ATADs, Odors, and Biofilters

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ATAD (autothermal thermophilic aerobic digestion) systems are becoming very popular in wastewater treatment plants for treating sludge, especially for small municipalities. Excess air is pumped into the final slurry, which heats up to the thermophilic range (in most cases, 55 to 70 degrees C) due to bacterial action. This high temperature is maintained for a "curing period" (usually several days) until all pathogens, etc., are destroyed. The resulting sludge has an approximately neutral pH.

The process is environmentally friendly and economical because the heat required is generated by bacterial action, few chemical additions are needed, and the final product can be readily applied to land without management restrictions for pathogen control (conforms to US EPA Regulation 503). The main drawback is that the process is odorous, and in some cases extremely so.

The compounds generated by ATADs are among the most odorous in the sewage treatment environment. They include mercaptans (1 to 150 ppm), dimethyl disulfide and dimethyl sulfide (0.5 to 40 ppm), and very high concentrations of ammonia (can be greater than 1,400 ppm). The first three are mostly insoluble and hence difficult to treat by most conventional methods. The ammonia concentrations are much higher than most biofilters are "supposed" to be capable of handling.

This problem has led to some extreme and expensive solutions being applied to ATADs, such as three-stage scrubbing, where the odor-control system has cost as much as, and in some cases more than, the ATAD–not to mention the high operating costs. These levels of reduced-sulfur compounds indicate clearly that many of these "first generation" ATAD systems are not truly aerobic.

Ambio Biofiltration Ltd. has installed five biofilters on ATAD systems, spanning the range of concentrations of the odorous compounds produced by the process. There have been no odor problems during the cumulative 11 years these biofilters have been operational. Many of the systems are in odor-sensitive locations and were causing many odor complaints before biofilters were installed.

Our operational experience at these installations demonstrates that suitably designed biofilters can readily handle the odorous air coming from any ATAD in a cost-effective, low-maintenance manner. Further, there are virtually no odorous situations in the wastewater treatment environment that a properly designed biofilter cannot handle.

INTRODUCTION

Odor problems in the sewage treatment environment seem to be on the increase. There are several reasons for this. The most obvious is that treatment plants built "out-of-town" are now located closer to, or even within, densely populated areas as cities have

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Table 1: Maximum Inlet Concentrations of Odorous Compounds and Other Data from Five ATADs with Ambio Biofilters for Odor Control

	Long Sault Ontario*	Cardinal Ontario	McMinnville Oregon*	Franklin Indiana	Princeton Indiana	Odor Threshold
Mercaptan (ppm)	~10.0	~6.0	128	~8.0	~10.0	0.02
dimethyl disulfide (ppm)	~1.0	N/A	14.8	N/A	N/A	0.002
dimethyl sulfide (ppm)	~1.0	N/A	9.63	N/A	N/A	0.01
ammonia (ppm)	1150	900	1400	1200	400	10
year installed	1994	1996	1997	200	200	
ATAD supplier	Fuch's	CBI-Walker	Fuch's	Fuch's	Fuch's	
empty bed residence time(s)	28	28	180	48	33	
air flow (cfm)	1500	1500	3000	600	600	
% of air flow from ATAD	14	14	100	100	100	

* Data from Long Sault and McMinnville are from GCMS; other data are from Gastec pump and colorimetric tubes and therefore are only semi-quantitative.

N/A = not analyzed

Outlet concentrations of ammonia and reduced-sulfur compounds from the biofilter are generally below detection limit and, given the lack of offensive odor, must be in the range of the odor threshold.

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grown outward. Also, in many cases odor control has been treated as an afterthought in the design process.

Sludge processing techniques such as ATADs, sludge drying and liming operations, and sludge composting are becoming more common as they produce a better final product that is lower in volume and easier to dispose of. Compared to classical sewage treatment, however, the odor levels are higher and the kinds of odorous compounds from these newer sludge-processing techniques are substantially different and more difficult to treat. In some instances, this has resulted in rather serious odor situations for new plants employing these processes.

Many different types of odor control have been successfully used in wastewater treatment plants under "normal" or "classical" odor situations, including chemical scrubbers, activated carbon, and biofilters. Biofiltration is, in North America at least, the latest addition, although the technology has been used in Germany and Holland in such applications for over 40 years.

Both chemical scrubbers and activated carbon have a poor track record controlling odors from the "new"sludge treatment processes. In fact, they have a mixed record even with the more traditional odor sources. Biofilters initially appeared to offer a relatively simple, cost-effective solution to a variety of odor problems. In spite of this and the very good track record in Europe, the results in North America have been less than overwhelming, although in the last few years performance has been improving.

Biofilters are, in principle, very simple. Odorous air is first conditioned in a humidifier/ scrubber to humidify the air to close to 100%, remove any particulates, and adjust the temperature if required. The air is then passed through a filter bed where naturally-occurring microorganisms break down and eliminate the offending compounds, essentially oxidizing them to simpler, odorless compounds (a good review is given by Leson and Winer, 1991). Biofilters are usually the lowest-cost option, especially when operating costs are factored in (Torres et al., 1997).

Ambio Biofiltration Ltd. has been designing and building biofilters since the early 1990s. German and Dutch practical experience strongly influenced early Ambio designs, and the company used the extensive European experience in biofiltration to begin work on this side of the ocean some considerable distance up the "learning" curve. Unfortunately, many other practitioners did not follow this model, and there has been little transfer of practical design and operating experience from Europe to North America.

Most researchers and engineers on this continent have learned the hard way, repeating the same mistakes that were made (and corrected) years ago in Europe. The simplicity in principle was mistakenly taken to mean that anyone could design and build biofilters, and many did–usually with poor results. Unfortunately, the somewhat greater success of biofilters in recent years is not the result of improved, efficient practical designs; but mostly the result of over-design.

There are virtually no circumstances in the wastewater treatment environment under which a properly designed biofilter will fail to control odors. This statement is borne out by the experience of Ambio in treating the odors from ATADs in five installations–several of which registered as among the most extreme odor situations ever documented in the wastewater treatment environment.

ATADS

Because of the high temperatures reached and maintained with ATADs, volatile solids are broken down, cell structure is at least partially destroyed, and several odorous compounds normally rare in the sewage treatment environment are produced in abundance–specifically, the reduced-sulfur compounds methyl and ethyl mercaptan (mercs), dimethyl disulfide (DMDS), and dimethyl sulfide (DMS) and ammonia. These reduced-sulfur compounds are products of protein breakdown. Data for these compounds from several ATADs that Ambio has worked on are given in Table 1, along with their odor thresholds.

The very high concentrations of these reduced-sulfur compounds in several installations such as McMinnville and Franklin indicate that the "aerobic" part of the ATAD name, in these cases at least, is certainly a misnomer. These installations have been called first-generation ATADs (Staton et al., 2001). Newer versions more closely approximate truly aerobic conditions and also have lower levels of these compounds. One of the best innovations is an ATAD designed by Thermal Process Systems, in which oxygen supply is varied with demand (Staton et al., 2001).

It is worth noting that in addition to the high levels of reduced-sulfur compounds produced by some ATADs, all produce very high levels of ammonia. Typically, these levels peak over 1,000 ppm. The concentrations of both the ammonia and reduced-sulfur compounds vary according to the feed cycle of the ATAD. They can also vary over an order of magnitude and they tend to peak at opposite times. These factors have important design implications; it is critical to measuring the levels of these compounds over the complete cycle in order to design for peak loads.

Collectively, Ambio has more than 17 years of biofilter operation on ATADs with virtually no odor problems. Let us examine a few of these installations in greater detail.

1) Long Sault, Ontario

This is the longest-running biofilter Ambio has on an ATAD system. It was commissioned in 1994 along with the plant (Higgot et al. 1996). The filter material was changed after five and a half years of operation. The biofilter treats all of the odorous plant air, 14% of which is from the ATAD. The plant is in an extremely odor-sensitive location just upwind from and adjacent to a Yacht Club. There have been no odor complaints here in over six years of operation.

2) McMinnville, Oregon

The levels of reduced-sulfur compounds and ammonia coming from the McMinnville ATAD are among the highest ever published from the wastewater treatment environment (Table 1) and represented a major odor-control challenge. The plant had a hypochlorite scrubber in place, but it could not handle the load. The city was receiving 15 to 20 odor complaints a day, and a local citizens' group was threatening court action. The odor complaints stopped about one week after biofilter startup, some four years ago. In hindsight, with an empty bed residence time of almost three minutes, the biofilter was over-designed; however, at the time there was no experience with these concentrations of reduced-sulfur compounds and there was not time here for pilot work.

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The high levels of ammonia from ATADs also present a challenge. Classical solutions for high levels of ammonia in the hundreds of ppm range usually involve acid scrubbing, especially since biofilters are not supposed to be able to handle high levels of ammonia (e.g. Harshman and Barnette, 2000). Typically, the approach Ambio takes is to "scrub" the ammonia levels down to below 500 to 600 ppm using a simple water scrubber and plant water, prior to the biofilter, which can then handle what is left. In all of the ATADs presented in Table 1, ammonia levels in the air stream after the biofilter were less than 0.5 ppm.

3) Franklin, Indiana

The biofilter on the ATAD at Franklin, Indiana, was added after both acid scrubbing and activated carbon had failed to solve the odor problem, which had become a local election issue.

Based on experience gained elsewhere, Ambio was able to treat the ATAD air with a residence time more typical of biofilters in use in wastewater treatment–in this case, approximately 48 seconds (Table 1). Again, biofilter outlet concentrations of reduced-sulfur compounds and ammonia were below detection limits (approx. 0.5 ppm) and approaching, if not below, the odor threshold.

DISCUSSION

The problem in treating mercaptans, dimethyl disulfide, and dimethyl sulfide is that they are almost insoluble in water, so chemical scrubbing is ineffective. And since the ATAD air is essentially 100% humid, activated carbon is also ineffective. This insolubility and the low odor threshold of these compounds mean they are also very persistent in the environment. These factors can lead to odor problems spread over greater distances than those generated by other compounds, as was the case in both McMinnville, Oregon, and Franklin, Indiana.

It is important to note that these compounds are the same ones that appear in composting, and in sludge drying and liming operations, albeit in lower concentrations. As environmental and economic requirements for sludge treatment become more stringent, they are likely to become the more common odor problem in the wastewater treatment environment, replacing H2S in this regard.

That they are well treated in a biofilter is also at first glance puzzling. Biofilters work best for compounds that are soluble because these compounds are broken down when they enter the biofilm within the biofilter bed, where the appropriate bacteria are living. The larger residence times required for effective removal of mercaptans, dimethyl disulfide, and dimethyl sulfide in a biofilter indicate that there is another mechanism important here, perhaps adsorption onto the surface of the biofilm. Whatever the mechanism, the data presented here indicate that very high levels of these quite insoluble compounds are treatable in a biofilter at residence times that are currently the norm in the design of biofilters for the sewage treatment environment.

Why do the Ambio biofilters work so well and at reasonable residence times? Part of the answer lies in maximum use of bed volume, part in proper selection of filter material, and part in

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Modular biofilter bed system (top down air flow), treating 600 cfm of ATAD air, Franklin, Indiana

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excellent humidity and pH control.

Maximum Use of Bed Volume: Ambio always uses an open plenum to deliver the air to the filter bed. Many biofilter designs in North America make use of a network of perforated pipe in coarse gravel to distribute the air under the filter bed. This is a poor choice for air distribution because much of the bed between the perforations remains unused; unless pipe diameters are varied extensively, the air will not be uniformly distributed. Also, there are often "anaerobic" locations within such a bed design that could contribute odor to the air, rather than remove it. It is always better to use an open plenum to deliver the odorous air under (or over) the filter bed.

Filter Material: It is very important to use a filter material that is resistant to compaction in order to keep the whole system aerobic and to make maximum use of the bed volume. Ambio uses a specially prepared coarse wood that is biologically friendly and has a low back pressure. The most common filter material used in North America–some mixture of compost, leaf mulch, and wood chips–is a poor choice. Since such a mixture inevitably has considerable fine material, it initially has a large surface area and works very well for a few weeks or even months, but compaction quickly reduces the effective surface area and its overall lifespan. Also, using water to wash out acid by-products from the bed is limited with such material because this practice also tends to increase compaction and hence shorten the life span of the bed.

Humidity and pH Control: All Ambio biofilters feature primary humidification prior to entering the filter bed and a secondary irrigation system of buried soaker hoses in the bed itself, primarily to wash out acid metabolites. This ensures pH control in the bed by preventing acid accumulation.

It is also critical to quantify the air stream with respect to temperature, relative humidity, and concentrations of odorous compounds in order to properly design a solution to the problem. Although this procedure may seem obvious, it is surprising how rarely it is done in a complete and systematic manner.

CONCLUSIONS

1) Properly designed biofilters can handle relatively high concentrations (up to several hundred ppm) of reduced-sulfur compounds–mercaptans, dimethyl disulfide, and dimethyl sulfide–at empty bed residence times less than one minute.
2) Biofiltration systems can treat levels of ammonia that exceed 1,000 ppm using only plant water and a biofilter bed, at residence times less than one minute.
3) Biofiltration should be the odor-control technology of choice for ATADs, sludge drying and liming operations, sludge composting facilities, and just about any other odor situation in the wastewater treatment environment. The only limitation to the use of biofilters is the space required for very large air flows.
4) Such systems are cost-effective and low-maintenance.

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