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To cite this article: L Svatovskaya *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **272** 022160

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Lithosphere Preservation with the Use of Silica Sol Properties

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Abstract. There are a number of problems of lithosphere preservation. Environmental pollution is one of them. The problems are related to the use of substances for detoxication. These substances must be the same as natural minerals, i.e. they must have detoxicating properties and form useful products after detoxication. The main aim of the paper is to find substance properties for lithosphere preservation. Silica sol is supposed to be a suitable substance. It was established that 4 properties of silica sol can be used for lithosphere preservation: 1) silica sol's conversion into silica gel which has absorption properties; 2) possible reactions with pollutions, e.g. heavy metal ion detoxication; 3) the colours of the sediments of silicates and hydroxides to identify heavy metal ions; 4) silica sol's conversion into silica gel which has binding properties. The research introduces the new qualitative express method of identification and detoxication of heavy metal ion pollutions based on the sediment colours and low solubility product to increase the strength of a geomaterial. The practical examples are also given.

1. Introduction

Preservation of lithosphere is considered to be a decrease of natural resource consumption, lithosphere restoration after pollutions and the use of alternative technologies. The main idea of the paper is to find substances and to show the possibility of their use for lithosphere preservation. Examination of silica sol properties [1-6] lets us draw a conclusion that it is one of the best substances for lithosphere preservation. 4 properties are the bases of silica sol use for this purpose. Since silica sol is the purest substance consisting of $\text{SiO}_2 \cdot n\text{H}_2\text{O}$, it has such properties for lithosphere preservation as ones listed in the Table 1.

Thus, the properties given above are the bases of the following technologies:

1. the first property – the basis of information technology of soil pollution by heavy metal ions;
2. the second property – the basis of detoxication technology;
3. the third property – the basis of preventive technology due to absorption properties of silica gel;
4. the fourth property – the basis of strengthening technology, e.g. anti-dusting technology for a soil.



Table 1. Silica sol properties for lithosphere preservation.

Silica sol properties for lithosphere preservation			
1. Formation of coloured sediments through silica sol reactions in order to obtain information which helps to identify pollutions.	2. Production of substances with very low solubility product, less than 10^{-8} , through silica sol reactions for detoxication and, as a result, formation of hydroxides and hydrates of silicates.	3. Silica gel production in a soil after sol's conversion into gel. Silica gel has absorption properties which are very important for pollution prevention.	4. Silica sol's conversion into gel having binding properties which helps in strengthening.

2. Methods

The methods of practical and experimental observation were applied. 30% silica sol solution and $\text{pH} \approx 10$ were used in the research. The sol had sizes of particles about 10-12 nm.

To examine information properties of silica sol the soil was polluted by heavy metal ions, namely: Ni(II); Fe(III); Cd(II); Cu(II); Pb(II). Their tolerable concentration (TC) was nearly 2000. Then the aqueous extract of the polluted soil was mixed with silica sol. The examination of the reaction results allows to make conclusions about the nature of the pollutions.

To demonstrate detoxication properties of silica sol the soil was polluted by heavy metal ions with $\text{TC} \approx 2000$, then the soil was saturated with silica sol and 1 day later, within 28 days, the aqueous extract was tested by means of selected electrodes.

To produce silica gel the sandy soil was mixed with silica sol. The sandy soil-sol solution had the ratio 3:1. A few days later, within 28 days, the strength of the system was examined. As silica gel has binding properties, they could be identified in the test of the system for strength when producing silica gel. In this case absorption properties of silica gel are of great importance because its use provides preventive protection of lithosphere. Therefore it can be applied to detoxicate free heavy metal ions.

The fourth property is also related to silica gel but in this case it is important to use its binding properties for soil strengthening or surface strengthening (anti-dusting).

3. Results and discussion

The Table 2 presents heavy metal ion identification based on the nature of the ions and the difference of the sediment colours in the water solution. Different colours of the sediments can be the base of the qualitative express method of heavy metal ion identification. The difference of the colours is quite evident, e.g. ions of Pb(II); Cd(II); Zn(II) have white colour of the sediments. In this case it is important to carry out other reactions, e.g. the reaction with KJ resulting in formation of yellow sediment which PbJ_2 has. The reaction with Na_2S is suitable for Cd(II) identification. CdS has lemon-yellow colour sediment.

Table 2. Heavy metal ion identification based on the sediment colours in the reactions with silica sol solution.

Heavy metal ions in the water solution and in the aqueous extract of the soil	Sediment colours after the reactions with silica sol
Ni(II)	light green
Co(II)	pink
Cu(II)	turquoise
Cd(II)	white
Zn(II)	white
Pb(II)	white
Cr(III)	dark green
Fe(III)	rust

The Table 3 gives the data which let us state that solubility product (SP) of the substances is the base of the heavy metal ion detoxication.

Table 3. Parameters of the substance solubility product and the heavy metal ion tolerable concentration.

Solubility product (SP) for hydroxides		Approximate concentration of heavy metal ions in the saturated solution		Tolerable concentration (TC) of heavy metal ions in the soil	
hydroxides	SP	mol/l	g/l	heavy metal ions	TC g/kg
Cd(OH) ₂	$3,98 \cdot 10^{-15}$ $1,2 \cdot 10^{-14}$ $12 \cdot 10^{-15}$	$1,07 \cdot 10^{-15}$	$1,2 \cdot 10^{-3}$	Cd(II)	$0,5 \cdot 10^{-3}$
Co(OH) ₂	$2 \cdot 10^{-16}$	$3,68 \cdot 10^{-6}$	$0,21 \cdot 10^{-3}$	Co(II)	$5 \cdot 10^{-3}$
Fe(OH) ₃	$3,72 \cdot 10^{-40}$	$1,8 \cdot 10^{-9}$	$0,1 \cdot 10^{-6}$	Fe(III)	$0,1 \cdot 10^{-3}$ (TC in water)
Ni(OH) ₂	$3,16 \cdot 10^{-16}$	$4,4 \cdot 10^{-6}$	$0,26 \cdot 10^{-3}$	Ni(II)	$4 \cdot 10^{-3}$
Pb(OH) ₂	$0,2 \cdot 10^{-15}$	$\approx 10^{-5}$	$2 \cdot 10^{-3}$	Pb(II)	$20 \cdot 10^{-3}$
Cu(OH) ₂	$5,6 \cdot 10^{-20}$	$\approx 4 \cdot 10^{-7}$	$0,25 \cdot 10^{-4}$	Cu(II)	$3 \cdot 10^{-3}$

Therefore, the difference of the sediment colours is the base of heavy metal ion identification, and a low value of solubility product is the base of detoxication.

According to principles of general chemistry, solubility product of heavy metal ion silicates is lower than that of hydroxides. That is why the methods of silica sol identification and detoxication are more reliable. The Table 3 shows solubility product of the substances such as hydroxides and tolerable concentration of the free heavy metal ions. One can see that it was possible to perform silica sol reactions with the fixed free ions in a solid state, e.g. hydroxides and silicates which have lower solubility product. It should be noted that the solution had pH \approx 10. Detoxication through the use of silica sol solution was tested taking into account the pollution containing up to 2000 TC of heavy metal ions. After detoxication processes the aqueous extract was investigated by means of selective electrodes each time and, as a result, it did not have free ions. The Table 4 illustrates the information about the presence of heavy metal ions and their detoxication. It is worth mentioning that after detoxication the sediments looked like silica gel of the different colours.

Table 4. Qualitative express method of heavy metal ion pollutions' identification and their detoxication.

Heavy metal ions in the soil	Identification and detoxication ability, number of TC	pH of the system	General detoxication of free heavy metal ions (aqueous extract)
Cu(II)	≈ 2000	6-8	not found
Co(II)	≈ 2000	6-8	not found
Fe(III)	≈ 2000	7-8	not found
Ni(II)	≈ 1000	6-8	not found
Pb(II)	$\approx 1000-2000$	6-8	not found
Zn(II)	$\approx 1000-2000$	6-8	not found

Silica gel's absorption and binding properties are the bases both for pollution prevention and strengthening respectively. In the practical experiment the finely-pulverized sand was saturated with silica sol and then silica sol's conversion into silica gel which has strength properties took place. According to the papers [6-12] it is possible to manage gel properties, e.g. using Ca(II) ions. Silica gel

is certain to be modified during its production when adding Ca(II) ions in order to form calcium silicate hydrates. According to the proceedings [18-23] these substances can strengthen silica gel which in its turn strengthens a soil. The test for strength has demonstrated that the sandy soil mixed with silica sol was strengthened about 0,1-0,2 MPa. This fact has double significance because first silica gel is produced and then it helps in strengthening. Silica gel has absorption properties and its presence in a soil is of great preventive importance.

So, one can suppose that there are two techniques of silica gel appearance. The first one is to produce silica gel through the chemical reactions between silica sol and heavy metal ions (see the Table 1). The second one is at first to produce silica gel which then results in the reactions between the gel's surface and heavy metal ions due to its absorption properties. In any case the surface of silica gel produced in a soil is of high priority both in absorption and detoxication as well as for soil strengthening due to the salt of polysilicic acid which results from the interaction between silica gel and heavy metal ions.

4. Conclusions

- 1) The research suggests the qualitative express method of free heavy metal ion identification and detoxication in a soil using silica sol reactions. The principle of the method is the different colours of the sediments for identification and very low solubility product of the sediments for detoxication.
- 2) The colours of the sediments are named for identification: light green – for Ni(II); turquoise – for Cu(II); rust – for Fe(III); pink – for Co(II) and white – for Cd(II); Pb(II) and Zn(II).
- 3) It is possible to detoxicate heavy metal ions with $TC \approx 2000$ in a soil.

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