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Comparative Analysis of Sorbents on Chromate Ion (VI) Sorption and Desorption: Influence of Composition and pH from Ilmenite Processing Solutions

Abstract. In this work, the processes of sorption and desorption of chromate ions from the solution obtained as a result of the processing of high-chromium ilmenite concentrate were studied using sorbents: Amberlite IR120 (Na), Amberlite IRA-35, PuroliteA-100, LewatitMono Plus M-500. The influence of pH factor and sorption system composition on the sorption process of chromate ions (VI) was investigated. Different polymers were tested to evaluate their combined effect on the recovery of chromate ions. A correlation was found between the increase in the efficiency of the sorption process of chromate ions (98%) and a decrease in pH from pH 13.5 to pH 2.5. In addition, the sorption process was improved at higher sorbent concentrations and the desorption efficiency increased at higher molar concentrations of sodium hydroxide (NaOH). The study's results will serve for the optimization of sorption processes for the extraction of chromate ions (VI) with the participation of various polymeric sorbents in the industry.

Keywords: adsorption, desorption, sorbents, chromium, Amberlite IR120 (Na), Amberlite IRA-35, PuroliteA-100, LewatitMonoPlus M-500.

Introduction

The study by Kenzhaliyev (2019) explores innovative technologies aimed at improving the extraction of non-ferrous, precious, rare, and rare earth metals. It discusses various advancements and methods that enhance recovery rates and efficiency in metal extraction processes. The study emphasizes the significance of these technologies for optimizing resource utilization and advancing sustainable practices in the mining and mineral processing industries. The increasing pollution of aquatic ecosystems with heavy metals seriously threatens the environment and human health. Among these pollutants, chromium (VI) ions attract special attention due to their widespread use in various industrial processes and their toxic effects on the biosphere (Briffa, Sinagra, & Blundell, 2020). Chromium (VI) water contamination is a serious environmental problem due to its toxicity and persistence (Xie, 2024). Effective removal of chromate ions from aqueous solutions is a key factor in reducing environmental and sanitary risks (Hammadi et al., 2024). Solutions obtained from the processing of ilmenite concentrate containing chromium (VI) are a potential source for extracting chromate ions. This study focuses on the sorption and desorption processes of chromate ions (VI) from ilmenite concentrate processing solutions, with special attention to the critical role of pH and sorbent concentration. Various sorbents, from natural to synthetic, are studied to determine the optimum conditions for the efficient removal of chromate -ions (VI). Understanding the relationship between pH levels and sorbent characteristics not only expands our understanding of sorption mechanisms but also provides a basis for developing sustainable sorbent recovery strategies.

The studies by Ultarakova et al. (2021), Mamutova et al. (2018), and Kenzhaliyev et al. (2024) collectively address critical aspects of resource recovery and waste management in the processing of ilmenite concentrate and titanium-magnesium production. Ultarakova et al. (2021) focus on optimizing methods to remove silica from pyrometallurgical wastes, aiming to enhance resource recovery and reduce environmental impact. Mamutova et al. (2018) examine the challenges of processing chloride waste from titanium-magnesium production, proposing solutions for effective management and improved industry practices. Kenzhaliyev et al. (2024) investigate the sorption of chromate ions from ilmenite processing solutions using various sorbents, analyzing the effects of pH and sorbent concentration on extraction efficiency. Together, these studies emphasize the importance of optimizing waste treatment processes to maximize resource recovery and minimize environmental harm in mineral processing industries.The main purpose of this study was to investigate the effect of solution pH and sorbent concentration on the extraction efficiency of chromate ions and to evaluate the effectiveness of sorbents under different experimental conditions.

Research material

Table 1 delineates the materials employed in the experimental procedure, along with their respective properties and characteristics. The sorbents utilized in this research include Amberlite IR120 Na, Anionite AMR, Purolite A-100, and Lewatit MonoPlus M-500 (refer to Table 1). In the course of the experiments, a solution comprising chromate ions, derived from the processing of high chromium ilmenite concentrate, henceforth designated as "the chromate ion solution," was systematically introduced into the measuring beakers.

Table-1. Materials used

Sorbentsused	Characteristics
Amberlite IR120 Na	Base - styrene-divinylbenzene copolymer Functional groups-Sulfonates Physical form-Amber granules Ionic form at delivery-Na+ Total static exchange capacity, Pe=2 mmol/cm^3 Moisture content - 50% Coefficient of homogeneity-1.9 Manufacturer: ROHM &HASS
Anionite AMR	A weakly basic macroporous resin with a styrene-divinylbenzene matrix. Appearance: Spherical-shaped grains of white to beige color. Total static exchange capacity, Pe=1.25 mmol/cm^3 Dynamic exchange capacity with a given re-generant flow rate, 538 mol/m^3, Mass fractionofmoisture, 45%
PuroliteA-100	Structure of polymer matrix Polystyrene cross-linked with divinylbenzene. Appearance- opaque spherical particles of white color. Functional groups-Tertiary amine Total exchange capacity1 .3 g-eq/L Residual humidity-62 % Homogeneitycoefficient-1.7 Manufacturer: Purolite (England)
LewatitMonoPlusM-500	LewatitMonoPlus M 500 is a strongly basic gel anionite based on styrene-divinylbenzene copolymer, with a monodisperse size. Ionic form at delivery: Cl- Functional group: quaternary amine type I Coefficient of homogeneity- 1.1 Average granule size*: 0.62 ± 0.05 mm Residual humidity: 55%. Manufacturer: LANXESS (Germany)

Methodology of experiments

The study of sorption processes was carried out under static conditions with periodic stirring until the equilibrium state in the studied systems was reached. After specified time intervals the solutions were analyzed for the content of chromium ions, after which the sorbent was separated from the solution by vacuum filtration. Solutions based on ilmenite concentrate with chromate ions were prepared in the range of pH values from 1.5 to 13.5. Sorbent concentrations were varied to determine their effect on chromium sorption efficiency.

The desorption processes were studied in the same way as in the case of sorption, under static conditions with periodic stirring until the equilibrium state was established. Chromium-saturated sorbents were treated with solutions of sodium hydroxide (NaOH) at pH 1.5 and sulfuric acid (H_2SO_4) at pH 13.5 with different molar concentrations (0.05 M, 1 M, 2 M). The desorption efficiency was evaluated by the amount of chromium ions released back into the solution.

Discussion of results

The efficiency of the sorption process was evaluated by analyzing aliquots sampled from 10 ml of solution at intervals over 24 hours from the start of sorption. The experiments were carried out at an initial pH value of 13.5, corresponding to the solution obtained during the processing of ilmenite concentrate. For each experiment, 0.1 g sorbent suspensions and 100 ml of ilmenite concentrate solution were used. The obtained filtrates were studied by methods of chemical analysis, the results of which are presented in Table 2.

Table 2. Results of chemical analysis.

№	Name ofobject	Abbreviations	C, g/dm^3
1	Initialsolution		1.66
2	MMA	MMA	1.48
3	PuroliteA-100	A-100	1.47
4	LewatitMonoPlusM-500	M-500	1.36
6	Amberlite IR120 Na	Amberlite	1.40

Based on the data presented in Figure 1, it can be seen that the best results for the sorption of chromate ions from the solution obtained during the processing of ilmenite concentrate at pH 13.5 demonstrated sorbents LewatitMonoPlusM-500 and Amberlite.IR120 Na. Thus, these sorbents were chosen for further experiments to study the influence of various parameters on the achievement of optimal conditions for sorption and desorption.

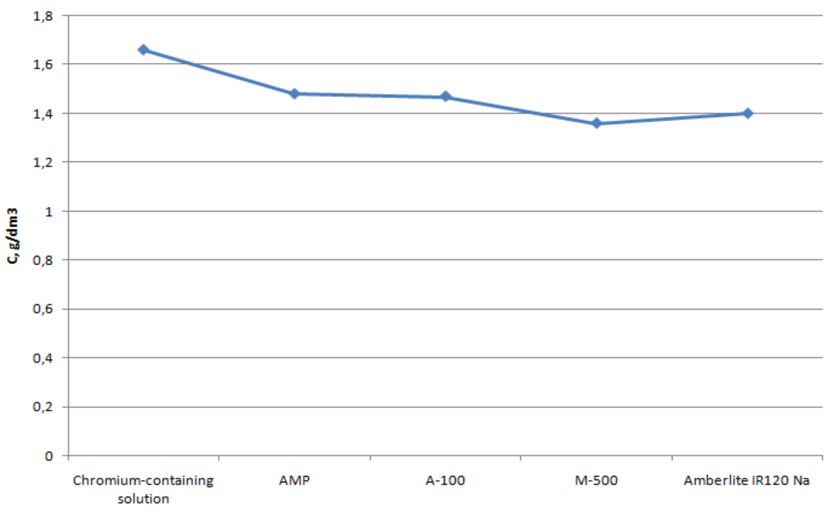

Figure 1. Sorption of chromate ions by different sorbents from the solution obtained during the processing of ilmenite concentrate

In the next series of experiments, the sorbents were suspended: Lewatit Mono Plus M-500 and Amberlite IR120 Na were taken in amounts of 5 g and 0.5 g at constant volume of chromate-containing solution (V = 50 ml) and sorption studies were carried out while varying the pH of the medium. After 24 hours, chemical analysis was carried out to determine the content of chromate ions in the solution. The results of the analysis are presented in Table 3.

Table 3. Results of sorption study.

sampleno.	Name ofobjects	Weight of sorbent m, g	mediumpH	C,g/dm^3
1	Chromium-containingsolution	50 ml	13.55	6.935
2	Amberlite IR120 Na	0.5	13.55	5.34
3	Lewatit Mono Plus M500	0.5	13.55	4.76
4	Amberlite IR120 Na	5	13.55	4.42
5	Amberlite IR120 Na	0.5	2.5	0.76
6	Lewatit Mono Plus M500	0.5	2.5	0.74
7	Amberlite IR120 Na	5	2.5	0.4

When the pH was reduced to 2.5, a significant increase in sorption efficiency was observed, which is reflected in Figure 2. At this low pH level, all the studied sorbents provided removal of chromate ions at the level of more than 90%. Increasing the concentration of the sorbent in turn also had a positive effect on the sorption process, it should be noted that increasing the concentration of the sorbent contributed to a more efficient removal of chromium ions.

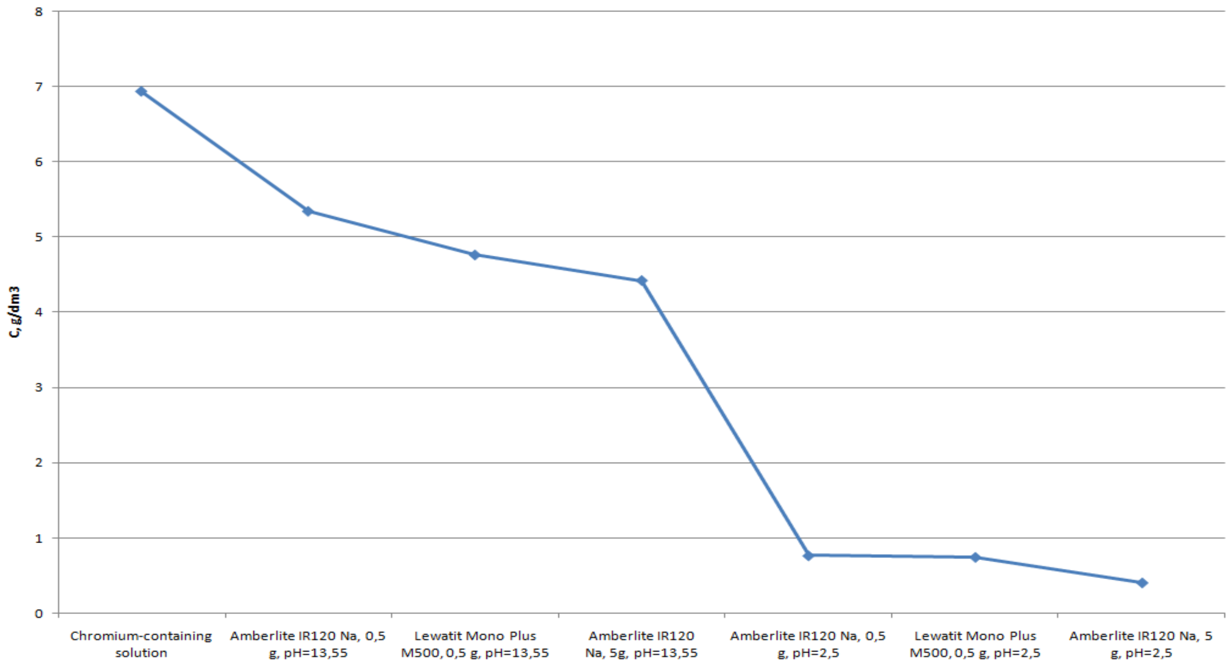

Figure 2. Effect of pH on the process of sorption of chromium from the solution obtained in the process of processing of ilmenite concentrate

Desorption was successfully carried out using 2M NaOH solutions. Increasing the molar concentration of NaOH led to an increase in desorption efficiency. The desorption efficiency was found to correlate with the alkali concentration, indicating that stronger alkaline conditions favor the release of chromate ions from the sorbent. The desorption efficiency was determined based on the chemical analysis data presented in Table 4.

Table 4. Results of chemical analysis

sampleno	Name ofobjects	Weight of sorbent m, g	mediumpH	C, g/dm^3
1	Initialchromium-containingsolution	50 r	13.55	5.838
2	Amberlite IR120 Na	5	13.55	0.31
3	Amberlite IR120 Na	0.5	13.55	0.13
4	LewatitMonoPlusM500	0.5	13.55	0.29
5	Amberlite IR120 Na	5	2.5	4.81
6	Amberlite IR120 Na	0.5	2.5	4.08
7	LewatitMonoPlusM500	0.5	2.5	4.79

Analysis of experimental data and their comparative review showed that pH has a significant effect on the process of sorption of chromium from the solution obtained from the processing of ilmenite concentrate. At high pH values, chromium sorption decreases, which is due to the formation of insoluble hydroxides or reduced availability of ions. On the contrary, at lower pH, the solubility of chromate ions and their ability to interact with sorbents increase, which contributes to the increase in sorption efficiency.

Figure 3 shows the graph demonstrating the effect of pH on the desorption process of chromate ions sorbed from the solution obtained during the processing of ilmenite concentrate.

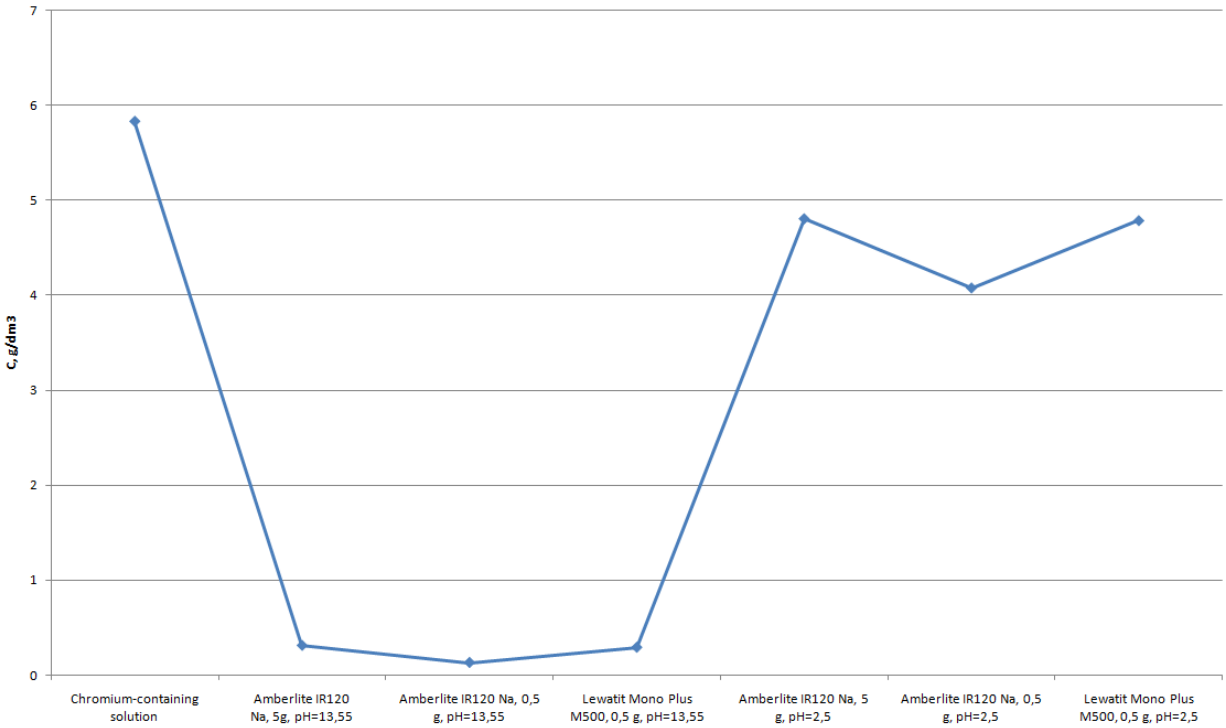

Figure 3. Effect of pH on the desorption process of chromate ions (VI)

The efficiency of ionite sorption is also determined by their amount in the sorbent:solution system. Increasing the ionite content in the solution obtained from the processing of ilmenite concentrate contributes to an increase in the available surface area for ion binding, which leads to an acceleration of the process and an increase in chromium sorption performance. The study confirms that optimization of the amount of sorbent plays a key role in improving the efficiency of the sorption process.

Desorption experiments showed that NaOH solutions are highly effective for sorbent regeneration. The desorption efficiency increases when more concentrated NaOH solutions are used because a more alkaline medium breaks the bonds between chromate ionomers and sorbent, which promotes their release.

Conclusion

The study results emphasize the key importance of pH and sorbent concentration in the processes of sorption and desorption of chromate ions from solutions of ilmenite concentrate. Lower pH values significantly improve the removal of chromate ions (VI), while increasing the sorbent concentration contributes to the efficiency of the sorption process. For the desorption process, higher molar concentrations of NaOH were found to provide better sorbent regeneration. These findings provide important data for the optimization of chromate ion purification methods and sorbent applications in industry. In the future, research should focus on a detailed study of the mechanisms of these processes and evaluation of the performance of different sorbents under different operating conditions.

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References

Briffa, J. F., Sinagra, E., Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon, 6(9), e04691.https://doi.org/10.1016/j.heliyon.2020.e0469

Hammadi, M.H., Kerakra, S., Bey, S. et al. (2024). Advancements in Cr(VI) Removal from Aqueous Solution Using PLA/PBAT/GO/Cloisite 30b Hybrid Nanocomposite Polymer Inclusion Membranes. Water Air Soil Pollut, 235, 730.https://doi.org/10.1007/s11270-024-07550-2

Kenzhaliyev, B. (2019). Innovative technologies providing enhancement of non-ferrous, precious, rare and rare earth metals extraction. *Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources*, 310(3), 64–75. https://doi.org/10.31643/2019/6445.30

Kenzhaliyev, B., Ultarakova, A., Toishybek, A., Sadykov, N. (2024). Processing of Ilmenite Concentrate with High Chromium Content. Processes, 12, 1462. https://doi.org/10.3390/pr12071462

Mamutova A., Ultarakova A., Kuldeev, E., &Esengaziev A. (2018). Modern condition and proposed solutions for processing chloride waste of titanium-magnesium production. *KompleksnoeIspolzovanieMineralnogoSyra = Complex Use of Mineral Resources*, 307(4), 173–180. https://doi.org/10.31643/2018/6445.44

Ultarakova, A., Karshyga, Z., Lokhova, N., Naimanbaev, M., Yessengaziyev, A., & Burns, P. (2021). Methods of silica removal from pyrometallurgical processing wastes of ilmenite concentrate*. KompleksnoeIspolzovanieMineralnogoSyra = Complex Use of Mineral Resources*, 322(3), 79–88. https://doi.org/10.31643/2022/6445.32

Xie, Sh. (2024). Water contamination due to hexavalent chromium and its health impacts: exploring green technology for Cr (VI) remediation. Green Chemistry Letters and Reviews. Volume 17, 1.https://doi.org/10.1080/17518253.2024.2356614