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PROCESSING OF INDUSTRIAL LIQUID WASTE BY THE LEACHING METHOD

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Abstract:
This paper examines the process of treating absorption waste generated during ethylene production at JV LLC “Uz-KorGas Chemical”. Particular attention is paid to the leaching method using alcohols. The conducted studies have shown that the use of alcohols makes it possible to effectively separate the waste into solid and liquid phases.
The solid phase consists of burkeite, a compound that can be used in the production of detergents, thereby creating prospects for its secondary utilization.
The liquid phase mainly comprises a mixture of water and alcohol. A separation method based on distillation is proposed, allowing the alcohol to be regenerated and returned to the technological cycle, thus ensuring solvent circulation. At the same time, purified water is obtained, which reduces wastewater volume and improves the environmental efficiency of the process.
Thus, the proposed technology not only enables the utilization of ethylene production waste but also ensures the recovery of valuable components, contributing to resource conservation and reduced environmental impact.

Keywords: absorption, leaching, ethanol, methanol, burkeite, solubility, vapor pressure.

1. Introduction

In ethylene production technology, absorption is applied at the final stage for the treatment of waste liquids and the reduction of their hazardous properties prior to disposal [1]. At this stage, alkaline solutions—most commonly sodium hydroxide—are used to neutralize acidic and toxic compounds. This approach ensures compliance with environmental requirements and reduces the toxicity of liquid emissions. Although these wastes do not contain highly valuable components, their processing is beneficial in terms of reducing pollution volumes and enabling partial substance recovery [2].

The aim of this study is to develop and investigate a technology for processing absorption waste generated during ethylene production in the Republic of Karakalpakstan, where acute water scarcity is observed. The study considers the use of alcohols for separating the solid and liquid phases of absorption waste, which would allow not only effective waste treatment but also a significant reduction in wastewater volume, as well as the recovery of purified water for reuse. Particular attention is paid to the regeneration of alcohol and its return to the technological cycle, contributing to resource conservation and reduced environmental impact under limited water resource conditions [3].

The literature describes various approaches to solving this problem, including:

Chemical methods: treatment of waste with reagents to reduce toxicity and extract valuable components;

Physicochemical methods: filtration, coagulation, precipitation, and other processes aimed at recovering useful substances;

Biological methods: the use of microorganisms for waste degradation and biodegradation;

Thermal methods: incineration and plasma treatment for energy recovery or safe residue formation.

In recent years, researchers from various countries have actively investigated effective waste processing and utilization methods. Analysis of scientific publications indicates the following trends:

In China, new catalysts are being studied for the decomposition of ethylene production waste to minimize harmful emissions.

In Russia, combined chemical and biological treatment methods are under development.

In Germany, technologies for recovering valuable compounds from waste for reuse in production are being developed.

In the United States, membrane technologies are being implemented for wastewater purification from absorption by-products[4].

Sludge (with pH 12.2 and containing Cu, Pb, Fe, Mn, Ni, and Zn ions at concentrations exceeding environmental discharge limits) was treated by vacuum filtration as an alternative to pond systems, which are environmentally less acceptable. A similar system using flocculation was also developed. The filtration system demonstrated improved performance, yielding a filtrate with pH 7[5].

Sulfide precipitation is an effective method for treating acidic wastewater containing heavy metals; however, it often results in fine particles with poor settling efficiency. Supersaturation calculations and XPS analysis showed that particle growth in gas–liquid sulfidation systems mainly depends on supersaturation, whereas in liquid–liquid systems it depends primarily on surface charge[6].

Industrial waste significantly affects water and soil quality. Elevated concentrations of Cr and Zn were observed in groundwater and soil samples in several studied regions, indicating a high health risk index for various age groups.

Construction and demolition waste management raises serious concerns due to the potential release of hazardous elements during leaching. Automated classification and hazard prediction approaches improve sustainable management strategies[7].

Studies on oil shale residue content indicate that 20% is the optimal proportion for favorable hydration product formation and microstructural density.

Expansion of the petroleum industry has increased oily refinery waste generation, necessitating sustainable biological treatment methods, including microbial strain optimization and advanced bioremediation systems[8].

Empirical findings support the load curve hypothesis (LCC), showing that municipal and industrial waste negatively affects load capacity factors, while innovation in waste management has limited direct impact.

Recovery of carboxylic acids and aromatic compounds from kraft black liquor represents a promising pathway for alternative biomaterial production. Multiple analytical techniques identified 22 organic compounds, with major aliphatic acids quantified at significant concentrations[9].

An economical two-stage pH-dependent treatment process for highly acidic steel mill effluents has been developed, enabling heavy metal removal and high- purity gypsum recovery while reducing operational costs by over 58%.

Overall, scientific research indicates that absorption waste processing in ethylene production is a relevant issue requiring an integrated approach. The development and implementation of advanced technologies will reduce environmental impact and improve industrial efficiency[10].

2. Materials and Methods

To determine the composition of the waste liquid from JV LLC "Uz-KorGas Chemical", the solution was evaporated and the resulting precipitate was analyzed. A semi-quantitative spectral analysis method was applied (Table 1).

Table 1. Elemental composition of the evaporated precipitate residues obtained from neutralization treatment of absorption waste in ethylene production. The analysis shows strong sodium content above 40 wt. %, which further supports the sodium-based nature of the precipitate by alkaline neutralization method with NaOH. Minor amounts of silicon, aluminum, calcium, iron and magnesium were also identified as well as some trace metals[11].

Table 1. Semi-Quantitative Spectral Analysis of Neutralized Absorption WasteКонец формы

Sample Name	Chemical Composition, Mass Fraction %											
	1	2	3	4	5	6	7	8	9	10	11	12
Neutralized Waste Liquid	Si	Al	Ca	Na	K	Fe	Mg	B	Mn	Ti	Cu	C
	0.05	0.03	<0.01	>40	<0.01	0.007	0.004	0.01	0.002	0.002	0.0004	+

It can be seen from the table that the precipitate mainly consists of sodium compounds, which is explained by the use of sodium hydroxide in the neutralization of the waste liquid. The waste liquid from the absorber in ethylene production at JV LLC "Uz- KorGas Chemical" was salted out using alcohols at various ratios. The experimental results are presented in Table 2.

Experimental results on salting-out of absorption waste with ethanol and methanol at various alcohol-to-waste liquid ratios are summarized in Table 2. This is a summary table from filtration rates and yields of liquid and solid phases. Data shows that the increase in the amount of waste liquid results in lower filtration rate values and higher solid phase yields. The salting-out ability of ethanol is stronger than that of methanol at the same concentration.

Table 2. Effect of Alcohol-to-Waste Liquid Ratio on Filtration Rate and Phase Yield during Salting-Out

No.	Alcohol:WL Ratio	Filtration Rate	Yield of	
			Liquid Phase, %	Solid Phase, %
Salting-Out of WL (Waste Liquid) with Ethanol				
1	9:1	2,42	96,86	1,07
2	8:2	2,04	91,90	2,60
3	7:3	1,78	87,92	5,01
4	6:4	1,47	86,73	6,82

5	5:5	1,22	85,18	8,48
6	4:6	1,09	84,35	5,52
7	3:7	0,84	81,21	5,79
8	2:8	0,90	84,41	5,82
9	1:9	1,06	84,61	5,83
Salting-Out of WL (Waste Liquid) with Methanol				
10	9:1	2,74	95,78	0,99
11	8:2	1,72	87,51	1,74
12	7:3	1,43	84,34	3,78
13	6:4	1,18	80,57	5,26
14	5:5	1,04	82,53	6,75

According to the obtained data, when ethanol is used as the salting-out agent, increasing the proportion of waste liquid (WL) in the system (from a 9:1 to 5:5 ratio) leads to a decrease in filtration rate from 2.42 g/s to 1.22 g/s. At the same time, the yield of the liquid phase decreases from 96.86% to 85.18%, while the yield of the solid phase increases from 1.07% to 8.48%. With a further increase in the WL proportion (ratios of 4:6 and lower), the filtration rate continues to decrease, reaching a minimum of 0.84 g/s at a 3:7 ratio. The solid phase yield stabilizes in the range of 5.5–5.8%. Ratios of 6:4 and 5:5 can be considered optimal in terms of balancing solid phase yield and filtration rate, providing an acceptable technological compromise[12].

A similar pattern is observed when methanol is used. Increasing the WL proportion from 9:1 to 5:5 reduces the filtration rate from 2.74 g/s to 1.04 g/s. The liquid phase yield decreases from 95.78% to 82.53%, while the solid phase yield increases from 0.99% to 6.75%. It should be noted that at all stages of the experiment, the solid phase yield with methanol was lower than with ethanol, indicating its lower efficiency as a salting-out agent[13].

3. Results and Discussion

Result

In the experimental study, the authors verified that salting-out effect resulted by alcohol can effectively segregate absorption waste to solid and liquid phase from mixture solution. Semi-quantitative spectral analysis indicated that the precipitate was composed mainly of sodium-containing compounds, which correlates with the neutralization using sodium hydroxide.

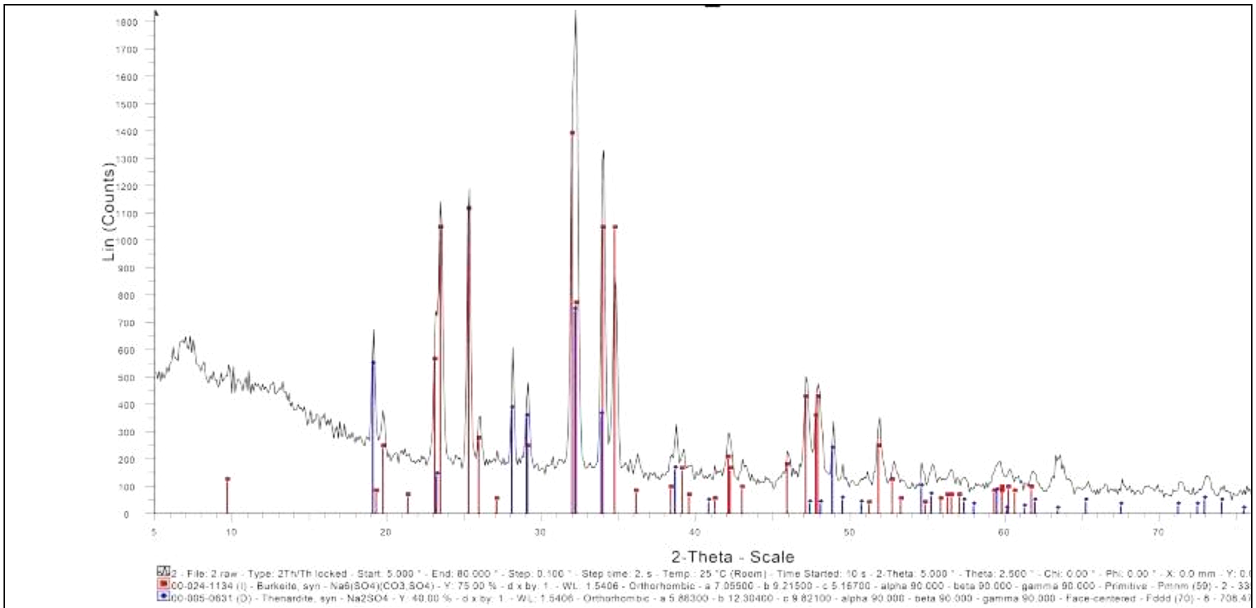
Using ethanol as the salting-out agent, the increase in waste liquid proportion caused its filtration rate to reduce from 2.42 g/s at the ratio of 9:1 to 1.22 g/s at the ratio of 5:5. At the same time, the yield of solid phase was raised from 1.07% to 8.48%. Methanol displayed a similar trend but the yield in solid phase was still lower than that of ethanol suggesting higher salting-out activity for ethanol under explore conditions[14].

Solution synthesis study results were analysed with X-ray diffraction, confirming crystalline phasesburkeite ($Na_2CO_3 \cdot 2Na_2SO_4$), mirabilite ($Na_2SO_4 \cdot 10H_2O$) and gypsum ($CaSO_4 \cdot 2H_2O$). Scanning electron microscopy has confirmed porous and heterogeneous microstructures with irregular particle morphology. High magnification images showed the coalescence between the crystals into well-defined prismatic and plate-like forms typical of burkeite growth. These results demonstrate how leaching induced by alcohol allows for a dialed-in phase separation while recovering inorganic compounds of interest.

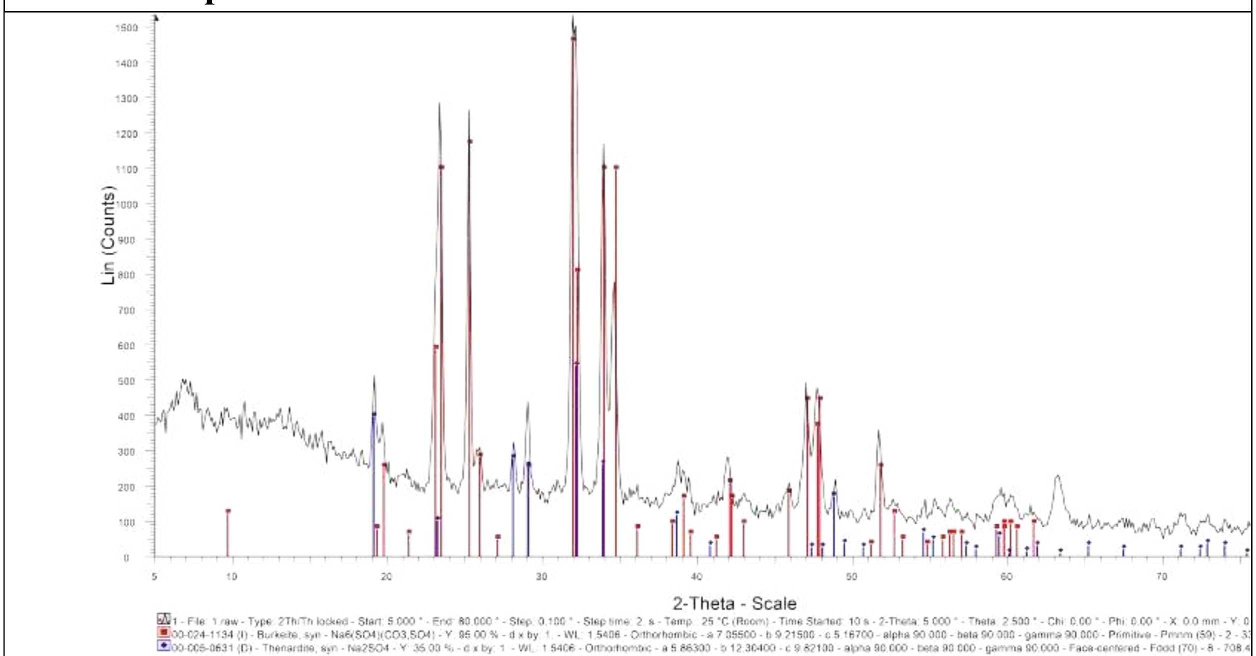
After filtration, the solid phase was dried and subjected to elemental analysis using X-ray fluorescence[15].Начало формы

Figure 1 presents the X-ray diffraction patterns of solid precipitates obtained after salting-out of absorption waste using ethanol. (a) Sample 1 corresponds to an alcohol-to-waste liquid ratio of 9:1, while (b) Sample 5 corresponds to a ratio of 5:5. The diffraction peaks indicate the presence of burkeite ($Na_2CO_3 \cdot 2Na_2SO_4$), mirabilite ($Na_2SO_4 \cdot 10H_2O$), and gypsum ($CaSO_4 \cdot 2H_2O$).

Конец формы



1- Sample

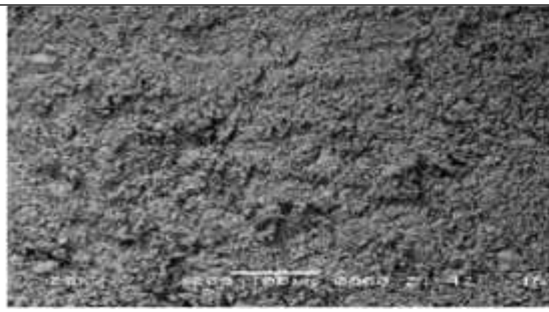
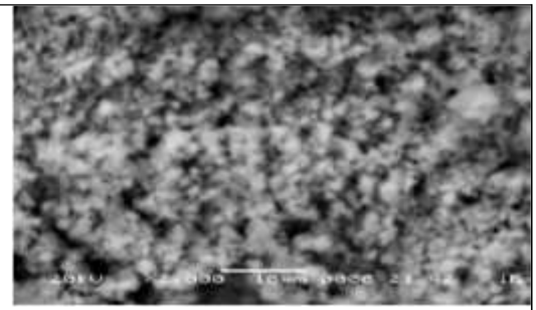


5- Sample

Figure 1. X-ray diffraction patterns of precipitated solid phases obtained at different alcohol-to-waste liquid ratios

Based on the conducted analysis, the optimal conditions for processing certain types of waste were identified. It was established that the combined use of thermal and biological methods allows for a significant reduction in the volume of non- recoverable residues. Additionally, a new technology for treating organic waste was developed, enabling faster decomposition and minimizing the release of harmful substances[16].

The image shows the microstructure of the material obtained using a scanning electron microscope (SEM) at 2000× magnification. Loose, porous formations with irregularly shaped particles are visible, which may indicate an amorphous or poorly crystalline structure. The particle surfaces are heterogeneous, with pronounced roughness, characteristic of aggregates of powdered substances, oxides, or corrosion products.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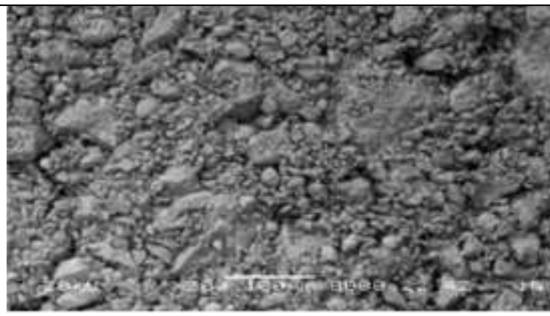	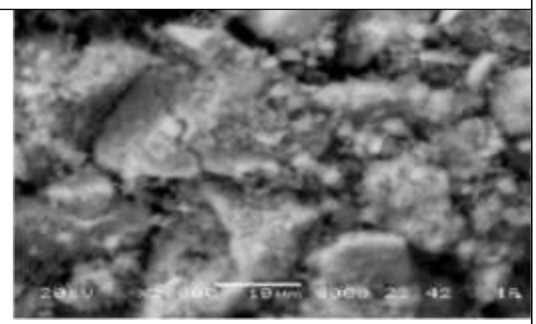
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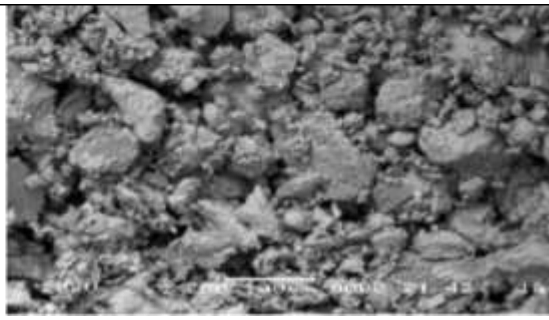	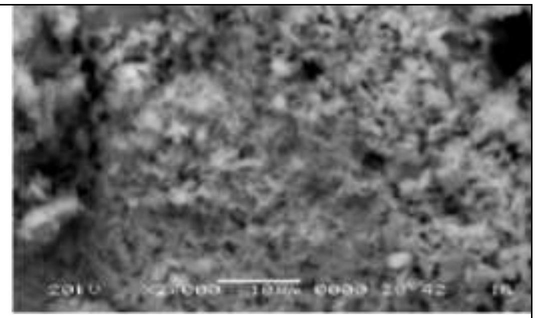
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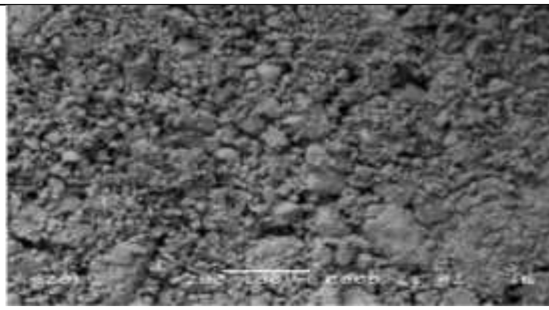	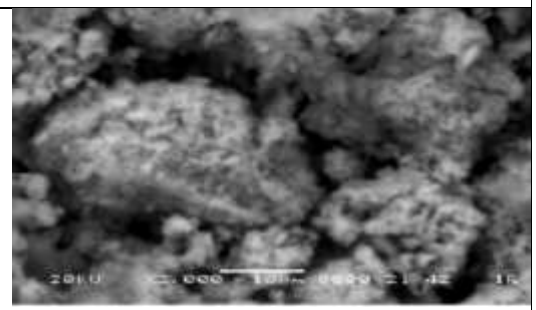
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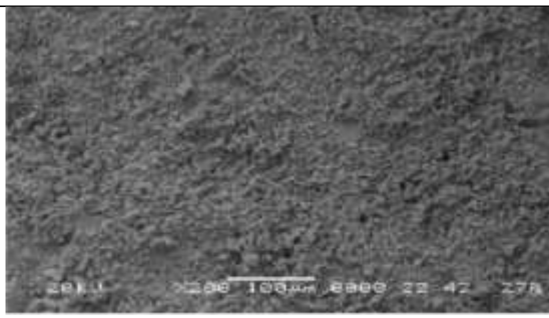
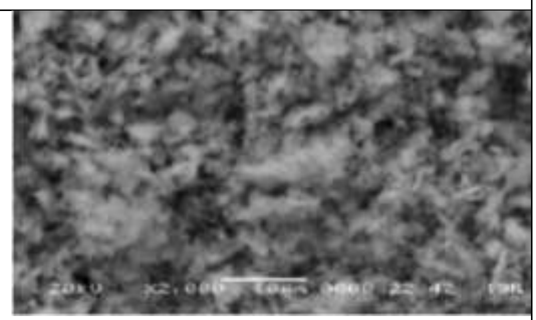
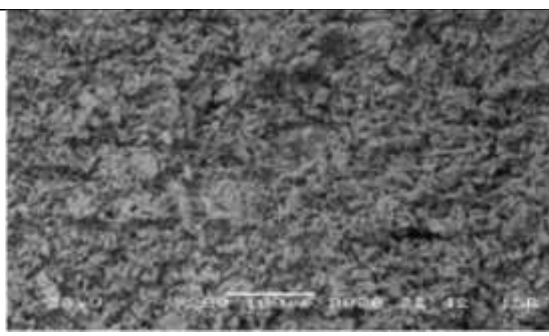
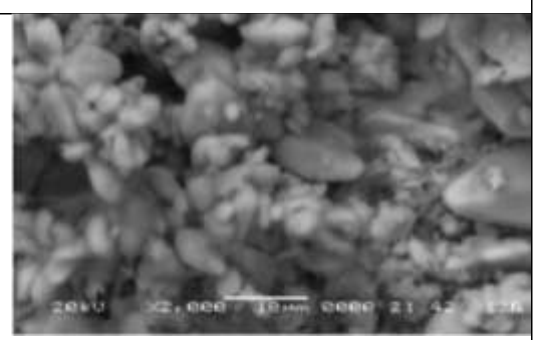
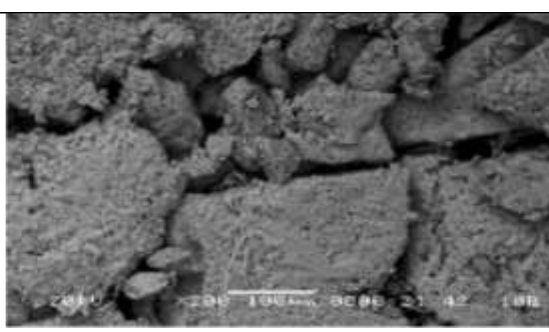
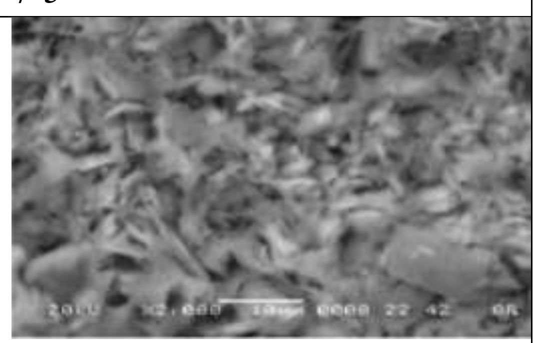
	
6-2	6-5
	
7-2	7-5
	
8-2	8-5

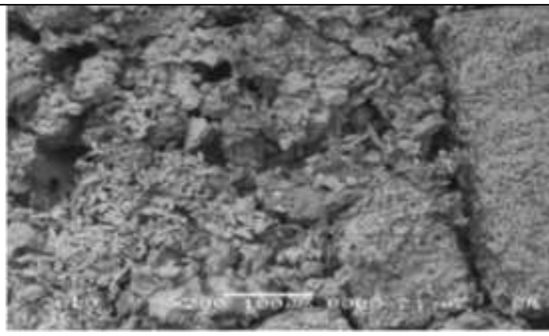
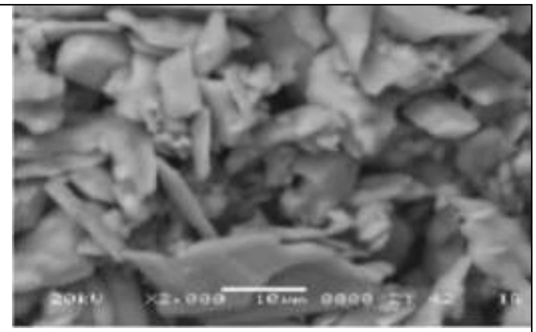
	
9-2	9-5

Figure 2. Morphology of precipitated salts in response to salting-out via ethanol.

Morphology of the Precipitated Salts Received from Salting-Out Waste Liquids of Uz-KorGas by Ethanol

Scanning electron micrographs of different morphologies of precipitated salts crystals obtained after salting-out waste liquids from the Uz-KorGas unit with ethanol X-ray diffraction (XRD) analysis of the crystalline phase showed observation of characteristic phases were burkeite ($Na_2Ca(CO_3)_2$), mirabilite ($Na_2SO_4 \cdot 10H_2O$) and gypsum ($CaSO_4 \cdot 2H_2O$).

The loose, amorphous and porous structure observed in Figures 2–4 reflects the nature of mirabilite and gypsum crystallization due to the solubility variations in both alcohol and aqueous media. These compounds can create aggregates of fine particles connected by hydrogen bonds and hydration shells.

Crystals with their characteristic sharp prismatic and plate-like shapes, typical of burkeite and mirabilite; Figures 5–9. They form during controlled crystal growth, at slow evaporation or variations in the ionic composition of the persecuted.

The results obtained reflect the regularities of salt precipitation formation in this process equipment and can be used to optimize waste liquid purification processes and control the phase composition of precipitates.

Discussion

The results obtained show that alcohol-assisted salting-out is an effective physicochemical treatment method for alkaline absorption waste produced in ethylene production. Ethanol is likely to affect crystal growth process, due to its higher polar characteristics and solubility parameters than methanol influences ionic-ionic interaction and supersaturation dynamics.

The defined formation of burkeite in this closed system suggests that secondary raw materials from industrial waste are therefore renewable and can be transformed into other products including detergents. The identification of mirabilite and gypsum is suggestive of a phase composition controlled by ionic equilibrium and evaporation kinetics in the alcohol–water system.

Regardless, we are proud to promote an environmentally friendly ethos as waste minimization and resource recovery is an integral part of our proposal. Alcohol is regenerated by means of distillation, allowing for the circulation of solvent while purified water can be reused in the industrial cycle. This closed-loop model is consistent with contemporary concepts of sustainable chemical engineering and circular economy approaches.

When analyzed for industrial application, the preliminary data show that this technology is potentially able to reduce the waste generated via neutralization and its subsequent disposal and can improve resource efficiency compared with conventional methods in a water scarce-scenario.

4. Conclusion.

The research presented in this article shows that salting-out induced by alcohol is a viable way to handle the absorption waste, which is generated during ethylene production. Ethanol outperformed methanol to form more solid phase and enhance the performance during filtration step.

The solid phase that was recovered is mainly made up of burkeite, which has industrial applications such as in the production of synthetic detergents and other products. The output of this distillation is the liquid phase containing regenerated alcohol and cleaned water that can promptly recirculate in the technological process.

Hence, this method combines the two functions of waste treatment and resource recovery, enhancing environmental protection and wastewater discharge reduction as well as economic efficiency. Optimization of operational parameters to further enhance the industrial applicability scale-up studies would be needed.

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