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# The Impact of Heat Stable Salts on the Acid Gas Removal Process and the Methods and Challenges of Their Elimination from Alkanolamine Solutions

[1]S. Hossein Mousavi, Seyed Abdollatif Hashemifard[*, 1], Mohsen Abbasi

[1]Sustainable Membrane Technology Research Group (SMTRG), Water research institute (WRI), Faculty of Petroleum, Gas and Petrochemical Engineering (FPGPE), Persian Gulf University, P.O. Box 75169-13798, Bushehr, Iran

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## 1. ABSTRACT

The removal of acid gases such as hydrogen sulfide ($H_2S$) and carbon dioxide ($CO_2$) from natural gas streams using aqueous alkanolamine solutions is a well-established and widely applied technology in gas processing plants, refineries, and petrochemical industries. Despite the high efficiency and operational flexibility of amine-based gas sweetening units, their long-term performance is significantly affected by solvent degradation and contamination. Among various degradation products, heat stable salts (HSS) represent one of the most critical challenges due to their irreversible nature and resistance to conventional thermal regeneration. Heat stable salts are formed through irreversible reactions between protonated amines and strong organic or inorganic acids that are thermodynamically more stable than $CO_2$ and $H_2S$. These acids originate from feed gas impurities, oxidative degradation reactions, corrosion inhibitors, oxygen ingress, and thermal degradation of alkanolamines. Unlike reversible acid gas salts, HSS cannot be decomposed in the regenerator and therefore accumulate progressively in the amine circuit. Their presence leads to a reduction in effective amine concentration, increased solvent viscosity, foaming tendencies, enhanced corrosion rates, solvent losses, and higher operational and maintenance costs. This extended abstract presents a comprehensive review of the mechanisms of HSS formation, their chemical and structural characteristics, and their detrimental effects on alkanolamine-based acid gas removal processes. Furthermore, conventional and advanced technologies developed for the control and removal of HSS are critically reviewed and compared. Based on a systematic evaluation of removal efficiency, solvent preservation, operational complexity, and industrial applicability, ion exchange-based reclamation methods are identified as the most effective approach for maintaining solvent quality. Membrane-based technologies such as electrodialysis and nanofiltration also demonstrate high removal efficiencies with reduced chemical consumption, although challenges related to membrane fouling and capital costs remain. This work provides practical guidance for solvent management and supports informed decision-making for selecting appropriate HSS control strategies in industrial gas sweetening units.

**Keywords:** Heat Stable Salts (HSS); Acid Gas Removal; Alkanolamine Degradation; Amine Reclamation; Membrane Technologies

## 2. INTRODUCTION

Natural gas sweetening is a critical operation in the oil and gas industry, aimed at removing acidic and corrosive components such as hydrogen sulfide ($H_2S$), carbon dioxide ($CO_2$), carbonyl sulfide (COS), and mercaptans from raw gas streams. These components must be removed to meet sales gas specifications, prevent corrosion of downstream equipment, ensure process safety, and comply with environmental regulations. Among the available separation

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technologies, absorption using aqueous alkanolamine solutions has remained the dominant industrial method for several decades due to its high efficiency, selectivity, and regenerability.

Commonly used alkanolamines include monoethanolamine (MEA), diethanolamine (DEA), methyldiethanolamine (MDEA), and various formulated amine blends designed to improve selectivity or reduce energy consumption. While modern amine units are capable of achieving high removal efficiencies under design conditions, their performance often deteriorates over time as a result of solvent contamination and degradation. One of the most persistent and problematic contaminants in amine systems is heat stable salts (HSS).

Heat stable salts are formed when alkanolamines react with strong acids whose conjugate bases are more stable than those of $CO_2$ and $H_2S$ (Fig. 1) [1]. As a result, these salts do not decompose under normal regeneration conditions and accumulate continuously in the circulating solvent. The accumulation of HSS alters the physicochemical properties of the amine solution, reduces the availability of free amine molecules for acid gas absorption, and exacerbates operational problems such as foaming, corrosion, and solvent losses. Despite extensive research on amine degradation, a comprehensive evaluation of HSS removal technologies from an industrial perspective remains essential. This extended abstract aims to address this need by summarizing formation mechanisms, impacts, and mitigation strategies for HSS in alkanolamine systems.

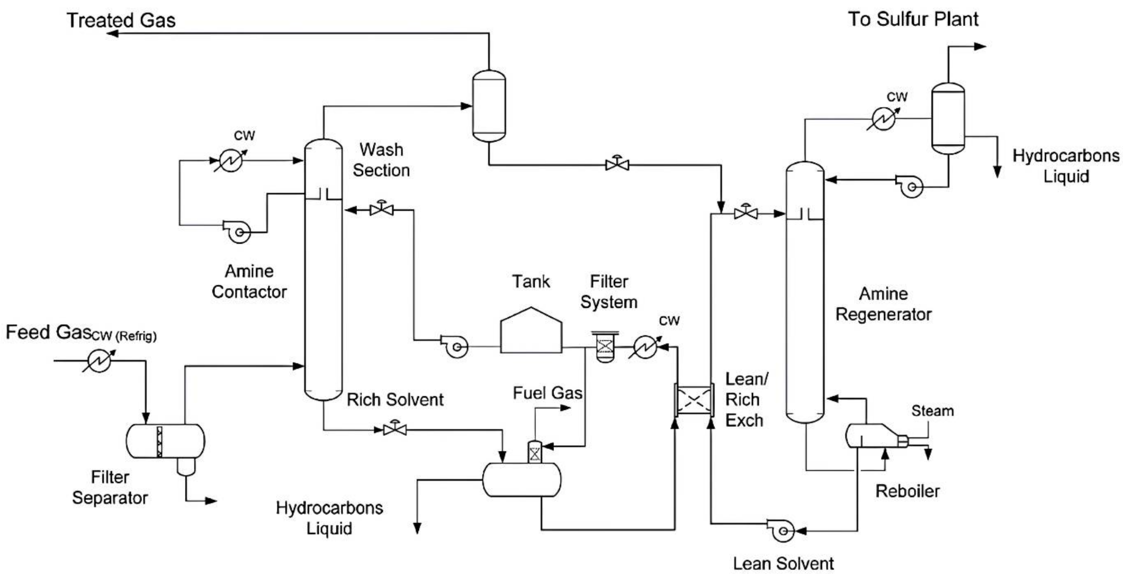


**Figure 1.** Process flow diagram of acid gas removal and amine regeneration

## 3. MATERIALS AND METHODS

This work is based on an extensive review and comparative analysis of published experimental studies, pilot-scale investigations, and industrial case studies related to heat stable salt formation and removal in alkanolamine-based gas treating units. Relevant literature was collected from peer-reviewed journals, conference proceedings, and industrial technical reports focusing on solvent degradation pathways, ionic properties of HSS, and amine reclamation technologies. HSS control and removal methods were classified into conventional approaches, including bleed-and-feed operations, chemical neutralization, and thermal reclamation, and advanced techniques such as ion exchange, electrodialysis, nanofiltration, adsorption, and emerging electromagnetic separation methods. These technologies were evaluated using key performance indicators including HSS removal efficiency, impact on solvent stability, amine loss, energy consumption, operational complexity, waste generation, and overall industrial feasibility. The comparative assessment was used to identify the most effective and sustainable strategies for managing HSS in industrial amine systems.

## 4. RESULTS AND DISCUSSION

### 4.1. Formation Mechanisms and Process Impacts

Heat stable salts are primarily formed through reactions between protonated amines and strong organic acids such as formate, acetate, oxalate, and propionate, as well as inorganic acids including sulfate, nitrate, and chloride [2]. These acids originate from oxidative degradation of amines, impurities in the feed gas, corrosion products, and chemicals introduced during upstream operations. Once formed, HSS remain ionically bound to the amine and cannot be removed in conventional regenerators.

The accumulation of HSS reduces the effective amine concentration available for acid gas absorption and increases solvent viscosity and density [3]. These results in lower mass transfer efficiency increased foaming tendency, higher corrosion rates, and elevated solvent losses. In severe cases, excessive HSS concentrations can lead to unstable operation and unplanned shutdowns. A summary of the most critical operational impacts caused by HSS accumulation is presented in Fig. 2, which outlines their detrimental effects on system performance and solvent stability.

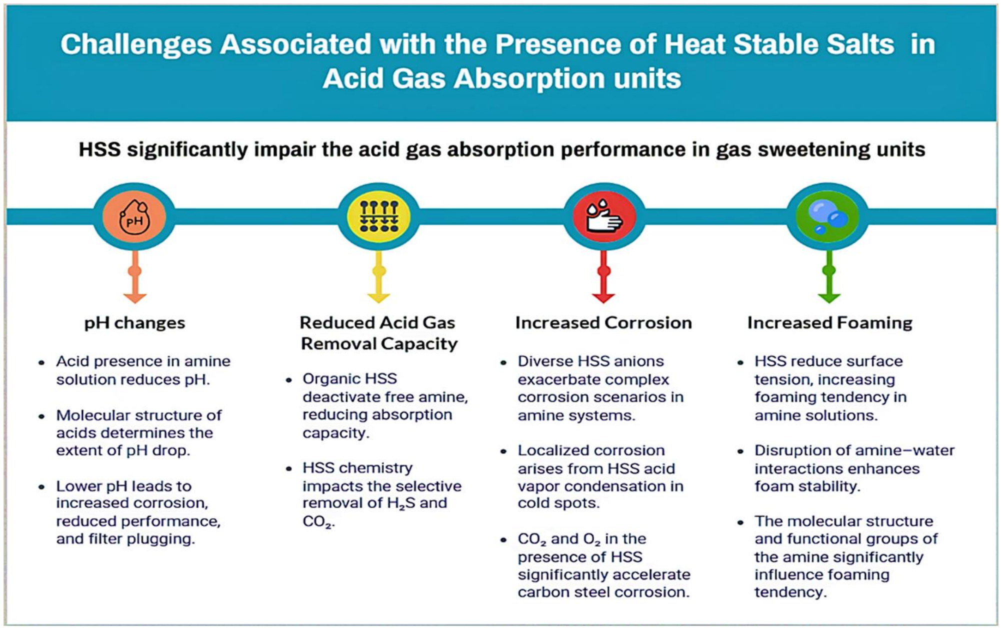


**Figure 2.** Operational and technical challenges associated with HSS accumulation in acid gas absorption units

### 4.2. Evaluation of HSS Removal Technologies

Among the evaluated technologies, ion exchange-based reclamation systems demonstrate the highest removal efficiency, typically reducing HSS concentrations to below 0.5 wt% of the amine solution while preserving solvent quality [4]. These systems are well-suited for continuous operation but require chemical regenerants and produce secondary waste streams. Membrane-based technologies such as electrodialysis and nanofiltration show promising performance, with reported HSS removal efficiencies ranging from 70% to 90% and relatively low amine losses [5]. These methods do not require chemical additives and allow selective ion separation; however, membrane fouling, capital costs, and operational sensitivity remain challenges.

Conventional methods such as chemical neutralization temporarily restore solvent capacity but do not remove salts from the system and may exacerbate long-term operational issues. Adsorption-based techniques using activated carbon or polymeric materials offer limited HSS removal and are mainly effective as supplementary treatments.

## 5. CONCLUSION

Heat stable salts represent a major challenge in alkanolamine-based acid gas removal systems, significantly affecting solvent performance, operational reliability, and economic efficiency. While conventional control methods provide short-term mitigation, advanced reclamation technologie particularly ion exchange and membrane-based processes offer more effective and sustainable solutions for long-term HSS management. The selection of an appropriate strategy should be based on process requirements, economic considerations, and desired solvent stability. The integration of complementary technologies presents a promising approach for optimizing industrial amine systems.

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