Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2025, 12(4):114-118**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Experimental Study of Long-Lasting VOCs Barrier in Water-Based Foams

PAN Shili

School of Safety Science and Engineering, Henan Polytechnic University, Jiaozuo Henan 454000, China

Abstract: Xanthan gum was used to increase the foam stabilizing properties of anionic/nonionic surface-activated compounding systems to obtain foams capable of long-lasting VOCs barrier. The experimental results showed that the foam performance was optimal when AES/APG0810 was compounded at a mass ratio of 7:3, and the addition of 0.2%wt xanthan gum improved the comprehensive performance of the foam the most, with the foam composite index reaching 30960.31. Covering the compounded foam with VOCs could immediately block their volatilization, and the best performance was for toluene, with the barrier rate of 90% within 16h. The concentration was maintained below 7.0 ppm, and the barrier rate was below 7.0 ppm, and the barrier rate was above 7.0 ppm. The best blocking performance was achieved for toluene, with a blocking rate of 90% within 16h. The concentration was maintained below 7.0 ppm, and the blocking effect was in the order of ethyl acetate ＜xylene＜toluene.

Keywords: Foam material; Xanthan gum; Barrier; VOCs

1. Introduction

Volatile organic compounds (VOCs) are a kind of air pollutants in industrial production and human life, which are widely sourced and have toxicity, carcinogenicity, and flammability, and once leaking not only cause damage to the environment, but also pose a certain threat to human production and life [1-2]. However, a comprehensive and effective solution has not yet been formed for the emergency leakage of VOCs. Water-based foam material has the characteristics of barrier, strong mobility, etc., which has been widely used in dust reduction and suppression, fire suppression, etc. [3-5]. The material has been initially concerned in the emergency barrier VOCs, the stability of the foam is the main research direction to improve its barrier performance.

The foam decay process includes four basic phenomena: liquid film discharge and bubble merging, coarsening and rupture [6-7].Wu et al [8] showed that the foam stabilization performance of binary surfactants is better than that of single surfactants.Zhou et al [9] found that the compounding of sodium dodecyl sulphate (SDS) and nonionic short-chain fluorocarbon surfactants has good foam performance and wetting ability.Sheng et al [10] found that proper concentration of xanthan gum and nano-silica can improve the foaming ability and stability of the foam.Gu et al[11] prepared a new foam material with vegetable protein, xanthan gum and alkyl glycosides as raw materials, and this foam can prevent 67% of paraxylene from escaping within 24h.

Summarizing the previous studies, it was found that the foam material still needs to be improved in terms of high efficiency in blocking VOCs and stability, so on the basis of the previous studies, this paper selects anionic surfactant, nonionic surfactant, and xanthan gum, and carries out the compounding with different ratios, in order to obtain the optimal performance foam that can be covered for a long period of time without defoaming, and thus increase the blocking performance.

2. Materials and Methods

In this paper, anionic/nonionic compounding system was used to carry out experimental research, in which the anion was selected as sodium aliphatic alcohol polyoxyethylene ether sulfate (AES). The nonionic surfactant was APG0810. Toluene, xylene and ethyl acetate were used as organic volatiles.

The foam scanner was utilized to carry out foam volume and discharge half-life performance tests. During the test, 60mL of solution was injected into the electrode pipeline, and the flow rate of air was 80mL/min. The foam performance test was carried out by the drum blowing method, and the foam volume, the liquid content of the foam at different heights, the Foam Capacity (FC), the Foam Maximum Density (MD) and other parameters were automatically measured by the Foam Scanner, and the CCD camera shot the foam volume and the half-life of discharge at 10s intervals. The CCD camera takes a picture every 10s. The test was repeated three times for each solution, and the average value was taken as the final result. The foaming time was set to 120s, and the foaming volume was used to characterize the foaming ability of different solutions, the larger the volume, the stronger the foaming ability. The change of foam volume with time can be used to study the liquid-carrying capacity and half-life of foam. Before the start of the barrier experiment, the soil was dried in a desiccator box for 2h, and the temperature was set to 300°C; 2 customized beakers were taken and labeled as A and B; deionized water was added to the soil to control the moisture content at about 20%; the soil was placed into A and B beakers, and the soil layer was 10 cm in height; the organic volatiles were injected into the soil through a syringe for 30 mL; the foamed foam was immediately covered on the soil in beaker B , covering height of 15cm, A beaker without foam; real-time monitoring of the concentration of organic volatiles in A and B beaker through VOCs detector, recorded as Ca and Cb, respectively. use equation (1-1) to calculate the barrier rate (ηi) at the ith moment:

$$\eta_i = \frac{C_{ai} - C_{bi}}{C_{ai}} \times 100\% \tag{1}$$

3. Results & Discussion

Research on the performance of surfactant compounding

In this paper, AES/APG0810 was used in different ratios of compounding (concentration of 0.1%), and its performance parameters are shown in Figure 1 below. In order to comprehensively consider the influence of foaming capacity and discharge half-life on foam performance, the foam composite index was utilized to evaluate the comprehensive foam performance of the compounded solution, in which FCI is the foam composite index, mL; VA is the foaming volume per unit time, mL/s; T1/2 is the foam discharge half-life, s. The formula is as follows.

$$FCI=0.75V_A T_{1/2} \tag{2}$$

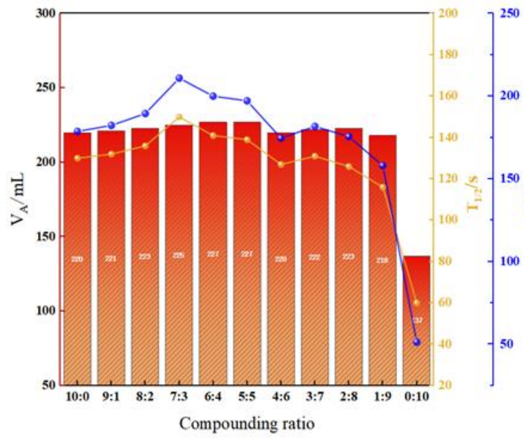


Figure 1: Trend of foam properties under different ratio conditions

As shown in Fig. 1, when the ratio of AES to APG0810 surfactant was changed, the foam volume, discharge half-life, and foam synthesis index varied significantly. When the mass ratio was in the range of 9:1 to 5:5, the foam volume and discharge half-life increased to a certain extent, especially when the mass ratio was 7:3, the foam synthesis performance reached the best, and the foam volume was increased by 2.3% and 64.2% compared with that of the respective monomers, and the discharge half-life was increased by 15.4% and 150%, which can be seen that the compounding system had a more obvious influence on the foam stability. It can be seen that the effect of the compounding system on foam stability is more obvious, indicating that the compounding system of AES anionic surfactant and APG0810 nonionic surfactant has produced a good synergistic effect.

Study on the effect of xanthan gum on foam properties

In order to enhance foam persistence, xanthan gum (XG) was used as a key additive, aiming to significantly improve the stability of the foam by enhancing its stabilizing mechanism, thus comprehensively optimizing the overall performance of the foam. With the change of xanthan gum concentration, the change of foam performance is shown in Fig. 2. When the concentration of xanthan gum is greater than 0.3%, the viscosity is too large to significantly reduce the foaming ability of the foam, which is not conducive to the subsequent study, and only the performance of the foam when the concentration is up to 0.3% is investigated here.

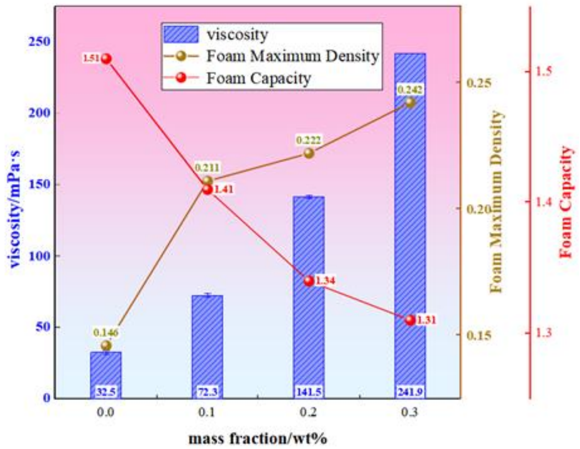


Figure 2: Variation trend of foam properties and viscosity under different XG concentrations

Observing Fig. 2, it can be seen that the concentration of xanthan gum increased from 0.0% to 0.3%, and the liquid phase viscosity increased from 32.5 mPa·s to 241.9 mPa·s. With the increase of the mass fraction of xanthan gum, the foaming capacity (FC) of the foam gradually decreased, and the foaming capacity was 1.51 without the addition of xanthan gum, and the foaming capacity of the foam was 1.31 when the mass fraction was 0.3%. the foaming capacity decreased by 13.2% compared with that at a mass fraction of The foaming capacity decreased by 13.2% compared with that of 0.0%. The decrease in foaming capacity was attributed to the increase in the dynamic viscosity of the liquid phase, which increased the fluid resistance and thus counteracted the stirring force required in the foaming process [12]. The density of the foam also increased with the increase of xanthan gum concentration, mainly because viscosity is one of the key factors affecting the stability of the foam, high viscosity liquid can provide better liquid film strength, better encapsulation of bubbles to resist gravity, surface tension and external disturbances on the structure of the foam, to prevent the merging of the bubbles and the rupture of the bubble wall, thus enhancing the foam stability.

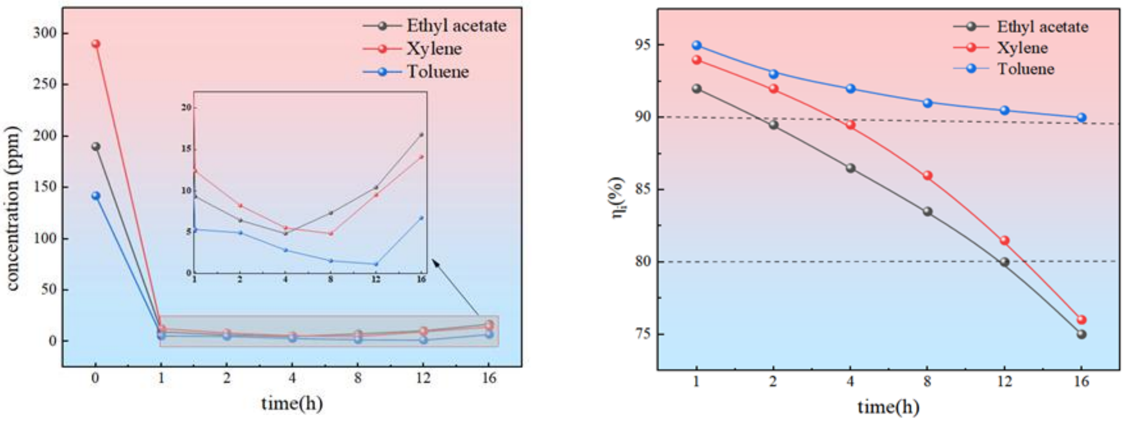
Table 1: Performance parameters of AES: APG0810: XG

XG concentration/wt%	V_A/ml	$T_{1/2}$/s	FCI
0	225	150	210.94
0.1%	220	3430	4710.63
0.2%	214	23150	30960.31
0.3%	158	30550	30168.13

Table 2 shows that with the increase of xanthan gum mass fraction, the discharge half-life appeared to be greatly improved, the xanthan gum concentration increased from 0.0% to 0.3%, and the discharge half-life increased from 150 s to 30550 s. The foam composite index increased from 210.94 to 30,168.13, which indicated that the xanthan gum improved the comprehensive performance of the foam significantly. The foam volume at 0.3% xanthan gum concentration was 158 ml, which was 26.2% lower than the concentration of 0.2%. Although the concentration of 0.3% had the highest discharge half-life, the concentration of 0.2% had the best overall foam performance, so the concentration of 0.2% xanthan gum was selected for the subsequent study.

Investigation on the performance of compounding system for blocking VOCs

In order to investigate the barrier performance of foam on VOCs, toluene, xylene, and ethyl acetate were selected as typical VOCs to carry out experimental studies to evaluate whether a satisfactory inhibition effect could be achieved, and the experimental results are shown in Fig. 3.



(a) Change in VOCs concentration after foam coverage (b) Barrier ratio with foam cover

Figure 3: Barrier effect of foam on VOCs

Observation of Fig. 3 reveals that different VOCs show different concentrations initially due to their different volatility. Foam material has obvious barrier effect on VOCs, the coverage of foam material can rapidly reduce the concentration of VOCs and the barrier rate is above 80% within 12h. Figure (b) shows that the barrier effect of foam material on xylene and ethyl acetate shows a decreasing trend with the increase of time, in which the inhibition effect of foam material on toluene is more obvious, and the concentration of toluene decreases from 142 ppm to 5.3 ppm at 0~1h, and the blocking rate reaches 95.2% at 1h, and toluene concentration reaches a minimum of 1.1 ppm at 12h, and the concentration is maintained below 7.0 ppm within 16h. The concentration of toluene reached a minimum of 1.1 ppm at 12 h, and the concentration remained below 7.0 ppm for 16 h, and the barrier rate was above 90%.

Comparing the trend of xylene and ethyl acetate concentration, it can be seen that with the covering of the foam material, the concentration decreased from 290ppm to 8.4ppm, 190ppm to 9.3ppm for 1h, and the barrier rate at 1h reached 94.1%, 92..5%, respectively, and the concentration of xylene reached a minimum of 4.1ppm at 8h, while the concentration of ethyl acetate was a minimum of 4.8ppm at 4h. Comparing the two barrier rates, it was found that the barrier rate of the foam to xylene was higher than that of ethyl acetate at 0~16h, indicating that the barrier effect of the foam material to xylene was better than that of ethyl acetate.

4. Conclusion

(1) The addition of XG can improve the foam stabilization performance of the AES/APG0810 composite system, but it will reduce the foaming performance of the composite system.0.2% xanthan gum has the greatest increase in the comprehensive performance of the foam, and the discharge half-life increases from 150s to 23150s, and the comprehensive index of the foam increases from 210.94 to 30960.31.

(2) At room temperature and pressure, the optimally proportioned AES/APG0810/XG composite foam material can rapidly and effectively inhibit the volatilization of VOCs (volatile organic compounds) when covering the surface of the VOCs, and continue to show excellent barrier performance within 16h. The foam material showed the best barrier performance against toluene, with the concentration of toluene reaching a minimum of 1.1ppm

at 12h, and the barrier rate was above 90% within 16h. The barrier effect was in the order of ethyl acetate < xylene < toluene.

References

[1]. Bhat, A.A., Afzal, M., Goyal, A., & Dua, K. (2024). The impact of formaldehyde exposuron lung inflammatory disorders: insights into asthma, bronchitis, and pulmonary fibrosis. Chemico-Biological Interactions, 394, 111002.

[2]. Rana, I., Dahlberg, S., Steinmaus, C., & Zhang, L. (2021). Benzene exposure and non-hodgkin lymphoma: a systematic review and meta-analysis of human studies. The Lancet Planetary Health, 5(9), e633-e643.

[3]. Jia, H., Zeng, J., Zou, Q., Zheng, L., & Pan, R. (2024). Fluorine-free foaming extinguishing agent: design route, fire extinguishing performance, foam stability mechanism. Arabian Journal of Chemistry, 17 (4), 105712.

[4]. Xiong, Y., Pang, B., Liu, Z., Liu, C., Hu, Z., & Ma, L. (2023). Effect of foam temperature on foam stability of foamed concrete and stabilization mechanisms. Journal of Building Engineering, 77, 107492.

[5]. Jia, H., Cui, B., Niu, G., Chen, J., Yang, Y., Wang, Q., & Tang, C. (2023). Experimental and mechanism study on the impermeability and thermal insulation of foam concrete regulated by nano-silica and fluorine-free foam. Journal of Building Engineering, 64, 105675.

[6]. Cheng, J., Ma, Z., Fu, Q., Ran, D., Borowski, M., & Xi, Z. (2024). Eco-friendly three-phase-gel foam with novel particle-gel crosslinking enhancing stabilization and fire extinguishing. Powder Technology, 445, 120134.

[7]. Zhao, G., Dai, C., Wen, D., & Fang, J. (2016). Stability mechanism of a novel three-phase foam by adding dispersed particle gel. Colloids and Surfaces a: Physicochemical and Engineering Aspects, 497,214-224.

[8]. Wu, P., Xue, T., Liu, G., Li, X., Peng, Z., Zhou, Q., & Qi, T. (2021). Interfacial behavior and micellization of binary surfactant mixtures in the concentrated sodium aluminate solution. Journal of Molecular Liquids, 334, 116530.

[9]. Zhou, Y., Jin, Y., Shen, Y., Shi, L., Bai, L., & Zhou, R. (2022). Adjustable surface activity and wetting ability of anionic hydrocarbon and nonionic short-chain fluorocarbon surfactant mixtures: effects of li+ and mg2+. Journal of Molecular Liquids, 350,118538.

[10]. Sheng, Y., Xue, M., Zhang, S., Wang, Y., Zhai, X., Ma, L., Hu, D., & Huang, X. (2021). Effect of xanthan gum and silica nanoparticles on improving foam properties of mixed solutions of short-chain fluorocarbon and hydrocarbon surfactants. Chemical Engineering Science, 245, 116952.

[11]. Gu, H., Ma, L., Zhao, T., Pan, T., Zhang, P., Liu, B., & Chen, X. (2023). Enhancing protein-based foam stability by xanthan gum and alkyl glycosides for the reduction of odor emissions from polluted soils. Journal of Cleaner Production, 398, 136615.

[12]. Zhang, Y., Diao, Y., Zhang, W., Xu, W., Hu, Z., & Yi, Y. (2022). Influence of molecular structure and interface behavior on foam properties of rice bran protein nano-particles. Lwt, 163, 113537.