CAUSES OF ANAEROBIC DIGESTION FOAMING – A REVIEW

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ABSTRACT

In the United Kingdom, anaerobic digestion foaming has been seen in a number of sewage treatment facilities. Water businesses are concerned about foaming because it has a substantial effect on process efficiency and operating expenses. Researchers have discovered a number of foaming reasons in recent years. However, the amount of supporting experimental data is minimal, and in some instances, non-existent. Foaming causes poor gas recovery from digesters, resulting in higher power generation costs. Foaming may also result in an inverted solids profile, with greater solids concentrations at the top of a digester, the formation of dead zones, and the decrease of the digester's active volume, resulting in sludge that has not been stabilized to the same degree. The purpose of this paper is to give a comprehensive overview of the current anaerobic digestion foaming issue and to identify knowledge gaps in the theory of anaerobic digester foam production.

KEYWORDS: *Anaerobic, Digestion, Foaming, Process Efficiency, Sludge.*

1. INTRODUCTION

For more than a decade, anaerobic digestion (AD) foaming has been seen in several sewage treatment works (STWs), with serious consequences for the entire digestion process. Foam in a culture medium is defined as a gas–liquid dispersion with a gas concentration of more than 95%, generated by vigorous agitation, aeration, and the addition of surfactants. Foams produced in anaerobic digesters may be described as a buildup of gas bubbles surrounded by a liquid layer on the surface of sludge based on the preceding assertions[1].

Foaming may also cause gas mixing device jams, sludge recirculation pump foam binding, fouling of gas collecting pipelines owing to entrapped foam particles, foam penetration between floating covers and digester walls, and floating cover tilting during foam expansion and collapse[2]. The wastewater industries are concerned about the economic problems that come from energy loss, labor overtime, and cleaning expenses. STW is based in Sweden. In 1996, a 10-week foaming issue at STW in Sweden resulted in a 40% biogas loss. The overall cost of suppressing foam was $150,000 US dollars, which included increased oil consumption for energy generation and the use of polymer for better dewatering[3].

However, this is the sole reference in the literature on the expenses associated with anaerobic digestion foaming episodes. A lot of studies have looked at the foaming issue in Alzheimer's disease in try to figure out what causes it. Foaming reasons were first identified as insufficient mixing, temperature variations, shock loads, extracellular polymeric substances (EPS), and hydrophobic compounds[4]. However, since the information given is either site specific or lacking experimental proof, the following studies do not constitute a comprehensive study of the foaming issue. The purpose of this study is to examine what is currently known about the causes of foaming in mesophilic AD and to look into the processes of foaming throughout the disease. In order to promote a better understanding of the mechanisms of foam formation and stabilization in biological processes where continuous degradation, solid contents, and the microbial population have an impact on foam initiation and stabilization, the following paragraphs address a well-studied foaming problem in biological processes, activated sludge (AS) foaming[5].

The comparison with the AS process was performed to: (a) see whether there was a link between AS foaming and AD foaming; and (b) look at a larger body of literature on foam initiation and processes than was available for AD. Other biological processes, such as aerobic digestion, produce foam. The activated sludge (AS) method, which includes the breakdown of organic materials by microorganisms under diffused or mechanical aeration, is widely employed in wastewater treatment[6]. Foaming is a common issue in AS plants, and there is a wealth of information available in the literature on the causes and management of foaming. This section intends to provide a short overview of the well-studied foaming issue of AS plants in order to acquire information from the literature on wastewater foams and perhaps identify a link between AS and AD foaming.

Many studies attribute foaming in activated sludge plants to a combination of surfactants (detergents), bio surfactants (substances generated during the metabolic activity of microorganisms), and the presence of two types of filamentous bacteria. Filamentous microorganisms are bacteria, fungi, and algae whose cells do not separate during cell division and therefore develop in the shape of filaments. Filamentous bacteria known as Actinomycetes that have highly hydrophobic cell walls owing to the presence of mycolic acids. It can store extra-long chain fatty acids in big globules and, owing to its hydrophobicity, has an edge over other bacteria when it comes to water-insoluble fats and lipids.

At three full-scale AS plants, large rod and coccoid mycolata populations (mycolic-acid-containing bacteria) ranging from about AS and accounting for more than 79 percent of the mycolata population were strongly linked to foaming occurrences. The presence of branching filamentous mycolata in foaming phases, on the other hand, was negligible, accounting for less than 21% of the mycolata population in the mixed liquid and foam samples tested. Furthermore, filamentous mycolata had no role in the substantial changes in mycolata concentrations found between foaming and non-foaming phases. These results suggested that filamentous bacteria were not to blame for the foaming this time. Foaming episodes were strongly related with huge rod and coccoid mycolata populations (mycolic-acid-containing bacteria) ranging from about of AS and accounting for more than 79 percent of the mycolata population at three full-scale AS facilities[7].

The presence of branching filamentous mycolata in foaming phases, on the other hand, was negligible, accounting for less than 21% of the mycolata population in the mixed liquid and foam samples tested. Furthermore, filamentous mycolata had no role in the substantial changes in mycolata concentrations found between foaming and non-foaming phases. These results suggested that filamentous bacteria were not to blame for the foaming this time[8]. According to the study, the start of foaming may be caused by high surfactant and biosurfactant loads in wastewater, which are subsequently stabilized by microorganisms that contain mycolic acid. The impact of three strains of the filamentous bacteria on foam formation and stability was studied in another research. Pure cultures of the three strains following separation of the microorganisms from foam or mixed liquor samples from full scale revealed that the biosurfactant generated during the exponential development phase of the bacteria, was the agent responsible for foam initiation.

Because the filtrates of each culture exhibited distinct foaming behavior, it was also discovered that each strain generated a different biosurfactant or in different amounts. The concentrations of biosurfactants were indirectly evaluated via surface tension and the foaming potential in this research, and surface tension levels below 60 mN m1 were required for foam start. The presence was credited with foam stability since P55 percent of the stresses were partitioned into the foam, resulting in lower foam drainage rates. The bacteria's partitioning in the foam was unrelated to the strains' origin (foam or mixed liquor sample) and did not vary significantly over time[9]. To summarize, foaming in AS plants is a well-studied issue that has major implications for process efficiency. Several investigations by different experts have shown a strong connection between AS foaming and the presence of surfactants, biosurfactants, and microorganisms that produce mycolic acid.Surfactants and biosurfactants are responsible for the start of AS foaming, but essential amounts for foam initiation have yet to be determined owing to the large number of chemicals involved and their diversity across sludge. Foam stabilization is mostly attributed to the filamentous, although there is evidence that non-filamentous mycolic-acid-containing bacteria, of which particular species have yet to be discovered, also play a role.

Due to the complexity of the process degradation pathways and the many surface active chemicals present in wastewater, further information on the precise processes of foam production and stabilization in AS plants has not been given. The current understanding of the AS foaming issue has given a basic understanding of wastewater foaming processes. The next paragraphs analyze the impact on foaming in connection to chemical (surface active agents) and microbiological components in order to find parallels in the processes of foam generation and stability in AD and perhaps the link between AS foaming and AD foaming. Surfactants and bio surfactants are classified as surface active agents. Oil, grease, volatile fatty acids, detergents, proteins, and particles are all surfactants. However, the word "particulate matter" as used in the literature is not defined explicitly, which may lead to misunderstandings[10].

2. DISCUSSION

The particulate debris may include inorganic sludge components like as metals, sand, and other indigestible material that collects at the bottom of digesters, often known as grit. Bio surfactants are hydroxylase and cross-linked fatty acids, glycolipids, proteins, lipoproteins, phospholipids, and polysaccharide–lipid complexes generated by the metabolic activity of microorganisms found in sludge. Hydrophilic and hydrophobic characteristics are seen in surface active compounds. Because of their hydrophobicity, the hydrophobic ends of surface active agents tend to migrate towards the air phase, forcing them out of the solution.

On the other hand, the hydrophilic ends tend to migrate towards the liquid phase. Surface active agents influence a solution's surface tension, which is defined as "a property of liquids arising from unbalanced molecular cohesive forces at or near the surface, as a result of which the surface tends to contract and exhibit properties similar to those of a stretched elastic membrane." The critical micelle concentration is determined by comparing surface tension to the concentration of a surface active chemical (cmc). That is the concentration at which the aggregation of molecules into clusters (micelles) begins with the hydrophobic ends of the molecules towards the center and the hydrophilic ends facing the solvent. The molecules of the chemical exist as monomers at concentrations less than the cmc, and as micelles at concentrations greater than the cmc.

When a substantial number of micelles are present, the compound's impact is highest at concentrations greater than the cmc. Simply put, if air bubbles were injected into solution, the cmc of a surface active chemical defines the concentration beyond which surface activity rises and foaming occurs. Pure water has a surface tension of about. At their isoelectric point, which is strongly dependent on the pH of the medium, proteins have the lowest solubility and the greatest foaming potential. There is currently no information in the literature on how various proteins influence the foaming potential in anaerobic digesters or what concentrations are required to cause foaming. BSA would cause foaming in digester feed sludge when aeration was applied.

Exonyms break down proteins to amino acids in anaerobic digesters, which has an effect on the foaming potential. Protein was less biodegradable in AD than fiber and lipids, and each non-foaming sludge had a final equilibrium concentration value of 8.41 mg g1 that was independent of the starting protein concentration. In this research, the highest initial protein content was 44.8 percent of the dry matter of the sludge. Protein accumulation at the air/liquid interface may be aided by their surface active characteristics during AD, which could contribute to increased foaming potential.

Protein interactions with other proteins, solids, and other substances in solution, such as the electrostatic interactions described, may, on the other hand, influence protein behavior. The combination of BSA and protamine created a molecular double layer that trapped liquid, reducing drainage and improving foam stability. Protein affinity for fat, as previously mentioned, is an example of another kind of interaction. By weight, the protein–fat mixture contained 9.75 percent molten butter (82 percent fat content), 11.3 percent spray dried skim milk powder (low heat), 12 percent sugar, 4 percent glucose syrup solids, 0.1 percent locust bean gum, and 0.1 percent guar gum, resulting in bridging between adjacent foam bubbles and between bubbles and the bulk solution, resulting in reduced foam drainage. However, the inclusion of non-ionic emulsions of monolaurate (0.9 lM), monolete (0.7 lM), and trioleate of sorbitan (0.3 lM) in the protein–fat matrix decreased the foaming potential and stability, according to the same study. The impact of proteins, proteins by-products, chemical interactions, and perhaps exoenzyme synthesis on the foaming potential of anaerobic digesters is complicated and varies across sludges. It is unclear if sludge containing highly surface active proteins, such as lysosome, decreased the surface tension of aqueous solution to below 58 at a concentration of 0.001 mM. Lipids are chemical compounds that are highly hydrophobic and do not dissolve in water. Lipids are linked to the solid particles in sludge due to their hydrophobicity. Fats and oils are the most prevalent lipids in municipal and industrial wastewater, and therefore in sludge.

Although surface active agents, fats and oils that enter a digester are hydrolyzed to simpler molecules (glycerol and fatty acids) and eventually organic acids. Given lipids' hydrophobicity but also their degradability during AD, it's unclear whether lipids could potentially accumulate on the surface of the bulk phase in an anaerobic digester, losing contact with the bulk phase's majority of bacteria and thus leading to partial fat and oil degradation and increased surface activity. Due to the surface active characteristics of the lipids, the biogas bubbles may get entrapped and cause foaming. However, there was no further experimental evidence in the literature showing a definite contribution of lipids to the sludge's foaming potential during AD. Due to the poor degradability of proteins and buildup of lipids at the air/liquid interface resulting in increased surface activity, there is evidence that lipids contribute less to foaming in AD than proteins.

This may be avoided by keeping a properly mixed homogeneous digester. Another class of chemicals known as surface active agents is detergents. Detergents in wastewater come from a variety of sources, including industrial effluents from breweries, dairies, paper and textile mills, as well as municipal wastewater. Detergent concentrations in STWs may be substantially increased by industrial effluents, to the point that biological treatment processes are inhibited. A thorough examination of AD operating factors such as gas mixing, temperature variations, organic loading, and digester geometry, as well as their connection to foaming, revealed that these variables may possibly generate ideal circumstances for foam start in anaerobic digesters.

As a result, it is essential to guarantee that the operation of anaerobic digesters does not promote the formation of foam. Minimizing temperature variations that may contribute to poor digestion and possible buildup of surface active chemicals, either as by-products of digestion or as found in feed sludge, are examples of parameters that can be managed by operators on a daily basis. Another preventive strategy against stratification and therefore poor digestion and foaming is to provide adequate but not excessive mixing by periodically maintaining digesters and avoiding grit buildup and dead spots.

Overloading and volatility of digester loading should also be prevented by monitoring solids loading rates and digestion performance on a daily and weekly basis. Although the usual organic loading rates for AD described in the literature are very wide, it is thought that there is a critical threshold of organic loading that varies across digesters and is mainly dependent on both feed and digested sludge properties, above which foaming may occur. All of the above, however, are just suggestions at this point for how foaming in anaerobic digesters can be avoided/minimized, as this paper has shown that there is a lack of experimental evidence and significant gaps in knowledge in order to fully understand how foaming can occur from digester operation, such as what temperature fluctuation is required to induce foaming in AD, how solids loading works, and so on.LAS is adsorbed onto the particles and organic matter of sludge and removed from the wastewater through primary sludge. Primary sludge is the only stream that will have significant detergent concentrations because to the strong degradability of LAS in aerobic conditions.

The quantity of LAS in the final sludge combination of primary and secondary sludge is, however, heavily influenced by the site operations. The literature on biosurfactants in sewage sludge, such as glycolipids, lipoproteins, phospholipids, and polysaccharide–lipid complexes, and their relationship to foaming is limited, possibly due to the large number of and complex compounds present, as well as the variability of these compounds between different sludges. Researchers have used wastewater, soil, and other bacterial culture medium samples to assess indirect biosurfactants. Surface tension measurements in a bacterial species' growth medium based on wastewater to track biosurfactant synthesis. At a concentration of 3 g l1, the bio surfactant, which was identified as a lipopeptide, decreased the surface tension of the culture medium to 26 mN m1, while its cmc was 33 mg l1.

The presence of a large and varied microbial community in anaerobic digesters suggests that biosurfactant generation is substantial. Biosurfactants, on the other hand, are present in AD in non-foaming circumstances. It's unclear if an alteration in the metabolic activity of microbes in AD is required to increase biosurfactant synthesis and promote foaming. As a result, biosurfactants may not be a direct cause of AD foaming, but rather a consequence of an underlying reason that causes biosurfactant formation. Furthermore, the probability of these chemicals causing foaming in a digester would most likely be determined by the kind and quantity of biosurfactants present. Due to a paucity of experimental data, no conclusion can be drawn on the role of biosurfactants in AD foaming at this time.

3. CONCLUSION

Foaming is a common symptom of Alzheimer's disease. Due to poor gas recovery, it creates major operational issues and lowers income. Foaming events have been linked to specific design and operational variables in the literature, and many probable causative theories have been suggested. However, there is a paucity of experimental data to back up these claims. This article used a unique approach in that it used current knowledge of activated sludge foaming to create a conceptual foundation for understanding foaming in Alzheimer's disease. Foams produced from wastewater are three-phase systems with gas bubbles, liquid, and solid particles. Foam initiating and stabilizing chemicals are required in this three-phase matrix. While the existence of potential foam initiating and stabilizing chemicals in AD systems has been confirmed in the literature, their critical concentrations have yet to be determined.

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