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IDENTIFICATION OF ODOR-CONTROL NEEDS FOR A MUNICIPAL WASTEWATER TREATMENT PLANT UPGRADE: A NEW YORK CITY SUCCESS STORY

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ABSTRACT

The upgrading of municipal wastewater treatment plants (WTPs) often triggers the need to identify controls necessary to ensure that nuisance-based, off-site ambient air standards are not contravened. This can be particularly challenging as it is necessary to consider not only the spatial and temporal emissions variability inherent in routine facility operations, but also the air quality "credit" to be realized by improvements to the wastewater process resulting from the upgrade itself. While these odors obviously need to be controlled, it is imperative to avoid overcontrol as the resultant capital and recurring costs can be extreme.

The 26th Ward WTP is located in Brooklyn, New York and operated by the New York City Department of Environmental Protection. It is a 170 million-gallon-per-day (mgd) activated sludge treatment plant with partial combined sewage overflow (CSO) treatment. A major upgrade is currently underway to correct a variety of plant deficiencies, as well as to improve instrumentation and process-control capabilities. One of the upgrade components is the inclusion of odor controls such that strict compliance with hourly, off-site hydrogen sulfide (H_2S) standards is ensured.

This paper presents the results of a facility-wide H_2S emissions characterization, as well as a discussion of predicted off-site impacts and resultant control requirements based on field measurements made between July and September, 2001. For each process source, H_2S emissions were measured during times when the facility was operating normally (conservatively reflective of the "build scenario") as well as when it was shown to be in upset mode. Upset conditions

resulting in increased H_2S formation and subject to remedy under the upgrade were considered. The emission rate representative of the build scenario was conservatively defined as the highest measured rate which could not be explained by the occurrence of a documented upset condition.

The source-attribution technique, essentially a mass-balance approach, was used to characterize H_2S emissions. For each open process source, this involved calculation of a single, downwind, path-averaged H_2S concentration for each 15-minute "monitoring event." Each event consisted of 34 near-ground (1m height) point measurements using two comparably performing Jerome meters. Emission rates were assessed using Gaussian dispersion relationships and on-site measurements of wind speed, wind direction, and atmospheric stability (as a proxy for vertical dispersion). Higher-emitting areas (such as weirs and other turbulent areas) were addressed by periodically measuring H_2S at representative locations, directly above the source surface, from which relative "hot-spot" source strengths were derived and assigned.

A refined characterization was performed for the preliminary settling tanks, as this was, by far, the highest-emitting source. The accuracy of the emission estimates was significantly improved by the site-specific treatment of vertical dispersion (sigma-z) during each monitoring event. An open-path Fourier-transform infrared (FTIR) spectrometer was configured along the H_2S measurement path to monitor two tracer gases released in a controlled manner from different upwind locations, thereby facilitating the direct determination of sigma-z coefficients across the downwind source dimension. A second-order sigma-z curve, unique to each of 77 monitoring events for this source, was developed and substituted directly into the dispersion model for H_2S emissions calculation. This eliminated the need to rely on somewhat crude relationships between atmospheric stability class and sigma-z values.

KEYWORDS

area source technique, hydrogen sulfide, open-path FTIR spectroscopy, path-integrated concentration, tracer method, vertical dispersion coefficients, vertical dispersion measurements, wastewater treatment plant emissions.

INTRODUCTION

The New York City Department of Environmental Protection (DEP), Bureau of Environmental Engineering (BEE), through its engineering consultant, Hazen and Sawyer, P.C., is currently upgrading the 26th Ward Wastewater Treatment Plant (WTP) in the Borough of Brooklyn, New York. The 26th Ward WTP is a 170 million-gallon-per-day (mgd) activated sludge treatment plant with partial combined sewage overflow (CSO treatment).

The primary goal of this major upgrade is to correct a variety of plant deficiencies concerning wastewater and sludge treatment, as well as to improve plant instrumentation and process control capabilities. Included in this upgrade is the continued compliance with State Pollutant Discharge Elimination System (SPDES) permit requirements through the design and construction of these facility-wide improvements which, either indirectly or directly, will also result in a reduction in emissions of air pollutants and other malodorous compounds to the community.

Legal Requirements

Existing law requires that the upgrade be performed in compliance with all City Environmental Quality Review (CEQR) requirements. At the heart of CEQR is the need to assess the significance of any "action" with respect to its overall environmental impact. This is accomplished by comparing the "future build scenario" to the "future no-build scenario." For this action (facility upgrading), the future build scenario is defined as future operations of the facility as if all planned upgrade activities have been completed. The future no-build scenario is defined as future operations of the facility without any upgrading. Full compliance with all applicable environmental standards and requirements, air and otherwise, must be demonstrated under the build scenario before the lead agency (in this case, the DEP) can issue a "negative declaration" and allow commencement of construction activities.

Off-site, odor-based air quality standards for hydrogen sulfide (H_2S) are very strict. The New York State Department of Environmental Conservation (DEC) site-perimeter standard is 10 parts per billion (ppb) or 13.9 micrograms per cubic meter (ug/m^3), and the DEP sensitive-receptor standard is 1 ppb (1.4 ug/m^3). Because these standards are so strict, it was imperative that the facility conditions and operating practices under which H_2S emissions are maximized were understood, as well as the extent to which the upgrade itself will provide remedy.

Accordingly, it was necessary to collect a sufficient amount of data from the more problematic sources under the various conditions and operating regimes so that the emissions inventory assigned under the build scenario could "take credit" for each upgrade component shown to materially reduce emissions. Had the data-collection program not allowed for this delineation to be made between the build and no-build scenarios, the result would likely have been an over-controlling of emissions and the City's incurrence of large, unnecessary costs.

The entire field investigation was conceived and carried out in full conformance with the U.S. Environmental Protection Agency (USEPA) data quality objective (DQO) process (U.S. Environmental Protection Agency, 2000a). Detailed quality assurance project plans were prepared in accordance with applicable USEPA guidance (U.S. Environmental Protection Agency, 2001).

Overview of H_2S Emissions-Assessment Methodologies

The field investigation employed both the mass-balance technique and the area-source technique. Hand-held instruments (Jerome meters) were used for all H_2S measurements.

The mass-balance technique was used for all buildings and simply involved multiplying the volume of ventilated air by a representative H_2S concentration derived from an appropriate treatment of indoor air.

The area-source technique was employed for all uncovered area-type H_2S sources. This technique, also based on mass-balance considerations, involves identification of source attribution based on a series of upwind and downwind measurements averaged along pre-

specified measurement paths, and the calculation of emission rates based on consideration of established Gaussian dispersion relationships together with on-site measurements of wind speed, wind direction, and atmospheric stability (as a proxy for vertical dispersion).

Two comparably performing Jerome meters were employed simultaneously to generate each downwind, path-averaged concentration. Field operations were carefully controlled to ensure that each "monitoring event" spanned precisely 15 minutes. Higher-emitting areas (such as weirs and other turbulent areas) were accounted for in the emissions calculations by periodically measuring H_2S at representative locations, directly above each source surface, from which relative "hot-spot" source strengths were derived and assigned.

Two meteorological systems were employed. The first system was set up and operated at a location judged representative of the microscale meteorology in the region between each source and the respective H_2S measurements. The second system was installed at a location representative of the local meteorology as influenced by the facility and its immediate environs.

Meteorological forecasting was employed to predict those days when the direction of the wind was most likely to be within acceptable "windows," identified in advance based on logistical considerations. Emphasis was placed on collecting emissions data during times of dry-weather flow, i.e., during those conditions, within the normal range of plant operating limits, likely to enhance anaerobic (septic) conditions necessary for H_2S generation. All measurements were made during the summer when influent temperatures were at their annual peak, as anaerobic activity is directly proportional to temperature.

Refined Treatment of Preliminary Settling Tank Emissions

Because the cost of controlling H_2S emissions is very significant for the preliminary settling tanks, a means of reducing the inherent emissions conservatism for this source was employed. This refined treatment of emissions, which involved use of a method to parameterize plume dispersion in the vertical dimension during the emission-rate assessment process, afforded more accuracy than the method described above. Open-path Fourier-transform infrared (FTIR) spectroscopy was utilized along the H_2S measurement path to monitor two tracer gases released in a controlled manner from different upwind locations, thereby facilitating the direct measurement of vertical dispersion coefficients across the downwind source dimension. A unique vertical dispersion curve was developed for each of 77 separate monitoring events and substituted directly into the model for H_2S emissions assessment.

All monitoring events for the preliminary settling tanks took place during 9 days between July 9 and August 9, 2001. A total of 84 monitoring events took place, but 7 were eliminated due to tracer-gas flow problems or unacceptable plume capture arising from oblique wind directions.

Evaluation of Plant Upsets

Numerous discussions were held with Hazen and Sawyer's design team to understand those facility conditions and operating practices which cause increased H_2S emissions to the

atmosphere and which will be remedied under the upgrade. A total of five such conditions and practices were identified and evaluated in detail.

Care was taken to ensure that a sufficient amount of field-measurement data was collected during the investigation to facilitate a meaningful evaluation of the effects of the conditions and practices which result in plant upset conditions. The correlation between the highest emission rates observed for affected sources and specific facility conditions and operating practices was examined based on assembly and review of relevant facility records and data, as well as discussion with DEP plant engineers.

INSTRUMENTATION

The following instrumentation was employed in the investigation: Jerome H_2S analyzers, open-path FTIR spectrometer, tracer-gas release systems, and meteorological systems.

Jerome H_2S Analyzers

The Jerome Model 631-X Analyzer (Jerome meter) employs a gold film sensor which, in the presence of varying H_2S concentrations, undergoes changes in electrical resistivity. This model also employs a dilution system which permits operation over four concentration ranges, the lowest of which allows a sensitivity to 3 ppb. H_2S measurements are reported based on "total" reduced sulfur representing the actual H_2S present, plus low-molecular-weight mercaptans, thereby providing concentrations which may be somewhat conservative.

The Jerome meter can measure H_2S in real time (a response time on the order of about 20 or 30 seconds) to levels as low as 1 ppb. When the sample button on the unit is pressed, an internal pump draws air into the instrument where it is analyzed. The electrical potential across the gold film is continually monitored, and the concentration is shown by means of a digital display where it remains until the next sample is taken.

Open-Path FTIR Spectrometer

The open-path FTIR spectrometer employed was an AIL Systems RAM2000 Remote Air Monitor. Open-path FTIR spectroscopy is able to provide real-time, simultaneous analysis of up to several dozen gaseous contaminants. The technology is identical in principle to classical laboratory FTIR spectroscopy, except the cell from which a sample is measured is essentially extended to the open atmosphere. A beam of light spanning a range of wavelengths in the near-IR portion of the electromagnetic spectrum (approximately 2 to 14 microns) is propagated from the transmitter portion of the instrument. In the most common configuration, a "retroreflector," comprised of an array of corner-cubed mirrors, is positioned to intercept this radiation and redirect it back upon itself to the receiver portion of the instrument.

An interferometer splits the returning beam of radiation into two paths and then recombines them in a way to generate an interference from the phase differences. The phase difference, and thus the interference, is dependent on the wavelengths present in the beam. In one of the paths, the

radiation is reflected off a moving mirror, resulting in an intensity variation which is measured as a function of the path difference between the two mirrors. The result is an interferogram.

The interferogram obtained from a monochromatic beam is simply a cosine wave. The broadband interferogram is a sum of cosine waves (the Fourier series) for each spectral component as a function of mirror pathlength separation. A spectrum in the optical frequency units, cm^{-1}, is obtained by performing a Fourier transform upon the interferogram.

Contaminants of concern are identified and quantified via a computer-based spectral search involving sequential, compound-specific analysis and comparison to the system's internal reference spectra library. The most widely employed technique for analyzing FTIR spectral data is the multicomponent classical least squares (CLS) technique. Any gaseous compound which absorbs in the IR region is a potential candidate for monitoring using this technology.

Resultant path-integrated concentrations are typically reported in units of parts-per-million-meters (ppm-m). It is often necessary to convert path-integrated concentrations (ppm-m) to units of milligrams per cubic meter times meter (mg/m^3 x m) or mg/m^2 to facilitate calculations which depend upon the compound's molecular weight. Generation of a path-integrated concentration yields contaminant information along the entire pathlength and not just at a single point (or collection of points) in space as with traditional point-monitoring methods.

Tracer-Gas Release Systems

Separate systems were employed to release carbon tetrafluoride (CF_4) and sulfur hexafluoride (SF_6) at controlled, uniform rates, coincident with each 15-minute monitoring event for the preliminary settling tanks.

Each tracer-gas release system included a cylinder of 99% pure compound which was delivered through a multistage regulator to a calibrated rotameter. Each rotameter was compound-specific with multipoint CF_4 and SF_6 calibration curves. In each system, the gas exited the multistage regulator and traveled through 10 or 20 feet of Teflon tubing to a delivery system consisting of the rotameter, a funnel, and a ring stand.

Meteorological Monitoring Systems

The first system (identified earlier) was a portable tower equipped to monitor wind speed at a height of 1 meter above the ground. The second system was a 10-meter tower equipped to monitor wind speed, wind direction, sigma-theta (standard deviation of the horizontal wind direction), and solar radiation at a height of 10 meters, and the change in temperature (delta temperature) between 2 and 10 meters.

Each system was calibrated and maintained in conformance with applicable USEPA requirements (U.S. Environmental Protection Agency, 2000b). All meteorological data was collected in user-defined, 15-minute blocks with capabilities for real-time, in-field display (both instantaneous and 15-minute-averaged).

All meteorological equipment was manufactured by Climatronics Corporation. Model F-460 wind speed and wind direction sensors were used on each system. These consist of three-cup anemometers with variable frequency output and variable-voltage wind direction sensors with balanced magnesium vanes. Delta temperature was measured using variable-resistance dual thermistors in stainless steel sheaths and housed in motor-aspirated shields.

AREA-SOURCE TECHNIQUE FOR ESTIMATING H_2S EMISSIONS

The area-source technique is applicable to all area-type sources, i.e., homogeneous sources (uniformly emitting) and non-homogeneous sources (having "hot spots"). It involves identification of a source attribution based on a series of near-ground (1m height) upwind and downwind measurements and the subsequent calculation of emission rates based on mass-balance considerations and Gaussian dispersion relationships inherent in most USEPA Guideline models (e.g., ISCST). In addition to the source-attribution information, coincident on-site measurements of wind speed, wind direction, and parameters relating to atmospheric dispersion are required.

Source-attribution is represented as a path-integrated concentration and relies on a direct contaminant measurement across the downwind plume. It is obtained by subtracting the upwind path-integrated concentration from the downwind path-integrated concentration. A path-integrated concentration (units of mg/m^2) can be derived by integrating a concentration at a point (mg/m^3) across the width (crosswind direction) of the plume (m). The benefit of working with a path-integrated (or cross-plume) concentration lies in its inherent spatial representativeness.

Ideally, path-integrated measurements are generated via some type of optical remote sensing technique -- such as open-path IR or ultraviolet (UV) spectroscopy -- which yields such data directly. However, H_2S is a notoriously poor absorber of IR and UV radiation and, as a result, associated minimum detection levels were not sufficient to meet the measurement quality objectives required for the program. Therefore, a source-attribution approach based on use of rapid-response point monitors (Jerome meters) was employed in which multiple measurements were taken along the downwind (cross-plume) path.

The area-source technique has been accepted in numerous regulatory applications by USEPA and is consistent with applicable USEPA guidance (U.S. Environmental Protection Agency, 1990). The technique, as modified for use with point monitors, is as follows:

1. Identify Source Attribution

This step consists of a series of 15-minute-averaged monitoring events in which concurrent (or sequential), near-ground-level H_2S measurements are made upwind and immediately downwind of the source to identify source attribution. Downwind measurements are made at pre-designated locations equispaced along the downwind source perimeters. Wind speed, wind direction, and atmospheric stability class are averaged over each monitoring event.

A minor variation of this step was employed in which the accuracy of each downwind path-averaged concentration was improved through the simultaneous collection of two sets of

H_2S data. Jerome meter measurements began at opposite ends of each downwind pathlength, and the results were averaged to reduce the error caused by plume meander (i.e., to address the inability to collect data across the entire measurement path simultaneously).

2. Predict Relative Path-Integrated Concentration Along Measurement Path

This step consists of using an appropriate dispersion model to predict the relative path-integrated concentration along the downwind measurement path defined in Step 1. This is accomplished by: (a) predicting the point concentration (mg/m^3) at every meter along the measurement path based on a unity emission rate (e.g., 1 mg/m^2-s) and actual meteorology and source configuration; (b) determining the arithmetic average of the point concentrations (mg/m^3); and (c) multiplying the average point concentration by the downwind pathlength (m).

Process-tank "hot spots" were represented in the unity modeling by assigning a scalar multiplier to the appropriate subarea of the source. This scalar multiplier was based on results of hot-spot monitoring (also using the Jerome meter) during source-attribution monitoring.

The USEPA Industrial Source Complex Short-Term Dispersion Model, Version 3 (00101, LF90 Version 4.52, 4/27/00), hereafter referred to as the ISCST3 Model, was selected as the best means to simulate emissions from this area-source complex.

3. Scale Unity Modeling Results to Estimate Emission Rate

This step involves estimating the actual emission rate, Q_A, in accordance with the following ratio:

$$\mathbf{C_M / Q_A = C_P / Q_U} \qquad \text{(Equation 1)}$$

where:

C_M	=	measured path-integrated H_2S concentration (attribution) (mg/m^2)
Q_A	=	actual H_2S emission rate (mg/m^2-s)
C_P	=	predicted relative path-integrated concentration (mg/m^2)
Q_U	=	unity-based emission rate (mg/m^2-s)

Path-integrated representations of measured H_2S point concentrations (Jerome meter) were generated via employment of the parabolic assumption (Simpson's Three-Point Rule). In this numerical technique, the line representing the value of the function is replaced by a second-order equation ($y = ax^2 + bx + c$), with unique values of a, b, and c determined for each subregion. The integral,

$$\int_{\alpha}^{\beta} \mathbf{f(x)\,dx}$$

is evaluated as follows:

(a) Break the interval $\alpha \le x \le \beta$ into n equal parts of width Δx each, where n is an even number.

(b) Compute $y_k = f(x_k)$, $k = 0, 1, 2, \ldots, n$; $x_0 = \alpha$, $x_n = \beta$.

(c) Then:

$$\int_{\alpha}^{\beta} \mathbf{f(x)\,dx} = \tfrac{1}{3}\Delta x\,(y_0 + 4y_1 + 2y_2 + \ldots + 2y_{n-2} + 4y_{n-1} + y_n)$$

where Δx is calculated by dividing the downwind pathlength (m) by the total number of downwind measurements minus one, and y_0 is the H_2S concentration at the first downwind location, y_1 is the H_2S concentration at the next downwind location, etc.

ASSESSMENT OF VERTICAL DISPERSION

As discussed above, application of the area-source technique requires some method of assessing vertical dispersion. Discussed below is the traditional treatment (as employed for all process area sources), as well as the refined treatment employed only for the preliminary settling tanks.

Traditional Treatment

The traditional treatment of vertical dispersion requires assignment of an atmospheric stability class for each 15-minute event to support emissions assessment. For a given downwind, path-averaged concentration, the associated emission rate is dependent upon how much H_2S has dispersed in the vertical dimension, above the source, prior to reaching the instrument.

In Gaussian theory, the amount of H_2S lost in the vertical dimension can be estimated through knowledge of the vertical dispersion coefficient, which may be thought of as the height one would have to go above a plume centerline before the concentration is reduced by a factor of 1/e, or about 36.8%. Sigma-z increases with increasing downwind distance from the source.

Because sigma-z is difficult to measure, it is generally approximated based on consideration of atmospheric stability class. For dispersion modeling purposes, stability classes A through F are typically identified, in which Class A is the least stable (large sigma-z values) and Class F is the most stable (small sigma-z values). For each stability class, a unique formula is used to assign a sigma-z value as a function of downwind distance.

A stability class was assigned to each monitoring event based on employment of the sigma-theta (standard deviation of the horizontal wind direction or σ_θ) method. A detailed description of this method can be found in Section 6 of the earlier-referenced USEPA meteorological monitoring guidance document (U.S. Environmental Protection Agency, 2000b), and is not reproduced herein.

Refined Treatment for Preliminary Settling Tanks

Limiting the vertical dispersion coefficient to one of six discrete values for a given downwind distance represents a simplification in the emissions assessment process, as vertical dispersion is actually a continuous function. Further, there are meteorological conditions under which the

above methods for stability class assignment may err on the conservative side; i.e., may overestimate sigma-z values, thus overestimating H_2S emissions.

The tracer method was employed to measure vertical dispersion coefficients on an event-specific basis. This method makes use of the crosswind-integrated form of Turner's general Gaussian equation for ground-level concentration downwind of a continuously emitting, ground-level point source which, solved for sigma z (σ_z), yields:

$$\sigma_z = (2\pi)^{½} Q (\pi C u)^{-1} \qquad \text{(Equation 2)}$$

where:

σ_z	=	vertical dispersion coefficient at the particular downwind distance (m)
Q	=	uniform tracer-gas emission rate (g/s)
C	=	ground-level crosswind-integrated tracer-gas concentration (g/m^2)
u	=	mean wind speed (m/s)

Small amounts of CF_4 and SF_6 were released at known, controlled rates, each from an elevation of 1 meter, from locations 22.3 meters and 46.9 meters, respectively, upwind of the FTIR beam path. These tracer gases were monitored as path-integrated concentrations, immediately downwind of the source, using open-path FTIR spectroscopy in accordance with USEPA Toxic Organic Compendium Method 16 (U.S. Environmental Protection Agency, 1999).

In order to accommodate winds from a southerly quadrant, the transmitter and retroreflector were positioned in a plant east-west orientation, about 1 meter north of the source's northern boundary during all measurements (i.e., in close proximity to the downwind Jerome meter measurement path). The beam pathlength (one-way) was 81.5 meters, and the beam was positioned at a height to coincide, as nearly as possible, with the height of the Jerome meter sampling locations (about 1 meter off the ground).

CHARACTERIZATION OF PRELIMINARY SETTLING TANK EMISSIONS

H_2S emissions from the preliminary settling tanks are presented based on both traditional treatment of vertical dispersion and use of measured vertical dispersion coefficients (refined treatment of vertical dispersion).

Because of space limitations and the large volume of data collected, results are arbitrarily presented for only 8 of the 77 valid monitoring events performed (the first 8 events of August 6).

Traditional Treatment of Vertical Dispersion

Table 1 presents emission-rate determinations for the preliminary settling tanks based on traditional treatment of vertical dispersion.

Table 1 - Emission-Rate Determinations for the Preliminary Settling Tanks Based on Traditional Treatment of Vertical Dispersion

Event No.	Unity ISCST3 Analysis		Measured Source Attribution		Actual Emission Rate (g/s)		
	Emission Rate (g/s)	Predicted Source Attribution (g/m^2)	(ug/m^2)	(g/m^2)	Quiescent Areas	Turbulent Areas	Total
E-169, 70	2.020521	0.104884	13593.6	0.0135936	0.0436	0.2183	0.2619
E-171, 72	2.020521	0.084805	13203.0	0.0132030	0.0523	0.2622	0.3146
E-173, 74	2.020521	0.114126	12838.7	0.0128387	0.0378	0.1895	0.2273
E-175, 76	2.020521	0.087240	7591.2	0.0075912	0.0293	0.1466	0.1758
E-177, 78	2.020521	0.116488	14283.3	0.0142833	0.0412	0.2065	0.2477
E-179, 80	2.020521	0.103449	11355.7	0.0113557	0.0369	0.1849	0.2218
E-181, 82	2.020521	0.121147	10949.3	0.0109493	0.0304	0.1522	0.1826
E-183, 84	2.020521	0.138256	6686.7	0.0066867	0.0163	0.0815	0.0977

The emission rate used in the unity ISCST3 analysis was derived by considering a unity emission rate of 0.0001 g/s-m^2 over the quiescent areas (calculated to be 3,362.38 m^2) together with a "hot-spot-adjusted" unity emission rate of 0.00976 g/s-m^2 over the turbulent areas (calculated to be 172.57 m^2), which yielded a total unity-based emission rate of 2.020521 g/s (0.336238 g/s + 1.684283 g/s). The "hot-spot-adjusted" unity emission rate of 0.00976 g/s-m^2 was derived based on results of a comprehensive hot-spot measurement program, in which the average H_2S concentration immediately above the weir (turbulent) areas (17 locations) was 97.6 times greater than the average concentration over the remaining (quiescent) areas (10 locations).

The predicted unity-based source attribution was obtained by running the ISCST3 Model with the above source strengths and configurations for the meteorology observed. This attribution may be thought of as the path-integrated concentration which would result based on a source emissions of unity for the quiescent areas and 97.6 times unity for the turbulent (weir) areas.

Each measured source attribution was derived by subtracting the upwind from the corresponding downwind path-averaged H_2S concentration (Jerome meter measurements).

The total actual emission rate was obtained by rearranging Equation 1 to solve for the actual emission rate (Q_A).

Finally, the apportionment of the quiescent areas and the turbulent areas to the total emissions was derived by adjusting the total emissions in proportion to the unity-based emission rates for these areas. For example, for Event 169-170, the actual emission rate for the quiescent areas is (0.336238 g/s ÷ 2.020521 g/s) x 0.2619 g/s = 0.0436 g/s. Similarly, the actual emission rate for

the turbulent areas is (1.684283 g/s ÷ 2.020521 g/s) x 0.2619 g/s = 0.2183 g/s. This source-strength apportionment was necessary to support subsequent dispersion modeling efforts for assessment of off-site H_2S impact.

Use of Measured Vertical Dispersion Coefficients

Tables 2 and 3 present the sigma-z calculations based on the CF_4 and SF_6 data, respectively.

Table 2 - Sigma-z Calculations Based on Carbon Tetrafluoride Data

Event	Meteorology			CF_4 Conc. (g/m^2)	Q (g/s)	Initial σz @ 22.3m (m)	Adjusted Downwind Distance (m)	Plume-Capture Adjustment		
	10m WD (°)	10m σθ (°)	1m WS (m/s)					Plume Capture (%)	Adjusted CF_4 Conc. (g/m^2)	Final σz (m)
169, 70	181	13.7	2.9	0.00767	0.0380	1.36	22.3	100.0	0.00767	1.36
171, 72	199	17.3	2.4	0.00748	0.0380	1.68	23.6	100.0	0.00748	1.68
173, 74	210	14.1	2.2	0.00690	0.0380	1.97	25.8	100.0	0.00690	1.97
175, 76	206	17.0	2.2	0.00691	0.0380	2.00	24.8	100.0	0.00691	2.00
177, 78	184	8.0	2.6	0.00667	0.0380	1.75	22.4	100.0	0.00667	1.75
179, 80	187	8.3	2.9	0.00657	0.0380	1.61	22.5	100.0	0.00657	1.61
181, 82	184	9.2	2.5	0.00550	0.0380	2.20	22.4	100.0	0.00550	2.20
183, 84	181	9.8	2.2	0.00485	0.0380	2.85	22.3	100.0	0.00485	2.85

Table 3 - Sigma-z Calculations Based on Sulfur Hexafluoride Data

Event	Meteorology			SF_6 Conc. (g/m^2)	Q (g/s)	Initial σz @ 46.9m (m)	Adjusted Downwind Distance (m)	Plume-Capture Adjustment		
	10m WD (°)	10m σθ (°)	1m WS (m/s)					Plume Capture (%)	Adjusted SF_6 Conc. (g/m^2)	Final σz (m)
169, 70	181	13.7	2.9	0.01657	0.1087	1.80	46.9	100.0	0.01657	1.80
171, 72	199	17.3	2.4	0.01460	0.1087	2.46	49.6	100.0	0.01460	2.46
173, 74	210	14.1	2.2	0.01497	0.1087	2.59	54.2	97.1	0.01542	2.52
175, 76	206	17.0	2.2	0.01340	0.1087	2.95	52.2	99.5	0.01347	2.94
177, 78	184	8.0	2.6	0.01268	0.1087	2.64	47.0	100.0	0.01268	2.64
179, 80	187	8.3	2.9	0.01416	0.1087	2.14	47.3	100.0	0.01416	2.14
181, 82	184	9.2	2.5	0.01172	0.1087	2.96	47.0	100.0	0.01172	2.96
183, 84	181	9.8	2.2	0.00763	0.1087	5.19	46.9	100.0	0.00763	5.19

Initial sigma-z (σ_z) values in Tables 2 and 3 are presented for each 15-minute monitoring event based on the crosswind-integrated form of Turner's equation solved for sigma z (Equation 2) and assuming that the wind is perpendicular to the beam path (i.e., from plant south or 180º).

Based on the departure of mean (actual) 10-meter wind direction from normal, adjustments were made to the distances downwind of the tracers at which each sigma-z value applies. This was accomplished by dividing the normal downwind distances of the tracers (22.3 and 46.9 meters) by the cosine of the absolute value of the difference between the mean wind direction and 180º.

Plume-capture of the tracer gases was assessed by modeling selected events using actual meteorology. Plume-capture adjustments were made, as required, to account for the fact that the FTIR beam was not always long enough to capture the outer edges of the tracer plumes owing to the departure from normal of the mean wind direction and to horizontal dispersion. Incomplete plume capture occurred most often for SF_6, as this was the tracer released furthest upwind.

Plume-capture assessment required appropriate treatment of atmospheric stability (i.e., horizontal and vertical dispersion) in the model. For CF_4, this involved use of the horizontal and vertical dispersion coefficients based on the P-G stability class as determined for each event using the sigma-theta method. For SF_6, this also involved use of the horizontal and vertical dispersion coefficients based on the P-G stability class; however, in this case, the P-G stability class was assigned to each event using the CF_4-based sigma-z data (vs. the sigma-theta method), as it utilized measured vertical dispersion coefficients across the source. The model was then configured to predict concentrations at every meter along the beam path (and along appropriate beam-path extensions), and plume-capture estimates were made for each event by dividing the path-averaged concentration along the beam by the path-averaged concentration along the entire crosswind direction of the plume.

Adjustments were made to the CF_4 and SF_6 concentrations for each event simply by dividing the measured value by the percent plume capture.

Final sigma-z values were calculated for each event by substituting the adjusted concentration (CF_4 or SF_6) into Equation 2.

Table 4 presents the derivation of event-specific sigma-z curves for substitution into the model used for H_2S emission-rate back-calculation. These curves were developed using the CF_4 and SF_6 data, and are specifically limited to the region across the preliminary settling tanks.

Table 4 - Derivation of Event-Specific Sigma-z Curves

Event	Sigma-Z Data					
	CF_4-Based (m)		SF_6-Based (m)		Coefficients ($y=ax^2+bx$)	
	Value	Distance	Value	Distance	a	b
169, 70	1.36	22.3	1.80	46.9	- 0.000919	0.081480
171, 72	1.68	23.6	2.46	49.6	- 0.000830	0.090783
173, 74	1.97	25.8	2.52	54.2	- 0.001051	0.103485
175, 76	2.00	24.8	2.94	52.2	- 0.000888	0.102660
177, 78	1.75	22.4	2.64	47.0	- 0.000892	0.098116
179, 80	1.61	22.5	2.14	47.3	- 0.001061	0.095428
181, 82	2.20	22.4	2.96	47.0	- 0.001432	0.130299
183, 84	2.85	22.3	5.19	46.9	- 0.000697	0.143342

The final CF_4- and SF_6-based sigma-z values and adjusted downwind distances (from Tables 2 and 3, respectively) are presented in Table 4 for each event. Also presented are the coefficients ("a" and "b") from the second-degree polynomial ($y = ax^2 + bx + c$) used to represent each curve, where "y" equals the sigma-z value at some downwind distance "x," and "c" is set equal to zero.

A second-degree polynomial was identified as the equation of choice, as it represents the simplest function which can be constructed to pass through the three known points on the curve (the origin and the two sigma-z measurement points). Because this function is used only to support the emissions back-calculation, we chose this strictly empirical approach to represent vertical dispersion within the very limited region between the upwind edge of the source and the downwind emissions-assessment measurement path. This avoids the need to address complex dispersion modeling issues and associated theoretical assumptions about the shape of the curve within this region.

Parameterization of sigma-z for modeling purposes is generally accomplished using an approach which applies some type of power law equation to an array of observed measurements at distances between several hundred meters and a few kilometers downwind of a source. Such representations yield sigma-z curves which are concave in form in order to take into account the fact that sigma-z must always increase with downwind distance.

In contrast, for all monitoring events shown in Table 4 (and for all but 2 of the 77 for the entire program), the curve is convex as evidenced by the sign of the "a" coefficient in the equation. Second-order polynomials having a negative "a" coefficient must, at some downwind distance, have a maximum beyond which the sigma-z value actually decreases with downwind distance. Nearly all of the 77 valid events occurred during a sea breeze situation, including the 8 events presented in these tables. The observed sigma-z data provides overwhelming evidence of the

role of mechanically induced turbulence over the preliminary settling tanks in this very stable sea breeze regime. This phenomenon, not accounted for in the model's extrapolation of sigma-z curves to downwind distances less than 100 meters, is clearly evidenced by CF_4-based sigma-z values which are large compared to the SF_6-based sigma-z values (and by the corresponding form of the resultant second-order polynomial).

Table 5 presents emission-rate determinations for the preliminary settling tanks using measured vertical dispersion coefficients.

Table 5 - Emission-Rate Determinations for the Preliminary Settling Tanks Using Measured Vertical Dispersion Coefficients

Event	Unity ISCST3 Analysis		Meteorology				Measured Source Attrib. (g/m^2)	Actual Emission Rate (g/s)		
	Emission Rate (g/s)	Predicted Source Attrib. (g/m^2)	10m WD (°)	1m WS (m/s)	P-G Stab. Class	Temp. (°K)		Quiescent Areas	Turbulent Areas	Total
169, 70	2.020521	0.250658	181	2.9	E-F	302.9	0.0135936	0.0182	0.0913	0.1096
171, 72	2.020521	0.236499	199	2.4	E-F	303.0	0.0132030	0.0188	0.0940	0.1128
173, 74	2.020521	0.234533	210	2.2	E-F	303.0	0.0128387	0.0184	0.0922	0.1106
175, 76	2.020521	0.220854	206	2.2	E-F	303.2	0.0075912	0.0116	0.0579	0.0694
177, 78	2.020521	0.222234	184	2.6	E-F	303.2	0.0142833	0.0216	0.1083	0.1299
179, 80	2.020521	0.221378	187	2.9	E-F	302.8	0.0113557	0.0172	0.0864	0.1036
181, 82	2.020521	0.204321	184	2.5	E-F	303.0	0.0109493	0.0180	0.0903	0.1083
183, 84	2.020521	0.160049	181	2.2	D	303.2	0.0066867	0.0140	0.0704	0.0844

All calculations in Table 5 are performed in a manner identical to those shown in Table 1. However, the predicted unity-based source attribution was obtained by running the ISCST3 Model with the above source strengths and configurations for the actual meteorology presented. This included incorporation of a new subroutine into the ISCST3 Model to allow for emissions calculation based on the event-specific sigma-z curves.

As discussed earlier, the P-G stability class (assigned using the CF_4-based sigma-z data) was required for treating horizontal dispersion in the model.

Table 6 presents the emission-rate reduction based on employment of site-specific sigma-z curves for the preliminary settling tanks.

Table 6 - Emission-Rate Reduction Based on Employment of Site-Specific Sigma-z Curves

Event	Emission Rate (g/s)		Emission-Rate Reduction (%)
	Traditional σ_z Treatment	Site-Specific σ_z Curves	
169, 70	0.2619	0.1096	58.2
171, 72	0.3146	0.1128	64.1
173, 74	0.2273	0.1106	51.3
175, 76	0.1758	0.0694	60.5
177, 78	0.2477	0.1299	47.6
179, 80	0.2218	0.1036	53.3
181, 82	0.1826	0.1083	40.7
183, 84	0.0977	0.0844	13.6
Average	**0.2162**	**0.1036**	**52.1**

For the events shown in Table 6, the reduction in emissions realized by the employment of site-specific sigma-z curves averaged 52.1%, and ranged from 13.6 to 64.1%. Although not depicted here, the average reduction over all 77 events was 52.5%, and the range was 13.6 to 69.7%.

METHODOLOGY FOR ASSIGNING FACILITY-WIDE H_2S EMISSIONS

As discussed earlier, facility-wide H_2S emissions inventories had to be developed for future operations of the facility as if: (a) all planned upgrade activities have been completed (build scenario); and (b) no upgrade activities have been completed whatsoever (no-build scenario). The following steps were followed so that the emissions inventory assigned under the build scenario could "take credit" for each upgrade component shown to materially reduce H_2S emissions:

- identification of relevant facility conditions and operating practices;
- assessment of upgrade benefit; and
- development of emissions inventories under the build and no-build scenarios.

Identification of Relevant Facility Conditions and Operating Practices

The first step involved identifying those facility conditions and operating practices under which observed H_2S emissions to the atmosphere are maximized, as well as reviewing all available

information which supports and demonstrates these causal relationships. This involved numerous discussions with DEP plant engineers, together with assembly and detailed review of a variety of facility records and data.

This review was not intended to be an exhaustive investigation of H_2S formation during wastewater treatment processes; instead, it was limited to the identification of the most significant facility-specific conditions and practices which result in maximization of H_2S formation and which potentially lend themselves to remedy under the upgrading. These conditions and practices were:

- receipt of septic influent from the Spring Creek combined sewage overflow (CSO) facility;
- difficulty in controlling pumping rates in the high- and low-level wet wells, which can lead to the introduction of increased septic solids to the plant through overpumping;
- preliminary settling tank flow imbalances and structural deterioration;
- problems with removal of sludge and scum from the final settling tanks; and
- difficulties in controlling sludge draw-off from sludge thickeners, which can lead to the formation of scum "blankets" on the tank surfaces.

Each of these conditions and practices was closely examined and appropriately documented over the duration of the investigation. The occurrence of each condition or practice was subsequently correlated with the H_2S emissions observed over each valid monitoring event (all sources).

Receipt of Septic Influent from Spring Creek

The Spring Creek facility is located about 1 mile east of the 26th Ward WTP. It consists of several large CSO holding tanks which regulate wastewater flow to 26th Ward. Wastewater is transferred once a week from Spring Creek through the low-level interceptor. The water level is sufficient to allow the transfer to begin via gravity, but pumping is eventually required as the water level drops. Transfer routinely commences each Tuesday at about midnight. However, in the event of rain, transfer is usually delayed until dry-weather flow conditions are re-established. Wastewater transfer lasts about 7 hours and is followed by tank-bottom rinsing, which generally takes from 4 to 6 hours.

Because no pre-treatment of any type is performed at Spring Creek, the held wastewater quickly becomes septic -- often resulting in the generation of significant amounts of H_2S. Conditions under which H_2S generation is maximized are a dry period, followed by a moderate rainfall which occurs several days prior to transfer. The rainfall after a dry period allows much of the septic solids which have been accumulating in the sewer line to be scoured out and introduced into Spring Creek. The several-day wastewater residence time at Spring Creek (before being transferred to 26th Ward) allows for the occurrence of maximum septic conditions.

The volume of wastewater transferred from Spring Creek can be as much as 10 million gallons. For the 7 hours of transfer, this would correspond to an average flow of 1.4 million gallons per hour or, on a daily-adjusted basis, an hourly flow rate equivalent to about 34 mgd. When compared to 26th Ward's average daily dry-weather flow volume of about 62 mgd, it is evident that the Spring Creek contribution is significant.

The rinsate water accounts for another 2 or 3 million gallons of flow to 26th Ward. However, its contribution to the total facility flow is less, as this volume is spread out over 4 to 6 hours (hourly flow rate equivalent to about 12 mgd).

Start times and end times of all Spring Creek transfers which occurred during the investigation were carefully reconstructed from review of plant logs and records and discussion with plant engineers.

Wet-Well Overpumping

Wastewater is conveyed to the plant through two interceptor sewers. The low-level interceptor handles about two-thirds of the total plant flow, and the high-level interceptor handles the remainder.

Wastewater from each interceptor passes through screening chambers before entering the two large pits (wet wells). One wet well serves each pump station (high- and low-level). During weekdays under dry-weather flow conditions, pumping is routinely increased in the early mornings and early evenings to coincide with a flow increase characteristic of weekday residential activity. Pumping is also increased during times of significant rainfall. Under dry-weather flow conditions, nighttime operation of the high-level pump station is generally not required; during such times, the high-level flow is diverted to the low-level wet well.

It is very difficult to control the water level in the wet wells. All pumping is currently performed manually using step-speed, dry-pit centrifugal pumps, thereby precluding the ability to precisely control the pumping rate (and, hence, the wet-well water levels). If the wells are allowed to overflow, the screening chamber area flood. If there is too little water, the pumps will become airbound and subject to possible damage.

When water is pumped too fast, large amounts of septic solids (which typically accumulate in the bottom of the wet wells and adjacent portions of the interceptor networks) may become dislodged over a very short time period and be introduced into the plant, thus causing sharp spikes of H_2S emissions. This is most likely to occur when wet-well water levels are low. Release of H_2S caused by overpumping can be especially significant after a prolonged dry period when large amounts of septic solids have had the opportunity to accumulate.

The hourly change in pumping rate over the duration of the investigation was tabulated based on detailed review of the daily plant flow logs. Pumping "anomalies," defined as a 1- or 2-hour period of increased pumping of at least 11.5 mgd, were identified.

Preliminary Settling Tank Flow Imbalances and Structural Deterioration

Flow imbalances in the preliminary settling tanks are caused by poor performance of the (upstream) influent-distribution system. They prevent achievement of optimum process efficiency, as two of the tanks are consistently overloaded while the other two are underutilized.

These flow imbalances lead directly to increased wastewater detention time (two tanks) which, in turn, allows for a grease-like scum layer to form on submerged surfaces such as tank walls and the cross-collector mechanism. In addition to the scum formation on these surfaces, an increase in the accumulation of septic solids on the tank bottoms can sometimes occur due to the tank overloading, as the solids cannot be removed quickly enough. The scum and septic solids can each be a significant source of H_2S emissions.

Structural deterioration of the preliminary settling tanks has progressed to the point where overall operating efficiency has become compromised. There are several large sections of tank-bottom surface which have become uneven, and these also act to accumulate H_2S-emitting septic solids as the cross-collector mechanisms cannot reach them.

Once a year, on a rotating basis, each of four tanks is emptied and undergoes routine maintenance. At that time, the cross-collector mechanisms are cleaned, and the scum layer (which falls from the walls and other surfaces as as the water level drops) is removed together with the accumulated septic solids from the tank bottoms. Tank cleaning is also performed whenever emergency repair is required.

The history of tank cleaning and cross-collector mechanism repair was reconstructed over the duration of the investigation.

Problems With Removal of Sludge and Scum From the Final Settling Tanks

The sludge-collection/return system for the final settling tanks often does not function properly because the syphons which handle the sludge draw-off from the tank bottoms cannot be adjusted. This can lead to excessive residence times in the system, thus resulting in increased H_2S emissions during those times when solids loading is significant. Sludge cascading over the telescoping valves in the center of the syphons can also result in increased emissions.

Problems also exist with the adjustable, open scum-collection channels (located along the western end of each set of tanks) which are intended to serve as conduits for the removal of scum from the tank surfaces. Due to their poor condition, these channels, which actually consist of a series of rotating pipes with weirs, are frequently mispositioned with respect to the water level, thereby causing the floating scum to remain on the tank surface. This floating scum can, at times, be a source of H_2S emissions (within an otherwise relatively insignificant source).

In addition to the potential for emissions from floating scum, minor localized emissions can also occur from the scum-collection channels themselves. The periodic, non-operational nature of the channels leads to stagnation of the trapped wastewater which can quickly become septic.

The increase in H_2S emissions from this source was evidenced by virtue of the hot-spot data collected.

Formation of Scum Blankets on Sludge Thickener Tank Surfaces

Proper operation of the sludge thickeners requires that a balance between sludge accumulation and draw-off be carefully maintained at all times. If too much sludge is allowed to accumulate in the tanks, high H_2S-emitting scum "blankets" can form on the tank surfaces. On the other hand, if the sludge is drawn off from the tank bottoms too fast, the sludge digestion process will be compromised as the solids content of the sludge will be too low.

Sludge draw-off is currently performed manually; as a result, a consistent balance between sludge accumulation and draw-off is very difficult to maintain. Sludge accumulation is dependent upon wastewater flow and solids content, and a wide variation in these factors is normally encountered during typical operating conditions.

Increased H_2S emissions from the sludge thickeners result mainly from the lack of proper instrumentation to maintain this balance between sludge accumulation and draw-off. Even though factors such as wet-well overpumping and Spring Creek wastewater transfers result in increased sludge loading to the thickeners, the tank capacity for this facility is more than adequate. Accordingly, only when the balance between sludge accumulation and draw-off is compromised would one expect to see significantly increased emissions.

The increase in H_2S emissions from this source was evidenced by the existence of a scum blanket on the surface of one or more of the thickener tanks.

Assessment of Upgrade Benefit

The second step in assigning facility-wide H_2S emissions involved assessing how such emissions will be reduced by implementation of the upgrade itself. In the context of the facility conditions and operating practices under which observed H_2S emissions to the atmosphere are maximized (discussed above), the following upgrade benefits will be realized.

Modification of the Spring Creek Transfer Schedule

The Spring Creek CSO facility operations is being revised such that wastewater transfer will take place immediately after each significant rainfall event, although this is not part of the upgrade *per se*.

Automation of Wet-Well Pumping

The high- and low-level pump stations will be retired under the upgrade, and a new, single pump station constructed. A feature of the new pump station will be the automation of the wet-well pumping using computer-controlled, variable-speed pumps to ensure that proper water levels are maintained at all times, thus eliminating overpumping and associated spikes of H_2S emissions.

Replacement of Preliminary Settling Tanks

Under the upgrade, the four existing tanks will be replaced with six new tanks, including a new scum removal system. This will eliminate the excessive scum and septic-solids build-up, and will reduce the H_2S emissions.

Upgrade of Sludge- and Scum-Removal Systems for the Final Settling Tanks

Under the upgrade, the existing sludge- and scum-removal systems will be replaced by fully automated systems. Positioning of the scum-collection channels will be performed automatically, and the syphons will be replaced by a series of higher-efficiency pumps, thus eliminating periodic H_2S excursions.

Automation of Sludge-Removal System for Sludge Thickeners

Under the upgrade, an automated sludge-removal pumping system will be installed. This system will include sensors to detect the formation of scum blankets, in which event the rate of sludge draw-off will automatically be increased thus eliminating periodic H_2S excursions.

Emissions Inventories Under the Build and No-Build Scenario

Table 7 presents the H_2S emission rates to support the build and no-build scenarios for all sources based on the field-measurement data.

Table 7 - H_2S Emission Rates to Support the Build and No-Build Scenarios for All Sources

Source	Emission Rate (g/s)	
	Build Scenario	No-Build Scenario
low-level pump station	0.0069	0.0899
high-level pump station	0.0036	0.0606
preliminary settling tanks	0.1000	0.3507
aeration tanks	0.0013	0.0107
final settling tanks	0.0009	0.0078
sludge thickeners	0.0010	0.0036
sludge storage tanks	0.0712	0.0534

Low-Level Pump Station

Each of the highest daily emission rates for the 5 top-ranked days (9 days of measurements), with one exception, correlated to facility operating conditions and practices to be remedied under the upgrade. Accordingly, the remaining daily emission rates were reflective of the build scenario,

and the highest of these, 0.0069 g/s, was conservatively designated the build-scenario emission rate. The highest of all daily emission rates, 0.0899 g/s, was conservatively designated the no-build-scenario emission rate.

High-Level Pump Station

Emissions from the high- and low-level pump stations generally tracked each other well, as the screening chambers are connected. Following the above logic for the low-level pump station, 0.0036 g/s was designated the build-scenario emission rate, and 0.0606 g/s was designated the no-build-scenario emission rate.

Preliminary Settling Tanks

Following the above logic, the highest daily emission rates for the 6 top-ranked days (9 days of measurements) were reflective of the no-build scenario, as the emissions, in each case, correlated to facility operating conditions and practices to be remedied under the upgrade. The build-scenario emission rate was 0.1000 g/s, and the no-build-scenario emission rate was 0.3507 g/s.

Aeration Tanks

The highest daily emission rate for the top-ranked day (2 days of measurements) was reflective of the no-build scenario, as the emissions correlated to facility operating conditions and practices to be remedied under the upgrade. The build-scenario emission rate was 0.0013 g/s, and the no-build-scenario emission rate was 0.0107 g/s.

Final Settling Tanks

The highest daily emission rates for the 2 top-ranked days (3 days of measurements) were reflective of the no-build scenario, as the emissions, in each case, correlated to facility operating conditions and practices to be remedied under the upgrade. The build-scenario emission rate was 0.0009 g/s, and the no-build-scenario emission rate was 0.0078 g/s.

Sludge Thickeners

The highest daily emission rates for the 6 top-ranked days (15 days of measurments) were reflective of the no-build scenario, as the emissions, in each case but two, correlated to facility operating conditions and practices to be remedied under the upgrade. The build-scenario emission rate was 0.0010 g/s, and the no-build-scenario emission rate was 0.0036 g/s.

Sludge Storage Tanks

The highest individual emission rate (4 days of measurements) for any of the three sludge storage tanks was 0.0178 g/s. The resultant source emission rate for all tanks, 0.0534 g/s (0.0178 x 3 tanks), was conservatively designated the no-build-scenario emission rate.

Although the individual tank emission rates will not be affected by the upgrade, the overall source emission rate will increase by 33 percent owing to the net increase in the total number of tanks (from three to four). The resultant build-scenario emission rate for all tanks was conservatively set at 0.0712 g/s (0.0178 g/s x 4 tanks).

AIR QUALITY COMPLIANCE ASSESSMENT RESULTS FOR H_2S

The ISCST3 Model was used for assessment of maximum H_2S impacts along the site perimeter and throughout the nearby residential community. The decision to use only refined modeling techniques in the impact assessment was made based on the magnitude of H_2S emissions from the preliminary settling tanks together with their close proximity to both the site perimeter and the sensitive-receptor locations.

Under the build scenario, a total of 17 point sources and 126 subareas were modeled, as compared to a total of 6 point sources and 111 subareas under the no-build scenario. The receptor network consisted of 269 discrete receptors (152 sensitive and flagpole and 117 site-perimeter) and 480 gridded Cartesian receptors. A detailed presentation of the modeling strategy, model input parameters, and receptor treatment is beyond the scope of this paper.

Table 8 presents a comparison of maximum combined-source facility impacts with applicable standards for H_2S under the build (upgrade) and no-build scenarios. Also shown are the reductions in maximum impact based solely on the process improvements to be realized under the build scenario.

Table 8 - Comparison of Maximum Combined-Source Facility Impacts with Applicable Standards for H_2S Under the Build and No-Build Scenarios

Receptor Type	Maximum Combined-Source Facility Impact (ppb)		Reduction Under Upgrade (%)	Applicable Standard (ppb)
	No-Build Scenario	Build Scenario		
Sensitive	947.4	91.5	90.3	1
Site-Perimeter	2447.6	111.5	95.4	10

Sensitive Receptors

The maximum sensitive-receptor impact from the facility was predicted to be 947.4 ppb under the no-build scenario, as compared to a predicted impact of only 91.5 ppb under the build scenario, or a reduction of 90.3 percent. Despite the huge reductions resulting simply from implementing the upgrade, the impact was still more than 90 times the sensitive-receptor standard which indicates that some type of emissions control is required.

Site-Perimeter Receptors

The maximum site-perimeter-receptor impact from the facility is predicted to be 2,447.6 ppb under the no-build scenario, as compared to a predicted impact of only 111.5 ppb under the build scenario, or a reduction of 95.4 percent. Despite the huge reductions resulting simply from implementing the upgrade, the impact is still more than 10 times the site-perimeter-receptor standard which again indicates that some type of emissions control is required.

ASSESSMENT OF ODOR-CONTROL NEEDS

Table 9 presents a comparison of maximum sole-source impacts with applicable standards for H_2S under the build (upgrade) and no-build scenarios. Shaded entries indicated exceedances of the respective standards. It is noted that emission controls for the sludge thickeners and sludge storage tanks are already included within the upgrade itself, thus accounting for the reductions shown for these sources.

Table 9 - Comparison of Maximum Sole-Source Impacts with Applicable Standards for H_2S Under the Build and No-Build Scenarios

Source	Maximum Sole-Source Impact (ppb)		Reduction Under Upgrade (%)	Applicable Standard (ppb)
	No-Build Scenario	Build Scenario		
Sensitive Receptors				
pump stations	39.8	0.6	98.5	1
preliminary settling tanks	947.4	91.5	90.3	1
aeration tanks	7.5	0.9	88.0	1
final settling tanks	5.0	0.6	88.0	1
sludge thickeners	3.9	0.4	89.7	1
sludge storage tanks	28.7	0.4	98.6	1
Site-Perimeter Receptors				
pump stations	51.0	0.9	98.2	10
preliminary settling tanks	2447.6	111.4	95.4	10
aeration tanks	15.3	1.8	88.2	10
final settling tanks	7.4	0.9	87.8	10
sludge thickeners	3.9	0.4	89.7	10
sludge storage tanks	36.6	0.2	99.5	10

Based on additional dispersion modeling, it was shown that full compliance with each H_2S standard could be achieved only by covering the entire preliminary settling tanks, treating these emissions with some type of removal system, and routing the treated emissions up a pair of dispersion stacks. However, because these results are conservative for a variety of factors, this method of achieving full compliance may well reflect a significant amount of "over-engineering." Therefore, consideration was given to a variety of compliance options and associated capital and recurring costs.

Until the new preliminary settling tanks are built, the only aspect of the full-compliance upgrade modification certain to be required is the covering of the weir areas. It is not known at this time whether the quiescent areas will need to be covered, or whether the emissions from the covered weirs will even need to be treated (i.e., a pair of dispersion stacks may be sufficient).

For this reason, the following phased approach (consistent with the approach for controlling criteria-pollutant emissions for major stationary-source modifications under the Clean Air Act) was recommended and currently remains under consideration by the DEP:

- Modification of the facility upgrade so that construction of the weir covers and dispersion stacks (two 70-foot stacks) proceeds in tandem with construction of the new preliminary settling tanks, and that such construction allows for the subsequent retrofitting of quiescent-area covers and activated-carbon systems to treat all tank emissions, if required.

- Installation and 1-year continuous operation of an on-site, fully equipped 10-meter meteorological tower.

- Performance of a focused field-measurement study, immediately upon completion of the new preliminary settling tanks, in order to ascertain the need for the above additional controls.

  Such a study would involve the measurement of H_2S emissions from the new tanks (quiescent area plus dispersion stacks), together with dispersion modeling using USEPA's new AERMOD Model and the 1 year of continuous on-site meteorological data to assess compliance with the H_2S standards.

- Issuance of a negative CEQR declaration which is conditional upon: (a) implementation of the above upgrade modification; and (b) the commitment to implement all additional controls as shown to be required to achieve full H_2S compliance based on results of the additional studies as described above.

Finally, implementation of this interim upgrade modification delays, and possibly eliminates altogether, the need for large capital expenditures. Also, covering the quiescent areas would create a large, hazardous, confined-space work environment, and any potential for eliminating the need to cover these areas should be aggressively pursued.

CONCLUSIONS

A facility-wide H_2S emissions-estimation methodology was employed over a range of plant operating regimes to facilitate development of a conservative representation of the build-scenario emissions. This representation "takes credit" for each upgrade component shown to materially reduce H_2S emissions to the atmosphere. In this manner, the chances of emissions over-control are minimized.

This methodology was selected because of the inherent spatial representativeness of the emissions data generated, as well as its ability to provide numerous emission-rate "snapshots" in any given measurement day.

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