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The study of the influence of the main parameters in separating the Pb^{2+} ions from diluted aqueous solutions through perlite absorption

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Abstract

Due to the perlite's remarkable properties, we used it in this paper as absorbent material for separating the Pb^{2+} ions from aqueous solutions. We studied the influence of different parameters on the separation process, such as: absorption time, perlite dosage, the pH of the separated solutions, initial concentration of Pb^{2+}, temperature. An efficient separation of the Pb^{2+} was achieved by shaking the solutions for 11 minutes, at optimal pH 5, using a perlite dose of 0.5 grams, initial concentration of the Pb^{2+} ions of 10 mg/dm^3 at a temperature of 35°C.

Keywords: absorption, perlite, pH, Pb^{2+} ions, aqueous solution

1. Introduction

Perlite is a naturally occurring siliceous volcanic rock. The characteristic that distinguishes perlite from other volcanic glasses is that, by being rapidly heated to 871°C, it increases its initial volume to 4-20 times the original, and this is due to the fact that perlite contains 2-6% water that evaporates when heated and creates small gaps, and that is why perlite is lightweight and it has other exceptional properties [1].

Perlite is used for manufacturing refractory materials where the temperature does not exceed 1100°C. Due to perlite having exceptional insulation properties, it is also used in the manufacturing of bricks. Also, it is a good absorbent of toxic liquids that leak from closed containers [2].

Perlite has been used in horticulture for many years. It provides an enabling environment for seed development, because it maintains a constant level of humidity and temperature. Perlite's white color protects the seeds from sunlight and reflects the light under the leaves, which enhances growth. Perlite retains water, and the quantity of retained water depends on the size of the particles. The finer particles retain a larger quantity of water. The humidity necessary to a plant can thus be adjusted by using perlite of different sizes [3].

Numerical and experimental studies were conducted to understand the Pb(II) transport through the fine-grained soil of low-hydraulic permeability under electrical fields. The numerical model involved multi-component species transport under coupled chemical and electrical potential gradients and incorporated several chemical reactions occurring within the kaolinite clay during the processing, such as aqueous phase reaction, adsorption, and precipitation. The model also emphasized physicochemical factors such as soil pH and zeta potential, which vary with location and processing time and directly affect the transport of species. The model predicted the soil pH distribution as well as the transport and fate of Pb(II). The validity of the model was confirmed by comparing the model prediction with experimental results. The model simulation and experimental results, using unenhanced and enhanced tests, clearly demonstrated

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that the change in pH within the soil specimen is a crucial factor affecting the solubilities of Pb(II) and its adsorption to the soil, resulting in governing the removal of Pb(II) by electrical fields. This study confirms that enhancement methods should be considered to control soil pH, in order to improve electrokinetic removal of heavy metal contaminants [4].

Minerals produced by lateritic weathering have been exploited to evaluate their potential for the decontamination of lead ions from aqueous solutions and for understanding decontamination mechanism in nature. Various physico-chemical parameters such as selection of appropriate electrolyte, equilibration time, amount of adsorbent, concentration of adsorbate, effect of diverse ions and temperature were studied in order to simulate the best conditions in which the particular material could be used as an adsorbent. Maximum adsorption was observed at 0.005 mol/L acid solutions (HNO_3, HCl, and $HClO_4$) using 0.2 g of adsorbent for 4.82 – 10^{25} mol/L lead concentration in five minutes equilibration time. Studies show that the adsorption of lead decreases with the increase in the concentrations of all the acids [5].

The sorption of lead ions on sawdust has been exploited to evaluate its potential for the decontamination of lead ions from aqueous solutions. Various physico-chemical parameters such as selection of appropriate electrolyte, equilibration time, amount of adsorbent, concentration of adsorbate, effect of diverse ions and temperature were studied in order to simulate the best conditions in which this material can be used as an adsorbent. Maximum adsorption was observed at 0.005 mol/L acid solutions (HNO_3, HCl, and $HClO_4$) using 0.2 g of adsorbent for 4.83-10^{25} mol/L lead concentration in 10 min equilibration time. Studies show that the adsorption of lead decreases with the increase in the concentrations of all the acids [6].

The adsorption of Pb^{2+} on different adsorbents has been found in the order: sludge, dust, slag, carbonaceous adsorbent. The least adsorption of Pb^{2+} on carbonaceous adsorbent even having high porosity and consequently greater surface area as compared to other three adsorbents, indicates that surface area and porosity are not important factors for Pb^{2+} removal from aqueous solutions. The adsorption of Pb^{2+} has been studied as a function of contact time, concentration, and temperature [7].

This investigation examines metal ion adsorption on mesoporous silicate, MCM-41, synthesized from sodium silicate solution and cethyltrimethylammonium bromide (CTAB). MCM-41 has potential as an adsorbent material, with a regular hexagonal pore structure, large specific surface area, and large pore volume. The MCM-41 synthesized for this investigation is characterized using powder X-ray diffraction and nitrogen adsorption and desorption isotherms data. The adsorption behavior for cadmium (II) and lead (II) onto MCM-41 was studied by contacting the

mesoporous silicate with an aqueous solution of metal salts and acetylacetone. Both Cd^{2+} and Pb^{2+} were found to quantitatively adsorb onto MCM-41. The results of this study suggest that MCM-41 may have applications in the recovery of toxic metals from waste waters [8].

The spectrometric methods are the most common method of analysis, both in the molecular and elemental analysis. In spectrochemical methods, the atomic spectrometry is considered to be the best method of qualitative and quantitative analysis, from major constituents to minor constituents and further to traces and ultratraces. The atomic absorption spectrometry is based on the measurement of radiant power absorbed by a population of free atoms found in the source of atomization (P_T) from the radiant power emitted by a source of lines (P_O) and it is part of the optical methods UV-VIS [9, 10, 11].

For these reasons, in this paper we proposed the separation of the Pb^{2+} ions from diluted aqueous solutions through the absorption process, by using perlite as absorbent material. The Pb^{2+} ions were determined through atomic absorption spectrometry.

2. Materials and method

Preparing the lead solution of concentration 1g Pb/dm^3 and of the solution of concentration 10 mg Pb/dm^3.

We prepared 1 dm^3 solution of lead salt with a concentration of 1g Pb/dm^3. The lead salt that was used is lead nitrate, with a molecular mass of 331.23.

In the analytical scales were weighed 1,5987 g $Pb(NO_3)_2$ and they were passed quantitatively in a volumetric flask of 1 dm^3, with distilled water. To the obtained solution was added for conservation 1 cm^3 of concentrated nitric acid and brought to the mark with distilled water.

From the prepared solution were taken 20 cm^3 solution of concentration 1g Pb/dm^3 that are inserted in a volumetric flask of 2 dm^3 and brought to the mark with distilled water, in order to obtain a solution of concentration 10 mg Pb/dm^3.

The adjustment of the pH to the desired values was made by using solutions of sodium hydroxide of 15% and 0.1 M, and nitric acid, solution of 0.1 M.

The concentration of the lead from the samples was determined with an atomic absorption spectrophometer, model PYE UNICAM SP 1900, and for the measurement of the pH was used a pH-meter WTW 96.

2.1 The influence of the absorption time

For the study of the influence of the absorption time we used the following method:

- we measured 50 mL samples of concentration 10 mg Pb^{2+}/dm^3 that were placed in Berzelius beakers, over which was added 1g perlite, at pH=3.8, and was stirred at a speed of 500 rotations per minute for different periods of time.
- after the stirring period was over, the samples were filtered on quantitative filter, in order to remove the perlite particles.

2.2 The influence of the solution's pH

For the study of the influence of the pH solution on the absorption process of the lead from aqueous solutions, the working mode is the following:

- 50 mL of Pb^{2+} solution of concentration 10 mg/dm^3 were measured and poured into Berzelius beakers;
- by using the pH-meter and the HCl and NaOH solutions, we obtained solutions with the pH ranging between 2.5 and 5.5;
- over each of the solutions with a different pH we added 1g perlite, previously weighed on the analytical scales;
- the samples were placed on a magnetic stirrer and were stirred for 11 minutes at a speed of 500 rotations per minute;
- after 11 minutes, the samples were filtered in order to remove the perlite, and then we determined the residual concentration of the lead ions.

2.3 The influence of the perlite dosage

For the study of the influence of the perlite dosage on the absorption process, we proceeded thus:

- 50 mL of Pb^{2+} solution of concentration 10 mg/dm^3 were measured and poured into Berzelius beakers;
- by using the pH-meter and the NaOH solution, we obtained pH=5 for each sample;
- we added different quantities of perlite over each sample;
- the samples were stirred for 11 minutes at a speed of 500 rotations per minute;
- after the stirring period is over, the samples are filtered in order to remove the perlite, and then we determined the residual concentration of the lead ions.

2.4 The influence of the initial concentration of Pb^{2+}

For the study of the influence of the initial concentration of Pb^{2+} on the absorption process, we proceeded thus:

- 50 mL solution of Pb^{2+} of different concentrations was measured and poured into Berzelius beakers. The solutions with concentrations lower than 10 mg/dm^3 were prepared from the solution of 10 mg/dm^3 through dilutions, and the solutions of concentrations higher than 10 mg/dm^3 were prepared from the solution of concentration 1 g/dm^3, also through dilutions;
- we brought the solutions from the beakers to pH=5, and then we added the optimal dose of perlite of 0.5 grams;
- the samples were stirred at a speed of 500 rotations per minute, for 11 minutes, and afterwards they were filtered in order to remove the perlite, and then we determined the residual concentration of the lead ions.

2.5 The temperature's influence

For the study of the temperature's influence on the absorption process, we proceeded thus:

- 50 mL of Pb^{2+} solution of concentration 10 mg/dm^3 were measured and poured into Berzelius beakers;
- by using the pH-meter, we brought the samples to pH=5;
- on the analytical scales, we measured 0.5 grams of perlite for each sample;

- we placed each sample on the magnetic stirrer and stirred each of them for 11 minutes at a speed of 500 rotations per minute;
- after the stirring period is over, the samples were filtered on quantitative filter in order to remove the perlite, and then we took samples to determine the residual concentration of the lead ions.

3. Results and discussions

We obtained good separation efficiencies, and we can notice from the graphic that the optimal separation time is 11 minutes, because for this period of time the separation efficiency is 100%. The separation efficiency (R) can be calculated with the formula:

$$R = \frac{c_0 - c}{c_0} \cdot 100$$

where: c_o = initial concentration of Pb^{2+}
c = final concentration of Pb^{2+}

From the experimental data, we can see that the best separation efficiencies are obtained at pH=5. For this reason, we considered that the pH optimal to the absorption process is of value 5. When we brought the sample to pH=6 it grew turbid, due to the lead beginning to precipitate under hydroxide form.

From the experimental data we can see that the dose of perlite optimal to the absorption process if of 0.5 grams.

From the experimental data and from the graphic we can see that 10 mg/dm^3 is the optimal concentration for the absorption process.

Table 1. The residual concentration of Pb2+ according to the absorption time

Stirring time[min]	3	5	8	11	15	20	30
Residual Pb^{2+} [mg/dm^3]	0.6	0.3	0.1	0.0	0.2	0.0	0.0
Separation efficiency (R%)	91.8	95.9	98.6	100,0	97.2	100.0	100.0

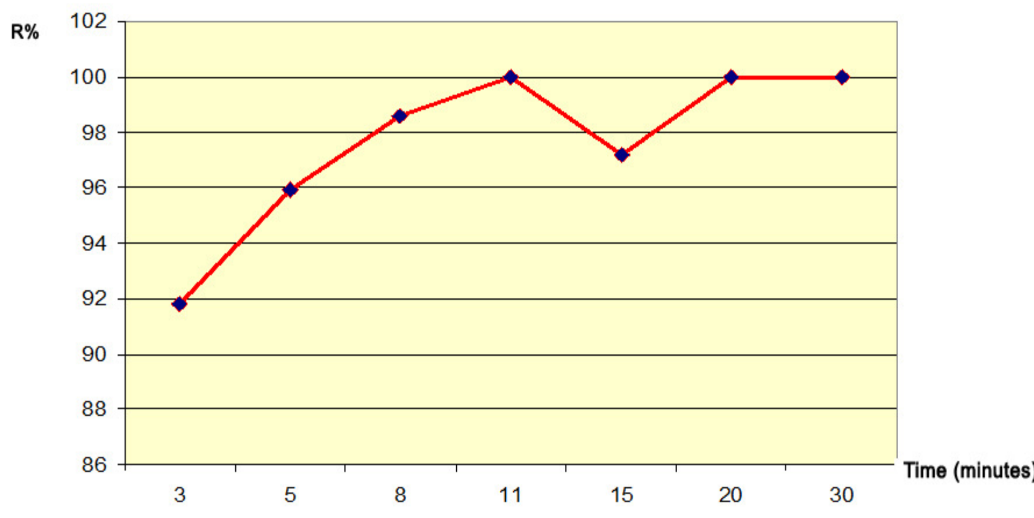

Figure 1. Separation efficiency (R) according to the absorption time

Table 2. The influence of the solution's pH on the residual concentration of Pb^{2+}

pH	2.5	3	3.5	4	4.5	5	5.5
Residual Pb^{2+} [mg/dm^3]	9.3	3.5	0.8	0.1	0.2	0.0	0.1
Separation efficiency (R%)	7	65	92	99	98	100	99

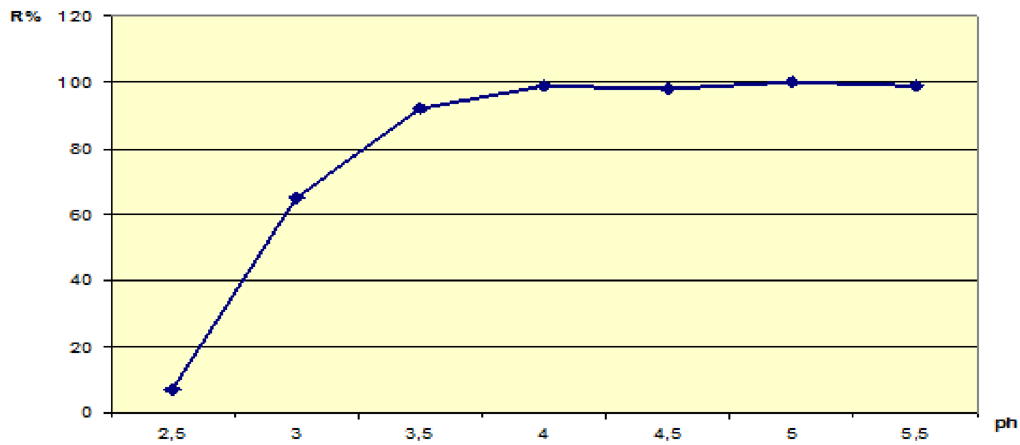

Figure 2. The separation efficiency (R) according to the solution's pH

Table 3. The residual concentration of Pb^{2+} according to the perlite dose

Perlite dose [g]	0.1	0.3	0.7	1.0	1.5	2.0
Residual Pb^{2+} [mg/dm^3]	1.3	0.0	0.0	0.0	0.0	0.0
Separation efficiency (R%)	87	100	100	100	100	100

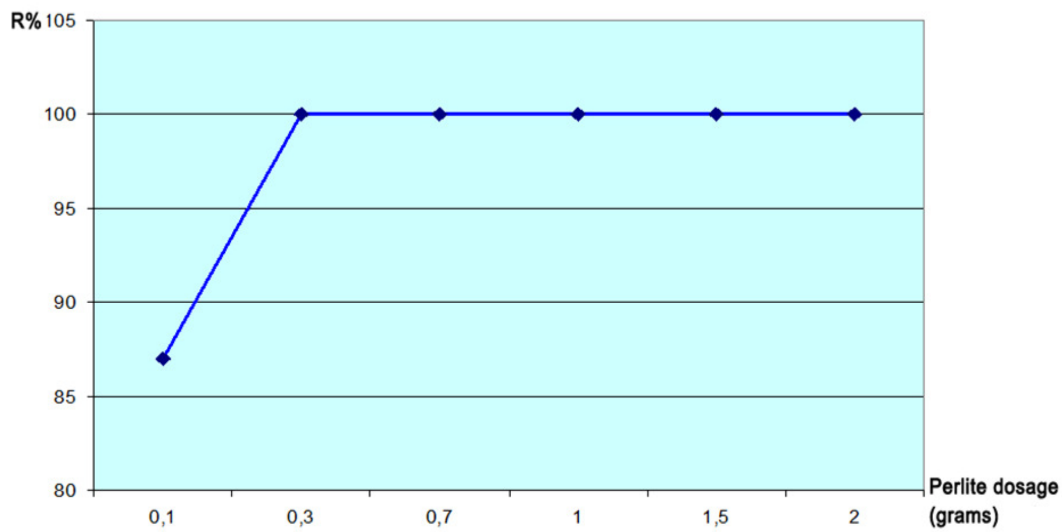

Figure 3. The separation efficiency (R) according to the pelite dosage

Table 4. The residual concentration of Pb^{2+} according to the initial concentration of Pb^{2+}

Concentration of Pb^{2+} [mg/dm^3]	1	5	10	20	50	100
Residual Pb^{2+} [mg/dm^3]	0.1	0.0	0.1	1.4	14.0	56.0
Separation efficiency (R%)	90	100	99	93	72	44

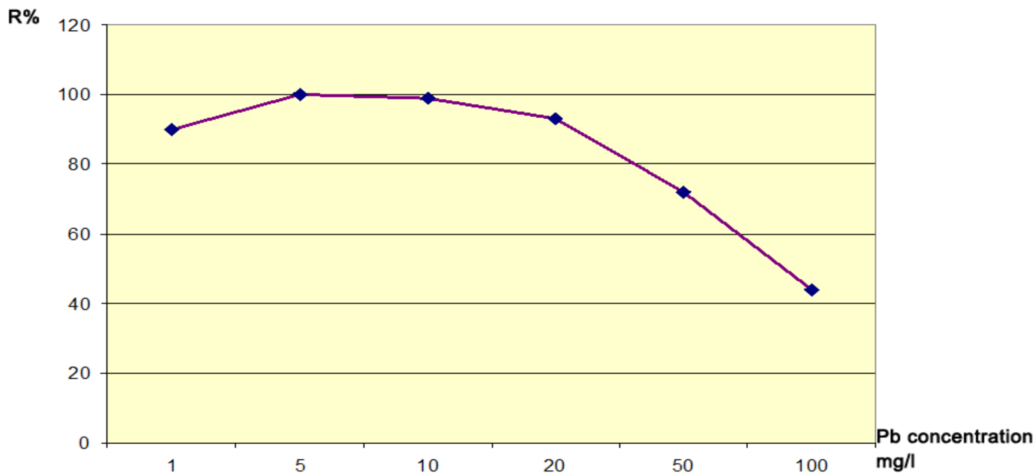

Figure 4. The separation efficiency according to the initial concentration of Pb^{2+}

The optimal temperature for the absorption process is 35°C.

Table 5. The residual concentration of Pb^{2+} according to temperature

T°C	10	20	30	40	50	60
Residual Pb^{2+} [mg/dm^3]	0.4	0.2	0.1	0.0	0.2	0.0
Separation efficiency (R%)	96	98	99	100	98	100

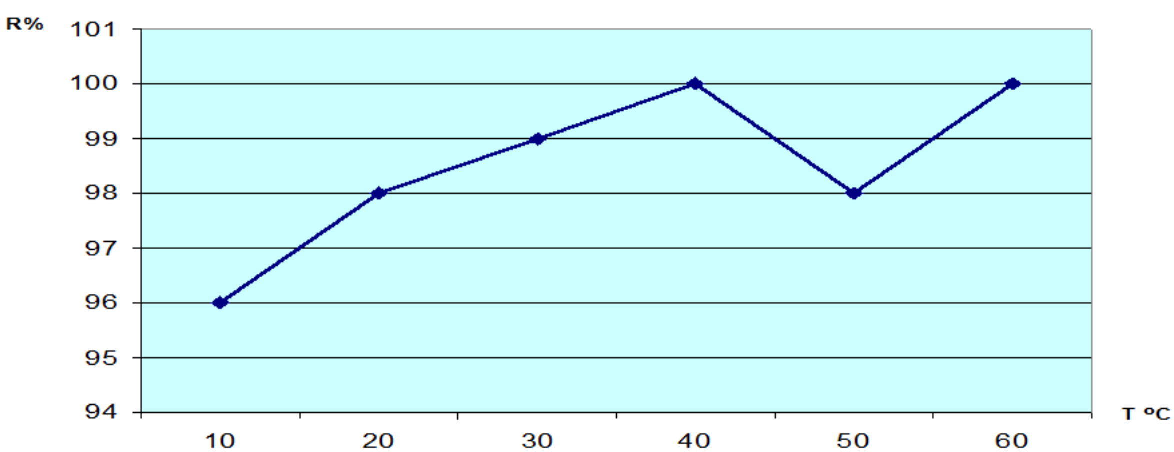

Figure 5. The separation efficiency according to temperature

4. Conclusions

The separation of lead ions from diluted aqueous solutions diluted through absorption, using perlite as absorbent material, gives very good results if there are given optimal conditions for the process. The studied main parameters that influence the absorption process are: the length of the process, the solution's pH, perlite dosage, initial concentration of Pb^{2+} and temperature.

- ✓ In order to obtain good results, it is necessary to stir the solutions for 11 minutes.
- ✓ The optimal pH for the absorption process is equal to 5. At this pH level is done a more efficient separation of the lead.
- ✓ The optimal dose of perlite with which we worked is of 0.5 grams. Increasing the perlite dose does not have a significant influence of the absorption process and therefore on the separation efficiency.
- ✓ The optimal lead initial concentration is of 10 mg/dm^3.
- ✓ The optimal temperature for the absorption process is 35°C.

Compliance with Ethics Requirements

Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human and/or animal subjects (if exists) respect the specific regulations and standards.

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