CHAPTER 18

Odor Management III — Completing the Odor Picture

INTRODUCTION

There are a number of aspects to the development and maintenance of a complete Odor Management Program. Methods of quantifying and treating odor were discussed in Chapter 16. Atmospheric meteorology, dispersion, and methods to enhance dispersion were studied in Chapter 17. This chapter completes the trilogy on odor management. The importance of establishing ambient odor standards or target odor objectives to guide design decisions is first discussed. This is followed by a series of Theorems or "truisms" about odor based on this author's experience in the field. Finally, the elements needed for a successful Odor Management Program are presented.

AMBIENT ODOR STANDARDS

Qualitative Standards

The design of new facilities, or the retrofit of additional odor controls to existing ones, requires numerous decisions balancing economics with the degree of odor control. To make such decisions it is helpful, if not necessary, to establish ambient odor standards or target odor objectives. This is not an easy task. Politicians and regulators want to say that "there will never be any odor." Plant managers might resort to "there will be no discernable odor beyond the plant boundary and no odor complaints." These all sound good, but they are difficult to use for guiding and making design decisions. Agencies have also had problems with terms like acceptable, permissible, allowable, or tolerable odor level. They imply a sense of acceptance of an undesirable situation.

Many regulatory agencies have resorted to qualitative measures of odor nuisance. For example, the New Jersey Administrative Code defines air pollution as "the presence in the outdoor atmosphere of one or more air contaminants in such quantities and duration as...would unreasonably interfere with the enjoyment of life or property." The courts have ruled that odor is an air pollutant under this definition. However, such a definition is of little help in guiding facility design.

Despite their shortcomings, qualitative standards are frequently used to make decisions on odor management. The most common and typical situation is where a facility is experiencing odor problems as evidenced by community complaints. Actions are then initiated with the goal of stopping the odor complaints or reducing them to a politically acceptable frequency (which may be zero). The measure of success becomes the reduction and hopefully cessation of the neighborhood complaints. A numerical odor standard for the ambient atmosphere in the community may never be established in such a case. This is an acceptable approach to the problem, but it is also a "trial and error" procedure that may involve a series of actions until the correct combination is reached. Establishing a numerical odor standard can be a tool to guide the decisions and avoid some of the "errors" of a trial and error approach.

Quantitative Standards

A theorem is presented later which states that "You can stop all of the odor some of the time, but you can't stop all of the odor all of the time." This is a recognition that nature will periodically impose such severe meteorological conditions that noticeable odors may occur despite our best efforts to avoid them. If the risk of odor cannot be reduced to zero, then an "acceptable odor risk" must be established.

A number of facilities have recognized the statistical nature of odor standards. The City of Sacramento established a fenceline odor objective of 2 ED_{50} with an occurrence no more than 3.3 days/yr and 5 ED_{50} no more than 0.5 days/yr.[1] 5 ED_{50} was the estimated threshold complaint level and 10 ED_{50} the definite complaint level. This means that predicted odor concentrations at the plant boundary would be below the threshold complaint level 99.8% of the time at all receptors beyond the plant boundary. A puff transport model was used in these studies. Dispersion coefficients for the puff model were developed from tracer release studies conducted at the plant site.

A standard of 1 ED_5 under all meteorological conditions modeled by the Gaussian formulas was used at the Montgomery County Composting Facility.[2] The ISCST model was then used to determine the effect of different control strategies on meeting the odor target. A somewhat similar approach was used at Plattsburgh, New York. Citizen groups agreed that a maximum of two or three odor incidents per year would be "acceptable". This translated into an odor free environment for the community 99.2% of the time. A criteria was chosen such that the calculated odor concentration from the facility was less than 1 ED_{10} (or 10% of the butanol detection limit) under worst-case meteorology using the ISCST model.[3,4] In other words, only 1 person in 10 would detect an odor at the point of maximum concentration.

A somewhat different approach was used by Duffee et al.[5] in studies conducted for the City of Akron, Ohio, and the Delaware Reclamation Project, New Castle, Delaware.[6] Dose/response curves were developed from odor panel results using Steven's Law to determine the ED_{50} level at the receptor that would produce an odor intensity of 3.5 on the Butanol Scale. This was assumed to be the threshold complaint level and was determined to be 8 ED_{50} at Akron and 7 ED_{50} at the DRP. These values became the target ambient odor levels. A Gaussian, fluctuating plume model was used to estimate "instantaneous" downwind odor concentrations and their frequency of occurrence at various receptor locations. Control strategies were then evaluated to meet the target concentrations. Duffee et al.[7] reported on other studies which used a Butanol Scale intensity of 2.0 to preclude essentially "detectable" odor levels. An intensity of 2.0 is an odor so faint it would not be detected unless someone called attention to it. Odor concentrations ranging from 2 to 6 ED_{50} were determined to be equivalent to an intensity of 2.0 for sewage type odors.

Gruwell and Goldenberg[8] used a criterion of 5 ED_{50} for a period of 5 minutes for eliciting an odor complaint. A modified version of the ISCST computer model was used which incorporated algorithms for computing short averaging times.

The State of Connecticut has established an odor nuisance level of 7 ED_{50}. According to Forbes et al.,[9] empirical evidence suggests that odor levels of 3 ED_{50} or less result in few odor complaints. In the range between 3 and 7 ED_{50}, odor complaints could arise from the more odor-sensitive individuals on an infrequent basis. As odor level increases beyond 7 ED_{50}, the potential for odor complaints increases. Several composting facilities have used the 7 ED_{50} criterion as a measure of objectionable odor.[9-11] In all cases, fluctuating plume models were used to estimate peak instantaneous concentrations for comparison with the criteria. Therefore, the above criteria should be interpreted as peak, short-term concentrations.

Efforts have been underway in several European countries to formulate odor standards. van Harreveld[12] reported that the Netherlands is using the following provisional odor standards: (1) For existing installations, an hourly average concentration of 1 ou may not be exceeded for more than 2% of yearly hours at locations with domestic dwellings; (2) for new installations, an hourly average concentration of 1 ou may not be exceeded on more than 0.5% of the yearly hours if domestic dwellings are present; and (3) the isopleths must be calculated using a national dispersion model based on the Gaussian plume algorithm. These provisional standards have been used in a large number of cases. Standard practices for olfactometry are also being developed with the goal of reducing differences between olfactometry laboratories to within a factor of 2 to 3.

From the above, it can be concluded that a variety of criteria have been used with varying degrees of success. It is also apparent that an ambient odor objective cannot be established separate from the type of atmospheric dispersion model. A lower ambient standard is needed if the Gaussian ISCST model is used with its 1-h time averaging. On the other hand, a higher standard may be appropriate if the dispersion model predicts instantaneous concentrations. The ambient odor objective must also consider the community demographics and prior history of odor problems. The complaint threshold probably depends on the exposure frequency, sensitivity, surroundings, education, and economic status of the community. These factors are very difficult to quantify, but it has been well demonstrated that a sensitized and organized community will tolerate only minimal odors.

THEOREMS ON ODOR MANAGEMENT

The following sections of this chapter use an informal essay style and are based on a presentation originally given at the U.S. EPA "Workshop on Controlling Sludge Composting Odors" held in Washington, D.C. in 1990 and subsequently published in *BioCycle*.[13] I have tried to conserve the original flavor of the oral presentation into this essay, for better or worse. Notice that I refer to this as an essay. These are my thoughts on the subject of odor management, thoughts developed from many years as a practicing engineer.

Composting of sludge, yard waste, manure, food waste, refuse and other substrates has become a very popular management option. The process makes use of nature's own microbes and produces a useful end product. In short, it accomplishes most of the things that environmentally minded folks like to see. Its one drawback, one that is a thorn in many sides, is its potential for odor generation. I think the general opinion of most practitioners is that odor is one of the biggest problems facing composting today. The story presented in Chapters 16, 17, and 18 is that odor can be managed if all the elements of odor management are brought to bear on the problem.

My first thought for presenting this subject matter was to list a series of truisms (i.e., an undoubted or self-evident truth) about odor. However, I quickly realized that folks in the composting industry are a diverse lot and agreement on something as elusive as odor is asking too much. So I dropped "truisms" in favor of "theorems". You may disagree with them, but they are still my theorems.

THEOREM 1 — MOST COMPOSTING SUBSTRATES SMELL

No argument here, I hope. All of the substrates which enter a composting process must be viewed as potential sources of odorous molecules. This includes sludge, sawdust, yard wastes, wood chips, refuse, food wastes, and all the other substrates we may throw into the starting mix.

Somewhere in the history of composting we got the idea that, if left alone, Mother Nature would be odor free. I don't know how this idea arose, but I assure you that it's not true, particularly with most composting substrates.

THEOREM 2 — MOTHER NATURE NEVER CLAIMED TO BE ODOR FREE

On many occasions I have heard speakers state with great pomp, "if composting is conducted properly there will be no odors." These speakers are never plant operators! Such statements have been implicated as a leading cause of anxiety complex among operators. Let me reassure the operators reading this book that I have never seen data to support such a claim. The starting substrates contain odorous compounds and more are formed as intermediates during the breakdown of complex substrates. Yes, this includes aerobic metabolism.

Boiling points and vapor pressures for some of Mother Natures's favorite odor compounds were presented in Table 16.1. Ammonia and H_2S boil at very low temperatures and will never stay in solution unless converted by pH to an ionized form. Many of the organic sulfides, such as dimethyl sulfide, boil at near ambient temperatures. Acetic acid, a favorite intermediate of aerobic microbes, has a vapor pressure of 100 mm Hg at 63°C. No wonder vinegar smells even at room temperature! Higher molecular weight compounds can also have significant vapor pressures. Terpenes, represented by eucalyptus and lemon oil, have about a 10 mm vapor pressure at 54°C. Again, this is why we can smell these fragrances, even at ambient temperatures.

THEOREM 3 — THERMOPHILIC COMPOSTING ACTS LIKE A HEAT DISTILLATION PROCESS

If you want proof for Theorem 3, I offer the observation that hot sludge or garbage smells more than cold sludge or garbage. New terms, like "low boilers" and "high boilers", are coming into use now that we recognize the physics of the problem. Vapor phase concentration of a compound is proportional to its vapor pressure and the latter increases with temperature. Many odorous compounds have significant vapor pressures and you can expect to see them in the process gases. Therefore...

THEOREM 4 — SOME RELEASE OF ODOROUS COMPOUNDS IS INEVITABLE DURING COMPOSTING

and

THEOREM 5 — WHAT SMELLS OK TO YOU IS PROBABLY AN ODOR TO SOMEONE ELSE

None of what has been said so far depends on the type of composting system. The only caveat is that anaerobic systems are not included. While there may be some differences between aerobic systems, their odor characteristics are all governed by the same laws of nature. Therefore...

THEOREM 6 — MOTHER NATURE DOESN'T MUCH CARE WHAT COMPOST SYSTEM YOU HAVE

and

THEOREM 7 — ITS NOT NICE TO FOOL MOTHER NATURE WITH A BAD DESIGN OR BAD OPERATION

Some odors will be produced even with good design and proper operation. However, a bad design or bad operation guarantees higher emission rates. One must also understand the energy balance and make sure that there is sufficient energy supply to meet the energy demands. If not, odors will usually increase because the process will be stressed and failure may be near. Therefore...

THEOREM 8 — YOU REALLY SHOULD KNOW SOMETHING ABOUT YOUR SUBSTRATES

The range of total solids, volatile solids, degradability, and rate constants should be known for each substrate entering the process.

Despite the best efforts of design engineers and the claims of equipment vendors you should always remember the following:

THEOREM 9 — ODOR TREATMENT IS NEVER 100%

The only possible exception to Theorem 9 is thermal oxidation which is capable of near complete odor destruction. Multistage wet scrubbing is generally capable of achieving outlet ED_{50}s in the range of 50 to 100. Lower levels are very difficult to achieve. For one thing, the contribution of the scrubbing chemicals to the outlet odor becomes significant at low outlet levels. The same is true of biofilters. Exhaust ED_{50}s in the range of 20 to 150 seem to be typical. Lower levels are not readily achievable because the biofilter matrix begins contributing to the outlet odor. There has been a subtle but persistent tendency for the design community to ignore Theorem 9. This leads to the following:

THEOREM 10 — MANY PAST DESIGNS DIDN'T RECOGNIZE THEOREM 9

Scrubbers and biofilters are often designed with no attention to dispersion of the treated gases. It is common to see scrubbers with short stub stacks, low outlet velocities, scrubbers located near large buildings with their plumes caught in the building downwash, rain caps on top of discharge stacks, and other examples of poor dispersion design. It's as though the designer assumed 100% deodorization. This should never be assumed.

The subject of atmospheric dispersion is complex and was discussed at some length in Chapter 17. There is one important theorem derived from my experiences with the atmosphere:

THEOREM 11 — THE WORST ODOR IS NEVER WHEN YOU'RE THERE

Another way of stating Theorem 11 is to say that odors usually result during worst case micrometeorological (micromet) conditions. The likelihood of your being at the site or in the surrounding community during the worst met conditions is small. Joe Manager might say "I was out there yesterday and didn't smell anything. We're not the cause of the odor." The fact is Joe probably just missed the odor.

With groundlevel sources, the worst met conditions usually occur in the evening, nighttime, and early morning hours. Dispersion is often limited during these periods because of strong, "micro inversions" which occur as a result of ground cooling. Groundlevel dispersion is usually highest during the day, after the sun has warmed the ground surface. Because most of us work the day shift, we would likely miss a worst case incident. Knowing this, Joe Manager should say "I was out there yesterday and didn't smell anything, but I'm going back tonight when I think the met conditions may be worse."

THEOREM 12 — MOTHER NATURE ALWAYS DISPERSES ODOR, BUT SOMETIMES SHE CAN USE A LITTLE HELP

This has something to do with entropy, maximum randomness, and other thermodynamic concepts. Whatever, I don't think we have to worry about nature reconcentrating odor on us. At the same time, we need not just accept the dispersion that nature alone supplies. We can design systems to improve dispersion, thereby giving nature a helping hand. The term "enhanced dispersion" has been used to describe such efforts. Even if you don't "enhance" the natural dispersion, the following is always true:

THEOREM 13 — KNOW YOUR MICROMET CONDITIONS

All major facilities should consider building an on-site micromet station to warn of worst-case atmospheric conditions. This will allow the operators to take corrective actions and, hopefully, avoid an odor incident.

Point sources have an advantage over groundlevel sources because the plume can be lofted above the ground by a combination of stack height and plume rise. This is particularly effective during wind calms, a met condition which is usually hard on groundlevel sources. It is important to always remember the following:

THEOREM 14 — THERE MUST BE A RECEPTOR TO HAVE AN ODOR

and

THEOREM 15 — MOST RECEPTORS ARE AT GROUNDLEVEL

For point sources, such as exhaust stacks from scrubbers, dispersion can be enhanced by (1) increasing stack height, (2) increasing stack velocity to increase momentum rise, (3) providing reheat to increase thermal buoyancy, and (4) providing forced dilution with ambient air. The latter will also increase the plume diameter, which in turn will increase the effective plume rise.

Things to avoid with a point source discharge include (1) locating the plume within the zone of building or stack downwash, (2) low velocity discharges from the sides or roofs of buildings, such as ridge ventilators, (3) using rain caps on roof ventilators or the scrubber discharge stack, (4) low stack velocity, and (5) bad topography such as valleys. Avoiding bad topography is like avoiding the common cold, easy to say but hard to do. The topography is always "greener" in the next political jurisdiction.

For groundlevel sources, such as open windrows, static piles, or biofilters, dispersion can be enhanced by (1) providing adequate buffer, (2) using wind machines to maintain minimum air flow over the area source, and (3) using barrier walls to induce turbulence. I realize that providing buffer really isn't an example of enhanced dispersion. It's more like giving nature enough room to solve the problem herself.

If the above measures are not adequate, the groundlevel source can be enclosed and converted to an elevated source. By comparison with elevated sources, groundlevel sources are subject to the worst met conditions and lowest dispersion rates. Also, the nearest downwind receptor will be the most effected. Therefore, ground-level sources, and their surrounding topography, must be carefully considered in any odor management plan.

THEOREM 16 — YOU CAN STOP ALL OF THE ODOR SOME OF THE TIME, BUT YOU CAN'T STOP ALL OF THE ODOR ALL OF THE TIME

Theorem 16 is a recognition that, after all the planning and design studies, after all attempts to reduce emission rates, after all the collection, treatment, and dispersion, nature will periodically impose such severe met conditions that odors may occur. If the risk of odor cannot be reduced to zero, then we must establish an "acceptable odor risk". Engineers may want to hide Theorem 16 from their politicians. Odor objectives vary from study to study. The point is not that they vary, but that they were established in the first place and provided a guide for evaluating alternative designs and solutions. Remember, every facility needs a target odor objective. Be the first on your block to have one.

Finally, my last theorem...

THEOREM 17 — DON'T DESPAIR, ODORS CAN BE MANAGED

Despite odor problems at some facilities, the future for composting is optimistic. The industry generally recognizes that odor compounds are likely to be released, a milestone of major significance. Recognition of the problem is the first step toward its solution. The science of odor treatment, particularly with wet scrubbers, biofilters, and activated sludge is advancing rapidly. More engineers and operators now speak about met conditions and dispersion as if they were amateur meteorologists. Finally, regulators and industry groups have moved with unusual leadership to help the industry by encouraging the spread of these new ideas to the composting community. Watching the industry mature as it gears up to solve current problems, it's hard not to be optimistic.

One concern is the apparent difficulty in transferring lessons learned by the sludge composters to other members of the composting community. For example, some recent refuse composting facilities in the U.S. have been implemented with essentially no provisions for odor control. These facilities are destined to repeat past mistakes already learned with sludge. Consultants and firms active in the sludge industry in the U.S. are generally not the same as those active with other substrates such as refuse. The flow of information from one group to another is not automatic. We all need to work on this.

THE ELEMENTS OF ODOR MANAGEMENT

Based on the above theorems, I offer the following elements of odor management:

ELEMENT 1 — DEVELOP AN ODOR MANAGEMENT PROGRAM AT THE EARLIEST STAGES OF PLANNING AND DESIGN

This may sound obvious, but there are numerous facilities that have ignored this first commandment of odor management. It's a little late to develop an effective program once odor complaints are received. Plan and design for odor management from the start.

ELEMENT 2 — OPERATE THE BEST YOU CAN TO REDUCE ODOR EMISSION RATES

Good operation is vital to odor management. Good operators can make a bad design work OK and a good design work great. Skilled operators, effective process control, good housekeeping, knowledge of the local micromet conditions, and a community involvement program are a powerful force.

ELEMENT 3 — CONTAIN, COLLECT, AND TREAT AS MUCH AS POSSIBLE or GO DIRECTLY TO DISPERSION

If your composting system allows collection of the process gases, then you should treat them to the extent possible before dispersing them to the extent possible. If you cannot contain the process gases, then you must rely entirely on atmospheric dispersion to dilute any emissions. There are no halfway measures between these two approaches.

Theorems 4 and 8 lead to one of the most important and often ignored elements of odor management:

ELEMENT 4 — DILUTION IS PART OF THE SOLUTION

Dilution is rarely the complete solution to any problem, particularly odors. However, it is equally true that dilution must be *part* of the solution.

Every management plan needs a goal or target. It's hard to achieve a goal if you don't know what the goal is. This leads to the last element in the odor plan:

ELEMENT 5 — A TARGET ODOR OBJECTIVE SHOULD BE ESTABLISHED

The industry has had a tough time with this one. Politicians want to say that "there will never be any odor." You can tell that politicians never took statistical thermo in school or they would know that "never" is very hard to achieve. Plant managers often resort to "there will be no discernable odor beyond the plant boundary." Sounds good, but no one really knows what it means. Another favorite is "there must be no odor complaints." Fortunately, a number of studies have developed target odor objectives which, when achieved by the facility, have successfully reduced odor complaints.

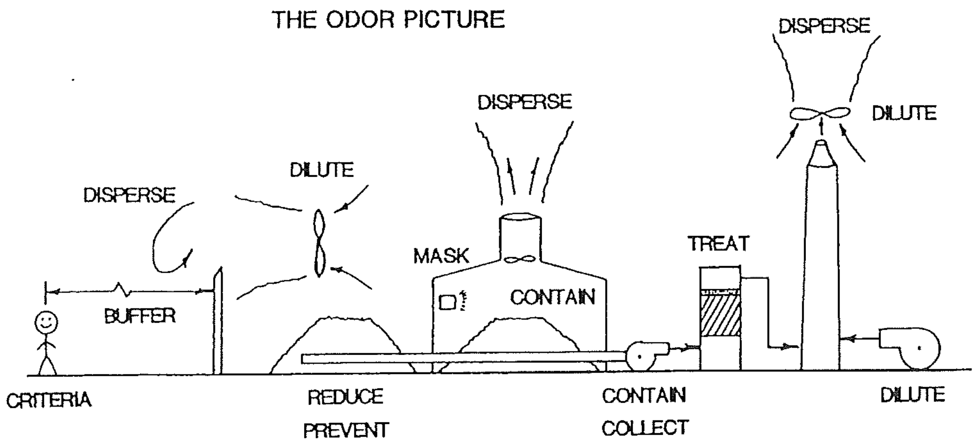

Figure 18.1. The tools of odor management.

A schematic showing the tools available for odor management is presented in Figure 18.1. This is the "odor picture". Embodied in the terminology are the elements necessary for an Odor Management Program: reduce, prevent, contain, collect, treat, dilute, disperse, buffer, odor objective, plan well, design well, and operate well. Good words by which to formulate your Odor Management Program. Good luck.

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