Odor Control at Wastewater Treatment Plants: A Significant Shift in Odor Objectives

Philip Wolstenholme

Engineers have used air dispersion modeling for many years to determine off-site odor impacts from wastewater facilities. The recent use of the European standard to measure odor concentration has resulted in significantly higher emission rates being measured and, because they are directly proportional to emission rates, higher off-site impact projections.

Goals and regulations based on the previous American standards are no longer valid if the new European standard is used. Plants with uncontrolled area sources comprising open tanks, channels, and basins should have great difficulty achieving single-digit odor unit impact goals unless there is a significant perimeter buffer.

Some simple measures to reduce off-site impacts from uncontrolled area sources include construction of barrier walls, use of wind machines to break up stagnant air, and good operational practices.

Air dispersion modeling for wastewater treatment plants (WWTPs) is presented, as are case studies at four North American plants, to illustrate issues of concern. The issue of most current concern is the source concentration when measured in "dilutions-to-threshold," also called "total odor" or "odor units." The term "odor unit" or OU is used here.

Practitioners have used air dispersion modeling for many years to determine off-site odor impacts from wastewater facilities, and hence, to help guide in the selection of odor control measures.

There are three key model inputs: topography, odor source concentrations, and meteorological data. While topography can be well-defined and annual meteorological data changes minimally from year to year, the odor concentrations, when measured in terms of odor units, have recently changed in a significant way. Wastewater plant source concentrations are now typically measured using the standards developed in Europe, rather than the American standards.

Odor Units and Emission Rate Calculation

The odor concentration of an air sample can be measured by odor panels with the result termed as odor units. The odor value is measured either in the field with a handheld instrument or in the laboratory using an olfactometer. In order to establish emission rates, odor units are sometimes assigned the pseudo-dimension of odor units per volume of air. This creates a concentration; for instance, odor units per cubic meter.

Dispersion model inputs have units of OU per second. Determining the emission rate of sources that are contained in ducts or stacks is relatively straightforward; the emission rate is the product of airflow rate and odor concentration:

cubic meters per second × OU per cubic meter = OU per second

For open surfaces or area sources, the measurement and calculation are more complex. It is critical that the air above the surface be shielded from wind effects that would otherwise dilute the sample. The use of a flux chamber with sweep air is the preferred sampling method. A flux chamber is shown in a sampling location in Figure 1.

Figure 1. Flux chamber sampling

In recent years, the olfactometry measurement of odor units has gravitated from the older American Society of Testing and Materials (ASTM) laboratory method to the new European Standard EN 13725 (EN). The EN olfactometry method employs higher sample airflow rates, and generally produces high OU values, when compared to ASTM. As described in a paper presented at the Water Environment Federation Technical Exhibition and Conference (WEFTEC) five years ago (McGinley 2008), the 1999 change in the method of measuring odor concentrations in North America resulted in significantly higher OU values being measured. The major reason for the difference is that the air sample presentation rate to the olfactometer by the ASTM standard is a range of 0.5 to 3.0 liters per min (L/min), whereas 20 L/min is used in the EN standard. The 20 L/min was reportedly selected to match the human sniffing rate. The conversion factor to change between a 0.5 L/min rate, at the low end of the ASTM range, and the EN 20 L/min rate, is presented in the McGinley paper, as shown in Equation 1.

$$Log\ OU_{0.5\frac{L}{min}} = 0.24 * \left(log\ OU_{20\frac{L}{min}}\right)^2 \qquad (1)$$

As an example, a value of 4 OUs in the previous system would be equivalent to 40 OUs in the newer system and 500 OUs would be equivalent to 2,257 OUs.

Continued on page 18

Philip Wolstenholme is odor control practice leader at Brown and Caldwell in Atlanta.

Table 1. Comparison of Model Performance for Odor Impact Assessment

Citation	Source type	Results
Diosey et al. (2000)	WWTP odor	CALPUFF produced more variable results than ISCST3. Although overall results for the ISCST3 and CALPUFF were similar, the results from AERMOD were 12 to 24 times lower.
Porter and Santos (2006)	WWTP tracer gas	SCIPUFF performed better than either ISCST3 or AERMOD. Note that CALPUFF incorporates features of the SCIPUFF model.
Porter and Elenter (2007)	WWTP odor	ISCST3 predictions were more widely (i.e., realistically) distributed than those predicted by AERMOD. Moreover, AERMOD's predicted concentrations were 26 percent to 40 percent lower than ISCST3 for clarifiers and aeration basins.
Sattler and Devanathan (2007)	WWTP odor	ISCST3 predicted higher concentrations than AERMOD, and more odor events than AERMOD.
Cesca et al. (2008)	WWTP odor	AUSPLUME greatly over-predicted odor in an area where there were no odor complaints. Study authors recommended use of CALPUFF for future modeling work.

Table 2. Off-Site OU Limits as Reported by North American Agencies (MOP 25)

	OU/m³ limit	Averaging period, min.
Ontario, Canada	1	10
Allegheny County, Pennsylvania	5	2
Bay Area Air Quality District, California	6	-
Connecticut	8	-
New Jersey	6	5
Oakland, California	50	3
San Diego, California	6	5

Table 3. Plant A Modeling Results, 1993 versus 2010

	Maximum fenceline concentration OUs	
	1993 model based on ASTM methodology	2010 model based on EN methodology
Fenceline impact	6.4	24

Table 4. Plant A Off-Site Impacts, 2010 Modeling

Maximum fenceline impact OUs	24
Highest contributing source	Primary sedimentation tanks
Impact from highest source, OUs	7.3
Second highest contributing source	Secondary clarifiers
Impact, OUs	6.8

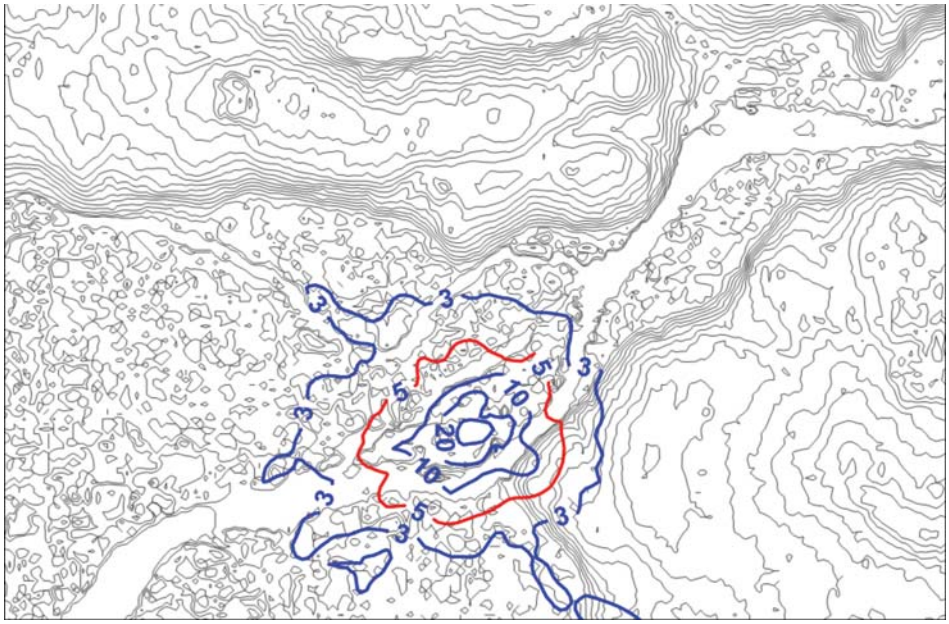

Figure 2. Plant A maximum predicted 10-min average odor concentrations (OUs)

Continued from page 16

There are very few regulatory limits previously set by North American agencies that have been modified to reflect the difference in expected results from the ASTM to EN analysis methods.

Comparison of Dispersion Models

Many dispersion models have been used for wastewater and other facilities. The three most commonly used models in North America are the Industrial Source Complex Short-Term Version 3 (ISCST3), CALPUFF, and AERMOD. The AERMOD model became the U.S. Environmental Protection Agency (EPA) preferred steady-state model in 2006. In recent years, comparisons have been made among these models, with varying and sometimes contradictory conclusions. Table 1 reports some of the recent papers comparing the models.

One model may calculate higher emissions for certain sources (e.g., point sources) under particular weather conditions (e.g., inversions). The CALPUFF model has been found to predict higher concentrations than the ISCST3 model for area sources that have the greatest impact on close-in receptors. An EPA report (EPA454/R98009) showed a five-fold overprediction of concentrations by CALPUFF at the closest receptors. As shown by the referenced papers, no model calculates the highest value for all source types under all conditions.

According to the Diosey paper, the CALPUFF model can model under calm conditions, while ISCST3 disregards calm hours. This can be important for ground-level odor sources where maximum downwind impacts may occur under calm/stagnant conditions.

Off-Site Odor Objectives

As stated, many North American agencies have historically set fenceline or off-site goals as low as 1 OU. Table 2 shows off-site goals or regulations for several agencies as reported in the Water Environment Federation Manual of Practice, MOP 25.

Very few wastewater plants cover and treat their secondary clarifiers. However, the mean OU value for secondary clarifier concentration in the McGinley paper was 96 OUs and the minimum value was 28 OUs. Aeration basins were reported with a mean of 134 OUs. At such emission values, and with relatively large areas, the dilution of the emissions from such surfaces between the source and the fenceline is extremely unlikely to be sufficient enough to avoid an odor impact.

Continued on page 20

Continued from page 18

The difficulty in attaining such low off-site limits is further supported by historical ambient concentration measurements. The McGinley paper reported that the mean concentration value of 26 ambient samples was 40 OUs and that the lowest value ever measured was 7 OUs. This suggests that single-digit OU goals are difficult to achieve on a continuous basis unless nearly all the wastewater processes are covered.

Case Studies

The previous statements are demonstrated by recent case studies. Four geographically diverse North American plants were examined for results of dispersion modeling studies performed in the last five years. All facilities are secondary treatment plants with biosolids processing.

Plant A

Plant A is a 500-megaliter-per-day (ML/day, 132-mil-gal-per-day[mgd]) average dry weather flow secondary plant, with a trickling filter/solids contact secondary process. Biosolids are digested and dewatered. Primary and secondary clarifiers are the only processes not covered and controlled. Odor treatment is by chemical scrubbing and biofiltration. Odor evaluations were completed in 1993 and 2010. The 1993 modeling used ASTM standard OU values and the ISCST3 dispersion model; the 2010 evaluation used EN standard OU values and the CALPUFF dispersion model. Residential and light industrial areas are adjacent to the plant, which currently receives very few odor complaints.

Table 3 summarizes the 1993 and 2010 modeling results for the same plant configuration. Modeling results from 1993 show significantly lower odor impact values than the 2010 modeling. While some of the difference may be attributable to the dispersion model type, the major difference is likely due to the difference between ASTM and EN standards.

Table 4 shows more detailed impacts for the 2010 modeling. For instance, the maximum fenceline impact in the 1993 modeling was 6.4 OUs, whereas the 2010 modeling showed 24 OUs.

Figure 2 shows the results of the dispersion modeling result for Plant A. The maximum fenceline impact is 24 OUs.

Plant B

Plant B is a 102-ML/day (27 mgd) average dry weather flow secondary plant, with an activated sludge process. Biosolids are dewatered and incinerated. Odor treatment of preliminary treatment and dewatering is by chemical scrubbing. Primary and secondary clarifiers, aerated grit tanks, and gravity thickeners are uncovered. An odor evaluation was completed in 2011.

Emission rates were calculated from sampling of sources and from historical values at this and similar plants. Sampling comprised stack testing and surface emissions testing using a flux chamber without sweep air. Odor analysis was performed with grab sample instruments, laboratory gas chromatography, and odor panel testing for OU values. Air dispersion analysis used the AERMOD model. The highest impact sources were the gravity thickeners, aerated grit tanks, and primary clarifiers. Peak off-site impact on a one-hour basis from all sources combined was calculated at 21 OUs. Table 5 provides off-site impacts for each source.

From Table 5, the difference is clear between the off-site impacts from area sources versus stack or point sources. All three point sources have lower impacts than even the lowest impact area source, which is the primary effluent box.

Figure 3 shows the off-site odor impact for Plant B. Critical receptors are shown in yel-

Continued on page 22

Table 5. Plant B: Off-Site Impact of Odor Sources

Source	Source concentration, OUs	Maximum 10min off-site impact, OUs	Ranking of source by off-site impact
Area sources			
Aerated grit tank	4100	6.3	3
Primary influent channel	4100	5.2	4
Primary sedimentation tanks (quiescent surface)	370	8.8	2
Primary effluent box	2900	2.2	8
Aeration tanks	150	4.8	6
Secondary sedimentation tanks (square)	96[a]	3.1	7
Secondary sedimentation tanks (circular)	96[a]	5.0	5
Gravity thickeners	4700	16	1
Point sources			
Scrubber stack	160[b]	0.56	11
Incinerator stack	2,000[a]	1.9	9
Dewatering building	28	1.6	10

Notes:
Concentration from laboratory results unless noted.
a. Concentration from historical data at other plants.
b. Concentration based on converted H_2S concentration.

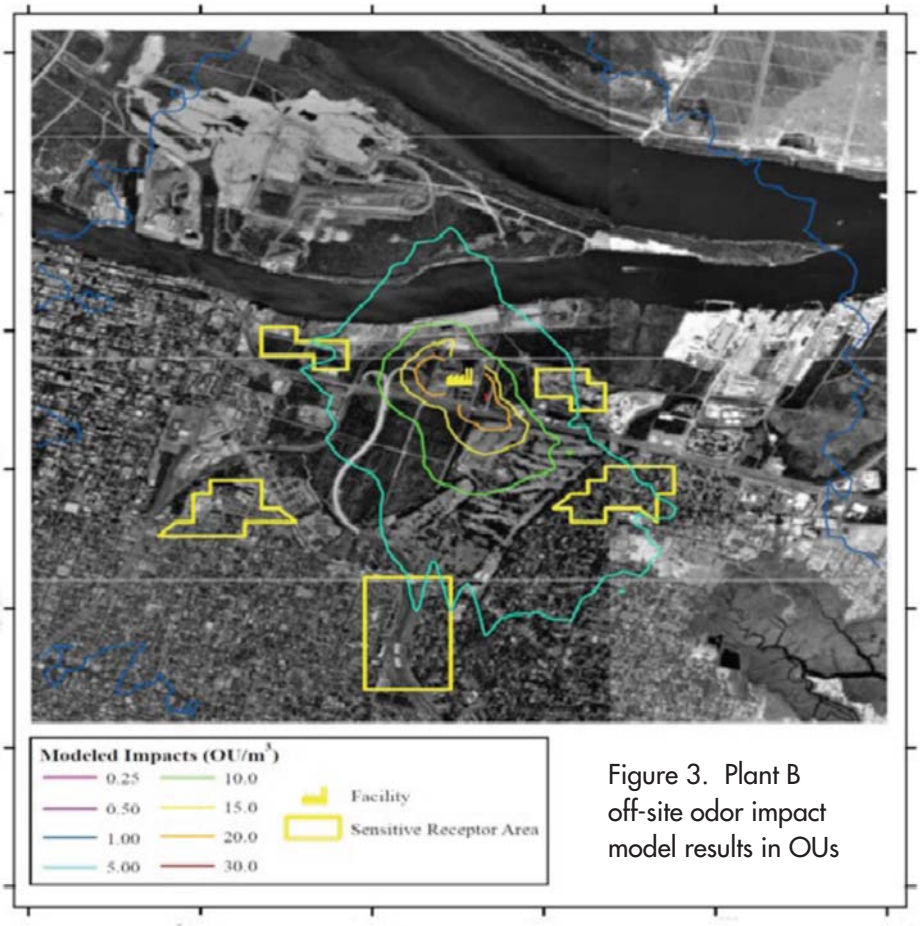

Figure 3. Plant B off-site odor impact model results in OUs

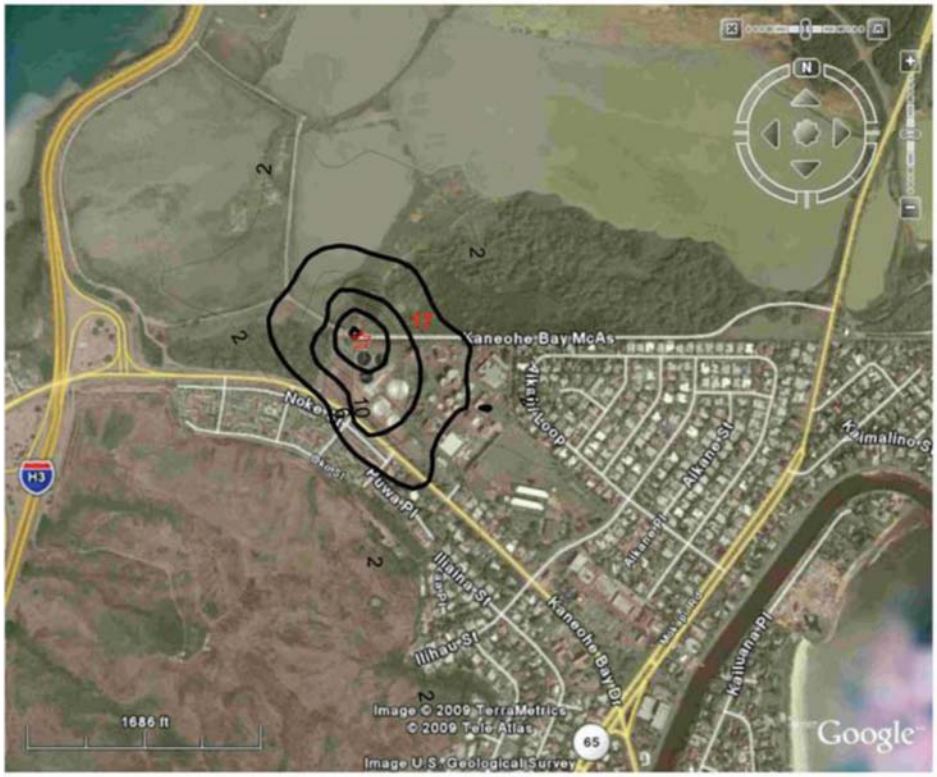

Figure 4. Plant C off-site odor impact model results in µg/m³ H_2S

Continued from page 20

low. The maximum off-site impact is 31 OUs, which occurs at the fenceline. The maximum impact at a critical receptor is 11 OUs.

Plant C

Plant C is a 60-ML/day (16 mgd) secondary plant with primary clarifiers, trickling filter/solids contact secondary, digestion, and dewatering. Modeling, which was performed using AERMOD, was based on hydrogen sulfide (H_2S) concentrations because the regulatory limit was 25 parts per billion (ppb) H_2S. The modeling results are compared to the regulatory threshold of 25 ppb H_2S at the facility fenceline. The only uncovered process is the secondary clarifiers. Other processes are treated by chemical scrubbers and carbon in series, soon to be converted to biotrickling filters and carbon in series.

Emission sources were comprised of 10 scrubber stacks and three area sources. The sources consisted of point source emissions from four secondary odor control scrubbers, four headworks odor control scrubbers, one dewatering odor control scrubber, one biotower odor control scrubber, and area source emissions from three secondary clarifiers. A significant issue was a measured H_2S concentration of 900 parts per million (ppm) within the covered primary clarifiers, albeit at a relatively low exhaust ventilation rate.

When the model results were analyzed, it was found that 51 percent of total mass H_2S emissions were from the secondary clarifiers compared to 49 percent from the scrubber stacks, but 97 percent of the off-site impact was attributable to the secondary clarifiers. The peak fenceline concentration of all sources, including the secondary clarifiers, was 13.7 ppb, whereas if the secondary clarifiers were excluded, the peak concentration dropped to 0.4 ppb. The high impact of the uncontrolled secondary clarifiers was due to their location close to the fenceline. This result is illustrated in Figure 4, showing the impact odor isopleths concentrated at the fenceline close to the secondary clarifiers. Concentrations are shown in micrograms per cubic meter (µg/m³). One µg/m³ is equivalent to 0.7 ppb H_2S. Because the H_2S detection threshold is 0.5 ppb, it can be approximated that 1 ppb is equivalent to 2 OUs, and therefore, 13.7 ppb H_2S is equivalent to 27.4 OUs.

Plant D

Plant D is a 56-ML/day (15 mgd) secondary plant with primary clarifiers, membrane bioreactor secondary system, aerobic

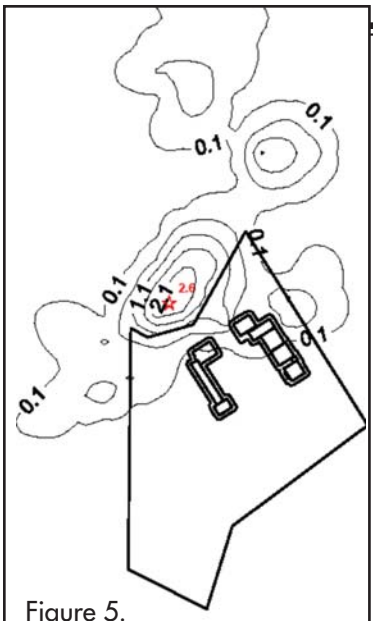

Figure 5.
Plant D off-site odor impact model results in OUs

Table 6. Summary of Odor Impacts, Studied Plants

	Plant A	Plant B	Plant C	Plant D
Plant capacity, ML/day (mgd)	500 (120)	102 (27)	60 (16)	56 (15)
Permit limit units	OUs	None	H_2S	OUs
Model	CALPUFF	AERMOD	AERMOD	ISCST3
Odor parameter	Odor units	Odor units	H_2S	Odor units
Averaging time, min	10	10	60	5
Exceedances, percentile	2	2	0	2
Source odor derivation	Sampled EN methodology, other plants' data	Sampled EN methodology	Sampled in H_2S units, previous reports	Other plants' EN methodology
Odor technology	Chemical scrubbing	Chemical scrubbing	Biotrickling filters	Chemical scrubbing
	Biofilters		Carbon	Carbon
Maximum off-site impact	34 OUs	31 OUs	14 ppb H_2S (28 OUs)	2.6 OUs
Highest off-site odor contributors	Primary clarifiers, secondary clarifiers	Gravity thickeners, primary clarifiers	Secondary clarifiers	Scrubber stacks
Notes			Very close fenceline	No exposed wastewater

digestion, and dewatering. The plant first became operational in 2010. No processes are left uncovered and all processes are treated by chemical scrubbers and carbon in series, with treated air dispersed through stacks.

Odor modeling was performed using the ISCST3 model based on OU concentrations and the off-site limit was 5 OUs. The modeling results showed a maximum 2.6 OUs at the facility fenceline.

The difference in odor impact between this facility and the other three facilities is apparent. With no uncovered area sources and all odorous systems covered and treated, the off-site impact of 2.6 OUs is approximately an order of magnitude different from the first three facilities that have uncovered wastewater processes.

Figure 5 shows the odor impact in the vicinity of the plant. The maximum modeled odor impact was 2.6 OUs.

Summary of the Four Plants

On examining data from the four plants, it is apparent that when there are uncovered, uncontrolled odor sources at a wastewater plant, it is challenging to achieve off-site odor impacts in single-digit values. The three plants with uncontrolled area sources had fenceline impacts ranging from 28 to 34 OUs. Even at a plant where secondary clarifiers were the only uncontrolled odor source, fenceline impacts were significant. Only when odorous air sources were controlled and the treated exhaust air was emitted through stacks did impact drop into single digits.

Conclusion

Odor impact goals and regulations, established based on the previous American standards, are no longer valid. Plants with uncontrolled area sources comprising open tanks, channels, and basins will have difficulty achieving the single-digit OU impact goals that have been historically set unless there is a significant perimeter buffer. It is probably difficult to meet 20 OUs, let alone single-digit numbers.

Examination of four wastewater plants with differing levels of odor control illustrates that those with open-area odor sources produce fenceline impacts in an order of magnitude higher than those with stack emissions only.

Odor impacts calculated from modeling are intended to reflect the impact of sources over and above the background ambient conditions. As the reported mean ambient concentration was 40 OUs (McGinley 2008), it seems unreasonable to set a goal of less than 10.

Although this article has discussed impacts based on odor units, the odor characteristics such as intensity, characteristic, and hedonic tone should also be considered. Secondary process systems have less objectionable, less offensive characteristics than primary or biosolids processes.

Other challenges in producing accurate models include identification of peak emissions that may occur for only a few days per year; the inappropriate, although often requested, summing of odor unit values from sources with different characteristics; statistical analyses, such as averaging periods and exceedances; and, of course, explaining all of these to the public.

References

- Cesca, J., A. Flanagan, and M. Cunnington. 2008. *Case Study: Odour Risk Management at the WTP, One of Australia's Largest and Most Unique WWTPs.*
- Diosey, P.G., M.E. Hess, and R.J. Pope. *Modeling Odors and VOCs: A Comparison of Models and Modeling Techniques.* Water Environment Federation. Proceedings Odors and VOC Emissions 2000.
- McGinley, M.A. and C.M. McGinley. 2008. *Odor Emission Factors for Common WWTP Processes.* Water Environment Federation/Air & Waste Management Association Specialty Conference: Odors and Air Emissions 2008, Phoenix, Arizona.
- Porter, R.C. and D. Elenter. *Comparison of Odor Impacts from a Wastewater Treatment Plant Using the ISCST3 and AERMOD Dispersion Models.* Water Environment Federation. WEFTEC 2007.
- Porter, R.C. and L. Santos. P*eak-to-Mean Ratios for Odor Impacts: A Tracer Study Revisited.* Water Environment Federation. Proceedings Odors and Air Emissions 2006.
- Sattler, M. and S. Devanathan. 2007. *Which Meteorological Conditions Produce Worst-Case Odors from Area Sources?* Journal of the Air & Waste Management Association.
- U.S. Environmental Protection Agency Report (EPA454/R98009).
- Water Environment Federation. *Manual of Practice 25, Control of Odors and Emissions from Wastewater Treatment Plants 2004.*