Australian Water Recycling
Centre of Excellence

Discussion Paper

Theme 4:
Sustainability - Life Cycle Assessment and Integrated Resource Management Strategies

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1 Introduction

The challenge of the sustainability theme is to acknowledge that water recycling is a complex system and to develop a strategy to understand and incorporate this complexity into a framework that allows for the delivery of sustainable water services in urban and regional communities. The framework developed must be sufficiently flexible to assess centralised or decentralised schemes, combined or separated waste sources, inland or coastal communities as well as regions with varying degrees of ecological sensitivity and capacity to absorb salts and nutrients. The sustainability theme must also factor in the reality that some resources are limited, that atmospheric greenhouse gas emissions must be capped and other environmental impacts minimised.

Water recycling schemes rely on various technologies to remove, inactivate or transform biotic and abiotic material in wastewater. The efficiency of the technology is important, however, it is equally important to engage with the political, regulatory (environmental, health, financial), economic/marketing and social forces that shape the use of technology. The industry recognises that recycled water should be fit for purpose, yet accepts that in many schemes the level of treatment far exceeds the requirements of the Australian Guidelines for Recycled Water as a result of these forces. In most cases it is apparent that some recycling schemes are over designed and produce water that exceeds the requirements of the end user. Such projects cannot be sustained. Therefore, it is hoped that by understanding the complexities of water recycling, and using the principles of sustainability as a platform we will achieve better outcomes for the water sector.

2 Background

Why do we need to acknowledge complexity and incorporate sustainability into the development of water recycling schemes? Because the current paradigm is not sustainable.

The current paradigm for water recycling in both urban and regional areas is built on the premise of adding an advanced water treatment (AWT) component to conventional wastewater collection, treatment and disposal systems. The efficiency of the system is measured by whole of costs, power consumption and sometimes greenhouse gas emissions per unit of water produced.

This ad hoc approach to recycling does not represent an integrated approach to the management of nutrients and water and has several inherent process inefficiencies, including unnecessary duplication of unit processes for nutrient management, which result in an unnecessarily high carbon footprint for the delivery or water, wastewater and nutrient management services. Moreover, this approach fails to recognise the complexity of water recycling systems. Water recycling is only one element of the water cycle. A narrow focus on a black box located at the "end-of-pipe" is oblivious to the role the water cycle plays in the flow of salts and nutrients through the environment. Furthermore, in a world that is constrained by energy consumption, greenhouse gas emissions and non-renewability of key resources such as phosphate, it is impossible to decouple the sustainability of water recycling from the sustainability of the water sector.

A case in point is the management of nitrogenous resources. The manufacturers of fertiliser will typically expend 14 kWh to produce a kilogram of urea, of which 80% on a mass basis will be collected through the sewer network and be presented to wastewater treatment plant, where a further 13 kWh/kg N will be expended in a biological nutrient removal (BNR) processes to convert this soluble biodegradable nitrogen to nitrogen gas. Additional energy will be expended when the product from the BNR process is further treated through the AWT plant to produce recycled water. This AWT process will typically consume 1 kWh of electricity and emit another 0.3 kg of carbon dioxide (associated with the consumption of chemicals and membranes) for every tonne of water treated. Ironically, several of the processes that are used in AWT schemes located in both coastal and in-land areas employ processes which can recover nitrogenous resources such as urea, ammonia and nitrates. These processes can also recover other essential nutrients such as potassium and phosphorous. Moreover, the ad hoc deployment of AWT technologies at the discharge end of the conventional collection, treatment and disposal system results in the transformation of the wastewater treatment plant from a net energy exporter (through cogeneration of electricity via the combustion of methane) to a net energy importer. Clearly, as stress on water resources has driven the need for recycling, the need to operate in a carbon constrained economy necessitates the need for a re-evaluation of the management of water and nutrient resources in the urban and regional areas.

Consequently, this research topic is focussed on the development of life cycle assessment (LCA) methods and integrated resource management strategies to minimise the environmental burdens (including the carbon footprint) and develop sustainable urban and regional water recycling programmes. LCA is a core tool that is used to quantify the environmental performance of different water and nutrient management scenarios and has the potential to inform key outputs generated in other themes in the Australian Water Recycling Centre of Excellence, that include technology, risk management and social aspects of water recycling.

3 Research Strategy

The research strategy is based on a suite of ***knowledge management*** projects and ***targeted technology*** projects that should be implemented concomitantly.

The ***knowledge management*** projects have been framed in the context of LCA methods.

LCA is a comprehensive quantitative assessment tool used for evaluating the environmental impacts of products or services. LCA is often referred to as a cradle-to-grave analysis whereby the entire life cycle of a product or process is followed from the extraction and processing of raw materials, manufacturing, transportation and distribution, use/re-use/maintenance, recycling and final disposal. In the water industry, the major determinants of the LCA score are energy use, expressed in kWh/m^3 and greenhouse gas (GHG) emissions (incl fugitive GHG emissions), expressed in kg CO_2-equivalents/m^3. Other environmental impacts commonly calculated by means of LCA are eutrophication potential, photochemical oxidant formation potential and various eco-toxicity potentials.

The alignment of this theme with the initiatives of the LCA community in Australia has the potential to make a valuable impact on the use of this method in the planning, assessment, design, regulation and operation of water recycling schemes. The following diagram illustrates how various stakeholders and contributors including utilities, companies and research organisations (Green Boxes) are currently engaged in core LCA activities (Yellow boxes) including data initiatives and data set projects, technology models and LCA methodology.

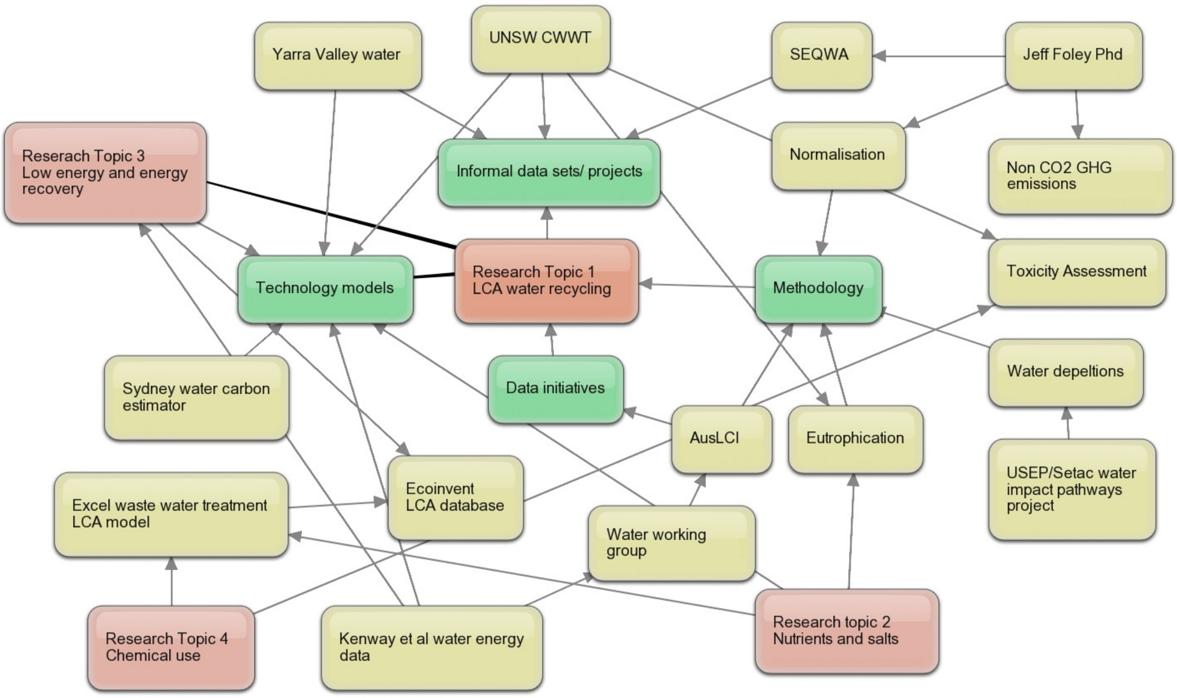

Figure 1. Connection between LCA resources and Research Topic 1 and other research topics

The interconnected nature of the LCA initiatives provide scope for all the projects in the Technology and Adaptation, Risk Management and Society themes to generate information that can be used in the tools developed by the LCA community. Specific details of the ***knowledge management*** projects are described in ***Research Topic 1***. “The alignment of water recycling with national and international LCA initiatives”.
The ***targeted technology*** projects are focused on the implementation of technology, techniques or strategies with the potential to improve water recycling. To this end, it will be necessary to develop new or reconfigure existing water recycling processes to achieve the following goals;

- Reduce energy requirements and expand water recycling in inland Australia through judicious management of dissolved salts in the water cycle.
- Achieve simultaneous recovery of water nutrients and energy.
- Reducing the consumption of chemicals and consumables associated with the water recycling process.

The specific details of the ***targeted technology*** projects are described in ***Research Topics 2,3 & 4***.

3.1 The alignment of water recycling with national and international LCA initiatives.

3.1.1 Key Issues & Challenges

What is required in LCA is not a single grand project that answers all questions for all time, but the development of the capacity to use LCA in an agile and routine manner to assess the many options and questions raised in the management of waster services and the water cycle in existing and proposed urban and regional developments. To this end, the research and development priorities are focused on the improvement of the methods, the integration of LCA in an overall sustainability framework, the availability of data and the capacity of human resources required for undertaking LCA and the programmes necessary to disseminate the LCA approach through the water industry.

3.1.2 Knowledge Gaps

The key areas that could be addressed include;

- Development of a Sustainability Framework that provides a methodology for evaluating the overall sustainability of water management systems;
- Generation of data on the use of consumables, expended energy, asset life and embodied energy of key components used in a range of centralised and de-centralised water recycling systems;
- Development of models for alternative water treatment, nutrient and energy recovery systems that can be evaluated using LCA methodology;
- Development of strategies for management of salts that result in decreased energy, avoided cost and expanded recycling opportunities that can be evaluated using LCA methodologies;
- Development of options for alternative approaches to operating recycling systems and managing and disposing consumable items in water recycling operations;
- Research on how water recycling schemes impact on nutrient and salt flows, particularly in inland Australia; and
- Research on how the generation of residual waste and consumables, particularly used membranes and UV lamps, impact waste management and land fill operations in urban Australia.

3.1.3 Recently Completed & Ongoing Research

Many groups are focussed on expanding the use of LCA techniques. The focus is very broad and the development of specific information on water recycling schemes is limited. The following is a brief list of two initiatives conducted by the national and international LCA community.

AusLCI is a national initiative of the Australian LCA Society to coordinate and publish life cycle inventory data for public use. The aim of the project is to avoid duplication of databases, co-ordinate the use of best available data and to promote the development of data by sectors and companies alike.

The Ecoinvent database is a European based LCI (Life Cycle Inventory) database. The objective of the initiative is to develop generic models that can be used on a global scale to assess domestic and industrial waste water systems. The models allow the user to develop LCI for wastewater treatment systems based on influent specification and technology descriptions.

3.1.4 Future Research Needs

The following projects could make a significant contribution to both national and international LCA initiatives.

1. Development and dissemination of sustainability decision-making frameworks.

Based on preliminary work for the Water Services Association of Australia further research has to be undertaken to develop and implement sustainability frameworks in organisations involved in making water management decisions. In the planning phase of water infrastructure projects, normally different options are developed and evaluated before a decision is made on which of the options delivers the optimal outcome. A framework combining the best of strategic planning and sustainability assessment approaches can support this in following a structured process which leads to the most sustainable scenario. As an integrated part of such a framework, LCA can deliver results for the environmental consequences of the options considered. Another important feature of such a framework is the participatory element seeking direct engagement with stakeholders. Such frameworks need to be refined and the widespread implementation and application in organisations has to be promoted.

2. Supporting the AusLCI database initiative

An industry sector working group of the AusLCI database initiative has been meeting for the past two years to develop a scope for inventory needs and has developed some important LCI data on water and sewage services. However, this specific activity of the AusLCI database initiative is not currently funded and there is scope to support projects to develop data on a range of components, such as membranes, cleaning chemicals, disinfection equipment that is commonly used in water recycling projects. The ARC recognises the data needs in this area and recently funded two research projects: one deals with the assessment of the sustainability of water and wastewater treatment chemicals, the goal of the second is to quantify GHG (mainly N_2O) emissions resulting from downstream marine wastewater disposal. Other than that, LCI data is required for the following items:

- Consumables; sorbents, cartridges, membranes, lamps;
- Fugitive GHG emissions from different wastewater treatment technologies
- Infrastructure components; civil components, process mechanical assets, electrical components and instrumentation and control components
- Geographical and demographic information; location of water recycling schemes, changes in population density and water consumption requirements; trends in nutrient flows (consumption by agriculture and fertiliser production and the flow on effect to wastewater treatment loading rates.

2. Collaboration with the Ecoinvent data base

Ecoinvent is an operational LCI database with approximately 4000 discrete inputs. Supporting a project within Ecoinvent would ensure free access to the data for research collaborators, and contribute to the quality of research and outcomes from other projects in the technology and risk themes.

A specific project could involve the development of process models, possibly based on a technology under evaluation in another research theme, associated with water recycling. The model should be developed with sufficient flexibility for calibration for local conditions based on geography and demographics. The Ecoinvent database could be used to assess the consequences of changing nutrient pathways through the water system, possibly as a result of treatment or recovery. Australian water utilities, such as Sydney Water have developed techno-economic models of waste water treatment systems which could help with this project.

3. Development of Improved Impact Assessment Methods.

Water recycling projects have the potential to alter the movement of nutrients and salts through the environment. For example, irrigation in either urban or regional situations can result in changes in soil salinity profiles, while the discharge of membrane concentrate will alter the nutrient density in effluent plumes entering rivers, estuaries, bays and coastal waters. In addition, the planned reuse and diversion of wastewater can increase or decrease the volume of water available for environmental flows. A rigorous LCA approach undertaken during the planning process will help identify the likely impacts of water recycling on salt, nutrient and water movements through the environment.

One approach to this ussue would be to expand the current impact assessment methods used in LCA to evaluate wastewater projects. In many cases the current impact methods covering conventional wastewater treatment in use in Australia are suitable, but specific areas such as nutrient dispersal and eutrophication potential need additional modelling. In addition, more work is needed if there is the potential for water recycling projects to decrease volumetric flows but increase nutrient and salt loads. Development of this work is particularly critical for the expansion of water recycling in inland Australia. There is scope to expand the model to deal with the fate of nutrients in key catchments, but also to look at the dispersal of salts from recycled water schemes (This would include the movement of salts from the product water through soils and river systems as well as the potential issues associated with the disposal of saline brine streams).

For water depletion, an assessment of water against the water stress index, rather than just kilolitres used, is needed to better reflect the impacts of water depletions in different areas. Work in this area is underway by the CSIRO and through the UNEP SETAC Life cycle initiative but additional support for the method is required.

4. Development of streamlined LCA tools

Several water utilities are using LCA methodology in planning water and wastewater services. In order to expand this work by including water recycling and other alternative water management scenarios it will be necessary to develop standard technology units which will lead to parameterised inventories, for the treatment processes and networks currently used in water recycling schemes. The Victorian SmartWater Fund supported the development of a Environmental Sustainability Assessment Tool (ESAT) which allows for the environmental and economic assessment of different water servicing scenarios. Sydney Water has developed a carbon estimator tool for different infrastructure items. These tools could seed the development of a more comprehensive LCA based techonology tool that can be extended to cover various water recycling systems.

5. Use of LCA to compare sustainability of decentralised and centralised systems

Decentralised water and wastewater systems are becoming an integral part of the integrated water management concept for sustainable water servicing either in combination with existing centralised systems or as standalone systems. There exist wide knowledge gaps in terms of understanding systems reliability, resilience, performance, energy requirements, GHG emissions including fugitive gases, operating costs, and interactions with centralised water systems. Moreover, there are numerous treatment technologies available now for adoption. The long-term suitability of these technologies is difficult to assess based on local conditions, size and intended use.

This project proposes to use LCA to compare the sustainability index of various centralised and decentralised water and wastewater systems for urban developments. The study could use the work of Lane & Gardner (2009), Foley (2009) as the departure point for the investigation. An important subsidiary project will advance the rationale to weight the relative impacts (e.g. resource depletion, GHG emissions, energy use, eutrophication, ecotoxicology) of the mid point assessment criteria used in LCA.

6. Economies of Scale in reuse water systems

The impact of scale on the per capita (connection) cost of providing alternative water services and whether all the components of these services are characterised by economies of scale is an important issue. The understanding of the economies of scale to the total system is important for planning new infrastructure, and the economies of scale characterises the transformation of inputs into a flow of outputs. The capital cost of the infrastructure, and operation, maintenance & administrative cost are the inputs and the number of connections of water and sewerage services are the outputs.

7. Quantifying the impact of small-scale systems at city/regional scales

Frequently, the assumption is made that the performance outcomes of a single decentralised system can be scaled linearly to predict the performance of such systems at city and/or regional scale. Decentralised systems can be either household scale systems such as rainwater tanks or cluster scale recycled, rainwater and stormwater use systems. City/regional scale performance outcomes are required to assess the impact of decentralised systems on supply/demand balance assessment and whole-of-system scale water quality assessment. Some preliminary work undertaken by the CSIRO indicated that when large numbers of household scale systems (e.g. rainwater tanks) are lumped with factors such as roof area and occupancy, set to average values, the performance outcomes at city and/or regional scale can generate biased and overestimated results for annual supply from such systems. Building on the current work, this study proposes to investigate how small scale recycling, rainwater and stormwater harvesting systems can be scaled up to city and/or regional scale performance assessment, to feed into regional scale supply/demand assessment; water quality assessment in receiving water bodies; and energy and GHG assessment. LCA can play an important role in quantifying the environmental impacts of systems at different scales.

3.2 Status and Prospects for the management of salts and recovery of nutrients

3.2.1 Key Issues & Challenges

This sub-theme is focused on the management of the deleterious impacts of salts and the potential benefits of nutrient recovery in water recycling schemes.

Impacts of salt

Treatment of inorganic compounds, in particular salt, requires processes for salt management, which result in unnecessary high carbon footprint for recycled water produced using advanced treatment systems. Sources of salt can be saline groundwater ingress via leaky sewers, diet, industrial waste, water softener regeneration, treatment chemicals and evaporative concentration in aeration lagoons.

The challenge is to manage the flow of salt through the water cycle to expand the use of recycling in areas that are sensitive to the accumulation of salt without the attendant problems of high energy requirements or disposal of saline concentrate streams.

Recovery of nutrients.

Phosphate is an essential compound that is available as a finite resource and one that is being rapidly depleted. The recovery of phosphate from human and animal wastes is widely regarded as essential for sustainable wastewater treatment.

The challenge is to identify reliable and efficient technologies that can be used at the centralised or decentralised scale for the recovery of a phosphate product that is biologically available.

3.2.2 Knowledge Gaps

The knowledge gaps associated with salt management and nutrient recovery in an expanded water recycling system are associated with the following issues.

- The barriers to expanding the role of trade waste policy to manage salt loads in collection systems
- The best approach to the management of ageing infrastructure, particularly leaky sewers
- The merits and practicalities of source separation in existing and new developments
- Issues associated with the storage and transportation of urine
- Identifying the optimum scale for water recycling systems
- The efficiency of treatment systems for the recovery of phosphates from liquid waste streams
- The efficiency of treatment systems for the recovery of phosphates from solid wastes

Central to the issue of salt management and nutrient recovery is source separation. In domestic waste systems the inclusion of urine adds more than 60% of the nitrogen load, 80% of the phosphorous load and less than 2% of the flow. Source separation through the expanded use of Urine Separating Toilets (UST) has the potential to alleviate problems associated with salt transport and phosphate recovery. Urine diversion offers the opportunity to effectively increase the capacity of existing Sewerage Treatment Plants (STPs). STP catchments that are subject to population growth but are constrained by load based nutrient discharge licences might benefit from the incorporation of UST into the new housing developments.

3.2.3 Recently Completed & Ongoing Research

Urine Separation Toilets (UST's)

Several pilot studies on UST's have been completed in Sweden and Switzerland. The results from the Swedish trials were sufficiently successful that all new homes in the local council of Tanum, in south-west Sweden, are required to have urine-separation toilets. However, recent work completed by EAWAG in Switzerland under the Novaquatis program has highlighted the problems associated with the development of uric acid scale, on-site storage of the urine and the energy associated with transport to a centralised processing facility. In Australia, a trial of UST is currently underway involving 10 toilets installed in communities in the Currumbin Valley, near the Gold Coast.

Phosphate Recovery

The University of Technology in Darmstadt, Germany in partnership with the University of British Columbia, Vancouver and CEEP, the joint research association of the European detergent and industrial polyphosphates industry (http://www.ceep-phosphates.org/) have developed a website (http://www.phosphorus-recovery.tu-darmstadt.de/index.php) outlining current research, technology, links and references related to phosphorus recycling.

Completed in 2008, the SUSAN project (http://www.susan.bam.de/) focused on the potential of phosphorus recovery by thermo chemical treatment of sewage sludge ash. The project was carried out within the 6th framework of the European Union sub-priority "Global Change and Ecosystems" with a total 1.6 million EUR in funding and partners including the German Federal Institute for Materials Research and Testing (www.bam.de), European fertiliser producer Kemira GrowHow (www.kemira-growhow.com) based in Finland, German engineering company BAMAG (www.bamag-water.com) and sludge incineration plant operator SNB (www.snb.nl) based in the Netherlands.

Another method to recover phosphorus is by precipitation as either struvite which can be used as fertiliser or calcium phosphate which is used in the phosphate industry. Full scale plants are already in operation in Japan and the Netherlands and there is ongoing research into optimising crystallisation reactor conditions and performance in Japan and the US. North

Carolina State University in cooperation with Multiform Harvest Inc and others are conducting pilot plant studies of a cone shaped fluidized bed struvite crystallizer using dairy and municipal wastewater (http://www.multiformharvest.com/about.php).

Source separation of urine and decentralisation of treatment systems for nutrient recovery is a focus area for research in Sweden and Germany. In Sweden a joint project between Split Vision Development AB (http://www.splitvision.se/en/bostad.aspx) and Göteborg University aims to develop an in-house recovery device using struvite precipitation and zeolite adsorption technology. In Germany, the DEUES 21 project studied two residential areas to evaluate possibilities for decentralised urban water infrastructure systems.
In the US and Italy, researchers are investigating the use of ion exchange processes to recover phosphorus. Researchers at Lehigh University have developed a new sorbent with high sorbent affinity toward phosphate which may be applied for trace phosphate removal (http://www.solmetex.com/5_contaminants/phosphate.html).

3.2.4 Future Research Needs

Several potential projects have been identified in the areas of source separation, salt management and nutrient recovery.

1. Urine Separation Systems.

This project will consider the likely reduction in N&P, the challenges associated with the storage urine and the energy and GHG implications for a source separated systems.

The initial objective of the project is to assess which catchments are suitable for urine separation. In this context key knowledge gaps include (a) whether there are any particular STP technologies that would benefit more than others; and (b) evaluation of the geography to determine which STP catchments fit the bill of having (1) the right type of STP; (2) the necessary population growth; and (3) are close enough to agricultural lands (or another type of urine sink) so as not to remove the GHG benefits due to an increased transport footprint. The project would include an assessment of the likely reduction in N&P based on mass balance analysis and the feasibility of using anaerobic digestion as the primary sewage treatment method, whilst still meeting nutrient discharge standards.

The major technical impediment to installing urine separating toilets in new urban developments is the transport and storage of the separated urine. In addition, community acceptance would have to be considered before any wide scale installation could be contemplated. Transport is challenged by pipe blockage from precipitation of uric acid scale, calcium phosphate and magnesium ammonium phosphate (struvite). This project proposes to develop a prototype source separated urine conveyance system that can operate over distances of hundreds of metres. It will be informed by much of the fundamental knowledge on urine chemistry published from the EAWAG Novaquatis.

Finally the project will explore whether urine diversion can improve the feasibility of using low energy wastewater systems (ie: the hybrid attached media growth plant at the Currumbin EcoVillage in Queensland) that can only deliver relatively higher effluent nutrient concentrations (compared to BNR systems). By taking the nutrients out up front, these systems might be able to deliver lower effluent nutrient concentrations, and still achieve their low GHG benefits.

2: Integration of ammonia and phosphate recovery into high grade water recycling projects

Recovery of phosphate at centralised wastewater treatment plants is seen as economically unviable because of low PO_4^{3}-levels compared with decentralised systems. However, the recent growth in membrane based water recycling projects, where reverse osmosis is used to produce high quality water has resulted in the production of liquid waste streams with high concentrations of PO_4^3. Moreover, as the population density in urban catchments increases and the water consumption per capita decreases with improved water efficiency measures it is likely that nutrient levels in waste concentrate will increase. The proliferation of dual membrane recycling projects in Qld, WA, Victoria and NSW presents the opportunity to look at the recovery of struvite (magnesium ammonium phosphate) from membrane concentrate. This project would examine options to achieve the optimum stoichiometry of N & P (1:1) for efficient struvite production.

3.3 Status and Prospects for the expanded use of low energy and energy recovery systems

3.3.1 Key Issues & Challenges

This theme looks at the expanded use of anaerobic treatment in water recycling applications as a method for reducing energy consumption.

The traditional industrialised paradigm for wastewater treatment has focused primarily on removal of nutrients at all costs via the aerobic activated sludge processes. That is, use of extensive energy in aeration to nitrify, followed by the use of wastewater and external carbon to drive denitrification. This produces a final effluent of outstanding quality, but is intensive in energy requirements, space (mainly due to clarifiers), and removes the nitrogen in a destructive process.

There is now a movement towards a new model for wastewater treatment, focused on (a) low physical footprint, (b) reduced carbon footprint, (c) full recovery of water as a valuable resource, and (d) recovery rather than destruction of nutrients and energy. This is the basis of this Topic, and is also the subject of recent influential position papers (Keller, 2008, Verstraete et al., 2009).

The three key treatment components for next generation treatment systems consist of membrane based nutrient separation and water recovery, anaerobic digestion to recover methane from organics, and to mobilise nitrogen and phosphorous, and metal ion precipitation to recover nitrogen and phosphorous. Anaerobic digestion is the core biological process as it is non-destructive of nutrients, generates renewable energy, and is a fully enclosed process. A further advantage to this project is that it is highly scalable, though there are research needs at smaller scale.

3.3.2 Knowledge Gaps

As the core biological component in such a train, anaerobic digestion can be applied in two ways:-

(a) As a pre-treatment option on domestic strength wastewater. Anaerobic digestion can be used in a high-rate configuration on dilute streams to remove organics and mobilise nutrients. This basic technology is widely used as a treatment option in Asia, Africa, and South America (Foresti et al., 2006), where nitrogen removal is not a priority. Key issues to be solved within the scope of this project involve improved efficiency, and full recovery of dissolved methane. The second issue in particular is very important with respect to improved RO membranes that can more effectively concentrate and recover methane on the concentrate side.

(b) As a concentrate treatment option to produce methane, and mobilise nutrients for nutrient recovery. This is also a well established technology, and the material should be far less challenging to degrade than conventional waste activated sludge (Batstone et al., 2008).

Challenges in application of this technology are minimal, and mainly include characterisation of the streams, scaling (especially of mixing at smaller scale), integration with other components, and optimisation, particularly of energy use in mixing and gas recovery.

3.3.3 Recently Completed & Ongoing Research

The Water Environment Research Foundation (WERF) has begun to develop a technology roadmap toward sustainable wastewater systems. The use of low energy wastewater treatment systems, such as anaerobic process in fixed film and sludge blanket configurations are being evaluated.

3.3.4 Future Research Needs

Research problems related to utilisation of the gas stream include (i) scaling of gas utilisation trains, and (ii) handling of gas phase contaminants, including siloxanes and sulfides. Both of these are likely to be solvable by application of newer generation electricity generation methods, including direct hot water generation, and use of methane driven fuel cells or chemical converters, as elsewhere covered in this document.

The life-cycle impact of anaerobic-based water recovery systems has been assessed for specific and more general cases, and is invariably favourable as compared to conventional treatment (Verstraete et al., 2009), particularly related to resource consumption and generation. The basic technology related to the treatment methods is not in doubt, but there is a high degree of opportunity available with respect to optimisation and integration. This is likely to be the key focus in the overall programme. Approaching integration between the different treatment components in a heuristic manner will likely provide very low cost, low impact, and highly scalable systems.

3.4 Status and Prospects for the reduction and reuse of chemicals and consumables in water recycling applications

3.4.1 Key Issues & Challenges

Existing water recycling schemes supply water for irrigation, industrial uses, domestic non-potable uses and augmentation of potable supplies. They use a variety of treatment process to remove suspended solids, dissolved solids and pathogens. Routine operation and maintenance of these systems generates a substantial volume of waste; spent cleaning solutions, used filter cartridges, used membranes and burnt out UV lamps. For example, in most cases the surfaces associated with the membrane processes are routinely cleaned using caustic or acidic solutions, with these solutions being used only once then discarded to the sewer. Solid consumable waste, such as membranes, filters and lamps are removed and ultimately disposed in landfill. Reducing the volume of waste by recovering or recycling cleaning solutions or recycling components of the consumable waste will reduce the environmental footprint of existing water recycling facilities.

3.4.2 Knowledge Gaps

The problem with recycling or reusing wastes from water recycling plants back in the treatment process is the potential for incidental poor performance. A good example of this is the problem associated with recycling spent cleaning solutions containing silica. When these solutions are reused at elevated pH there is the potential for the conversion of silica to silicate which can then react with trivalent metals to form scale on the membrane process surfaces.
Consequently, it is necessary to identify and characterise potential “incidental” fouling events associate with the reuse of cleaning chemicals and develop treatment systems that can regenerate the cleaning solutions for reuse.

Similarly, measures to recycle, reprocess or recover components from spent cartridges, membranes and lamps is an area that is currently not addressed in the literature or in operating protocols for recycling plants.

3.4.3 Recently Completed & Ongoing Research

The dairy industry has developed strategies using electrodialysis to regenerate spent caustic cleaning solutions. This is a major problem for dairy operations because of the volume of caustic waste generated as a result of daily membrane cleanings.

The membrane manufacturer Filmtec and the not for profit organisation Skyjuice (www.skyjuice.com.au) are actively investigating uses for spent membranes from desalination plants.

3.4.4 Future Research Needs

There is an opportunity to investigate and possibly adapt strategies from the dairy industry for recycling cleaning chemicals and to develop an alliance between end users and manufacturers to handle the waste generated from Australian water recycling plants.

4 Summary and Conclusions

The sustainability theme affords the opportunity to critically review existing and proposed water recycling projects for urban and regional communities in centralised and decentralised systems. By using LCA methods as an overarching tool to quantify the impact of the projects it will be possible to assess the expansion of recycling operations to include nutrient recovery, energy recovery and reduction in, or alternatives to the consumables used in recycling operations.

5 Linkages

The sustainability theme was developed with the valuable input from the following individuals and organisations.
Specific Contributors:

Life Cycle Assessment

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- Professor Stuart White, Institute for Sustainable Futures, University of Technology Sydney
- Matthias Schulz, Sustainability Assessment Program WATER RESEARCH CENTRE University of New South Wales

Anaerobic Systems

- Dr. Damien Batstone, Centre for Adavnced Water Management, University of Queensland

Salt Management

- Dr Shiroma Maheepala, Principal Research Scientist, Water for a Healthy Country Flagship - Integrated Water Systems Analysis. CSIRO Land and Water

Phosphate Recovery

- Zenah Bradforde-Harke, UNESCO Centre for Membrane Science and Technology, University of New South Wales

- Associate Professor Linda Zhu, University of South Australia
-

Industry Contributions were received from:

- Gutteridge Haskins & Davey (GHD)
- Veolia Water
- Gold Coast Water
- Melbourne Water

www.australianwaterrecycling.com.au

The Australian Water Recycling Centre of Excellence has developed four discussion papers and is seeking industry and research practitioner feedback on these papers to inform development of the Centre's Strategic Research Plan.
Copies of the discussion papers can be requested via the Centre's website at www.australianwaterrecycling.com.au or by contacting the Centre at enquiries@australianwaterrecycling.com.au

Submit Your Comments

Please email your organisation's feedback on the Centre's research discussion papers to

submissions@australianwaterrecycling.com.au