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Gulnara Toilanbay
Satbayev University, Institute of Metallurgy and Ore Beneficiation JSC, Kazakhstan
E-mail: toilanbay_g@mail.ru
ORCID ID: https://orcid.org/0000-0001-5926-6610

Arman Baishibekov
Satbayev University, Institute of Metallurgy and Ore Beneficiation JSC, Kazakhstan
E-mail: abayshibekov@mail.ru
ORCID ID: https://orcid.org/0000-0003-3704-9425

Mrutyunjay Panigrahi
Vellore Institute of Technology, Tamil Nadu, India
E-mail: mrutyunjayjapan@gmail.com
ORCID ID: https://orcid.org/0000-0003-2738-502X

Małgorzata Rutkowska-Gorczyca
Wrocław University of Science and Technology, Poland
E-mail: malgorzata.rutkowska-gorczyca@pwr.edu.pl
ORCID ID: https://orcid.org/0000-0003-2712-5914

Adsorption of chromate ions (VI) from solutions formed during processing of high-chromium ilmenite concentrate using interpolymer systems

Abstract: The paper presents the results of the sorption of chromium (VI) ions from solutions, obtained during the processing of high-chromium ilmenite concentrate using the simultaneous co-presence of anionite (AB-17-8(Na)) and cationite (KU-2-8(Na)). Under static conditions, the sorption behavior of two polymer hydrogels was studied at different molar ratios of polymers to determine their sorption capacity towards chromium (VI) ions. The investigated polymer systems were formed at molar ratios of KU-2-8(Na) and AB-17-8(Na), respectively: 6:0, 4:2, 3:3, 2:4 и0:6. The sorption efficiency of interpolymer hydrogel systems towards chromate ions (VI) in solutions obtained during the processing of ilmenite concentrate has been studied. An interpolymer system with two types of hydrogels: anionic (AB-17-8(Na)) and cationic (KU-2-8(Na)) was studied. Different molar ratios of these polymers were tested to evaluate their combined effect on the sorption of chromate ions. A Shimadzu atomic absorption spectrometer was used to analyze the samples. The results showed that the simultaneous presence of the two polymers in the system enhanced the efficiency of the sorption process compared to using either of them individually. It was also demonstrated that the best sorption occurred when both polymers were present, with optimum performance at a ratio of 2:4. The combined presence of anionic and cationic polymers enhances the sorption process of chromium compared to the use of either polymer alone.

Keywords: interpolymer systems, hydrogels, chromium, adsorption, desorption.

Introduction.

The studies by Mamutova et al. (2018) and Kenzhaliyev (2019) address critical issues in the processing and extraction of metals from mineral resources. Mamutova et al. focus on the modern conditions surrounding the management of chloride waste generated by titanium-magnesium production, proposing solutions to mitigate environmental impacts and enhance resource recovery. In contrast, Kenzhaliyev examines innovative technologies designed to improve the extraction of non-ferrous, precious, rare, and rare earth metals. Together, these studies highlight the importance of advancing processing techniques and adopting innovative solutions to optimize resource utilization while addressing environmental challenges in the mining industry. Panichkin and Kshibekova (2023) assess how different flux compositions affect the efficiency of removing non-metallic inclusions in high-chromium cast iron. It likely explores the relationship between flux materials and the quality of cast iron, aiming to improve manufacturing processes and product performance by optimizing inclusion removal.

Chromium is a heavy metal widely used in industries including metallurgy, electroplating and leather tanning (Monga et al., 2023). Chromium exists in several degrees of oxidation, but the most toxic and carcinogenic is Cr (VI) (Prasad et al., 2023). It is often found in industrial wastes and can cause serious environmental and human health problems if improperly handled (Sharma et al.,2021). Effective removal and recovery of chromium from contaminated solutions is critical to reduce its impact on the ecosystem

and the health of living beings (Hussain et al., 2020; Islam et al., 2023). Conventional purification methods are usually expensive and consume large amounts of energy, they produce harmful by-products and can cause secondary contamination. The main indicators of adsorption that enhance its advantages over other methods are their efficiency, speed, simplicity and safety, and economic feasibility. However, modern science is faced with the challenge of developing new materials that could potentially improve existing sorption methods.

Extraction of chromate ions (Cr (VI)) from solutions using interpolymer systems represents a promising direction in the field of sorption technologies, providing a more efficient and environmentally friendly alternative to existing methods of water treatment. Traditional physical and chemical methods are aimed at the treatment of industrial effluents and are often accompanied by high costs, significant energy consumption (Grzegorzek et al., 2023) also the formation of harmful by-products, which can cause repeated pollution of nature. In light of these problems, there is a need to develop new and more efficient approaches to water treatment, especially for the removal of toxic metal ions such as hexavalent chromate ions.

One such approach is adsorption (Amosa et al., 2021), which offers several advantages including high efficiency, speed of sorption processes, ease of implementation and safety of use. Adsorption methods are also cost-effective as they can achieve high degrees of purification with minimal operating costs. At the same time, current research in materials science is focused on the development of new sorbents (Aarab et al., 2020) and adsorption systems that could significantly improve the efficiency of water treatment and reduce the environmental burden on nature.

Interpolymer systems, including the use of polymeric sorbents of different natures, allow flexible control of sorption characteristics, including selectivity to certain ions, sorption capacity and resistance to aggressive media (Jumadilov et al., 2023). Such systems can efficiently adsorb chromate ions from solutions obtained during the processing of high-chromium ilmenite concentrate (Kenzhaliyev et al., 2024). This makes interpolymer systems not only economically feasible but also environmentally friendly for the extraction of hexavalent chromium from solutions.

Materials used.

Two hydrogels were used in this study**:** anionic polymer AB-17-8(Cl) (styrene and divinylbenzene copolymers with benzyltrimethylammonium functional groups) and cationic polymer KU-2-8(Na) (styrene and divinylbenzene copolymers).

Results and discussion.

Two sorbents were used for the conducted research: cationite KU-2-8(Na) and AB-17-8(Na) in salt forms, both separately and in different ratios from 6:0 (in case of 6:0 ratio, six parts of this ratio represent KU-2-8(Na) sorbent) to 0:6 (in case of 0:6 ratio, six parts of this ratio represents AB-17-8(Na) sorbent) (Table-1). During the experiments, a solution containing chromate ion obtained during the processing of high chromium ilmenite concentrate, hereinafter referred to as "Solution containing chromate ion", was introduced into measuring beakers. We used 0.1 g of sorbent suspensions per 200 ml of solution.

Table-1. Materials used

Sorbents used	**Solutions used**
6-0 (net KU-2-8(Na).	Solution containingchromateions
4:2 (4 moles of KU-2-8(Na) vs. 2 moles of AB-17-8(Cl))	Solution containingchromateions
3:3 (equal number of moles of KU-2-8(Na) and AB-17-8(Cl))	Solution containingchromateions
2:4 (from 2 moles of KU-2-8(Na) to 4 moles of AB-17-8(Cl))	Solution containingchromateions
0:6 (net AB-17-8(Cl))	Solution containingchromateions

Aliquots were taken at a certain time interval from the beginning of the sorption process for 24 hours. The filtrates were investigated by chemical methods of analysis. The data are summarized in Table 2.

Table-2. Results of chemical analysis

№	Name	C, g/dm^3
1	Initial solution	1.66
2	6:0(Ku-2-8(Na))	1.61
3	4:2(Ky-2-8(Na):AB-17-8(Cl))	1.33
4	3:3(Ky-2-8(Na):AB-17-8(Cl))	1.41
5	2:4(Ky-2-8(Na):AB-17-8(Cl))	1.29
6	0:6(AB-17-8(Cl))	1.58

The effect of different ratios of sorbents KU-2-8(Na) and AB-17-8(Cl) on the process of sorption of chromate ions (VI) from the solution containing chromate ions (VI) obtained during the processing of ilmenite concentrate is presented in Figure 1.

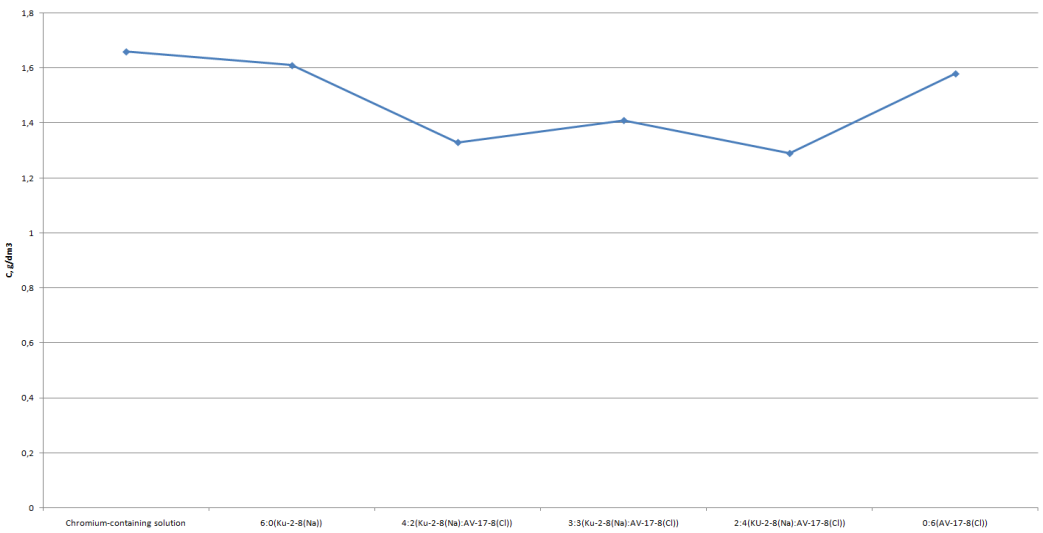

Figure 1. Effect of different ratios of sorbents KU-2-8(Na) and AB-17-8(Cl) on the process of chromium sorption from a solution containing chromate ions (VI)

Experimental data showed that chromium (VI) is sorbed more efficiently in the presence of both polymers (Figure 1). In particular, at a molar ratio of KU-2-8(Na) and AB-17-8(Cl) of 2:4, the highest sorption capacity was achieved. This improved performance is attributed to the synergistic effect of the anionic and cationic polymers, which interact with chromium ions more effectively than the individual polymers. The dual presence of both types of polymers probably provides a more complete ion exchange environment in which chromium from the solution is well sorbed.

We also studied the desorption process at different pH. Since the initial environment of the solution obtained during the processing of ilmenite concentrate was alkaline (pH-13.5), the desorption was carried out with sulfuric acid (H_2 SO_4 0.05M), in the presence of sorbents at a ratio of 2:4 and 4:2, as these ratios showed the highest efficiency of sorption of chromium from solutions obtained during the processing of ilmenite concentrate (Table-3).

Table-3. Results of chemical analysis

№	Name of research objects	C, g/dm^3
1	Initial solution	2.152
2	2:4(Cu-2-8(Na): AB-17-8(Cl)) desorption	0.167
3	4:2(Cu-2-8(Na): AB-17-8(Cl)) desorption	0.228

Figure 2 shows the effect of different ratios of sorbents KU-2-8(Na) and AB-17-8(Cl) on the process of desorption of chromium(VI) from the solution obtained during the processing of ilmenite concentrate.

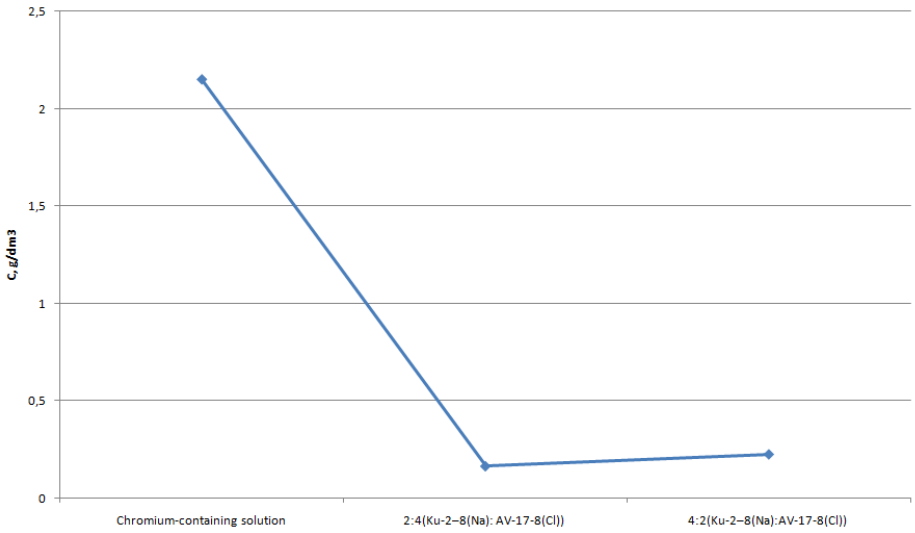

Figure 2. Effect of different ratios of sorbents KU-2-8(Na) and AB-17-8(Cl) on the desorption process of chromium(VI) from solution, obtained in the process of processing ilmenite concentrate

Studies of desorption processes have shown that chromate ions (VI) can be effectively released from hydrogels, indicating that the materials can be reused for multiple cycles of sorption and desorption. The reusability is an important factor in evaluating the cost-effectiveness of hydrogels for industrial-scale applications.

The obtained results of the study are not only the practical nature of the application of two-polymer systems in the extraction of chromate ions, but the purpose of this study is to demonstrate the possibilities of sorption and desorption of chromium from the solution obtained during the processing of ilmenite concentrate, to show that the system of two polymers in one container, due to the forces of van der Waals and other interactions adsorbs chromium(VI) ions better than these sorbents separately. We have to study the influence of various parameters such as concentration, pH, temperature, etc. on the sorption and desorption processes. In this way, we will achieve the ideal sorption and desorption of chromate ion (VI) from the ilmenite concentrate solution.

Conclusion

Experimental data were obtained indicating the effectiveness of using a combination of anionic and cationic hydrogels for the sorption of chromium ions. The results demonstrated that a balanced molar ratio of both polymers improves the sorption of chromium from industrial wastewater and is an acceptable application. Further research and optimization of the use of these polymeric materials may lead to more efficient and cost-effective solutions for the disposal of chromium (VI) contaminants.

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References

Aarab, N., Hsini, A., Essekri, A., Laabd, M., Lakhmiri, R., Albourine, A. (2020). Removal of an emerging pharmaceutical pollutant (metronidazole) using PPY-PANi copolymer: kinetics, equilibrium and DFT identification of adsorption mechanism*Groundwater Sustain. Develop*., 11, Article 100416. https://doi.org/10.1016/j.gsd.2020.100416

Amosa, K.M., Aderibigbe, F.A., Adeniyi, A.G., Ighalo, J.O., Bello, B.T., Jami, M.S., Alkhatib, M.F.R., Majozi, T., Abdulkareem S.A. (2021). Auto-correlation robustness of factorial designs and GAMS in studying the effects of process variables in a dual-objective adsorption system. *Appl. Water Sci*., 11(2), pp. 43-57. https://doi.org/10.1007/s13201-020-01349-2

Grzegorzek, M., Wartalska, K., Kaźmierczak, B. (2023). Review of water treatment methods with a focus on energy consumption. International Communications in Heat and Mass Transfer. 143, p. 106674. https://doi.org/10.1016/j.icheatmasstransfer.2023.106674

Hussain, F.S., Memon, N. (2020). Chapter: Materials and Technologies for the Removal of Chromium from Aqueous Systems.*Sustainable Agriculture Reviews,*40*,* 113-177. https://doi.org/10.1007/978-3-030-33281-5_4

Islam, Md.M., Mohana, A.A., Rahman, Md.A., Rahman, M., Naidu, R., Rahman, M.M. (2023). A Comprehensive Review of the Current Progress of Chromium Removal Methods from Aqueous Solution.Toxics, 11(3), 252.https://doi.org/10.3390/toxics11030252

Jumadilov, T.K., Imangazy, A.M., Khimersen, Kh., Haponiuk, J.T. (2023). Remote interaction effect of industrial ion exchangers on the electrochemical and sorption equilibrium in scandium sulfate solution. *Polym.Bull,* 81, pp. 2023-2041.https://doi.org/10.1007/s00289-023-04800-x

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, p. 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. *Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources*, 307(4), 173–180. https://doi.org/10.31643/2018/6445.44

Monga, A., Fulke, A.B., Giripunje, M.D., Dasgupta, D. (2023). Chapter: Microbial Remediation Technologies for Chromium Removal: Mechanism, Challenges and Future Prospect. *Chromium in Plants and Environment,* pp 319-384

Panichkin, A.V., Kshibekova, B.B. (2023). Assessment of the flux composition effect on the removal efficiency of non-metallic inclusions in high-chromium cast iron. *Challenges of Science*. Issue VI, 2023, pp. 290-297. https://doi.org/10.31643/2023.36

Prasad, Sh., Yadav, K.K., Kumar, S., Gupta, N., Cabral-Pinto, M.M.S., Rezania, S., Radwan, N., Alam, J. (2021). Chromium contamination and effect on environmental health and its remediation: A sustainable approach. *Journal of Environmental Management,*285, p. 112174. https://doi.org/10.1016/j.jenvman.2021.112174

Sharma, N., Sodhi, K.K., Kumar, M., Singh D.K. (2021). Heavy metal pollution: Insights into chromium eco-toxicity and recent advancement in its remediation. *Environmental Nanotechnology, Monitoring & Management,* 15, p. 100388. https://doi.org/10.1016/j.enmm.2020.100388