskaya GRES [13, 14]. Its essence lies in the fact that a strong oxidant is introduced into the exhaust gases - ozone, which oxidizes the lower low-reaction oxides of sulfur and nitrogen (SO₂ and NO) to higher (SO₃ and N₂O₅). In turn, higher oxides easily dissolve in water and aqueous solutions, which makes it possible to obtain in the process of gas purification acid solutions, which are then neutralized by ammonia.

Table 1. The salt composition of the extract on the monolith to acidification (Experimental demonstration farm «Elkinsky» Bagaevsky district, Rostov region).

| Depth, sm | Cations, m·eq. | Anions, m·eq. |
|----------|----------------|---------------|
|          | Ca²⁺         | Mg²⁺         | Na⁺         | CO₃⁻         | HCO⁻         | SO₄²⁻         | Cl⁻           |
| 0 – 20   | 1,60 0,064   | 0,10 0,001   | 7,30 0,168  | 3,51 0,105   | 1,63 0,099   | 0,99 0,049   | 2,87 0,101   |
| 20 – 40  | 2,06 0,082   | 0,33 0,004   | 7,92 0,182  | 2,11 0,063   | 3,99 0,243   | 2,13 0,104   | 2,08 0,073   |
| 40 – 60  | 2,43 0,097   | 0,48 0,006   | 8,09 0,186  | 0,90 0,028   | 4,42 0,270   | 3,21 0,157   | 2,43 0,085   |
| 60 – 80  | 2,80 0,112   | 0,50 0,006   | 8,80 0,202  | 0,48 0,014   | 5,80 0,354   | 2,50 0,123   | 3,32 0,116   |
| 80 - 100 | 3,00 0,080   | 0,41 0,005   | 10,00 0,230 | - 0,073     | 7,80 0,475   | 2,00 0,098   | 2,61 0,091   |

Nitrogen - one of the main elements necessary for plants. It enters into all simple and complex proteins, which are the main component of the protoplasm of plant cells.

However, nitrogen is most accessible to plants in the form of mineral compounds and, only in an insignificant proportion, in the form of amides dissolved in water and the simplest amino acids. Meanwhile, the bulk of nitrogen in the soil, which is in various organic compounds, is not available to plants. Only a small amount of nitrogen (about 1% of the total) is found in the plant-assimilated mineral compounds.

With this specific bioavailability of nitrogen, a progressive increase in crop yields is possible only with a combination of legumes that provide biological synthesis of nitrogen, along with symbionts (nodule bacteria) with full use of manure and extensive use of mineral nitrogen fertilizers. The results are shown in table 5.

Comparing the required nutrients (without taking into account the synergy of effects), we can conclude that nitrogen fertilizer has a priority effect on the harvest, since the yield increase from nitrogen is half the total effect of the total mineral fertilizer.

The yield of the main crop - wheat in the Russian Federation over the past four years (2015-2018) ranged from 21 to 28 centners per hectare, which required a steady average of 70 kg of nitrogen per hectare of arable land. The results are shown in table 5. The amount
of crops under grain crops is about 40 million hectares, which will require the introduction of mineral fertilizers to about 2.8 million tons of nitrogen only [14, 15], not to mention the other elements necessary for restoring soil fertility.

**Table 2.** Salt composition of the extract on the monolith after the introduction of ameliorant (Experimental demonstration farm «Elkinsky» Bagaevsky district, Rostov region).

| Depth, sm | Cations, m · eq. | Anions, m · eq. |
|-----------|------------------|-----------------|
|           | Ca²⁺            | Na⁺            | CO₃²⁻ | HCO₃⁻ | SO₄²⁻ | Cl⁻ |
| 0 – 20    | 3.00            | 3.01           | -     | 1.07  | 5.91  | 0.15|
|           | 0.120           | 0.069          | 0.065 | 0.290 | 0.005 |
| 20 – 40   | 2.90            | 4.02           | -     | 1.87  | 6.30  | 1.05|
|           | 0.116           | 0.092          | 0.114 | 0.309 | 0.037 |
| 40 – 60   | 6.01            | 4.05           | 0.23  | 2.88  | 6.56  | 2.42|
|           | 0.240           | 0.093          | 0.007 | 0.321 | 0.085 |
| 60 – 80   | 5.12            | 3.06           | 0.25  | 3.01  | 5.81  | 3.61|
|           | 0.205           | 0.070          | 0.008 | 0.285 | 0.126 |
| 80 - 100  | 5.01            | 4.47           | 0.25  | 3.61  | 4.62  | 3.00|
|           | 0.200           | 0.102          | 0.008 | 0.226 | 0.105 |

**Table 3.** Salt composition of the extract on the monolith after acidification and washing (Experimental demonstration farm «Elkinsky» Bagaevsky district, Rostov region).

| Depth, sm | Cations, m · eq. | Anions, m · eq. |
|-----------|------------------|-----------------|
|           | Ca²⁺            | Na⁺            | CO₃²⁻ | HCO₃⁻ | SO₄²⁻ | Cl⁻ |
| 0 – 20    | 1.02            | 2.20           | 0.20  | 1.30  | 5.82  | 0.24|
|           | 0.041           | 0.051          | 0.006 | 0.154 | 0.032 |
| 20 – 40   | 2.00            | 4.52           | 0.20  | 2.53  | 6.22  | 0.92|
|           | 0.080           | 0.021          | 0.006 | 0.285 | 0.032 |
| 40 – 60   | 3.00            | 4.60           | 0.20  | 2.53  | 6.22  | 1.13|
|           | 0.120           | 0.106          | 0.006 | 0.305 | 0.040 |
| 60 – 80   | 3.01            | 4.00           | 0.10  | 3.08  | 5.46  | 0.87|
|           | 0.120           | 0.092          | 0.003 | 0.267 | 0.031 |
| 80 - 100  | 3.00            | 4.21           | 0.20  | 3.05  | 4.61  | 1.85|
|           | 0.120           | 0.097          | 0.006 | 0.226 | 0.065 |

**Table 4.** Change of agrochemical properties of the soil (Experimental demonstration farm «Elkinsky» Bagaevsky district, Rostov region).

| Experience options | Nutrient content of soil horizons |
|--------------------|----------------------------------|
|                    | Nitrogen, mEq / 100 g | Phosphorus, mEq / 100 g | Potassium, mEq / 100 g |
|                    | 0-30  | 30-60 | 0-30  | 30-60 | 0-30  | 30-60 |
| Before land        | 0.080 | 0.061 | 4.9   | 8.7   | 16.3  | 18.6  |
| reclamation        |       |        |       |       |       |       |
| After land         | 0.083 | 0.064 | 5.8   | 10.6  | 13.6  | 17.5  |
| reclamation        |       |        |       |       |       |       |
Table 5. Approximate removal of basic nutrients with the yield of some crops in kg / ha of active substance.

| Crops      | The harvest of the main products t / ha. | Delivered with a crop, kg / ha. |
|------------|-----------------------------------------|---------------------------------|
|            |                                         | N     | P$_2$O$_5$ | K$_2$O |
| Cereals    | 30-35                                   | 90-110 | 30-40      | 60-90  |
| Winter rye | 25-30                                   | 85-90  | 36-40      | 78     |
| Winter wheat| 30                                       | 75     | 52         | 82     |
| Spring wheat| 30                                       | 60     | 24         | 84     |
| Legumes    | 25-30                                   | 100-150| 35-45      | 50-80  |
| Potatoes   | 200-250                                 | 120-200| 40-60      | 180-300|
| Barley     | 30                                      | 80     | 33         | 63     |
| Sugar beet | 400-500                                 | 180-250| 55-80      | 250-400|
| Corn (h. mass) | 500-700                             | 150-180| 50-60      | 180-250|
| Cabbage    | 500-700                                 | 160-230| 65-90      | 220-320|
| Cotton     | 30-40                                   | 160-220| 50-70      | 180-240|
| Linen      | 7                                       | 78     | 30         | 69     |

Considering that the average selling price for mineral fertilizers in the country is significantly lower than export, most of the fertilizers produced in Russia go to foreign markets - about 70%.

Russian agricultural producers often do not have the necessary funds to purchase mineral fertilizers in full.

In turn, the prices of agricultural products are not so high that its producers can receive large profits. The results are shown in table 6.

Table 6. Prices for main grains (according to the materials of the newsletter dated December 7, 2018 and Federal State Budgetary Institution «Special center in the agro-industrial complex»).

| Price (RUB / t, VAT included) | wheat grade 3 | wheat grade 4 | wheat grade 5 | rye prod. | barley fodder. | corn for grain |
|-------------------------------|---------------|---------------|---------------|-----------|----------------|----------------|
| Central Federal District      | 9500-10500    | 9200-10500    | 9000-10300    | 7000-8300 | 7300-8400       | 8600-9000       |
| Southern Federal District+ North Caucasian Federal District | 10500-11500 | 10450-10700 | 10000-10200 | -         | 8600-9200       | 8700-9500       |
| Volga Federal District        | 9500-10500    | 9200-10200    | 8400-9600     | 6200-7500 | 7300-8000       | 8200-8900       |
| Ural Federal District         | 8500-9600     | 8500-9300     | 8200-9200     | 6000-7000 | 7000-8500       | -              |
| Siberian Federal District     | 8500-10000    | 8000-9700     | 8000-9300     | 6500-7000 | 6700-8400       | -              |

Considering that in 2018, due to weather conditions, a smaller crop was obtained against previous years, and most of the suppliers' deals were futures, prices for main grains...
increased almost twice as compared to the previous year. However, even higher prices for agricultural food do not allow independent profitable reproduction by agricultural producers of their goods without state subsidies.

**Conclusion**

In connection with the above facts we can draw the following conclusions.

1. There is a tendency to loss of fertility by soils due to their salinization and removal of substances with the crop in the most agricultural-producing subjects of the Russian Federation.

2. Mineral acids, for example, sulfuric acid are a very effective ameliorative for soil salinization, the most toxic of all types of salinization.

3. Use as a raw material for the production of sulfuric acid ameliorates sulfur oxides trapped from the flue gases of energy enterprises operating on coal, will solve a dual problem: to reduce pollution of the zone of influence of enterprises and to improve the condition of the land with soda salinization.

4. Given the active use of arable land, which is accompanied by the removal of nutrients from the crop, it is necessary to constantly maintain the fertility of these lands by introducing various types of fertilizers.

5. Taking into account the difference between the selling price for mineral fertilizers inside the country and on the world market, as well as the financial condition of the agricultural sector, the offer for sale of effective fertilizers produced on the basis of waste may be a promising alternative to traditionally obtained.

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