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Bulking control made easy with hydrogen peroxide

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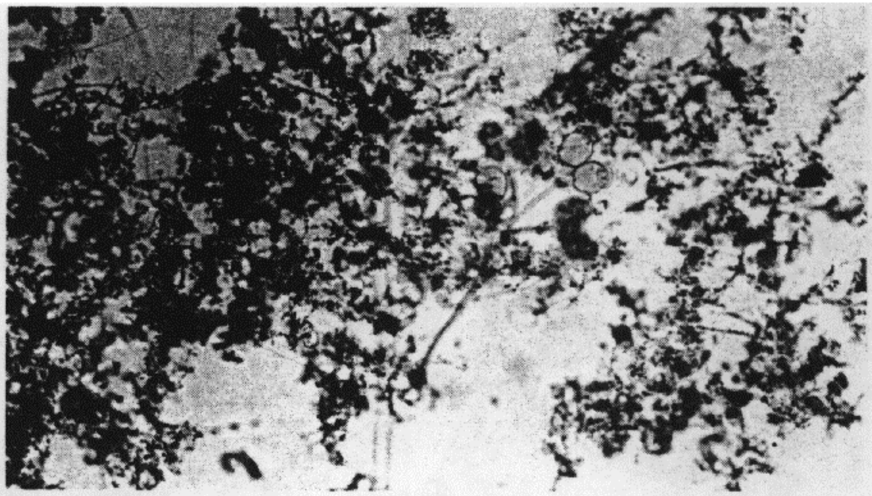
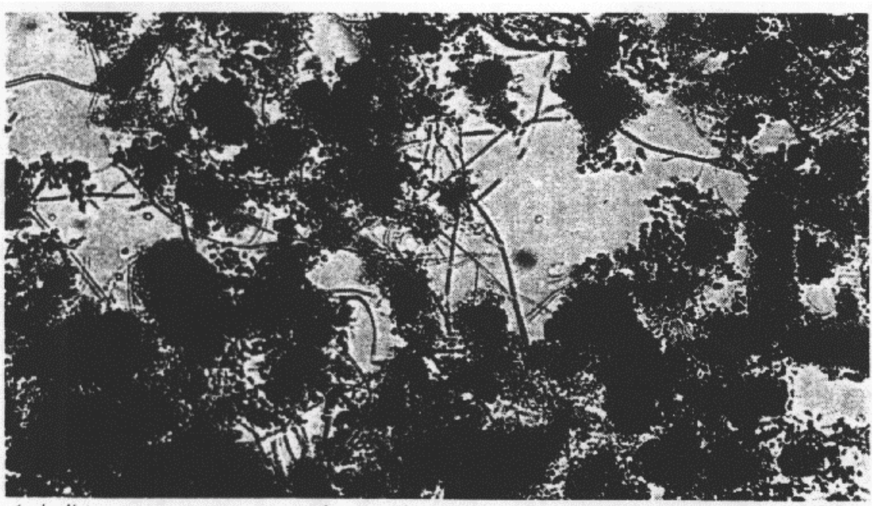


In a normal activated sludge, a sample will show compact particles with healthy protozoa attached

The beauty of the activated sludge process is that it is based on natural phenomena: the action of aerobic organisms in stabilizing wastes, the effect of dissolved oxygen in supporting these organisms and the tendency of solids to settle out of still waters. But there is another natural phenomenon of the process that is not so beautiful - sludge bulking, when sludge fails to settle adequately and suspended solids pass out with the effluent. This is most frequently caused by the growth of filamentous bacteria, resulting from underaeration, carbohydrate loads or improper sludge age. In the past few years, a new bulking control process has evolved that center around the use of hydrogen peroxide. A number of municipal and industrial waste management operations have found this to be effective and economical in controlling most forms of bulking. And FMC Corp. has developed visual means for predicting a potential bulking situation and pinpointing the time at which hydrogen peroxide treatment should begin.



As bulking progresses, protozoa become less noticeable and filamentous growth becomes apparent. This is the state at which treatment with hydrogen peroxide should begin

Bulking defined

To understand how hydrogen peroxide affects activated sludge, it is necessary first to discuss what bulking is and how it arises. Usually bulking is defined as a condition where solids are lost with the effluent. This occurs because bulked sludge has a high sludge volume index (SVO, a measure defined as the volume in ml occupied by I gm of sludge. Sludge with an SVI of about 200 or more generally yields an effluent with excessive suspended solids.

For convenience, bulking can be split into two major classes, depending on the absence or presence of filamentous bacteria. These are organisms, which can be observed attached to sludge particles. Non-filamentous bulking is caused by several conditions - floating sludge, rising sludge and pin floe, or macroscopic suspended particles. These may occur where conditions at the bottom of the sludge tank become anaerobic, favoring nitrogen-generating bacteria. Nitrogen bubbles attach themselves to sludge particles, causing them to rise and remain suspended in the water. In other cases, floating particles contain a large number of dead stalked protozoa and other micro-organisms, apparently killed off by lack of oxygen. These can usually be prevented by stimulating aerobic conditions in the sludge, preventing denitrification and permitting protozoa and other oxygen using organisms to function normally. Filamentous bulking, the commonest form, results from excessive growth of filamentous bacteria and certain types of fungi. Strands of bacteria or fungus grow within sludge particles or attach themselves to it and buoy up the sludge, which becomes dispersed and generally has an SVI above 200 ml/gm.

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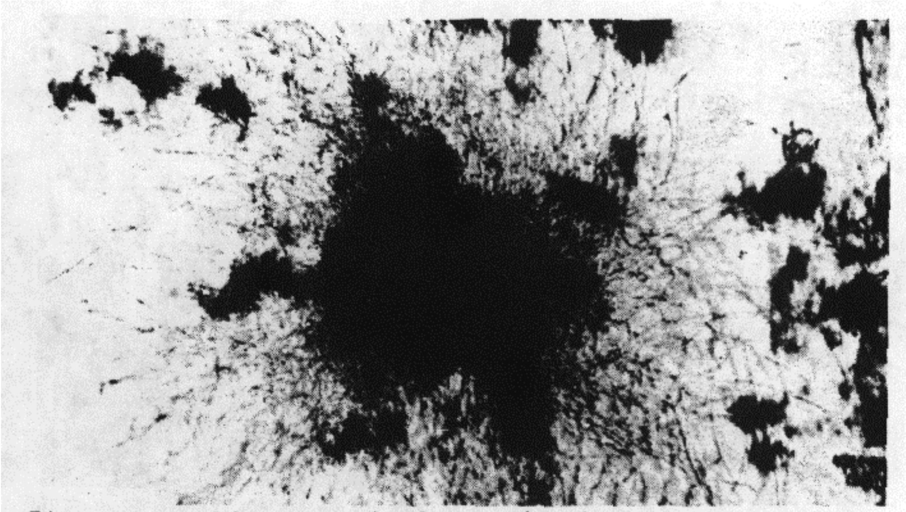
Filamentous growth has progressed to the point where the sludge is heavily bulked

Filamentous bacteria include sphaerotilus natans, beggiatoa and thiothrix. They also appear as slime in streams receiving waste liquors from paper mills, canneries, breweries and some municipal sewage treatment plants. Sphaerotilus natans is a common form in bulking sludge. However, since other organisms (such as the fungus geotrichurn candidum) have a similar morphology, it is not always possible to identify it as the bulking species. It has a prominent, contiguous, closely-fitting sheath (the means of attachment to solid surfaces) enclosing a chain of rod-shaped cells. This organism uses many simple soluble organic compounds as its carbon source and appears to be a strict aerobe, although it can survive in systems with dissolved oxygen as low as 0. 1 PPM. Beggiatoa is commonly associated with systems containing hydrogen sulfide. It's long, colorless, and cylindrical filaments range in length from 80 to 1,500 microns and are sometimes intertwined. A strict aerobe that requires vigorous aeration for good growth, beggiatoa oxidizes hydrogen sulfide at low concentrations. Sulfur granules can usually be detected within the cells-Thiothrix occurs in waters containing sulfide and grows in rosettes and even knots. It is reported to oxidize hydrogen sulfide and to deposit sulfur in intracellular granules, but has not been cultured in the laboratory and knowledge of it is fragmentary. On the whole, filamentous bulking can result from any one of a number of upset conditions, such as underaeration, heavy organic loading, improper sludge age, improper loading nutrient imbalance. Many control methods - chlorination, flocculating agents, lime addition and sludge age modification have been tried, but none has had complete success. The most effectivehas been chlorination, although this can also destroy the bacteria necessary for good settling so it must be carefully controlled. Hydrogen peroxide appears to furnish an effective answer with no adverse side effects. Laboratory and field tests, as well as prolonged experience in municipal and industrial activated sludge plants, have shown that the addition of the chemical **will** improve settling, prevent denitrification and selectively control filamentous bacteria.

How hydrogen peroxide works: Detailed studies of hydrogen peroxide have been made by FMC Corp.. aleading producer of the chemical, and its action in combatting both major forms of bulking is well understood. In non-filamentous bulking, it can prevent the formation of nitrogen gas from nitrates. When sludge in a settling tank packs firmly as sediment, oxygen is soon used up in the lower layers and clenitrification begins generating bubbles that carry sludge particles back into the effluent. If hydrogen peroxide is introduced into the feed line of the clarifier, denitrification stops. Dissolved oxygen is returned to the sludge, development of anaerobic bacteria is halted, nitrogen release ceases and aerobic bacteria are given new impetus to continue breaking down solids. In the control of filamentous bulking, peroxide fragments the Filamentous bacteria strands that amalgamate bulking sludge particles by attacking the bacterial sheath, which is a transparent shelf composed of polysaccharides. Hydrogen peroxide selectively oxidizes it, causing the strands to break up, and permits sludge particles to settle. A series of' controlled tests to measure hydrogen peroxide's effect on filamentous bulking was conducted at FMC's environmental equipment laboratories in San Jose, Calif. Highly bulked mixed municipal and cannery waste, drawn from the Santa Clara municipal sewage treatment system, was studied in two reactors simulating a conventional plug-flow activated sludge plant. Both reactors had identical porous stone diffusers for aeration and were filled with mixed liquor. One acted as a control, while hydrogen peroxide was added to the other. A return activated system was simulated by, removing the supernate after the solids had a chance to settle, the peroxide was added to the settled sludge. Testing was in two phases: the first used a hydrogen peroxide dosage of 40 ppm and the second 200 ppm. Feeding was on a two-cycle-per-clay fill and draw schedule, and the system was operated on a six-to-seven-day cell retention time. Initial microscopic analysis of sludge's showed two or three types of filamentous bacteria present one could be isolated and identified as sphaerotilus natans. Individual cells, 1.6 microns wide and 6 microns long were encased in sheaths with clear or vacant sections visible. In the first phase of the tests, 40 ppm of hydrogen peroxide decreased the SVI of the sludge from 630 to 160 with in eight days, while the SVI in the control drum remained around 650. In the second phase, conducted on a mixed waste with initial SVI of about 800, a peroxide dosage of 220 ppm reduced the SVI to 400 in three days and 100 in eight days. Filamentous growth was controlled in both phases. Microscopic observation showed that, after peroxide was introduced, the strands of filamentous organisms attached to sludge particles began to shorten. Continued treatment resulted in near-total elimination of the organisms. Eventually, the remaining filaments appeared as broken strands.

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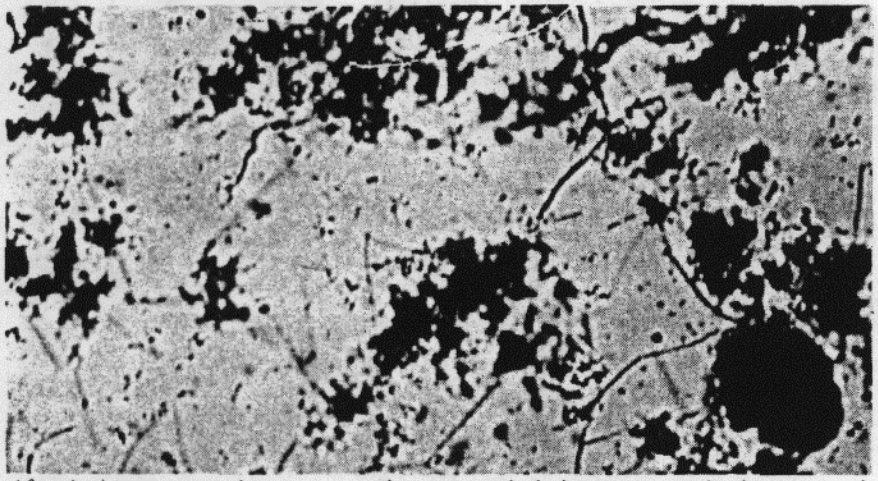

After hydrogen peroxide treatment, the activated sludge system is back to normal. Massive clumps of filamentous growth no longer clog the tank . . . at most, samples show only broken strands

During the summer of 1973, severe bulking problems appeared in the activated sludge process at the Water Pollution Control Plant, in Petaluma, California. This plant treats domestic as well as industrial effluents, with about 40 per cent of its organic loading coming from a nearby creamery. SVI's during the second half of July ranged from 400 to 750. Initial attempts to correct the situation with chlorination and in creased air flow were unsuccessful. Hydrogen peroxide was then in-troduced. For five days peroxide concentrations ranging from 10 to 70 ppm were added in the final quadrant of the aeration section. During this time, the SVI decreased from 550 to 300, and after peroxide treatment ceased it continued to decrease. By the end of the second week the activated sludge system was no longer bulked and the SVI was 190 and still decreasing. During one week, 2,300 lb of hydrogen peroxide were used to treat the 3 mgd plant. Microscopic observations indicated that Petaluma's bulking was filamentous and that a sphaerotilus-type bacteria was present. At the height of bulking, numerous long filaments were observed extending out from sludge particles. Hydrogen peroxide treatment shortened the filaments, but after treatment ceased and when the SVI had fallen below 200, filamentous bacteria were still observed. The remain-ing strands, however, were short and either attached to sludge particles or dispersed through the medium.

How to anticipate bulking: It is not necessary to wait for bulking to occur before applying the cure. It is possible to anticipate a bulking situation and take steps to prevent it before operational difficulties begin. When bulking is imminent, changes take place in the animal and bacterial life in the sludge that can be observed by microscope. Activated sludge, in its "healthy" state, consists of a gelatinous matrix harboring filamentous and unicellular bacteria, fungi, protozoa and rotifers. The bacteria are responsible for stabilizing organic matter, and the predominant species is determined by the nature of the organic compounds in the waste.
In properly settling sludge most are unicellular rather than filamentous and are imbedded within the floc, not usually visible at magnifications of less than 450X. Filamentous bacteria, however, are easily seen at 100X magnification but are rare in a sludge which compacts and settles readily. Protozoa, single-cell animals commonly ranging in size from 10 to 100 microns, are easily observed at 100X magnification. Consequently, they form the best index to the health of activated sludge. Although they do not contribute directly to stabilizing waste, they feed on the bacteria and thus indicate the size of the bacterial population. Since all protozoa in activated sludge are strict aerobes, their survival also depends on the maintenance of dissolved oxygen. Animal life typically found in activated sludge can be roughly grouped into stalked and free-swimming protozoa, and rotifers. This classification is an oversimplification, but it offers a convenient basis for an uncomplicated microscopic approach. In practical waste plant operations, it is more important to recognize the form, activity and function of the protozoa than to know their specific scientific classification. The commonest stalked protozoa are vorticella and epistylis, which use their hair-like cilia (tentacles) to capture food, and podophyra and acineta, which have rigid tentacles to transport food into the cell. During early growth they can exist as free swimmers, but as soon as they find a good food source they attach themselves to a sludge particle in the area of the food supply. Commonest free-swimming protozoa include paramecium, aspidisca and amoeba. The rotifers, which are also free swimming, differ from protozoa in that they are the simplest of the multi-cellular animals in activated sludge. They use hair-like cilia for locomotion and to capture food. Several microbiological investigators have suggested that the predominance of stalked protozoa is a good indication of a well-stabilized sludge. It also appears that a good system with an organic loading sufficient to give a relatively high BOD will have a large population of both free-swimming and stalked protozoa. However, if the BOD is low, stalked organisms will predominate probably because free swimmers require more energy for survival than stationary stalked protozoa.

Microscopic observations: Observations of activated sludge at FMC's Princeton, NJ, laboratory showed four distinct stages of microbiological activity as sludge goes from a healthy state, through incipient bulking, to full bulking and back to the healthy state again. These observations were made on mixed liquor from FMC's sewage treatment plant in Princeton.

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- **Stage 1.** Initial microscopic observation showed the sludge contained a variety of protozoa, but no readily identifiable filamentous bacteria. Since vorticella predominated many sludge particles had large numbers of these stalked protozoa attached this organism was used as the primary indicator of any subsequent change.

- **Stage 2.** Bulking was initiated by over loading the system with sugar (sucrose). In a short time, the sludge flocs began to be highly dispersed, filamentous growths extended out from sludge particles and the vorticella population began to decrease substantially. Free-swimming protozoa seemed unaffected. It was assumed that, as filaments increased in length and number they tended to deplete the oxygen supply in the vicinity of sludge particles. The vorticella, limited in movement by their attachment to the sludge, could not obtain sufficient oxygen for survival. Free swimmers, however, were able to move to other areas where oxygen supply was plentiful.

- **Stage 3.** Bulking was allowed to continue into the third day and the remaining vorticella began to shrink. Many reverted to a cyst-like form and became inactive. Rotifers showed the same characteristics. However, the increasing filamentous growth had not yet affected the aspidisca activity. By the end of the third day the treatment tank was heavily bulked and the next morning hydrogen peroxide treatment was started. In practice there is little need to let the situation go this far. The initial growth of filamentous bacteria is easy to observe at stage 2 - the point at which corrective action should be initiated.

- **Stage 4.** Five days after the study had begun, the activated sludge system was back to normal. Overnight, animal activity had begun to re-appear, although all were quite sluggish. Massive clumps of filamentous growth had begun to break up and at the end of the five days only broken strands remained.

These four stages can be easily identified with a little microscope experience. The average plant operator or laboratory technician can quickly learn to use a daily microscope sludge examination as an early warning system, to head off a bulking situation with hydrogen peroxide treatment.