Collection System Ventilation

Concern about odor and corrosion in wastewater collection systems has been escalating as prevention and control costs increase, collection systems age, and revenues decline. While there is some understanding of the causes of odorous gases and their deleterious impact in collection systems; the underlying science and mechanisms of odor generation, prevention, and control is lacking. This research study was the second in a three-phase project to address these issues.

Upstream manhole at North Seattle.

Phase I was an extensive review of over 4,000 published technical abstracts and literature supplied by utilities, manufacturers, and vendors. It resulted in a single, less technical guide to address odor and corrosion in collection systems which explained how odor- and corrosion-causing compounds form and how to control them; provided information on odor-sampling methods; and identified highest priority research needs. This second phase of the project investigated the effectiveness of sewer ventilation as a method to control odors. Phase III, drew from the prior two phases to develop a web-based tool which provides guidance to utility managers and operators on strategies for how to control odors.

Sewer Ventilation Research

The purpose of this second phase study was:

- To measure air ventilation within full-scale gravity collection system components.
- To simultaneously measure parameters related to ventilation.
- To use the field experimental results to evaluate current ventilation models.
- To develop a concept for an improved ventilation model.

Field experiments were conducted at four different locations within the Los Angeles, California and King County, Washington wastewater collection systems. Sewer components included concrete gravity pipes ranging in diameter from 33-96”. The locations represent a set of full-scale gravity collection system components of varied length, slope, and diameter. The experiment used carbon monoxide tracer measurements. At each location, pure carbon monoxide gas was injected at the upstream end of the gravity sewer, and the concentration was measured at the downstream end. The time difference between each pulse tracer release and corresponding downstream concentration peaks was used to determine the average headspace air velocity during the travel time.

A stand pipe and hotwire anemometer arrangement was used to measure air entering or exiting the sewer components. Ambient wind speed, temperature, and relative humidity; headspace temperature and relative humidity; and wastewater flow and temperature were measured with information recorded continuously using data loggers. The field experiments resulted in a large database of measured ventilation and related parameters characterizing ventilation in full-scale gravity sewers. The field data were used as input to three current ventilation models to evaluate their accuracy compared to the measured field data. Strengths and weaknesses of each model are summarized in Table 1. Observations from the study were then used to develop a concept for an improved ventilation model based on conservation of momentum equations in connected collection system components.

BENEFITS

- Provides a database that can be used to understand collection system ventilation.
- Demonstrates field measurement techniques that can be used to characterize ventilation in a range of different collection system components.
- Shows how various forces influence collection system ventilation.
- Provides an understanding of the strengths and weaknesses of current ventilation models.
- Provides scientific basis to develop future modeling tools to predict sewer ventilation.
- Proposes new ventilation model that can be superior to current models.

RELATED PRODUCTS

Minimization of Odors and Corrosion in Collection Systems: Phase I (04CTS1)

Collection System Odor and Corrosion Study Tools and Database: Phase III (04CTS1AT)

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Table 1. Strengths and Weaknesses of the Three Ventilation Models.

Model	Strength	Weakness
Empirical	Most accurate of the models evaluated (average relative error = 103%) Easy to use	Tends to overpredict Does not reflect real-world variation Does not consider influences other than liquid drag
CFD	Easy to use Amenable to improvement by additional CFD simulations with expanded set of boundary conditions	Tends to overpredict Low accuracy (Average relative error = 173%) Does not reflect real-world variation Does not consider influences other than liquid drag
Thermo-dynamic	Most accurate where buoyancy was an important factor Based on fundamental physical principles Accounts for range of influences in addition to liquid drag	Unacceptable error related to difficulty in estimating heat transfer from air to ground (Average relative error = 3,400%) Difficult to apply May overpredict

Major Findings

- The evaluation showed that existing models were not quite accurate – primarily due to their approach of modeling sewer components in isolation. Much of the measured variation (which the models failed to reflect) appears to be caused by forces outside the system, as indicated by upstream and downstream pressure.

- An improved model was proposed to estimate sewer ventilation based on conservation of momentum. This approach is similar to the thermodynamic model in that it relies on fundamental physical principles. However, it has the advantage that each of the terms in the momentum equation is similar in magnitude and directly relevant to air movement. The proposed model requires a drag coefficient to characterize forces at the air–water interface. However, experiments are still needed to determine drag coefficients with interference from fewer variables than were present in this project. The improved model accounts for all the forces acting on air within the headspace of a gravity collection system component. The approach could be adapted to other components, and ventilation in multiple components could be solved simultaneously in a network model. Such a network model, with the proposed momentum equation at the core, would represent a significant improvement over current modeling technology.

- A method was developed to rigorously measure ventilation into, out of, and within collection system components with only moderate expense. The method was successfully applied at four locations, and is suitable for use in calibrating ventilation models or for other applications where an accurate measurement is needed.

- Existing models may have inadequate predictive accuracy, depending on the application. The most accurate of the models evaluated, the empirical model, had a relative error across all data points that averaged 103%. Based on the results of this study, the empirical model should be considered a screening tool, with the understanding that variability of ventilation in real collection systems may be much greater than model-predicted variability.

- Ventilation within a single gravity collection system component may be influenced as much by forces upstream or downstream of the component as by forces within the component. Although air moved consistently downstream at all four locations, measured upstream–downstream pressure gradients were sometimes reversed. This implies serious limitations when modeling individual collection system components in isolation. A more appropriate approach (though one that has yet to be developed) would be to model collection system headspaces as a network of interconnected components.

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The research on which this report is based was funded in part by the U.S. Environmental Protection Agency (U.S. EPA) through Cooperative Agreement No. CR-83155901-1 with the Water Environment Research Foundation (WERF). Unless an U.S. EPA logo appears on the cover, this report is a publication of WERF, not U.S. EPA. Funds awarded under the agreement cited above were not used for editorial services, reproduction, printing, or distribution.

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