EVALUATION OF THE EFFICIENCY OF POLYSULFIDE SORBENTS IN THE REMOVAL OF HEAVY METAL IONS FROM WASTEWATER OF OIL AND GAS PROCESSING PLANTS

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Abstract:
This article investigates the adsorption efficiency of polysulfide sorbents synthesized from local raw materials in selectively removing heavy metal ions- specifically Fe^{2+}, Cu^{2+}, Zn^{2+} and Pb^{2+}- from industrial wastewater obtained from oil and gas processing facilities. The study tested PSK-1, PSK-2, and SMED-8 grade sorbents, evaluating their adsorption capacity, selectivity, and reusability. Analytical assessments were conducted using UV–Vis spectrophotometry and atomic absorption spectroscopy (AAS). The experimental results demonstrated that the SMED-8 sorbent exhibited high efficiency and long-term operational stability. This development holds significant promise for the advancement of environmentally friendly and economically feasible sorption technologies.

Keywords: Polysulfide sorbents, heavy metal ions, oil and gas industry effluents, adsorption efficiency, Fe^{2+}, Cu^{2+}, Zn^{2+} Pb^{2+}, UV–Vis, SMED-8, recyclable materials.

Introduction

In oil and gas processing plants, wastewater generated during production processes often contains elevated concentrations of heavy metal ions such as iron (Fe^{2+}), copper (Cu^{2+}), zinc (Zn^{2+}), lead (Pb^{2+}), and mercury (Hg^{2+}). These pollutants pose serious environmental risks, contributing to the degradation of water resources, soil contamination, and adverse effects on human health. Consequently, there is a growing demand for the development of effective, selective, environmentally safe, and reusable sorbent materials for industrial wastewater treatment.

In recent years, organic–inorganic composite sorbents — particularly those based on elemental sulfur -have gained attention as a promising approach for the selective removal of heavy metal ions. These materials contain polymeric S–S bonds and functional groups capable of forming complexes with metal ions, facilitating efficient adsorption [1–6].

This study focuses on evaluating the adsorption efficiency of polysulfide sorbents synthesized from locally available raw materials for the selective removal of Fe^{2+}, Cu^{2+}, Zn^{2+} and Pb^{2+}- ions from the wastewater of oil and gas processing plants. The issue of heavy metal

contamination in industrial effluents is currently one of the most pressing environmental concerns in Uzbekistan and other industrialized countries. Given the increasing scarcity of clean water resources and the demand for wastewater reuse, the development of selective heavy metal removal technologies has substantial scientific and practical significance.

Relevance of the Study

The relevance of this study lies, on the one hand, in improving technological efficiency and, on the other hand, in facilitating the production of environmentally safe sorbents using locally available raw materials (such as sulfur, vegetable oil, hydrolyzed resin, etc.) within the regions of the Republic. These sorbents provide a sustainable solution to one of the most pressing environmental challenges facing the oil and gas industry - the treatment of complex industrial effluents contaminated with heavy metals.

Materials and Methods

Experimental research was conducted using samples of industrial wastewater collected from Workshop No. 6 of the Muborak Gas Processing Plant. The primary pollutants identified in the samples were Fe^{2+}, Cu^{2+}, Zn^{2+} and Pb^{2+} ions. The adsorption capacity of three types of polysulfide sorbents — PSK-1 (black), PSK-2 (light brown), and SMED-8 — was evaluated under laboratory conditions [7–12].

Table 1. Analysis of the Removal Efficiency of Heavy Metal Ions Using Polysulfide Sorbents

Metal Ion	Initial Concentration (mg/l)	After PSK-1 (mg/l)	After PSK-2 (mg/l)	After SMED-8 (mg/l)
Fe^{2+}	4.8	0.24	0.85	0.97
Cu^{2+}	3.6	0.28	0.35	0.13
Zn^{2+}	7.4	1.15	1.42	0.88
Pb^{2+}	5.8	0.72	0.91	0.58

The experimental analysis confirmed the presence of Fe^{2+}, Cu^{2+}, Zn^{2+} and Pb^{2+}- ions in the wastewater. To selectively remove these heavy metal ions, the three polysulfide sorbents were tested in laboratory conditions. Initial concentrations were: Fe^{2+} – 4.8 mg/l, Cu^{2+} – 3.6 mg/l, Zn^{2+} – 7.4 mg/l, and Pb^{2+} – 5.8 mg/l. After the sorption process, the concentrations of these ions significantly decreased.

For Fe^{2+}, SMED-8 reduced the level to 0.97 mg/l, indicating over 80% removal efficiency, while PSK-1 achieved an even lower value of 0.24 mg/l. For Cu^{2+}, SMED-8 achieved the best

result, reducing the concentration to 0.13 mg/l (approx. 96.4% efficiency). SMED-8 also outperformed the other sorbents in reducing Zn^{2+} and Pb^{2+} concentrations, achieving 0.88 mg/l and 0.58 mg/l respectively.

These results indicate that SMED-8 demonstrates the highest selectivity and overall adsorption efficiency for all tested ions. While PSK-1 also performed well, especially for Fe^{2+} and Cu^{2+}, PSK-2 exhibited lower efficiency across the board.

Stability and Reusability Study

To assess reusability, the PSK-1, PSK-2, and SMED-8 sorbents were subjected to five adsorption–regeneration cycles. The regeneration was performed using 0.1 M HCl washing. The table below presents the adsorption efficiency after each cycle.

Table 2. Adsorption Efficiency (%) Across Regeneration Cycles

Cycle	PSK-1 (%)	PSK-2 (%)	SMED-8 (%)
1	92.4	91.5	96.1
2	90.1	91.0	94.7
3	88.2	89.1	93.5
4	85.7	84.5	91.6
5	83.9	81.8	89.4

The table shows that all three sorbents retained high adsorption activity over multiple regeneration cycles. SMED-8 began with a 96.1% efficiency, dropping to 89.4% by the fifth cycle — still within acceptable limits for industrial applications. PSK-1 also showed good reusability, maintaining 83.9% efficiency by the fifth cycle. PSK-2, while initially effective, showed a more noticeable decline, dropping to 81.8%, but may still be suitable for low-cost applications.

Conclusion

This study evaluated the adsorption efficiency of locally synthesized polysulfide sorbents for the selective removal of Fe^{2+}, Cu^{2+}, Zn^{2+}, and Pb^{2+} ions from the wastewater of oil and gas processing plants. All tested sorbents exhibited high adsorption performance, with SMED-8 showing the most promising results in terms of both efficiency and stability. SMED-8 retained over 89% efficiency after five cycles, making it the most suitable candidate for industrial-scale application. While PSK-1 demonstrated moderate stability, PSK-2 was less stable but could still be economically viable under certain conditions. Overall, the study confirms that polysulfide sorbents synthesized from local raw materials offer a technologically,

economically, and environmentally viable solution for heavy metal removal from complex industrial effluents. The results serve as a scientific foundation for the development of modern and green wastewater treatment technologies.

References

1. Nazarov S.I., Djalilov A. T. , Nurqulov F.N. Xlororganik chiqindilar asosida polisulfid kauchuk sintezi, uning fizik-kimyoviy xossalari va tuzilishining IQ -spektroskopik tadqiqoti. Qo‘qon DPI. Ilmiy xabarlar 2025-yil 5-son. 203-208 b
2. Djalilov A. T. , Nazarov S.I., Nurqulov F.N., Bahonurova M.F. Natriy polisulfidi va 1,1,2-trixloretan asosida sintez qilingan polisulfid oligomerining fizik-kimyoviy xossalarini tadqiq etish. Development of science, 2025/6 vol 4, pp.327-335.
3. Nazarov S.I., Djalilov A. T. , Nurqulov F.N. Elementar oltingugurt asosida samarali odorant birikmalarini sintezi. Qo‘qon DPI. Ilmiy xabarlar 2025-yil 5-son. 209-213b
4. Файзиев Ж. Б. и др. Термический анализ сульфированного фталоцианина меди //Universum: химия и биология. – 2022. – №. 10-2 (100). – С. 41-44.
5. Назаров С. И., Ширинов Г. К. Изучение физико-механических свойств крахмалофосфатных загусток //Ученый XXI века. – 2017. – №. 1-3. – С. 3-7.
6. Назаров С. И. Получение крахмалофосфата и загусток на его основе //Ученый XXI века. – 2016. – №. 2-3.
7. Amonov M. R. et al. Physico-chemical properties of compositions based on natural and synthetic polymers //Technical Sciences. – 2015.
8. Niyozov E. et al. Investigation of physicochemical properties of guanidine-based corrosion inhibitor //E3S Web of Conferences. – EDP Sciences, 2024. – Т. 587. – С. 03004.
9. Zarina A. et al. Synthesis of Composite Inhibitors and Their properties //The Peerian Journal. – 2023. – Т. 17. – С. 25-29.
10. Раззоков Х. К. и др. Способ получения шлихтующих ингредиентов на основе природных и синтетических полимеров и их применение //Universum: химия и биология. – 2020. – №. 2 (68). – С. 41-45.
11. Fayziev J. et al. IR spectrum and differential thermal analysis of zinc-phthalocyanine pigment based on zinc chloride //AIP Conference Proceedings. – AIP Publishing LLC, 2025. – Т. 3304. – №. 1. – С. 040080.
12. Nazarov S. et al. Synthesis and spectroscopic study of adhesive polymer materials based on urea-formaldehyde and isoamyl alcohol //BIO Web of Conferences. – EDP Sciences, 2024. – Т. 130. – С. 06003.