THE SEWER CORROSION & ODOUR RESEARCH (SCORE) PROJECT

Delivering outcomes to the water industry

R Rootsey, Z Yuan

Abstract

Optimal corrosion and odour management has been hindered by limited understanding of several key in-sewer processes contributing to the problems, as well as a lack of tools and reliable technologies to support strategic decisions and cost-effective sewer operations. A major step forward to fill in the above gaps is being taken in Australia with a $20 million collaborative research project funded by the Australian Research Council Linkage Program, called the Sewer Corrosion & Odour Research (SCORe) Project.

In this paper, the state-of-the-art knowledge and practice based on both published and grey literature is reviewed and key knowledge gaps and challenges to be addressed in the SCORe Project are identified. Some of the early findings from this initiative are presented.

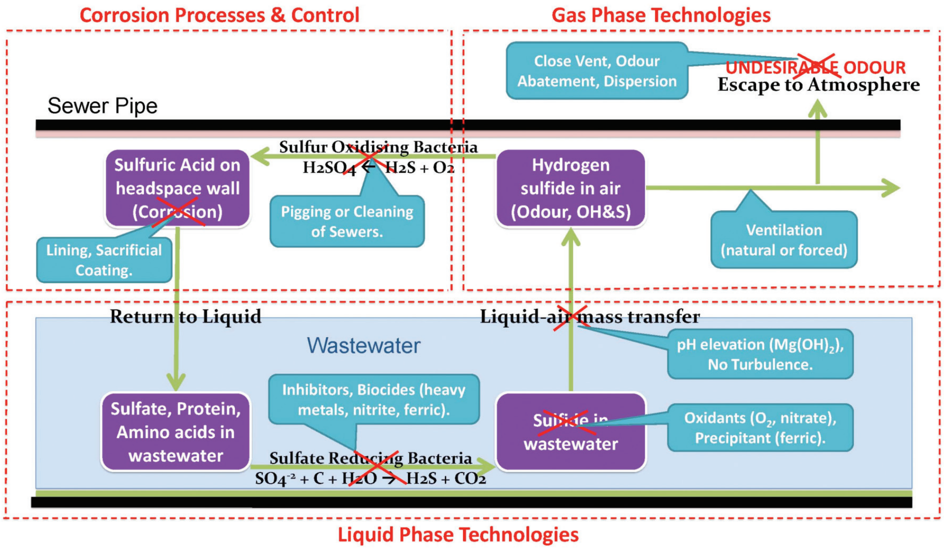

Figure 1: Odour and corrosion processes and control methods in a sewer.

Introduction

Odour and corrosion in sewers has often been taken as a *fait accompli*, with sewer vents being closed if odour problems occur and the odours vented elsewhere in the system or at the inlet to the wastewater treatment plant. However, odour problems persist and the value of public assets is being diminished by hundreds of millions of dollars each year in Australia alone as a result of corrosion problems, with concrete sewer pipes estimated to corrode at an average rate of 1–3mm a year.

The generation of hydrogen sulfide (H_2S) has long been known to be a major cause of corrosion and odour problems in sewer systems (Latham, 1873; Pomeroy, 1946). When anaerobic conditions prevail in a sewer system, sulfate present in the wastewater is reduced to sulfide by sulfate-reducing bacteria residing in biofilm on the walls of the pipelines. This results in the emission of H_2S to the sewer atmosphere, causing odour and corrosion problems in partially full pipe sections, manholes, vent pipes and other places in contact with air. Rising mains, which operate with a full flow under anaerobic conditions, contribute considerably to H_2S production in a sewer system.

Development of fundamental scientific knowledge of sewer processes has been limited since the publication of the *Hydrogen Sulphide Control Manual* in 1989. The Pomeroy algorithms for predicting sulfide generation in sewers, which were first developed in 1946 and later improved by Thistlethwayte (1971) and Pomeroy and Parkhurst (1976) before being published in the *Hydrogen Sulphide Control Manual*, are still commonly used by industry (see Shammay 2010) for the prediction of sulfide generation in sewers.

New Drivers

It is no accident that Australia has traditionally been at the forefront of odour and corrosion research (Parker, 1945). Odour and corrosion problems are generally exacerbated in Australia by the hot climate as well as relatively flat coastal terrain with low population densities, resulting in long rising mains being employed. In addition, the coastal catchments often have sandy soils with a high potential for intrusion of sulfate-rich seawater. In Australia, separate wastewater and stormwater systems are employed (for sound economic and environmental reasons) rather than combined systems, as is the case in most of Europe. This results in higher concentrations of pollutants in the wastewater system, which are then more prone to generate odour and corrosion.

There has been heightened interest in the management of odour and corrosion in sewers in recent years for a number of reasons:

1. Sewer systems are being extended to fringe populations around the major cities (Shammay, 2010), with ever-increasing size of the collection systems, greater dependency on the pumping of sewage and, hence, greater generation of sulfides in the system.
2. Water restrictions and demand management of water supplies are resulting in significantly lower flows and higher concentrations of COD, sulfates and other pollutants. This then produces longer detention times in rising mains and the quicker onset of anaerobic conditions, which cause generation of more H_2S and potentially higher concentrations (due to higher sulfate and/or COD concentrations).
3. Warmer climates over the last decade (IPCC, 2008), which lowers the solubility of oxygen, encourages

the more rapid depletion of the oxygen in the wastewater and stimulates the generation of H_2S by the sulfate-reducing bacteria (SRB).

4. Trade waste regulations have reduced the amount of heavy metals (and other pollutants) that is discharged to sewers, thereby reducing the precipitation of metal sulfides in sewers. Precipitation of the heavy metal sulfide would reduce the H_2S concentration in the sewage. In addition, it is believed that the heavy metals have an inhibitory effect on the microbes responsible for H_2S production.

There do not appear to be any off-setting system changes to reduce the odour and corrosion problems, which from inferred evidence are becoming more severe. In fact, there is a suggestion that odour complaints are increasing due to a lowered tolerance to odours by the general public, which exacerbates the problem further.

Knowledge Gaps

The fundamental processes of odour and corrosion that are covered by the *Hydrogen Sulfide Control Manual*, 1989, are shown in Figure 1. Over the last few decades development of odour and corrosion knowledge has been left mainly to the practitioners, who have applied this knowledge to their specific sewer systems where odours and/or corrosion problems occurred (WERF, 2007).

It is seldom feasible to completely prevent the bacterial biofilm activity that leads to problems in sewers. Control strategies usually focus on H_2S as it is the major primary odorous product of the biofilm, although other odorous compounds such as organic sulfides (mercaptans, dimethyl sulfide, etc) and volatile organic compounds (VOCs – aldehydes, ketones, hydrocarbons, etc) are also a concern in sewers. H_2S is a highly odourous (and poisonous) gas that can be readily detected and exists in aqueous equilibrium as dissolved sulfide ions. The common control strategies for H_2S involve dosing chemicals that either oxidise it to less problematic forms (for example, sulfate), or "lock" it into forms that are not volatile (HS^-/ S^{2-} ions that dominate the equilibrium at alkaline pH, or metal precipitates such as iron sulfide). $H_2S_{(aq)}$ has very low solubility in water and will volatise into the headspace above the wastewater, particularly under turbulent conditions. H_2S in the headspace may be oxidised to sulfuric acid by bacteria which grows on surfaces under moist, aerobic conditions. This sulfuric acid can cause corrosion of concrete, mortar or metal sewer infrastructure. Steel and alloys of copper are readily corroded to flakes of metal sulfide.

Basic knowledge gaps still exist in our fundamental understanding of odours and corrosion, including the following:

- **Corrosion Processes & Control:** The estimation of the corrosion rate and the life expectancy of pipes are very difficult to predict and almost entirely based on empirical data about the past performance of pipes under similar conditions.
- **Gas Phase Technologies:** It is difficult to quantify and characterise odours from sewers without relying purely on costly, problematic and time-consuming human olfactometry systems. In addition, applications of odour abatement systems rely on empirical data with little fundamental understanding of the processes occurring for the removal of the odour.
- **Liquid Phase Technologies:** A lack of understanding of the chemical and biochemical transformations that occur in wastewater, and the impact of variables such as flow velocity, sediments and changes in wastewater composition. This makes it difficult to predict the impact of chemicals commonly used to control H_2S in sewers, such as O_2, NO_3, $Mg(OH)_2$, Fe_2Cl_3, etc. Without closing these knowledge gaps it is not possible to optimise dosing systems for the control of odours in the liquid phase, or to reliably predict the impact of dosing systems on the receiving wastewater treatment plants.

New Approach to Research

Optimal corrosion and odour management has clearly been hindered by limited understanding of several key in-sewer processes contributing to the problems, and the lack of tools and reliable technologies to support strategic decisions and cost-effective sewer operations. By filling in the above gaps, the SCORe Project aims to provide knowledge and technology support to the Australian water industry for cost-effective and efficient corrosion and odour management in sewers.

The size of this problem is reflected in the broad support being provided to the Project by water utilities throughout Australia. There are 11 Industry Partners and five Research Partners. The Project started in late 2008 and will run for five years with a total budget of around $20 million, including the highest ever Linkage Project Grant from ARC to the water industry of $4.7 million.

A new approach is being taken by this project. Field experience is being used to identify problems, which are then mimicked in lab systems to reveal fundamental scientific understanding of odour and corrosion processes under controlled conditions. This new knowledge is being integrated with mathematical models using lab results for calibration. The mathematical models are then being validated with field studies and used to optimise odour and corrosion control systems. This new industry linkage methodology is shown in Figure 2.

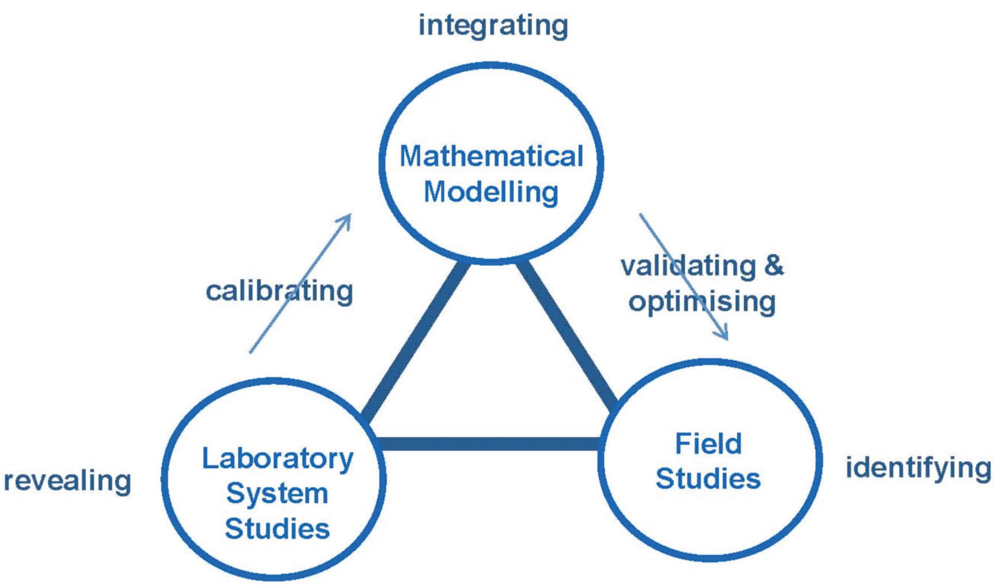

Figure 2: Research methodology for the SCORe Project.

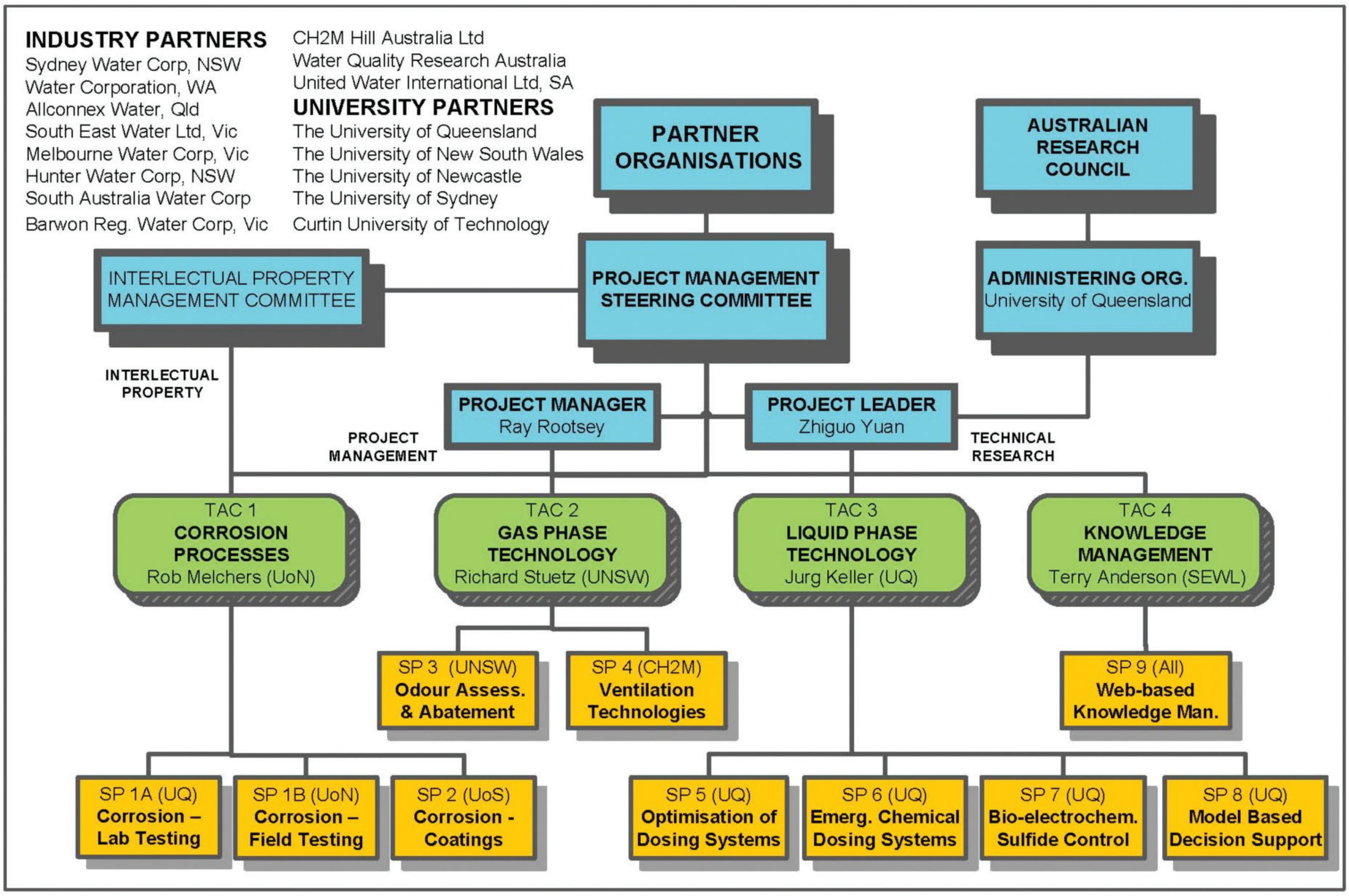

Figure 3: Organisation of the SCORe Project.

The project comprises four themes under which 10 sub-projects are managed (see Figure 3). Each sub-project has a dedicated research team located at one or more research centres around Australia. Each of the four Themes has a Technical Advisory Committee (TAC) comprising Industry and Research Partners. The TACs oversee and guide the sub-projects under their control. The overall project is managed by a Project Management Steering Committee (PMSC), which is made up of one member from each of the 16 Industry and Research Partners. All TACs and the PMSC meet quarterly.

Project Outcomes

The outcomes from this Project will be used to develop a user-friendly decision, support and knowledge management system. This will include a framework with a selection of solutions to problems, case studies and a reference library. Development is in progress with all Partners, and it is proposed that the final system will be available on the Water Services Association of Australia (WSAA) website. The major outcomes proposed from the Project are shown in Figure 4.

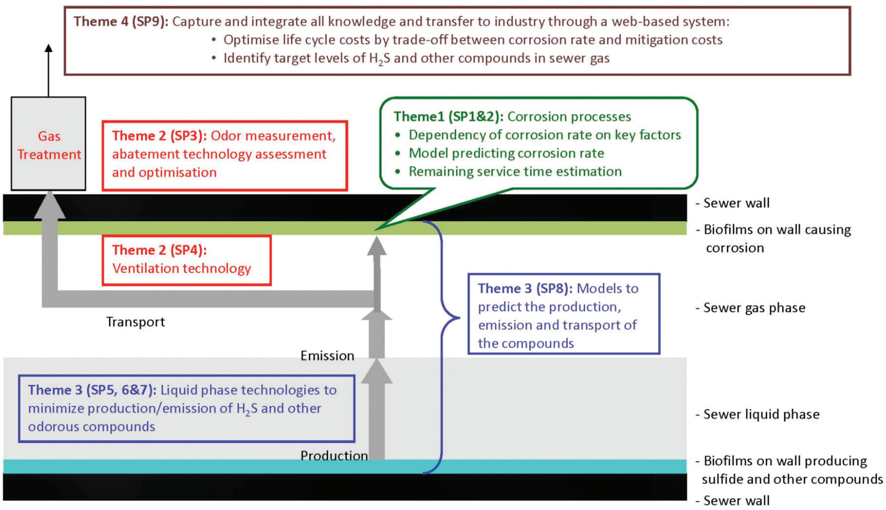

Figure 4: Planned outcomes from the SCORe Project.

Despite being operational for only two years, the Project has achieved many milestones and has been able to provide to Industry Partners many deliverables. Some of the milestones and deliverables achieved to date are listed below:

Theme 1 – Corrosion Processes

- Laboratory corrosion chambers for testing corrosion of concrete coupons under controlled conditions have been developed and are in operation, with coupons being recovered on a six-monthly basis for analysis (see Figure 5a).
- Concrete coupons have been installed in sewers in Sydney, Melbourne and Perth to allow analysis of corrosion processes in the field under various conditions. Coupons are being recovered on a six-monthly basis for analysis (see Figures 5b to 5d).

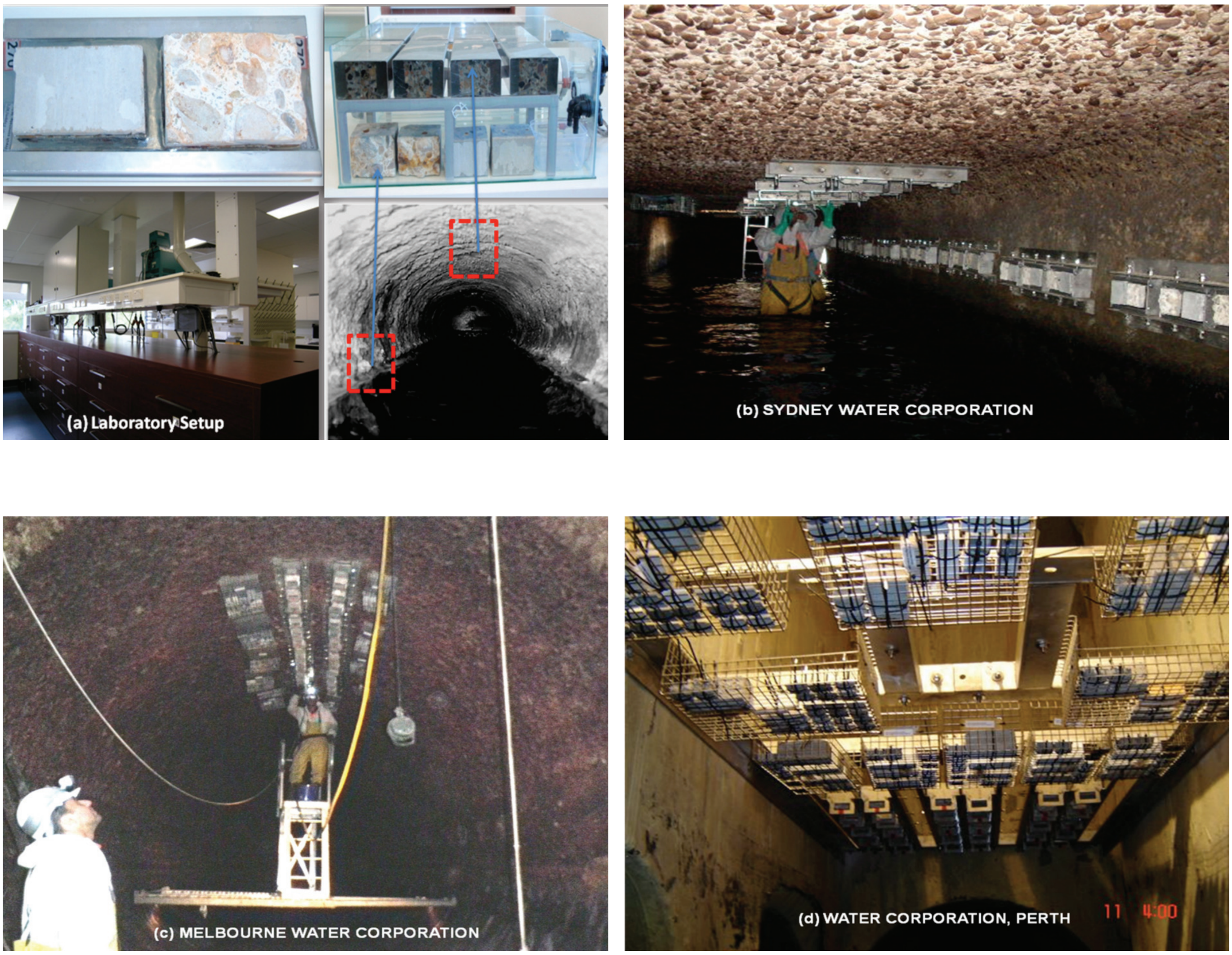

Figure 5: Laboratory corrosion chambers (a) and field corrosion coupon installations (b), (c) and (d).

- Concrete coupons with common internal coating systems have been prepared and installed with the concrete coupons both in the laboratory corrosion chambers and the field sites at Sydney, Melbourne and Perth.
- Standard protocols for the physical, chemical and biological analysis of corrosion processes of concrete and coatings have been established using biological and physical samples from sewers.
- A new understanding of the microbial community contributing to the corrosion of concrete pipes is being revealed through modern gene amplicon sequencing (PyroTags) and phylogenetic analysis.
- A photogrammetric method for measuring corrosion both in the lab and in situ in the field has been developed for rapid and accurate measurement of corrosion.

Theme 2 – Gas Phase Technologies

- An industry survey has been conducted and a report prepared on the methods used by Australian industry for monitoring and analysis of sewer odorants, with recommendations for improvements.
- An industry survey has been conducted and a report prepared on the odour abatement technologies used by Australian industry for control of sewer odours, with recommendations for further research.
- An activated carbon (AC) odour adsorption test rig has been developed and is being used to determine adsorptive capacity and the service life of various AC types.
- A new ventilation model has been developed based on the conservation of momentum and conducted field testing in Adelaide and Perth to verify the model.
- Guidelines have been prepared for the design and evaluation of forced and natural ventilation systems in sewers using the newly developed ventilation model.

Theme 3 – Liquid Phase Technologies

- A sewer laboratory-based reactor, SCORe-CT, using real wastewater and typical diurnal patterns, has been verified and calibrated to simulate a real rising main (based on Gold Coast UC09 pump station), to test the effectiveness and response to chemical dosing for control of sulphide.
- A literature review has been conducted of new and emerging biochemical products that are available for odour control in sewers and a report prepared with recommendations of products to be tested under laboratory conditions. Testing of three of these products has been completed.
- An industry survey has been conducted on the chemical dosing systems used

by industry to control odour and this information has been used to select chemicals to be studied further in this Project to optimise their performance.

- A fundamental understanding of how popular chemical dosing systems such as oxygen, nitrate, magnesium hydroxide and ferric chloride work has been established through a combination of lab and field testing, and this has been modelled so that bench-top optimisation studies can be carried out for any sewerage system.
- The inhibitory effect of both ferric chloride and nitrite on the generation of both sulfide and methane has been identified. This may significantly reduce the amount of chemicals required to be dosed to control sulfide and methane to acceptable levels.
- Proof of concept for electrochemical control of sulfide in sewers has been demonstrated and a laboratory scale pilot plant is currently being trialled in a sewerage system in the field.
- The sulfide generation model, SeweX, has been enhanced to better reflect carbon transformations and the effect of trade wastes and flow velocity on sulfide generation.
- Training of Industry Partners on the use of the SeweX model has been delivered. Some Industry Partners have now linked the SeweX sulfide model to their hydraulic network model to predict potential 'hot spots' for odours in their sewer networks.

Theme 4 – Knowledge Management

- A web-based knowledge management system has been developed and a website established (www.score.org.au) to make knowledge generated in SP1-SP8 readily available to Industry Partners.
- The website is being used by the researchers from around Australia as a means of collaboration for the Project and by all Partners for documentation control.
- Project deliverables are being made progressively available to all Partners through the website as they become available.

Outcomes from the SCORe project are already having a major influence on Industry Partner practices and decisions, which are providing significant financial benefits. Some examples include:

- Improved specifications for coating systems have been recommended by WSAA based on early results of testing of epoxy coatings;
- Testing of some odour control chemicals has been postponed by Industry Partners based on outcomes from lab and field testing of the Project;
- The SeweX model is now being used by several Industry Partners to optimise dosing of proven chemicals to sewerage collection systems.

Acknowledgements

The authors acknowledge the Sewer Corrosion and Odour Research (SCORe) Project LP0882016, funded by an Australian Research Council Industry Linkage Project Grant and supported financially and in kind by the following key members of the Australian water industry:

- Sydney Water Corporation, New South Wales
- Water Corporation, Western Australia
- Allconnex Water, Gold Coast, Queensland
- South East Water Limited, Victoria
- Melbourne Water Corporation, Victoria
- Hunter Water Corporation, New South Wales
- South Australia Water Corporation
- Barwon Regional Water Corporation, Victoria
- CH2M Hill Australia
- Water Quality Research Australia
- United Water International, South Australia

The authors also acknowledge the work done by the Research Partners led by the following Chief Investigators and their teams:

- Prof Zhiguo Yuan, University of Queensland
- Prof Jurg Keller, University of Queensland
- Prof Rob Melchers, University of Newcastle
- A/Prof Richard Stuetz, University of New South Wales
- Dr Phil Bond, University of Queensland
- Dr Marjorie Valix, University of Sydney
- A/Prof Anna Heitz, Curtin University of Technology
- Dr Korneel Rabaey, University of Queensland

For more details see: www.score.org.au.

The Authors

Dr Ray Rootsey is Project Manager for the SCORe Project (email R.Rootsey@awmc.uq.edu.au); and

Professor Zhiguo Yuan, Deputy Director of the University of Queensland, is Director of the Project. Both are at the Advanced Water Management Centre, University of Queensland, St Lucia, QLD 4072.

References

IPCC Technical Paper VI (2008): *Climate Change and Water*, IPCC Secretariat, Geneva.

Latham, B (1873): *Sanitary Engineering*, Oxford University, UK

Melbourne & Metropolitan Board of Works (1989): *Hydrogen Sulfide Control Manual*, Melbourne.

Parker, CD (1945): The corrosion of concrete 1. The isolation of a species of bacterium associated with the corrosion of concrete exposed to atmospheres containing hydrogen sulphide. *Australian Journal of Experimental Biology and Medical Science*, 23, 81-90.

Pomeroy R & Bowlus, FD (1946): Progress report on sulfide control research. *Sewage Works Journal*, 18(4):597-640.

Pomeroy, R & Parkhurst, D (1976): *The Problem of Hydrogen Sulfide in Sewers*. Cross Courtenay Ltd, Manchester, UK.

Shammay, A, Bates, R, Kynaston, P, Kennedy, C, Evanson, I (2010): *How to Eliminate Odour Complaints in New Schemes Involving Pressurised Sewer Systems*. Proceedings of AWA Specialty Conference: Odours 2010, Sydney.

Thistlethwayte, DKB (1971): *The Control of Sulfides in Sewerage Systems*, Butterworth, Sydney.

WERF (2007): Comprehensive Literature and Research Needs Survey Associated with Wastewater Collection Systems. Report for Project 04-CTS-1.