Contents lists available at <http://www.jmsse.org/>

Journal of Materials Science & Surface Engineering



Selecting an optimal way to remove sour gases at Sweetening unit in Refinery Facilities

Ali Rahimi Koohestan¹, Mohsen Mahmoudi², Reza Nasiri³, Heydar Maddah^{4*}, Mojtaba Karimi⁵ and Reza Aghayari⁶¹Department of Chemical Engineering, Sciences Faculty, Ghochan Branch, Islamic Azad University, Ghochan, Iran.^{2,3}Department of Chemical Engineering, Sciences Faculty, Marvdasht Branch, Islamic Azad University, Marvdasht, Iran.^{3,6}Fakhr Razi Institute of Higher Education, Iran.^{4*}Department of Chemistry, Sciences Faculty, Arak Branch, Islamic Azad University, Arak, Iran.⁶Sama Technical and Vocational Training College, Islamic Azad University, Saveh Branch, Saveh, Iran.

Article history

Received: 15th-April-2015

Revised: 13th-May-2015

Available online: 23rd May, 2015

Keywords:

Biofiltration,
processes,
H₂S

Abstract

H₂S compounds discharged into the environment create ecological and health hazards. In the recent past, H₂S removal processes using amine, biofiltration and carbon active absorption method have gained popularity in control of H₂S, since they offer a cost effective and environment friendly alternative to conventional technologies. This review provides an overview of the various H₂S removal processes, along with details on their configuration and design, mechanism of operation, insights into the microbial biodegradation process and future R&D needs in this area.

© 2015 JMSSE All rights reserved

Introduction

Hydrogen sulphide is a colourless, flammable gas with a characteristic smell of rotten eggs. Its vapor pressure at 21.9 °C is 1929 Pa and with an order threshold of about 0.47 ppb. It is soluble in water; the water solubility at 20 °C is 1 g in 242 ml. The taste threshold for hydrogen sulphide in water is between 0.05 and 0.1 mg/litre [1]. It is released to the atmosphere as a by-product of industrial processes including sour gas flaring, petroleum refining, wastewater treatment, food processing, pulp and paper manufacturing and the treatment of fuels [2]. The removal of H₂S from waste gases is necessary because it is harmful for living organisms and its maximal allowed concentration (MAC) is 10 ppm. At concentration of 50 ppm, body develops symptoms; at 150 ppm, the smell disappears and at around 500 ppm it causes rapid knock down of exposed person. Therefore, Removal of H₂S from gases is required for reasons of heat, safety, and corrosion during transmission and distribution and to prevent pollution with sulphur dioxide and strict regulations are necessary for controlling the emission levels. There are number of removal technologies available including physical-chemical processes, absorption and biofiltration have been developed to remove this dangerous contaminant from industrial waste gas streams[3-4].

An understanding of the desulfurization methods and their design and configuration, as well as necessary parameters for their operation will not only help in increasing the efficiency of the removal process but also give insights to develop newer and better techniques. This review attempts to provide an overview of the various removal mechanisms of H₂S and their important operational parameters and future R&D needs in this area[3-6].

Experimental

Amines for Removing Units

The technology of using alkanolamines for removal of hydrogen sulphide from natural gases has been employed for decades. Since the 1960's and 70's several amines have come into general use, however, limited information has been reported in the literature concerning the amine best suited to a particular service. simply changing amine solution help to optimize amine units which are operating very inefficiently. [7]

The major benefits of the amine treatment is that it is the most widely commercialized technology in which the hydrocarbon loss is almost negligible. However, the operating and capital costs increase drastically as the concentration of hydrogen sulphide in the feed gas increases [8].

The first concern in the design of the process, is that the sweetened gas meet the required purity specifications with respect to H₂S. The secondary objective is to select the amine which optimizes equipment size and minimizes plant operating cost. The alkanolamines solution groups include monoethanolamine (MEA), diethanolamine (DEA), methyl-diethanolamine (MDEA), diisopropanolamine (DIPA), and diglycolamine (DGA).

Figure 1 represents a basic flow scheme for amine treating facility. Sour gas is introduced in the absorber where it contacts lean amine solution moving down the column. The acid gas H₂S, is absorbed by the amine and the sweet gas leaves the absorber for further processing. The rich amine solution is sent to a flash tank(D-103) and absorbed hydrocarbons exit as the flash-tank vapor. The rich amine flows through the lean/rich exchanger (E-101) to increase the temperature to about 90–110 °C. The hot rich amine is stripped at low pressure to remove the absorbed acid gases, dissolve hydrocarbons and some water. The energy required to strip the amine is the sum of the sensible heat required to raise the solution temperature, the energy of absorption, and latent heats [7-9].

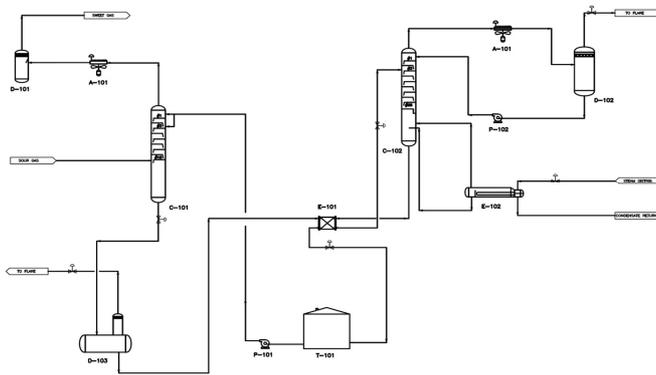


Figure 1: Basic flow scheme for amine treating facility

The pressure of stripping column should be operated at as high as possible to increase the reboiler temperature for optimum stripping. However, the amine degradation temperature should not be exceeded. The stripped or lean amine is sent back through the lean/rich exchanger to decrease its temperature. A pump boosts the pressure such that it is greater than the absorber column. Finally, a heat exchanger or air cooler cools the lean solution before the loop is back to the absorber completely.

The general consideration for amine selection in sweetening plants have changed over the years. Until the 1970's monoethanolamine (MEA) was the amine first considered for any sweetening application. Then in the 1970's, as exemplified in papers by Beck (1975) and Butwell and Perry (1975), switching from MEA to diethanolamine (DEA) yielded favourable results. In the past decades, MDEA, DGA, and mixed amines have steadily gained popularity. As different operating conditions are tested and proven with a particular amine, they become accepted on an industry-wide basis. Thus each amine has a currently "accepted" range of process conditions and parameters associated with it. These "accepted" conditions and parameters are discussed below. Some of the typical operating conditions for common amines are summarized in Table 1.[7-12]

Table 1: typical Operating Conditions and Data for Amine

Amine	DEA	MDEA	DGA	MEA
Solution strength wt. %	25-35	20-50	50-70	15-20
Acid gas loading, mole/mole	0.3-0.35	unlimited	0.3-0.35	0.3-0.35

Biofiltration

Biofiltration is one of the most promising clean technologies for reducing emissions of malodorous gases and other pollutants into the atmosphere [12]. This technology is based on microbial degradation of compounds from a gas stream. This technology has been designed to control effectively sulfur compounds [13–16]. The H₂S biological elimination has been extensively studied with different strains of Thiobacillus [9]. The effect of different operational parameters and the microbial processes involved in H₂S biofiltration have also been investigated in the literature. Significant differences have been reported in the performance of biofilters for H₂S removal packed with different materials. van Langenhove used wood wark, Hirai used peat, Yang and Allen reported the use of compost, Chung et al. utilized calcium alginate pellets, Morton and Caballero used lava rock and Wani et al. used various mixtures of compost-perlite hog fuel. Recently, Cho et al. investigated the biological deodorization of H₂S using porous lava rock; these authors reported some potential benefit properties of lava rock. Although some micro-organisms, such as Thiobacillus

sp., are able to growth under highly acidic conditions, most bacteria growth takes place over a pH range of 4.5–8.0. A pH lower than 3.2 could lead to the inactivation of the biological population, therefore the removal efficiency would decrease progressively [13–16]. On the other hand, removal processes for H₂S have been conducted with microbial treatment using biofilters and biotrickling filters due to their low operation costs and efficiency. According to the reported literatures, biofiltration is a suitable technology for treating gaseous streams containing H₂S. Recently, Chung reported the performance of a biofiltration system developed to remove composting exhausted air, the experimental results reported in this work showed that sulfur-containing compounds were completely removed[13–18] The basic flow scheme for an biofiltration unit is shown in Figure 2.

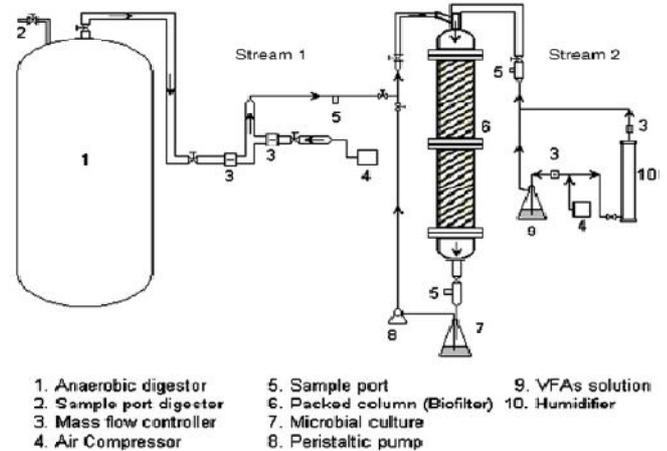


Figure 2: The basic flow scheme for an biofiltration unit

Absorption method

Activated carbon that is a highly porous material was used for removal of impurities from gases and liquids including gas separation and purification, vehicle exhaust emission control, and environmental technology [19]. For low concentration H₂S removal, the adsorption by activated carbon was known as an efficient process. Moreover, activated carbon has a high activity and long-lasting. In Thailand, it is inexpensive adsorbent as compared to inorganic adsorbents such as alumina, zeolite and metal oxide. It was produced from agricultural waste such as coconut shell, palm shell, and corncob. The adsorption capacity of activated carbons was determined by their physical or surface property, but also influenced by their chemical property. Typically, the surface properties of activated carbon such as surface area, pore volume, and pore size effect on the adsorption capacity.

Activated carbon that was impregnated with alkaline material such as sodium hydroxide (NaOH) and potassium hydroxide (KOH) was used for the H₂S removal at ambient temperature. At surface of the impregnated activated carbon, acid-base reaction occurs. The advantages of impregnated activated carbon in the removal of H₂S are high efficiency and fast kinetically reaction. However, the adsorption of H₂S on alkaline impregnated activated carbon under the adsorption temperature program has not been investigated[20-23].

Results and Discussion

The carbon active method of the three research methods commonly H₂S removal industrial has been assessed. In the carbon active method without changing the structure of molecular materials, pollutant gas phase of gas is be into a solid phase absorbent. Because this type of absorptive capacity to be a large

volume of gas in pollutant in a site equipped with small-absorbent surface be removed. The chemical absorption method with using amines group, compounds pollutant nature of H₂S common to form a more dangerous form into low-risk and finally the biofilters method using microorganisms compatible with the desired concentration pollutant compounds can be contaminated in a phase of biological materials without the risk like carbonic dioxide and water into and pollutant as remnants of microbial mass in the reaction environment.

Conclusions

This review provides an overview of the various methods used for H₂S removal. Clearly, many of the methods discussed herein still require improvement, and confirmation of significantly better performance compared to existing designs. and among the sited methods, biofiltration is considered an attractive alternative, when compared to chemical and physical treatments, since it is environmental-friendly way and economical and does not produce residues. Using a large amount of activated carbon or amine groups has high investment cost.

References

1. WHO, 1993d. Environmental Health Criteria No. 146: 1,3-dichloropropene, 1,2-dichloropropane and mixtures. World Health Organization:International Chemical Safety,Geneva.
2. Chung, Y.C., Huang, C., Tseng, C.P., (1996). Operation optimization of Thiobacillus thioparusCH11 biofilter for hydrogen sulfide removal.J. Biotechnol., 52(1): 31-38.
3. M. Maroni, C. Colosio, A. Ferioli, A. Fait., H₂S removal of natural gas., Toxicology 143 (2000) 5–8
4. Chung, Y.C., Lin, Y.Y., Tseng, C.P., (2004). Control of H₂S waste gas emissions with a biological activated carbon filter.,J. Chem. Technol. Biotechnol., 79(6): 570–577.
5. Namini, M.T.,Heydarian, S.M.,Bonakdarpour, B., (2007). Removal of H₂S from synthetic waste gas streams using a biotrickling filter. Iranian Chemical Engineering Journal, 5(3): 40-51.
6. N. Abdehagh, M. Taghinejad Namini, S. M. Heydarian, B. Bonakdarpour, D. Zare., Performance of a biotrickling filter employing thiobacillus thioparus immobilized on polyurethane foam for hydrogen sulfide removal., Iran. J. Environ. Health. Sci. Eng., 2011, Vol. 8, No. 3, pp.
7. John Polasek., Jerry A. Bullin., Selecting Amines for Sweetening Units ., Bryan Research and Engineering, Inc. - Technical Papers
8. Wael A. Fouad, Abdallah S. Berrouk., Using mixed tertiary amines for gas sweetening energy requirement reduction., Journal of Natural Gas Science and Engineering 11 (2013) 12e17
9. R. Abedini ,A. Abedini, I. Zanganeh ., Investigation of mixed amine solution in gas sweetening plant., Journal of Natural Gas Science and Engineering 2 (2010) 36e40
10. Butwell, K. F. and C. R. Perry, "Performance of Gas Purification Systems Utilizing DEA Solutions," Gas Conditioning Conference (1975).
11. Beck, J. E., "Diethanolamine an Energy Conserver," Gas Conditioning Conference, Norman Oklahoma (1975).
12. A Behroozsarand1,A.Zamaniyan,Multiojective optimization scheme for industrial synthesis gas sweetening plant in GTL process., Journal of Natural Gas Chemistry 20(2011)99–109
13. Y. Yang, E.R. Allen, Biofiltration control of hydrogen sulphide. 2. Kinetics, biofilter performance and maintenance, J. Air Waste Manage. Assoc. 44 (1994)1315–1321.
14. E. Smet, P. Lens, H. van Langenhove, Treatment of waste gases contaminated with odorous sulfur compounds, Crit. Rev. Environ. Sci. Technol. 28 (1998)89–117.
15. S.J. Ergas, E.D. Schroeder, D.P.Y. Chang, R.L. Morton, Control of volatile organic compounds emissions using a compost biofilter,Water Environ. Res. 67 (1995)816–821.
16. R.L. Morton, R.C. Caballero, Using full scale biotrickling for the removal of hydrogen sulfide and odor from waste water facilities air streams, in: Proceedings of the USC-TRG, Conference on Biofiltration, Los Angeles, California, 1998, pp.107–114.
17. D. Ramírez-Sáenz, P.B. Zarate-Segura, C. Guerrero-Barajas, E.I. García-Peña., H₂S and volatile fatty acids elimination by biofiltration: Clean-up process for biogas potential use., Journal of Hazardous Materials 163 (2009) 1272–1281
18. M. Hirai, M. Ohtake, M. Shoda, Removal kinetics of hydrogen sulfide, methanethiol and dimethyl sulfide by peat biofilters, J. Ferment. Bioeng. 70(1990) 334–359.
19. Roque-Malherbe RMA. Adsorption and Diffusion in Nanoporous Materials. United States of America: CRC Press. Taylor & Francis Group; 2007.
20. Xia Jiang, Joo Hwa Tay., Removal mechanisms of H₂S using exhausted carbon in biofiltration., Journal of Hazardous Materials 185 (2011) 1543–1549.
21. R. Sitthikhankaew, S. Predapitakkun, R. (Wibulswas)Kiattikomol, S.Pumhiran, S. Assabumrungrat and N. Laosiripojana., Comparative Study of Hydrogen Sulfide Adsorption by using Alkaline Impregnated Activated Carbons for Hot Fuel Gas Purification., Energy Procedia 9 (2011) 15 – 24
22. Thakur Prabhat Kumar, Rahul1, Mathur Anil Kumar and Balomajumder Chandrajit., Biofiltration of Volatile Organic Compounds (VOCs) – An Overview., Res.J.Chem.Sci Vol. 1(8), 83-92, Nov. (2011).
23. Chen-Chia Huang*, Chien-Hung Chenb, Shu-Min Chua., Effect of moisture on H₂S adsorption by copper impregnated activated carbon., Journal of Hazardous Materials B136 (2006) 866–873.

