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The Use of Sorbents in Removal of Selected Cations from Wastewater After Soda Ash Production †

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† Presented at Innovations-Sustainability-Modernity-Openness Conference (ISMO'19), Bialystok, Poland, 22–23 May 2019.

Published: 3 July 2019

Abstract: Wastewater generated in the soda ash production process can be characterized by a strong alkaline reaction, high electrolytic conductivity and high concentration of chlorides, ammonia, sulphates, phosphates, calcium, potassium, sodium and magnesium. Protection of water against pollution should be not only connected with rational management of water resources and the restoration of the water environment to the required state, but also with prevention of pollution. It is an increasingly important element of protective measures. The strict control of pollution at the source is important. Therefore, it is necessary to develop methods of broadly defined waste disposal from industry. The article presents the results of research aimed at the removal of sodium, calcium, potassium, magnesium and ammonium ions from wastewater from soda ash production using three sorbents: Halosorb, Compakt and Damsorb K. The ion removal process was carried out dynamically with different load on the deposit. The concentration of all these anions was reduced to some extent, which indicates the possibility of further, more accurate tests. It was found that the type of sorbent does not differentiate the results of the experiment. The load on the deposit, on the other hand, has an impact on the efficiency of sorbents in wastewater treatment.

Keywords: sorbents; sodium; potassium; magnesium; calcium; ammonia; soda ash; wastewater treatment

1. Introduction

Plants involved in the production of soda ash belong to the chemical industry. Most often in their production processes they use the Solvay method, which is associated with the formation of saline waste [1–3]. Limiting the negative impact on the environment consists of pre-treating post-production sewage and limiting its contact with underground water [4]. By striving to improve water quality and reduce costs associated with environmental protection causes, industrial plants are actively seeking innovative and effective ways to protect water resources. One of the promising methods in purifying post-production sewage has become the use of easily accessible, simple to use, low cost and, what is important, non-toxic sorbents [5].

The aim of the research presented in the article was to remove selected cations from wastewater from the production of soda ash in the sorption process.

2. Methods

Three sorbents were used for the tests: Halosorb (processed halloysite), Compakt and Damsorb K (both are diatomaceous earth, calcined).

Wastewater produced in the production process of soda ash is a liquid waste mixed from two production plants: Soda Mątwy in Inowrocław, and Janikosoda in Janikowo. It is characterized by a strongly alkaline reaction, a high electrolytic conductivity and a high concentration of chlorides, ammonium ion, sulphates, phosphates, calcium, potassium, sodium and magnesium. The tests included concentration of five cations: ammonium, sodium, calcium, potassium and magnesium. The whole cycle of tests was carried out on wastewater collected on the same day.

The cation removal process was carried out by the dynamic method in three columns, each of which was filled with 250 g of another sorbent. Before the basic examination, the beds were rinsed with distilled water. Sewage with a volume of 500 cm^3 was filtered through the research material. At the end of the process, 250 cm^3 of each sample was taken. Four series of tests were carried out. In each of them a different load of the bed was applied (from 0.579 $m^3 \cdot m^{-2} \cdot h^{-1}$ to 1.937 $m^3 \cdot m^{-2} \cdot h^{-1}$). After the experiment, the sorbent columns were again rinsed with distilled water. The described research was carried out twice.

3. Results and Discussion

The degree of cations removal from wastewater after soda ash production is presented in Table 1.

Table 1. Degree of cations removal in the sorption process on the tested materials: Halosorb, Compakt and Damsorb K.

Ion	Range of Removal Efficiency [%]		
	Halosorb	Compakt	Damsorb K
Sodium	62.68–82.04	62.94–92.05	65.68–86.58
Calcium	62.87–79.99	63.25–90.59	64.18–85.67
Potassium	62.82–85.23	60.02–88.7	55.97–84.08
Magnesium	18.62–89.77	22.03–90.48	19.89–92.94
Ammonia	64.08–81.74	65.74–93.88	67.13–85.67

Shapiro–Wilk's, Scheffe's and Kruskal–Wallis' statistical tests were used to draw conclusions. The use of statistical tests allowed for a more accurate interpretation of the impact of individual factors on the process.

After performing detailed analyzes, it was found that the results obtained for individual sorbents are not significantly different, which indicates that the type of deposit used does not affect the degree of removal of any of the examined ions. A similar effect can be obtained by using any of them.

In the case of all cations, it was found that the load on the deposit significantly influences the results of the experiment. Sodium removal on Halosorb and Damsorb K was most effective at 0.969 $m^3 \cdot m^{-2} \cdot h^{-1}$, and for Compakt at 1.937 $m^3 \cdot m^{-2} \cdot h^{-1}$. At the same time, it was observed that for all materials, the lowest effect was achieved with the bed load of 0.579 $m^3 \cdot m^{-2} \cdot h^{-1}$. On the basis of subsequent tests, it was noticed that calcium is removed most effectively by all materials with a bed load of 0.969 $m^3 \cdot m^{-2} \cdot h^{-1}$. All sorbents showed the highest efficiency of lowering potassium at a 0.969 $m^3 \cdot m^{-2} \cdot h^{-1}$ bed load. The ammonium ion on Halosorb and Damsorb K was most effectively removed at a load of 0.969 $m^3 \cdot m^{-2} \cdot h^{-1}$, while for Compakt it was at a load of 1.937 $m^3 \cdot m^{-2} \cdot h^{-1}$. Magnesium removal was different than the other ions. Halosorb showed the highest efficiency at the bed load of 0.579 $m^3 \cdot m^{-2} \cdot h^{-1}$, while for Compakt and Damsorb K at the load of 1628 $m^3 \cdot m^{-2} \cdot h^{-1}$.

The concentration of all the mentioned anions was reduced to a large extent, which indicates the possibility of further, more accurate tests. For this purpose, one should take into account: the availability of material on the market, the pre-treatment of natural material including process economics, determining the probable sorption mechanism, determining the sorption capacity and the method of utilization or sorbent utilization after its saturation [5]. The sorption capacity can be additionally increased by modifying the surface of sorbents, which, however, is associated with an increase in their cost [6].

4. Conclusions

The following conclusions were drawn from the conducted research:

- The type of sorbent does not affect the removal degree of the studied ions.
- The removal of the sodium and ammonium ions is most effective at the bed loads of 0.969 $m^3 \cdot m^{-2} \cdot h^{-1}$ and 1.937 $m^3 \cdot m^{-2} \cdot h^{-1}$.
- The degree of removal of calcium and potassium is highest when using a bed load of 0.969 $m^3 \cdot m^{-2} \cdot h^{-1}$.
- The magnesium concentration is most effectively reduced at the bed loads of 1.628 $m^3 \cdot m^{-2} \cdot h^{-1}$ and 0.579 $m^3 \cdot m^{-2} \cdot h^{-1}$.

Author Contributions: A.G. performed the experiment; A.G. and J.P. conceived and designed the experiments, analyzed the data and then wrote the paper.

Acknowledgments: The research was carried out as part of the work MB/WBiIS/1/2017 and statutory work S/WBiIŚ/3/2014 and funded by the Ministry of Science and Higher Education.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, and in the decision to publish the results.

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