Proactively Monitoring and Managing Odors using Real-Time Odor Plume Prediction

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ABSTRACT

The Trinity River Authority Central Regional Wastewater System (CRWS) retained Perkins Engineering Consultants, Inc. to research, specify and assist with procurement of a real-time odor plume prediction system. The real-time model is used to monitor the CRWS odor production and as a tool for assessing strategies for reducing the CRWS odor footprint.

The real-time odor plume prediction system was designed to achieve the following objectives:

- Use field-measured odor and atmospheric values, along with programmed fixed emission values for selected processes, to project, on a real-time basis, and to continuously record, in a graphic format, the projected intensity and locations of impact of odors from the CRWS facility.
- Notify staff when odors approach or exceed predetermined levels at selected locations on or off the plant site.
- Provide information to be used in evaluating the potential effectiveness of alternative strategies for preventing or reducing odors perceived offsite.
- Provide information to project the estimated intensity and frequency of odors experienced by the traveling public on Interstate 30 south of and other selected receptor locations.
- Provide a model to help with optimization of odor control chemical feed in reducing the probable off-site odor impact.

An odor dispersion model predicts the intensity, frequency, and spatial extent of nuisance odors generated by the treatment facilities. Continuous monitoring and modeling systems display odor isopleths in real-time based on live atmospheric data. Real-time odor plume prediction systems can use onsite continuous measurement sensors correlated to odor units (OU) and an onsite weather station as input to calculate the resulting odor plume. The number of onsite sensors depends on the size of the facility and available budget.

The features, capabilities, and limitations of real-time odor plume prediction systems as well as lessons learned through the procurement of a real-time model for the CRWS facility are discussed later in this paper.

KEYWORDS

Real-Time Odor Plume Prediction, Odor Modeling, Odor Control Optimization

INTRODUCTION

Odor dispersion modeling illustrates how odors generated by wastewater conveyance and treatment are transported offsite. Odor dispersion models can be used to depict emissions of specific odorants, such as hydrogen sulfide, or more commonly in recent years, the overall odor impact using odor units. Odor dispersion model output, or odor isopleths, show the spatial extent at which specified levels are predicted to be perceived.

Modeling with odor units allows for emissions to be evaluated for the total impact since numerous compounds can contribute to the odorous character of the ambient air. Caution is required as the odor intensity or strength may not vary proportionally with the concentration of odorants and odors from different treatment processes are not additive. For example, the intensity of an odor at a concentration of 100 may only be twice as great as its intensity at a concentration of 10 and odor emissions from two equal sources typically do not result in double the odor impact on surrounding areas.

Factors impacting odor dispersion include:

- Odor intensity of sources
- Flux and discharge air flow rates
- Meteorological conditions (especially wind speed, wind direction and atmospheric stability)
- Surrounding topography and building obstructions
- Water surface elevations and stack heights
- Stack discharge velocities

ODOR DISPERSION MODELS

The two models used for regulatory dispersion modeling of contaminants, as well as for odor dispersion modeling, are the steady state model AERMOD and the non-steady state model CALPUFF. Details on the two most widely used air dispersion models include:

- AERMOD – The American Meteorological Society (**A**MS)/Environmental Protection Agency (**E**PA) **R**egulatory **Mod**el (AERMOD) was specially designed to support the EPA's regulatory modeling programs. AERMOD was designed for short-range dispersion, up to 50 kilometers, of air pollutant emissions from stationary industrial sources. AERMOD incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts.

- CALPUFF – **Cal**ifornia **Puff** model (CALPUFF) is a Lagrangian puff model originally developed by the Sigma Research Corporation (SRC) in the late 1980s. CALPUFF can be applied on scales of tens to hundreds of kilometers. CALPUFF is approved as a long-range model for regulatory purposes, which is typically defined as transport over distances beyond 50 kilometers, as well as on a case-by-case basis for near-field applications involving complex terrain or wind conditions and for coastal applications.

AERMOD has historically been the regulatory dispersion model most commonly used to model wastewater odors as it was designed for short-range dispersion, but CALPUFF is gaining popularity. Historical use of the non-steady state CALPUFF model for regulatory applications for distances within 50 kilometers has been limited because of the lack of appropriate model validation studies.

Under unstable conditions, the results of the two models are generally in agreement. Under calm wind stable conditions, CALPUFF may be more accurate than AERMOD. AERMOD generates a long plume concentrated at the source, whereas CALPUFF generates puffs that stagnate over the source.

If susceptible, odor complaints often occur during inversion conditions. On damp, cold days, odors may collect in low lying areas adjacent to conveyance and treatment facilities and impact offsite receptors as a pocket of odorous air. CALPUFF appears to more accurately model these conditions.

REAL-TIME ODOR PLUME PREDICTION MODEL INPUTS

The inputs to a real-time odor plume prediction system are similar to the inputs for a conventional odor dispersion model, except meteorological and possibly one or more odor source inputs are real-time.

Meteorological Data

Meteorological conditions can be highly localized. An onsite weather station is recommended for real-time applications. The onsite weather station should measure and transmit the following at a minimum:

- Wind speed and direction
- Atmospheric pressure
- Solar radiation
- Relative humidity
- Temperature

The weather station must be installed far from buildings and other structures to prevent interference with collecting accurate atmospheric data. Weather stations typically require 120 V power.

Cellular data communication technology is recommended for transmitting data from the weather station to a cloud server. It is estimated a weather station would consume about 100 to 200 MB of cellular data monthly, if data is collected in nominal four-minute increments.

Meteorological data collected at nearby station(s) could be used during an onsite weather station outage to continue with odor plume prediction. The National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) and Weather Underground are potential sources of meteorological data.

Terrain and Other Static Data

Terrain, land use and other static data are typically incorporated into a real-time odor plume prediction system during model development. Both dispersion models include data preprocessors to incorporate complex terrain using USGS digital elevation data. The National Elevation Dataset (NED) is the primary elevation data product of the USGS.

Structures, such as buildings, can affect plume rise and odor dispersion. Turbulent wake zones can be created around buildings, forcing emissions to the ground instead of rising freely before dispersing. Stacks which are not tall enough to avoid downwind turbulent wake zones should be modeled considering building downwash.

EPA's Building Profile Input Program (BPIP) program can be used to process building information to account for the influence of building dimensions on plume dispersion. Current building downwash algorithms only model the effects of nearby point sources; area and volume sources are not included.

Building downwash algorithms are currently one of the biggest sources of confusion and unexpected results with AERMOD. An effort to update building downwash algorithms by the Air and Waste Management Association (A&WMA) Atmospheric Modeling and Meteorology subcommittee is underway.

Odor Sources

The wastewater treatment processes that have been found to cause the greatest off-site odor typically include preliminary and primary treatment and solids handling. Activated sludge processes, especially trickling filters, may impact off-site if sensitive receptors are close to the fence line. The anaerobic and anoxic zones associated with biological nutrient removal have the potential to make activated sludge processes more odorous than historically perceived by our industry. Secondary clarifiers, effluent filters and disinfection typically do not impact off-site receptors.

Dispersion models can incorporate multiple point (scrubber stacks or vents), area (uncovered process units) or volume (open doors, etc.) emission sources. Typically, a combination of area and point sources are used to model odors from wastewater treatment facilities.

Real-time odor plume prediction systems can incorporate from one to all of the potential odor sources at a treatment facility. If no online sensors are provided, odor emission rates can be modeled as fixed values or with programmed fluctuations. Potential fluctuations typical to odor emissions include diurnal or seasonal ups and downs.

Fixed or pre-programmed variable odor emission rates could be based on one or more samples. Sampling for OU includes collecting odorous air from selected treatment units in inert Tedlar® bags and testing the collected foul air in a laboratory with an olfactometer and a panel of trained individuals. Probable variabilities in odorous emissions are not accounted for with grab OU sampling.

Using fixed or pre-programmed emission rates significantly reduces the instrumentation and thus the initial cost of a real-time monitoring system, but this approach may result in a loss in resolution in respect to diurnal fluctuations in emission rates. Fixed or pre-programmed odor source assumptions could either overestimate or underestimate emissions. The user must also use care to see that the fixed rates accurately reflect the basins that are out of service.

Online sensors specific to individual treatment units can be used to provide real-time odor emissions to include in the real-time model. Sensors should ideally be surrounded by the odor source to allow for monitoring of selected source regardless of wind direction. Surrounding sensors by each odor source can prove impractical in some situations.

Options for online sensors include electronic odor monitors and gas sensors. Electronic odor monitors include an array of metal oxide and other sensors. System suppliers calibrate the metal oxide and other sensors in the electronic odor monitors to “smell” odor units, as based on OU sampling conducted during equipment calibration. Electronic odor monitors may not accurately account for odorous compounds for which the monitor was not calibrated.

Individual gas sensors could be selected for OU monitoring based on the composition of the emissions from an odor source. The concentration of the most odorous compound from a specific treatment unit could be calibrated to OU. The most odorous compound may not be the compound with the highest concentration, as some odorous compounds have higher detection and recognition thresholds than others.

Actual treatment unit locations, footprints, elevations, stack heights, stack diameters, etc. would be used for modeling selected odor sources. Multiple units carrying out the same treatment process could be modeled using the same odor emission rates but as separate treatment units.

The real-time odor plume prediction system should provide users with the ability to turn off or on individual odor sources to match current operations.

As with the weather station, cellular data communication technology is the currently preferred method for transmitting data from the sensor(s) to a cloud server. It is estimated a single gas sensor would consume about 100 to 200 MB of cellular data monthly, if data is collected in nominal four-minute increments. Multi-gas sensors and electronic nose monitors would use more cellular data than single gas sensors.

REAL-TIME ODOR PLUME PREDICTION MODEL OUTPUTS

The receptor grid associated with a real-time odor plume prediction system is similar to the receptor grid for a conventional odor dispersion model. Rather than a static odor plume, a real-time odor plume prediction system will provide a frequently updated animated odor plume, taking into account online weather station and odor sensor inputs.

Real-time odor monitoring systems can be programmable to alarm when a situation could result in odor complaints. Systems allowing the user to define geographic points with defined odor exceedance thresholds enables the user to make process adjustments to potentially reduce offsite odor impacts for sensitive receptors.

The accuracy of the model results should not be considered absolute. Model results are only as accurate as the aggregate of the inputs and the model itself.

CRWS REAL-TIME ODOR PLUME PREDICTION SYSTEM

CRWS serves approximately 1.2 million people in the Dallas/Fort Worth area. CRWS has a comprehensive and wide-ranging odor-control program including liquid-phase chemical odor control in the collection system and at the treatment plant as well as foul air collection and treatment with bioscrubbers and biofilters.

CRWS procured and installed an OdoWatch™ real-time odor plume prediction system in 2015 consisting of the following:

- Two electronic odor monitors or eNoses with emission rates applicable to three and four treatment units each for a total of seven treatment units monitored by eNoses
- Six fixed odor emission rates applicable to between one to twelve treatment units for a total of 25 fixed sources
- One weather station on a freestanding tower
- One cloud based central computer with the OdoWatch™ platform based on the dispersion model AERMOD

The OdoWatch™ system at CRWS was supplied by a partnership of Kruger, a Veolia Water Solutions company, and Odotech. The OdoWatch™ system was developed by Odotech in Montreal. Odotech has over 70 OdoWatch™ installations worldwide. In December 2017, Odotech was acquired by the Brisbane and San Francisco based Envirosuite.

CRWS installed the electronic odor monitors and weather station with in house personnel. Odotech calibrated the electronic odor monitors and developed the cloud based AERMOD real-time dispersion model. A third eNose to monitor a second set of primary clarifiers was installed by CRWS and calibrated by Odotech in early 2017.

The odor emission rates used for calibrating the electronic odor monitors and designating the fixed sources were based on OU sampling conducted by Odotech in November 2015 as well as OU testing results from odor abatement master planning work in July 2010. The OU measurements from the two sampling events as well as the OUs assumed for the real-time odor plume prediction system are listed in Table 1.

Table 1 – Odor Source OU Inputs and Supporting Data

	Testing by Odotech November 2015	Testing for Master Planning July 2010	OU Selected for OdoWatch™ System
Primary Clarifier Nos. 1 to 4	Approx. 11,000	> 60,000, 14,000, 9,500	eNose 1
Pump Station 6 (Influent Hatches)	Approx. 100,000	> 60,000	eNose 2
Onsite Storage Basin (OSSB)	548	Not Measured	548
Headworks Grit and Screening Dumpster Building	421	1,700	1,061
Grease Concentrator Building	14,426	Not Measured	14,426
Equalization Basin Nos. 1 to 6	20,154	14,000	17,077
Aeration Basin Nos. 1 to 12	4,270	2,500, 1,000	2,590
Primary Clarifier Nos. 5 to 8	21,039	12,000, 4,400, 3,800	eNose 3 (formerly 10,310)

Solids handling was not included in the real-time odor plume prediction system due to ongoing major changes to the process, including but not limited to the addition of thermal hydrolysis. Real-time model output indicates the odor impact of Aeration Basin Nos. 1 through 12 may be currently overestimated. Lowering the odor emission rate from the Aeration Basins in the real-time odor plume prediction system is currently under evaluation.

Figure 1 is photos of the outside and inside of the electronic odor monitor or eNose at an influent pump station.

Figure 1 – Photos of Inside and Outside of eNose

eNoses use an array of gas sensors and mathematical algorithms to provide detailed information on the real-time odor fluctuations of a source. eNoses do not measure individual odorous compounds, but rather correlate electrical and other responses of the gas sensors to odor strength through multiple calibration curves. The eNoses include:

- Metal-oxide semiconductors
- Metal-oxide-silicon field effect transistors
- Conducting polymers
- Surface-acoustic-wave devices
- Quartz resonators
- Fiber-optic chemical sensors

eNoses and other odor sensors should be surrounded by odor source to allow for monitoring of selected source regardless of wind direction.

A screen shot of the real-time odor plume prediction system online interface is provided as Figure 2.

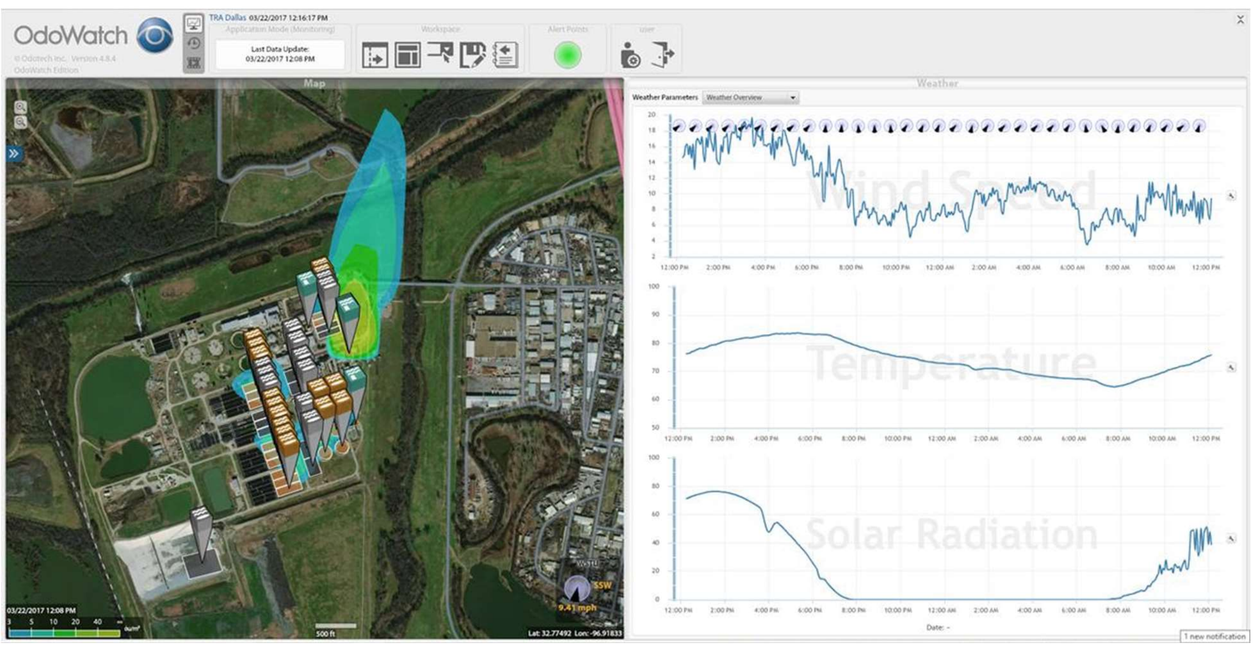

Figure 2 – Real-Time Odor Plume Prediction System Interface

Windows displayed can include odor plume and odor source contributor maps, weather data graphs, historical and current alert tables, alert point odor prediction and source contributor graphs, odor source emission rate graphs, etc. Screens are highly customizable and can be modified depending the preferences of each user type.

Odor plumes are predicted with real-time weather and odor source data every four minutes. Historical predicted odor plumes can be viewed through the platform by selecting the time frame of interest. Predicted odor plumes are displayed sequentially to allow a full day of results to be viewed in about one minute.

Sensor, odor contributor, weather, alert, emission rate and other data can be exported to .csv, .pdf, images and video. Videos can be especially helpful as a public relations tool.

Receptor alert points allow close and continuous monitoring of specific geographic locations. Alert points can be easily added through the OdoWatch™ interface by the user. The system is able to incorporate up to 250 separate alert points. The user can set low, medium and high odor exceedance thresholds at each alert point.

The system can be tailored to send email and/or text alerts to different selected personnel when the model predicts low, medium and high odor exceedances at the specified alert points. The CRWS system sends email alerts to a progressively larger group of users when one or more of the several alert points predict odors exceeding a low of 10 OU, medium of 20 OU and a high of 40 OU.

The alerts allow staff to be proactive rather than reactive, giving them actionable data in real-time to improve operations.

Figure 3 illustrates how the model presents contributing treatment units when odor exceedances are predicted for an alert point via a map display. Other methods of presenting odor exceedance predictions, such as tabular and graphical formats, are available via the user interface.

Figure 3 – Identification of Odor Contributors for Alerts

CRWS has several potentially odorous neighbors, including but not limited to landfills, special waste processors, food processors, prepared food distributors and its own collection system. Confusion by the public between odors from the treatment facility and odors generated by its industrial and other neighbors has been an ongoing issue. Real-time odor plume prediction has enabled staff to retroactively evaluate if odor complaints with designated specific times of occurrence are attributable to the treatment facility.

Odor source contributor data will be useful in planning future odor control capital improvements. Model results can be used to identify which of the odorous treatment processes to control to effectively reduce offsite impact.

Costs for the real-time odor plume prediction system are summarized in Table 2.

Table 2 – Cost of Real-Time Odor Plume Prediction System, 2015 Dollars

Item	**Budgetary Costs**
Initial System including: • Two Electronic Noses • Six Fixed Sources • Weather Station • Cloud Based Control System • Startup and Training	$ 240,000
Additional Electronic Noses	$ 40,000
Additional Fixed Sources	$ 7,000
Annual Electronic Nose and Other System Maintenance Costs	10-percent of Purchase Price
Annual Cloud Hosting Costs	Nominal $3,000 to $ 5,000 depending on Size of System

The real-time odor plume prediction system can be expanded incrementally when budget allows for the addition of more real-time odor sensors and fixed sources. The dispersion model itself and the recommended onsite weather station, if budget allows, are all that is required to start real-time odor plume prediction monitoring.

CURRENT AND FUTURE USES & BENEFITS

As discussed earlier, Envirosuite acquired Odotech in December 2017. The real-time odor plume prediction system available from Envirosuite is subscription based. The subscription covers system access, updates, data storage and support services. Capital expenditures would be needed for an onsite weather station, real-time odor monitoring equipment, and odor emission rate evaluations specific to the treatment facility, if desired by the user, as monitoring and other equipment is not included in the subscription costs.

Several odor control chemical suppliers offer monitoring and control systems which use sulfide concentrations measured at a targeted monitoring location for adjusting odor control chemical dosage rates. Similar control logic could allow for chemical dosage rates to be adjusted up or down to keep one or more sensitive receptors out of the predicted area of odor impact, as based on the results of a real-time odor plume prediction system. Manual adjustment of chemical odor control dosage rates based of odor plume predictions is already attainable.

Software geo-referencing odor complaint data with location and timing information is readily available. At least one supplier offers a timeline feature animating received odor complaints to visually depict how complaints relate with meteorological conditions or process conditions. Odor complaint locations could be evaluated against the predicted odor plume either within or outside of the system.

Odor plume prediction using forecasted meteorological data would allow users to act to control emissions before odors impact sensitive receptor locations. Using forecasted data would provide time to implement process adjustments, such as chemical addition or postponement of intermittent odorous operations, for reducing odor emissions when meteorological conditions could result in offsite impacts.

CONCLUSIONS

The real-time odor plume prediction system has been a useful tool for monitoring the CRWS odor production, alerting management when thresholds may be exceeded, and assessing strategies for reducing the odor footprint. The addition of monitored and fixed odor sources to the existing real-time system is planned as budget allows, particularly after the solids handling improvements project is complete and fully operational as designed.

Cloud based systems allow for data to be accessed from anywhere with an internet connection. System alerts to selected personnel, even the interested public, allow for planning to avoid and if unsuccessful in avoiding, respond to predicted odor impacts.