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Model assessment of odour and corrosion in sewer network

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Summary of key findings

An integrated model solution has been developed enabling the modelling of entire cities sewerage networks including hydraulics and water quality processes in order to identify areas with increased risk of formation of hydrogen sulphide odour and corrosion.

The state of art in H_2S modelling is models based on the Wastewater Aerobic/anaerobic Transformations in Sewers (WATS) conceptual model /1/ The fact that the WATS model is integrated with a hydraulic and advection-dispersion model provides an efficient, reliable, accurate, highly detailed, and cost-effective desktop analysis method supporting diagnostic simulations, simulation of future development scenarios and mitigation strategies, and visualisations of critical areas.

As such a clear cause and consequence of corrosion and odour risks due to changes in water and pollution loads, operation strategy, and future system developments can be established and used in developing cost effective mitigation options involving i.e. chemical dosing and changed pump operation to prevent the formation of hydrogen sulphide.

The described model solution enables water utilities, local and national authorities, universities and research institutions, and consultants to better manage and control the hydrogen sulphide formation in a complex and highly dynamic sewerage networks. Additionally, the model solution is developed in an open modelling framework providing i.e. universities and research institutes full flexibility to reconfigure or add biological and chemical processes and state variables.

Background and relevance

The formation of hydrogen sulphide (H_2S) is a serious a problem that affects large areas of a typical sewerage system all over world.

The corrosion of material can require premature repair or replacement of concrete pipes, manholes, wet wells, pumping stations, pumps, wastewater treatment plant (WWTP) facilities, and ductile iron force mains. Globally, costs related to the mitigation of corrosion damages exceed approximately 50% of the overall sewer rehabilitation costs.

In addition, hydrogen sulphide frequently causes serious odour nuisances.

Over the last decade odour and corrosion of the sewerage infrastructure in the cities around the world have become an increasing problem due to:

- reduced rainfall or drought conditions in some cities due to climate changes may lead to increased wastewater concentrations
- reduced dry weather flow partly due to water saving programmes and rehabilitation of sewer network limiting the I/I may lead to increased wastewater concentrations
- increased urbanization causing higher wastewater loads to the network
- centralised wastewater treatment increasing the need for pumping in long rising mains resulting in higher retention times and anaerobic conditions
- changes in characteristics of water source in water supply i.e. leading to higher sulphate content
- high organic industry wastewater point loads

In order to tackle these problems an integrated reliable modelling approach of the odour and corrosion issues in the sewerage network is required by many Water Utilities. The state of modelling concept for modelling H_2S is the WATS model. The request for assessing the risk of H_2S formation by WATS in sewer network has even been written into some cities Sewer Design Manual.

Results

The WATS model is a conceptual model designed for predicting the hydrogen sulphide production in gravity sewers and rising mains. As such the WATS model can simulate both the aerobic and anaerobic processes as wells as the transition between the states.

The hydraulic model represents the state of art hydrodynamic model for simulations of unsteady flows in pipe networks with alternating free surface and pressurised flow conditions. The computation is based on an implicit, finite difference numerical solution of basic 1-D, free surface flow equations (Saint Venant). The implemented algorithm provides efficient and accurate solutions in multiply connected branched, looped pipe networks, pump schemes and rising mains. The waste water loads to the model is described by connection point, load type, and diurnal and seasonal variation. The simulated water levels and discharges are used as input to the advection-dispersion equations for transporting the substances i.e. COD.

By integrating the hydraulic and advection-dispersion model with the WATS model provides a powerful platform for studying the dynamic behaviour of hydrogen sulphide formation in city wide complex sewerage networks. It complements traditional field investigations and improves overall efficiency, reliability and costs of proposed mitigation measures.

A calibrated hydrodynamic sewer network model extended with WATS includes:

- the simulation of pollutant transport by advection-dispersion,
- dissolved oxygen depletion and reaeration,
- hydrogen sulphide formation,
- hydrogen sulphide release into the sewer air phase.

The hydrogen sulphide-related processes are simulated by the integrated model in all of the model's computational grid points. The relevant hydraulic parameters and actual sewage properties used by the WATS model individually in each grid point are provided by the hydrodynamic and transport models. This results in realistic and accurate process dynamics due to the use of location specific information for time-varying sewage flows and key properties such as pH, temperature and organic matter contents, pumping schedules, prolonged detention times in wet wells and other in-line storages and rising mains during low flow periods.

External control of the WATS model parameters allows the hydrogen sulphide formation process to be controlled beyond the default model operation, making it possible to calibrate the model based on sewage temperature, pH, COD, SO_4 and hydrogen sulphide measurements. All this creates an unprecedented level of detail and accuracy when studying hydrogen sulphide in large and complex sewerage networks. The integrated model implementation has further been extended to include the formation of H_2S in wet wells caused by the detention time.

For the assessment the integrated model output contains both numerical and graphical elements, including user-defined tables with extreme values of relevant variables, time series graphs and detailed spatial result maps of the sewer network. The detailed spatial result maps can illustrate the level of hydrogen sulphide, the amount of hydrogen sulphide released to the air, dissolved oxygen concentrations, and retention times.

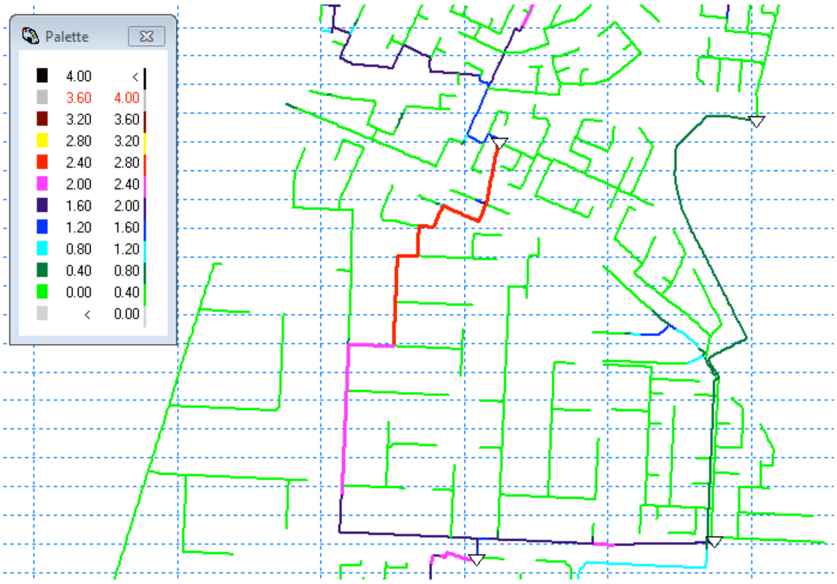

Figure 1.1 Example - Overview over max concentrations of HS in sewage (mg/l) in sewer network

Animation of the different result maps supports the fully understanding of the process dynamics throughout the simulation period.

Additionally, the integrated model solution has been extended with simulation of selected chemicals dosing for H_2S removal either by precipitation or inhibition. Simulations of dosing of nitrate and iron salt based chemicals are supported and can be used to assess advanced dosing strategies to both prevent H_2S formation and facilitate its removal. This ensures a reliable means for identifying an optimal city-wide mitigation strategy including selection of dosing facility locations, chemicals and injection profile, dosing facility installation costs, and future chemical costs.

Discussion

The integrated modelling approach provides an accurate, highly detailed and cost-effective diagnosis of actual hydrogen sulphide-related risks. It establishes clear causes and consequences of corrosion and odour risks due to changes in water and water quality parameter loads, operation strategy, and future system developments for developing a cost-effective mitigation strategy. As such the modelling approach support model assessment of various dosing strategies by nitrate and iron salt based chemicals for optimising the removal of H_2S.

References

Hvidtved-Jacobsen, T, Vollertsen, J, Haaning Nielsen, A. (2013). Sewer Processes. Microbial and Chemical Process Engineering of Sewer Networks, Second Edition, CRS-Press, ISBN: 978-1-4398-8177-4.