FOAMING ORGANISMS IN SEWAGE TREATMENT- FRIEND OR FOE: VICTIM OF BAD PUBLICITY

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ABSTRACT

Foaming bacteria are a common occurrence in many activated sludge sewage treatment plants. The accumulation of foams on secondary clarifiers can result in increased solids carryover in the final effluent possibly causing licence limits to be exceeded. The hosing down of clarifiers to break up the foams is labour intensive. Various methods of controlling the foaming bacteria have been proposed and implemented over the years. These control measures have met with varied success and many failures.

The fundamental question of "what causes foaming organisms to proliferate" was answered by research undertaken in Australia. Applying this research and based on full scale plant studies within Australia, it is possible to identify why foaming bacteria occur, why the severity of foaming varies and why "overnight" foaming events occur.

1.0 INTRODUCTION

The occurrence of biological foams in activated sludge plants has been reported globally for over 40 years. Foam accumulations on secondary clarifiers can result in increased solids carryover in the final effluent possibly causing licence limits to be exceeded. The hosing down of clarifiers to break up the foams is labour intensive.

The discharge of foaming bacteria to anaerobic digesters has been linked to severe foaming in the digesters. This results in overflow of the digesters and clogging of gas systems including pressure and vacuum relief valves.

Under severe conditions, "overnight" foaming events can occur. This can result in the overflow of structures by biological foams as demonstrated in the following figure.

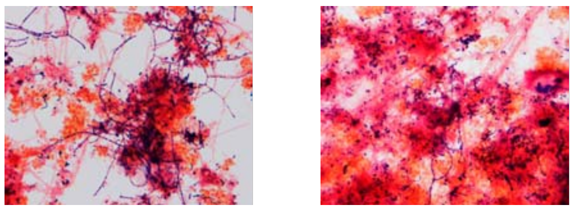
__Figure 1:__ ***Examples of severe biological foaming at activated sludge plants.***

Proposed methods of controlling the foaming bacteria include the provision of "Selectors" (anaerobic, anoxic or aerobic selectors), chlorination of return activated sludge and operation at reduced sludge ages. These control measures have met with varied success and many failures.

In order to address the issues associated with biological foams and identify the appropriate control measures, it is first necessary to understand the fundamental nature of the foaming organisms and what causes there proliferation.

2.0 NATURE OF FOAMING ORGANISMS

Foaming organisms are heterotrophic bacteria (use organic substrates as a food and energy source). In many activated sludge plants, the foaming bacteria present themselves as a string of bacteria or filaments as shown in Figure 1. However, a foaming bacteria does not need to be present as a filament in order to cause foaming. An investigation of severe foaming at an activated sludge plant treating wool scour wastes demonstrated that the bacteria were present as individual cells and, when the cells were cultured in the laboratory, they presented themselves as filaments. It is also important to note that there exists a broad range of organisms that can grow as strings or chains of bacteria and appear as filamentous bacteria. Not all of these filamentous bacteria are foaming bacteria.



<u>**Figure 2:**</u> ***Micrographs of Activated Sludge with Filamentous Foaming Bacteria***

There have been many theories proposed as why foaming bacteria proliferate. It has been suggested that, due to their filamentous nature, the foaming organisms gain a competitive advantage when the food source is highly diluted. The adoption of the low substrate theory (with minimal proof) has resulted in selectors being proposed to control foaming. The selectors are small tanks at the head of the activated sludge plant receiving the influent sewage and the return activated sludge. The intention is to have a high concentration of food within the selector. Selectors used have included aerobic, anoxic and anaerobic. The success of these selectors has been limited in controlling foaming bacteria although some success has been experienced in controlling the proliferation of other filamentous bacteria; particularly with the use of aerobic selectors.

Foaming has also been reported to be more severe in some countries during winter and some countries during summer. Thus, temperature appears to play a role in the proliferation of foaming bacteria.

3.0 TRUE CAUSES FOR THE PROLIFERATION OF FOAMING BACTERIA

Despite all of the theories proposed for the proliferation of foaming bacteria and extensive efforts made into the identification and naming of foaming bacteria, there was very little fundamental research carried out into the basic feeding mechanisms of the bacteria. Fortunately, applied microbiological investigations were undertaken by Prof Seviour's team at the La Trobe University, Bendigo campus.

This team identified a number of key factors for the foaming organisms (Stratton, 1997) that provided meaningful information as to why foaming bacteria occur and what approach should be adopted to dealing with them.

1. The foaming organisms have a hydrophobic ("water hating") cell surface. Effectively, the outer cell wall is "greasy". Many foaming bacteria have an outer surface composed of mycolic acids. The ends of the mycolic acids facing out have a structure similar to that of fats, oils and greases.
2. The foaming organisms grow slowly in "normal" media used for culturing organisms in the laboratory however, the foaming organisms grew quickly in "shaker flasks" in various solutions containing oily substances such as olive oil.

This information demonstrated several key factors:

1. The foaming organisms "foam" because they are water repellent and want to float on the surface (similar to fat and grease).
2. The foaming organisms are growing on the fats, oils and greases as their surface mimics the fats , oils and greases and they can attach to these hydrophobic substrates.

Essentially, the foaming bacteria, having a hydrophobic surface layer, are the only organisms that can attach to the hydrophobic substrates and then consume them as a food source. The non-hydrophobic bacteria simply "bounce" off the hydrophobic substrates. At plants where foaming organisms are not present, small, white globules of fats and grease can be seen on the surface of the secondary clarifiers. These globules are not all removed by surface skimmers and emerge in the effluent.

The major finding of the research is that the foaming organisms are actually fulfilling a treatment role in that they are breaking down and consuming fats, oils and greases. It is therefore clear that foaming organisms; rather than being an undesirable nuisance; are actually carrying out an essential part of the treatment process, Rather than get rid of the foaming organisms, it is more important to manage them.

The research at La Trobe University also listed the mechanisms to form a stable foam. To form a stable, you need gas bubbles (provided by aeration), a surfactant (detergent type compounds that are present in the raw sewage and also produced by some bacteria during treatment) and hydrophobic particles less than 300 microns (the foaming bacteria).

The question must be asked as to why foaming has only become a problem in the past 40 years. This is readily explained by the development of the activated sludge process during this period. Most early activated sludge plants were only focusing on the removal of organics (BOD_5) and operated at relatively short sludge ages of the order of 3 to 4 days. With the advent for the removal of nutrients from wastewater effluents, longer sludge ages of 10 days or more were adopted to permit nitrification and denitrification. Although the foaming bacteria grow faster on fatty, oily substances, they still grow relatively slowly as the fats, greases and oils are difficult to digest. They therefore require a minimum sludge age of the order of 10 days to grow and form a stable population. Thus early attempts to "control" foaming centred on reducing the sludge age (increasing wasting) to "wash out" the foaming bacteria. This is fine in theory however, it usually also resulted in failure of nitrification.

The research demonstrates that other foaming preventative actions such as selectors or dosing of chlorine to RAS cannot work. If sufficient chlorine has been dosed to kill the foaming bacteria with their strong, hydrophobic surface, it is likely that most of the protozoa and nitrifying bacteria have also been killed.

It is true that some plants do not suffer from foaming and some plants only suffer from seasonal foaming. Again, the research readily explains this phenomena. Many plants have reticulation systems incorporating numerous pump stations. Frequently, "fat balls" form in these pump stations. This prevents some of the fats and greases being discharged to the treatment plant thus limiting the food for the foaming bacteria and therefore limiting the number of foaming bacteria generated. Similarly, during colder weather, the fats, oils and greases tend to congeal. With warmer weather, some of the fats and oils will soften and disperse into the water and therefore be discharged into the treatment plant increasing the number of foaming organisms.

4.0 MANAGEMENT OF FOAMING BACTERIA

Once it has been accepted that foaming bacteria play a key role in treatment process, the issue becomes one of management of the foams. Scum beaches on secondary clarifiers do not have sufficient draw off capacity to remove the mass of foam generated. Therefore, in order to prevent foam accumulations on the secondary clarifiers, it is first necessary to prevent the biological foams from reaching the secondary clarifiers. This is achieved by simply providing an underflow baffle on the outlet from the bioreactor to the clarifiers.

It is then necessary to provide some form of outlet for the foam from the bioreactor. Various systems have been trialled including bell mouths and "tipping" scum pipes as shown in the following figure. These devices suffer from "bridging" of scum with the scum mat remaining static after an initial flush and only mixed liquor flowing underneath the foam mat. Surface wasting of waste activated sludge has proven more effective when bridging can be avoided.

Figure 3: ***Trial bell mouth scum withdrawal, tipping scum pipe and surface waste activated sludge***

In order to achieve effective removal of biological foams it is beneficial to provide a positive mechanical removal mechanism. The device must also be located in an area where the foam has separated and is flowing towards the device. Two such devices were independently developed on opposite sides of the world. Australian Pollution Engineering (APE) of Bendigo, Australia developed a device similar to the surface skimmers on primary sedimentation tanks fitted with buckets to collect, raise and discharge the scum. A second device was developed in Germany (and now marketed in Australia) that resembles an inclined gravity drainage deck with a cloth belt to collect, raise and discharge the scum. The two devices are presented in the following figures.

<u>Figure 4:</u> ***Biological foam harvester developed by APE showing dewatering beach with discharge hopper and collection buckets with scum baffle behind.***

<u>Figure 5</u>: ***German developed scum harvester showing inclined belt drawing up scum to collection hopper.***

The harvesters tend to produce a thick product with approximately 2.5% w/w solids. Therefore, on plants where biological foam harvesters are provided, the small amount of residual scum from the secondary clarifiers is discharged directly back to the bioreactor for separation and collection by the scum harvesters.

The foam collected by the harvesters must be disposed off. With plants incorporating belt presses, the collected foam can be pumped to the belt presses during waste activated sludge dewatering. The collected foam should never be discharged upstream of magnetic flow meters as it contains significant entrapped air and will cause problems with flow measurement. The collected foam can also be discharged directly to aerobic digesters where they are provided. The foam should never be discharged directly to anaerobic digesters as it will cause severe foaming in these process units with disastrous consequences.

5.0 ISSUES WITH FOAM MANAGEMENT

Excessive harvesting of foam at treatment plants has resulted in fat and grease particles again being present on the surface of the secondary clarifiers. This is due to almost all of the foaming bacteria being removed from the system and there being insufficient population of the foaming bacteria to remove all of the fats, oils and greases.

Severe apparent foaming and this can be due to a combination of foaming bacteria and non-foaming filamentous bulking bacteria. Under conditions of severe filamentous bulking, the filamentous bulking organisms become enmeshed with the filamentous foaming bacteria and are lifted to the surface with the foaming bacteria forming a very thick and stable mat. The problem is therefore more of an issue with severe bulking rather than severe foaming. The foaming bacteria get the blame, or bad publicity, for the impact of filamentous bulking.

The combination of filamentous bulking and filamentous foaming results in the capacity of the foam harvester being exceeded. This situation recently occurred at the Logan WWTP when commissioning the augmented oxidation ditches. Microbiological examination of the Mixed Liquor and the foam demonstrated a high content of Type 0092 Filamentous bacteria (a bulking, rather than foaming filamentous bacteria). Once the filamentous bacteria had been identified, the appropriate corrective action for this type of bacteria could be taken and the filamentous bulking bacteria enriched foam declined.

The other event that will overwhelm the capacity of the foam harvesting device is the so called “overnight” foaming event. Many of the fatty and oily substrates for the foaming bacteria are only weakly hydrophobic and will mix with water with some agitation. The foaming bacteria that consume these weakly hydrophobic substrates have weakly hydrophobic surface layers as the surface layer “mimics” the chemical composition of the substrate. However, weakly hydrophobic material can become strongly hydrophobic if the characteristics of the liquid change. Factors that lead to changes in the characteristics of the liquid usually centre on aeration failures (reduced nitrification and increased denitrification raises the pH and changes the nitrogen ions present from predominantly negative nitrate to positive ammonia). Thus a 25 day sludge age plant could have 25 days worth of weakly hydrophobic bacteria mixed in with mixed liquor. These weakly hydrophobic cells can become strongly hydrophobic and an “over night” foaming event occurs with 25 days worth of foam separating out.

6.0 SUMMARY AND CONCLUSIONS

Filamentous foaming bacteria have long been considered a nuisance in activated sludge plants. Fundamental applied microbiological research at La Trobe University, Bendigo, has demonstrated that the foaming fulfil a desirable treatment role in that they attach to and consume fats, oils and greases from the influent that would otherwise pass through the treatment process un-degraded and emerge in the final effluent.

Foam harvesting devices have been independently developed on different sides of the world and using somewhat different approaches. These devices are effective in managing foaming organisms. Several similar devices are now provided by other equipment suppliers.

The harvesting of foams needs to be carefully managed as over harvesting can result in influent fats, oils and greases not being treated due to the lack of sufficient foam forming bacteria. The harvested foam can be dewatered with waste activated sludge on belt filter presses or aerobically digested prior to dewatering.

Severe foaming can be due to the entrainment of filamentous bulking bacteria in the foam with the foaming bacteria. This requires bulking to be addressed rather than foaming as it the bulking that is the problem rather than the foaming. The application of microbiological identification of the filamentous bulking bacteria present in the foam permits the most appropriate corrective action to be taken to reduce the filamentous bulking bacteria numbers.

7.0 REFERENCES

Stratton, H. M. 1997. Studies on bacteria causing stable foams in activated sludge systems. Ph D Thesis