

Impact of dissolved and undissolved organics on foaming of industrial amine



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ABSTRACT

The effect of soluble and insoluble organics i.e. liquid paraffin, carboxylic acids, and BTEX on foaming behavior of industrial fresh and lean amine solution was investigated. Different fresh and lean amine samples were saturated with different organics through mixing the amine solution with the organics in thermodynamic cell until equilibrium. Saturated amine samples were extracted from the equilibrium cell and foaming study was carried out for each saturated amine solution. The effect of insoluble organics on the amine foaming behavior was tested through adding excess organics to the saturated amine. The results of this study showed that dissolved organics increased the foam volume in fresh 50 wt% MDEA solution. However, adding excess organics, above the solubility limit, into the fresh amine decreased the foam volume. Interestingly, saturated industrial lean amine with normal liquid paraffin (C6–C7) decreased the foam volume of the industrial lean amine. Moreover, the foaming tendency decreased significantly when the concentration of normal liquid paraffin exceeded the solubility limit in the tested lean amine solution. It is noted that cyclohexane has more influence in amine foaming than *n*-hexane. Saturated industrial lean amine solution with carboxylic acids dramatically increased the foam volume. Adding excess carboxylic acids above the solubility limit decreased the foam volume of the saturated amine, however, it remains higher than the foam volume of the original lean amine. Soluble toluene and xylene increased the foam volume from 120 ml to 647 ml and 471 ml, respectively. Adding excess BTEX over the solubility limit to the saturated lean amine reduced the foaming tendency of the saturated amine. However, as observed with the carboxylic acids the foam volume with excess BTEX still showing higher volume over the original lean amine. The findings of this study highlight the importance of controlling the concentration of BTEX compound entering to the amine unit over the liquid hydrocarbons as a common foaming mitigation practice. Also, the findings of this study highlight the importance of monitoring the generation of carboxylic acids due to amine degradation and control its concentrations for smoother operation.

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1. Introduction

In natural gas processing, it is needed to remove the acid gases i.e. H₂S and CO₂ from the natural gas. Acid gases are extremely corrosive and harmful. The process for removing acid gases from sour gas is called gas sweetening (Mokhatab et al., 2012). Alkanolamine based absorption process is one of the most common used process for acid gases removal from natural gas. Alkanolamines have high capacity to absorb acid gases (Rahimpour et al., 2016). However, alkanolamine based absorption processes have several

operational problems i.e. amine degradation and amine foaming (Alhseinat et al., 2016). Foaming can take place in both the adsorption column and in the regeneration (desorber) column. However, foaming is shown to be worse at lower pressure and at higher temperature (Yanicki and Trebble, 2006), thus foaming is more likely to occur in the regeneration (desorber) column.

Foaming problem generally leads to serious consequences such as loss of absorption capacity, reduced mass transfer area and efficiency, and carryover of amine solution to the downstream plant (Chen et al., 2010). Foaming can be induced by various contaminants including organics contaminates i.e. liquid hydrocarbons, and organic acids (Alhseinat et al., 2014). Organics compounds may present in amine unit through the feed stream or generate within the unit due to amine degradation. Organics compounds i.e. normal liquid paraffin, carboxylic acids, and BTEX have different

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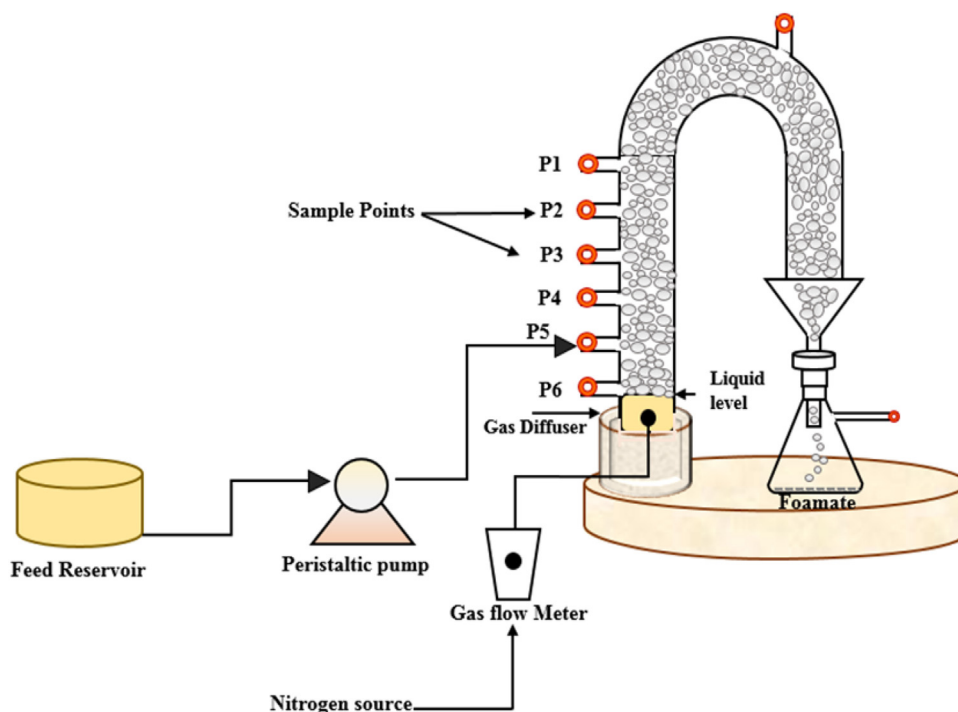


Fig. 1. Schematic diagram of foam fractionation setup.

affinity to dissolve into the amine solution. Normal liquid paraffin has lower solubility than carboxylic acids, and BTEX (Alhseinat et al., 2015a; Coquelet et al., 2008; Valtz et al., 2007, 2003; Danon et al., 2016). The operators of amine gas sweetening units usually stress to operate the absorption unit above the dew point of liquid hydrocarbons. It is believed that liquid hydrocarbons i.e. *N*-paraffin condensation plays a major role in foaming tendency in unit. Unfortunately, there are a few studies considering systematic and quantitative investigation addressing the effect of soluble and insoluble organics on amine foaming. The effect of hydrocarbon and organic acids on the foaming tendency of monoethanolamine (MEA), methyldiethanolamine (MDEA), diethanolamine (DEA), and formulated MDEA was investigated by Pauley et al. (1989) and Pauley (1991), it was found that the investigated contaminants increase the foaming tendency and foam stability of amine solutions to various extents. The foaming tendency of DEA solutions in the presence of various contaminants such as carboxylic acids was studied by McCarthy and Trebble (1996), it was observed that carboxylic acids with more than five carbons substantially enhanced the foaminess compared to a clean DEA solution. Recently, the effect of amine concentration and various additives, including electrolytes, liquid hydrocarbon, and degradation products on foaming were investigated by Chen et al. (2011). It was found that formaldehyde substantially increases foaming in piperazine (PZ). Also it was found that the tendency of PZ to foam was increased by 40% with the addition of iron (II), but dissolved iron had no significant effect on MEA. More recently, our research group (Alhseinat et al., 2014, 2015b) has studied the effects of formic acid, acetic acid, propionic acid, butanoic acid, pentanoic acid, hexanoic acid, heptanoic acid, dodecanoic acid, *n*-pentane, *n*-heptane, *n*-octane, formaldehyde ferrous sulfate, ferrous sulfide and ferric chloride on foaming behavior and physical properties of synthesized 50 wt% MDEA aqueous solution. However, still there is lack in the available literature concerning the effect of soluble and insoluble organics on amine foaming particularly for industrial lean amine. Moreover, there is no available literature on the effect of BTEX compounds on foaming. Even though, sour natural gas and other feed gases

to amine absorption units may have significant quantity of aromatics; several articles and industrial reports have been published reporting the present of BTEX (Coquelet et al., 2008; Valtz et al., 2003; Aleghafouri et al., 2015). This acted as a motivation to go further in our study and investigate the effect of soluble and insoluble organics on the foam behavior of industrial fresh and lean MDEA solutions. This study arises as a part of the ongoing project studying the deterioration of solvent quality and foaming problem in Habshan Gas Sweetening Unit (HGSU), GASCO, Abu Dhabi. In GASCO 50 wt% MDEA is used for acid gas removal.

The main objective of this paper is to investigate the effect of different soluble and insoluble organics on the foaming behavior. This will enhance the understanding of role of soluble and insoluble organics on the foaming problem and will facilitate the tracking of the sources of foaming and alleviate them or reduce their impact.

2. Material and methods

2.1. Materials

Fresh MDEA and lean MDEA were obtained from GASCO, Habshan, Abu Dhabi. *N*-hexane, *n*-heptane, *n*-octane, *n*-hexadecanen and Cyclohexane supplied from Merck. Propanoic, pentanoic, hexanoic and heptanoic acids were obtained Merck. Xylene and toluene were obtained from Fisher Scientific. All chemicals used are analytical grade despite the MDEA industrial samples.

2.2. Experimental setup and experimental procedure

2.2.1. MDEA saturation with organics

Simple equilibrium cell was used to reach thermodynamics equilibrium. The equilibrium cell was filled with solvent 170 ml of aqueous MDEA solution and 40 ml of tested organics i.e. *n*-paraffin, organic acid or BTEX compound. The aqueous phase was mixed for long time, to ensure reaching to the equilibrium (Alhseinat et al., 2016). Then stirring was stopped for 5 h and the saturated MDEA

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