Environment and Sustainability Institute

India-UK Workshop on

Knowledge transfer on the sustainability of innovative wastewater treatment technologies to India

Final Report

Date: 3rd April 2018
Time: 09:00 – 17:30
Venue: Seminar Hall, Kongunadu Arts and Science College, Coimbatore, Tamil Nadu, India

David Benson, Brenda Parker, Vandana Mishra, K. Muthukumar and Senthilarasu Sundaram

1. Executive summary

Untreated industrial wastewater pollution, primarily from textile production, threatens water resources in central Tamil Nadu, India, where the Noyyal River flows through several densely populated urban centres. The workshop consequently aimed at knowledge transfer on innovative wastewater treatments between UK and Indian collaborators to potentially address these pollution problems within the river basin, with wider applications to wastewater remediation. A key objective of the workshop was developing recommendations for scaling up these technologies to support future wastewater remediation strategies both in Tamil Nadu and other regions in India. Workshop discussions therefore focused on the viability, accessibility and cost efficiency of technological options, including algal bioremediation, anaerobic digestion and nanoparticles. Primary findings are detailed below but suggest that significant potential exists for scaling up technologies. However, institutional ownership and political support for this process must be further developed within an overall multi-stakeholder collaborative approach.

2. Context

India has 16% of the world's population and has only 4% of its water resources [1]. Multiple interlinked problems have emerged in India involving the security of these scarce resources. In particular, water pollution poses a particular threat and is occurring through urbanization, industrial discharges, improper agricultural practices and poor sewerage and wastewater management [2]. As a result, many major river basins in India suffer chronic levels of contamination, which presents a constraint on socio-economic development since the majority of citizens rely on such surface and ground waters for domestic and agricultural consumption [3]. According to UN reports, India's water quality ranks at 120th out of 122 nations, which results in over one million people dying through water-borne diseases and 37.7 million subjects to associated illness annually [4]. Water pollution also seriously constrains India's progress towards meeting the UN's Sustainable Development Goals (SDGs), particularly SDG 6 which sets targets for clean water and sanitation [5]. Addressing this Goal also has implications for inter alia the realisation of SDG 12 (for responsible production), SDG 3 (good health and well-being) and SDG 9 (industry, innovation, infrastructure) [6].

Untreated industrial wastewater pollution is a particular threat to river water resources in Tamil Nadu, India, home to some 70 million people and a growing economy. One nationally significant example is the Noyyal River, which flows through the densely populated urban centres of Coimbatore, Erode, Karur and Tiruppur, in western Tamil Nadu. The river's basin is 110 miles long and 16 miles wide, covering a total area of 1,400 sq miles. Located in the centre of this basin, Tiruppur is a major knitwear centre, containing 9000 small-scale factory units producing one-third of the total apparel exports from India. This sector is also a significant contributor to the local economy, directly employing 40,000 people. They are employed in more than 700 dyeing and bleaching industries that discharge around 100 million litres/day of mostly untreated effluents into the Noyyal River. The textile industry uses bleaching liquids, soda ash, caustic soda, sulphuric acid, hydrochloric acid, sodium peroxide, and chemicals for its dyeing and bleaching processes. Other harmful substances include dyes, many based on benzidine structures or heavy metals, both known to be toxic. Most chemicals are discharged in wastewater. The wastewater is acidic, noxious and contains dissolved solids, which increase the biological and chemical oxygen demand in water. Open wells and bore wells in and around Tiruppur and the downstream stretch of the Noyyal exhibit high levels of total dissolved solids (TDS) (most areas > 3000 mg/l and some places even up to 11,000 mg/l) and chloride (generally > 2000 mg/land certain areas up to 5000 mg/l) due to industrial pollution. With no freshwater available for dilution, the ground water from Coimbatore and Tiruppur is now unsuitable for irrigation, washing or drinking. After a 2011 ruling from the Indian courts making zero liquid discharge (ZLD) a prerequisite for industries, Tiruppur became the first industrial hub to install systems to reclaim water and salts from wastewater with the objective of achieving ZLD. However, energy requirements, costs and residual sludge disposal present significant obstacles to meeting this objective at present. Contamination of water sources therefore significantly constrains regional development, while limits India's progress towards the SDGs.

These pollution challenges, however, provide significant opportunities for developing innovative wastewater treatment technologies. The workshop organisers, from the University of Exeter and University College London, are experienced in conducting novel pollution remediation research in both India and the UK, using integrated anaerobic digestion, hydrothermal carbonization and algal bioremediation, which have particular relevance to treatment of dye effluent within this context. Development of such techniques could therefore help support surface and ground water pollution reduction within the river basin, thereby promoting its sustainable development. In addition, scaling up of such innovations has evident strategic-level implications for resolving chronic industrial wastewater pollution across India, since these techniques can be applied to remediating other biological, toxic, organic and inorganic pollutants. The research could also inform policy and legal frameworks for pollution reduction at local, regional (state) and national levels, while supporting India's SDG strategy. Opportunities also exist for knowledge transfer to other developing countries suffering similar environmental risks, in addition to commercializing the research to further extend UK-India business collaborations. The environmental technology sector in India is expanding rapidly, with evident opportunities for driving pollution abatement technological innovations.

3. Workshop aim and objectives

The research therefore aimed to transfer knowledge on the socio-economic sustainability of industry relevant intervention solutions for wastewater treatment of textile production effluent from the UK to partners in Tamil Nadu. Meeting this aim was undertaken through attaining three main objectives, discussed further below:

- To synthesise existing research on the economic, social and environmental benefits of innovative wastewater remediation technologies developed by the applicants;
- To feedback findings on the sustainability benefits to industry, policy makers and other stakeholders via a workshop and site visits;
- To co-develop recommendations for industrial scaling up of these technologies, in conjunction with industry and governmental actors.

A fourth objective, to further develop research opportunities and networks as part of the workshop, was also pursued. Non-academic impact was generated and will subsequently be measured through the co-creation of future project outputs with industry and policy actors. Knowledge transfer was created through a workshop, site visits and a mini-conference held for industry partners, academics, students and other external actors. This report summarises the main findings of the workshop sessions.

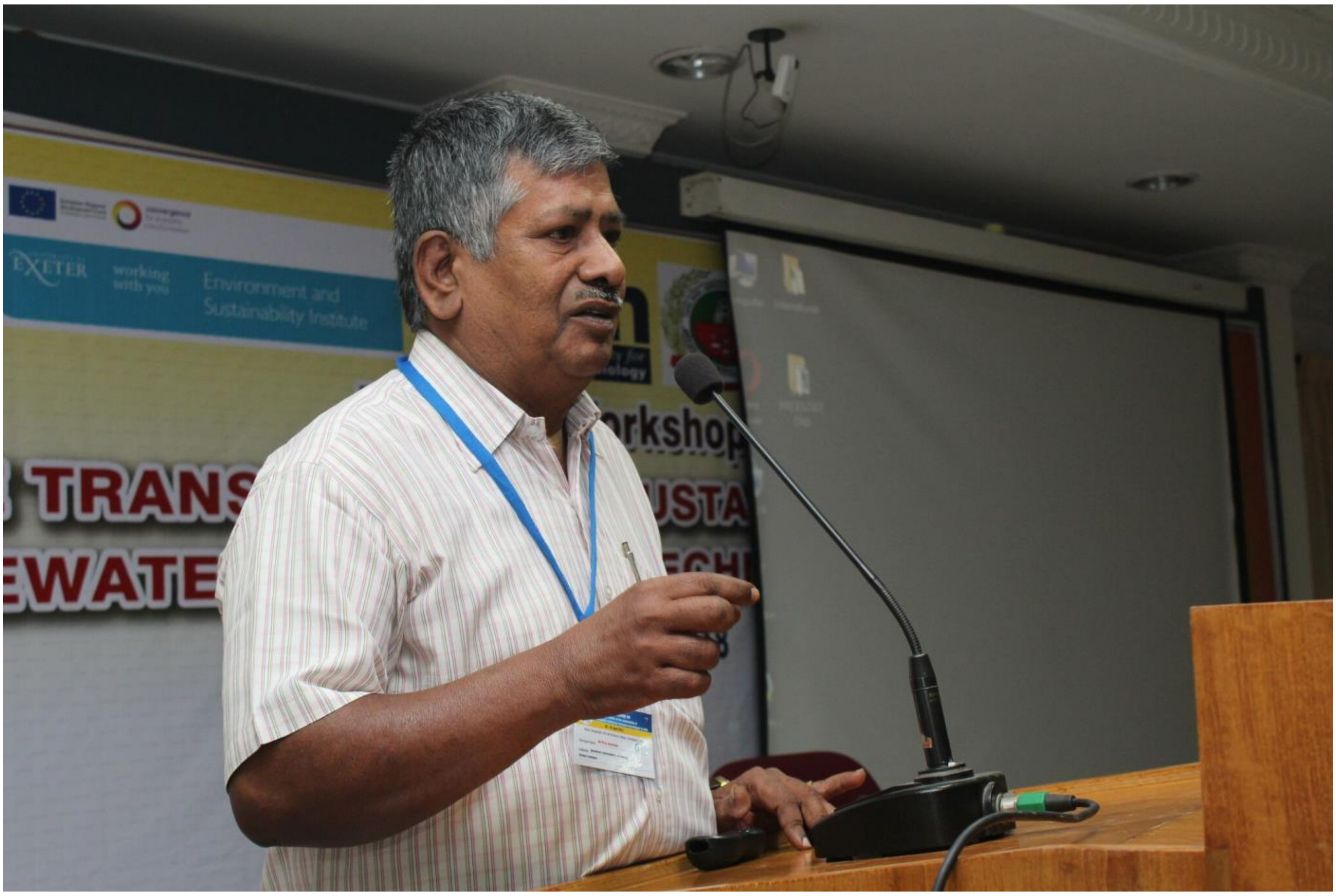
4. Summary of sessions

The morning workshop sessions were divided into three broad areas: context to the river pollution issues; existing wastewater management approaches; and potential technological solutions (see Appendix 1). Three parallel panels were formed in the afternoon to consider potential socio-economic and technological research priorities. Key findings from these events are summarised in this section.

4.1 Workshop presentations

Several presentations initially provided context to the workshop. **Mr. Perur Jeyaraman** outlined how the Noyyal River basin has been the centre of commercial and religious activity for two millennia, highlighting the river's 'sacred status' for local people. He also described the unique phenomena of constructing 'System Tanks' by the ancient Chalukya Chola dynasty, in order to reduce monsoon flooding, maintain groundwater levels and water for irrigation. He referred to how the river was depicted in ancient scripts and the pre-existing governance of the river which was achieved through local communities and tax exemption for river and tank managers. It was argued that the wealth of the region has historically relied on the river, with everyone responsible for maintaining its health. A non-governmental organisation view was then given by **Mr. Kalidassan** of the Indian NGO OSAI Environmental Agency, who also highlighted the role of system tanks for maintaining water resources in the river basin. He explained how the links between the river and the tanks are now broken, resulting in significant pollution problems. People living downstream of the industrial centres experience the impacts of untreated sewage water discharged into the Noyyal. Farmers also suffer from prolonged pollution from the Orathuppalayam Dam. In response, people in the region are motivated to restore the river water quality but suitable mitigation practices must be designed in collaboration with local communities. Scientific studies on the Noyyal River basin were then presented by **Prof Avudainayagam**, Head of the Dept. of Environmental Sciences, TNAU.

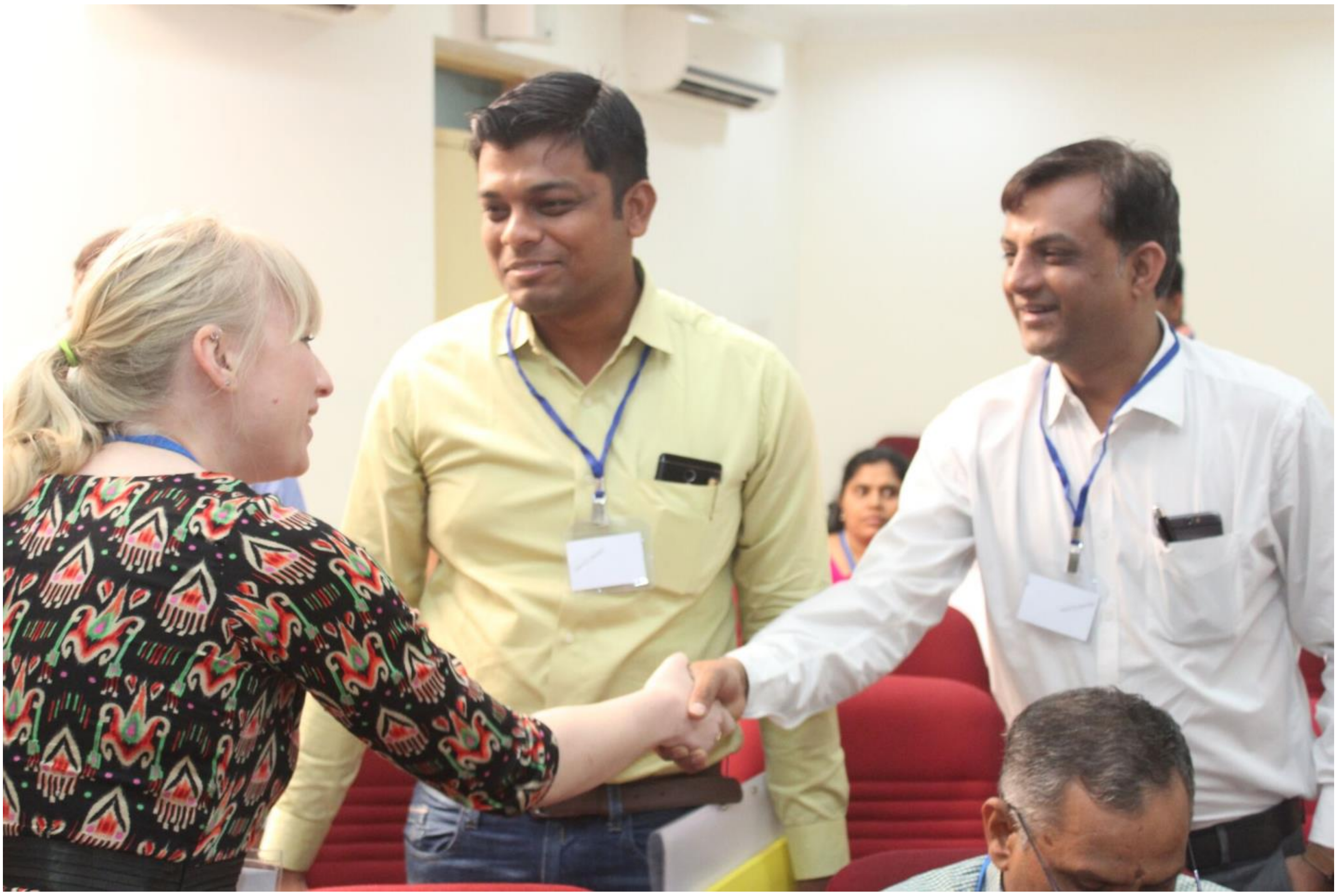
Several research projects have been undertaken by TNAU to understand water pollution issues, including investigations into integrated remediation for managing soil and water contamination, remediating dye effluents from contaminated soil using plant-microbe interactions, plus conducting soil and water quality assessments. Conclusions show that water resources are severely affected, including 50% of irrigated land within the basin. These findings led to proposals for identifying 'hotspot' areas that can be prioritised for bioremediation through constructed wetlands. **Dr Ilangovan** (PWD, Tamil Nadu) discussed some of the government policies in relation to the Noyyal pollution issues. The current pollution mitigation plan developed by PWD was presented. It divides the Noyyal basin into three 'Reaches', each with its own plan for specific interventions. He explained how existing treatment methods do not remove all pollution: sludge must be disposed of in open landfills. Other problems included structural damage to anicuts (small irrigation dams), encroachment, invasive aquatic species (e.g. water hyacinth) and dumping of solid wastes into the river. Interventions undertaken by PWD include inter alia: construction of short terrain rainwater tanks and long-term system tanks; desilting of shallow lakes; construction of wildlife habitats; weed removal and drying; an algae system to restore the Ooty lakes; bioremediation through growing Eucalyptus and sunflowers on industrial wasteland; and various other treatment methods. Legal measures, management approaches (e.g. catchment management, engineering, restoration of polluted lakes) and biological, non-structural approaches were suggested as alternatives. Integrated solutions, combining water for industrial, domestic and agricultural uses, were also identified.



Following on from this talk, the next session discussed existing attempts to manage industrial wastewater. **Prof Karthikeyan** (TNAU) outlined current wastewater treatment practices in textile industries. He identified that the industry is nationally economically significant since it generates approximately 4% of national GDP and 27% of foreign exchange earnings. Water recycling by the industry is not widespread and can be contrasted with the 54% of the Indian population that faces water scarcity.

A key point made was that capital investments in wastewater treatment are low but biological, physical and chemical technological solutions can be employed. Reuse of dye materials should be considered within a sustainable development approach, i.e. SDG 12. Here, researchers could develop methods for reclaiming residual dyes from effluent, using technologies such as rhizo-phyto remediation, algal bioremediation and phytoremediation . Policy innovation is also required to support industrial disruption. **Prof Reddy** (IITM) also set out some potential technological approaches, including solar PV desalination techniques already employed in India, but that their use should be driven by accessibility, acceptability, affordability and availability since large scaling up would be required. Cost, in this respect, was identified as critical to technological uptake. Without urgent action, the impacts on local populations will continue to grow: a point also raised by **Dr. K. Muthukumar** (Kongunadu Arts and Science College, Coimbatore). Due to the pollution, no agricultural cultivation now occurs in the downstream parts of the Noyyal River basin. Wells, ponds and land are contaminated leading to loss of agricultural productivity and health impacts, with farmers now engaged in conflict with dyeing industries. Compensation is not equitably distributed. The responsibility of industry in ensuring that water resources are not polluted was also emphasised. In responding to these points, **Mr. S. Nagarajan** (President of the Dyers Association of Tiruppur) accepted the necessity to find industry-relevant solutions but also expressed a need to examine all the evidence. It was argued that, following the 2011 court ruling on achieving zero liquid discharge, the industry has responded through constructing primary treatment. Out of the 100 million litres of effluent generated by the industry, it was claimed, 94% of water is being recycled, with 4-5% of the brine concentrated and used again. In addition, the Tamilnadu Pollution Control Board (TNPC) has already set mandatory standards for treatment. One problem is funding further treatment: economic incentives must be provided for industries to innovate in achieving zero liquid discharge. Here, it was suggested that the costs of reclaimed water could be reduced below that of fresh water required for dyeing and a 'Green tag' could be developed to enable manufacturers to charge an environmental premium on their products. The reuse of materials may also provide an answer as waste dyes can be converted into new forms of profit generation.

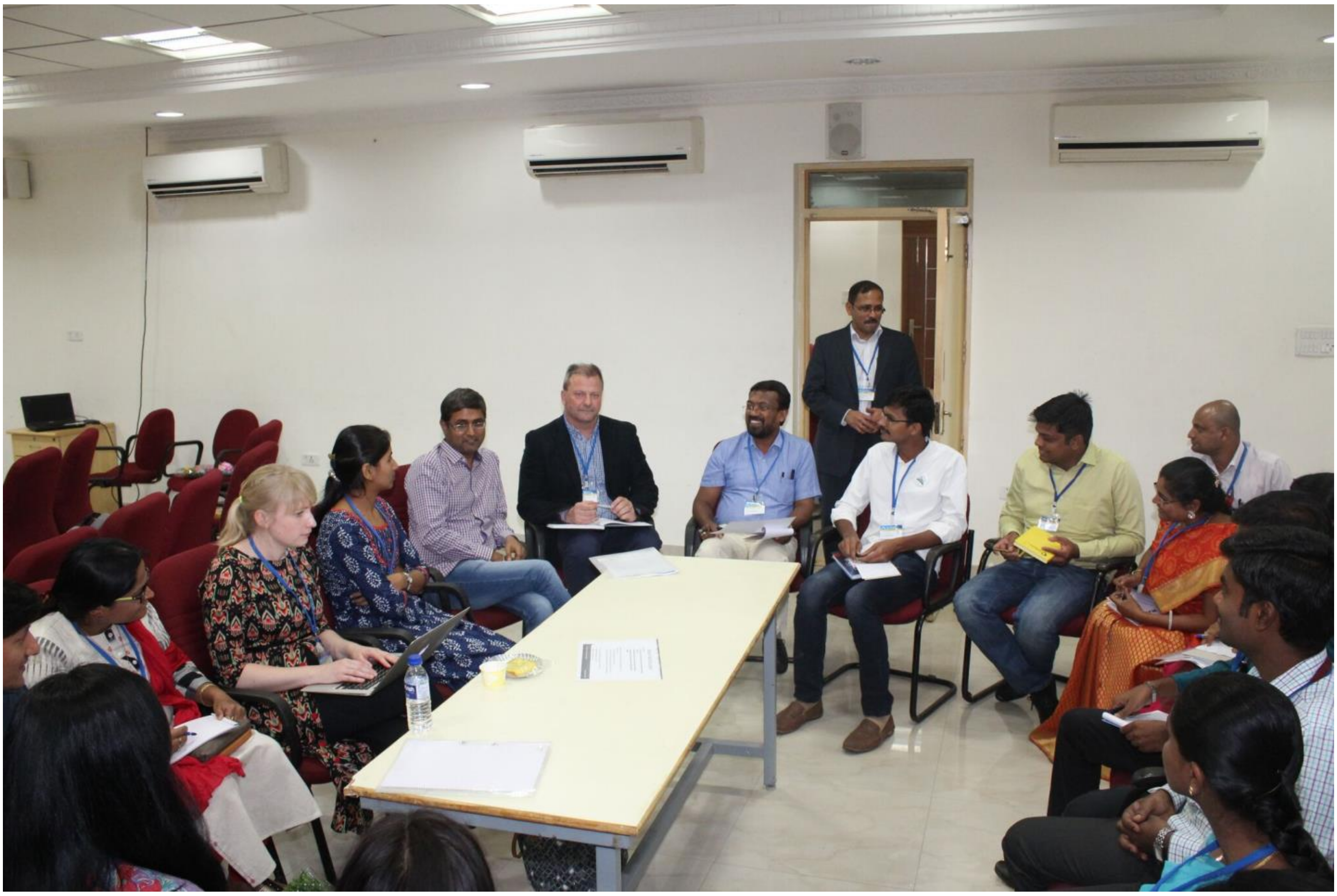
The final session considered some emerging technological approaches to wastewater treatment that could potentially address this observation. **Dr Brenda Parker** (University College London) showed how algal bioremediation of wastewater could be linked to an emerging circular economy [7], whereby material is reused within industrial cycles thereby adding value to production chains. Here, microorganisms could be employed in-situ or ex-situ to remove pollutants from wastewater and reuse these wastes within subsequent production. She presented case studies on how algal bioremediation was utilised to manage waste, including how nitrogen-rich brine waste was used to grow algal biomass and also how algae were employed to remove and upgrade (or transform into a less toxic form) heavy metals in contaminated land. In this respect, **Dr Mishra** (University of Delhi) described how dye waste products, which present significant toxic risks to human health and the environment, could be detoxified. She discussed evidence from the academic literature and studies conducted in her laboratory that show how unregulated and nontoxic parent dye can be transformed into toxic substances which can cause mutagenicity, cytotoxicity, phytotoxicity and chromosomal damage in the organisms exposed to them. She further highlighted the lack of toxicity assays in the literature, necessitating further study into the wider ecological impacts of the dye effluents that are released (treated, partially treated or untreated) into the environment. As the dye industry is economically significant, a need for further research into industry and ecologically relevant bioremediation methods, for example by using chlorination, was identified. Other potential technological innovations were then presented, with **Prof Tapas Mallick** (University of Exeter) explaining how solar systems – both thermal and PV – are amenable to water purification. He suggested the use of membrane systems such as solar electrodialysis for dye removal from wastewater. There are nonetheless constraints to this type of purification, primarily accessibility but also affordability. One potential option is membrane desalination powered by solar PV. Nanoparticles is another emergent technological area for wastewater remediation, as identified by **Dr. Bhuvaneshwari** (Kongunadu Arts and Science College). Various forms of nanoparticles including metal oxides, nanotubes, bioactive nanoparticles, biomimetic membranes, graphene and nano structural catalysts are potentially applicable. Another potential technique, Graph Air, which is the only filtration technology which can remove 99% of organic matter from wastewater at low pressure, was also identified as potentially applicable. **Dr Mann** (Bennamann Ltd. UK) then discussed how bioenergy technologies could be applied to this problem. By converting waste farm slurry to biogas, his company is able to generate revenue for farmers through application of an innovative cryogenic process that allows efficient commercial distribution of the product. He proposed that the entire process is carbon neutral as well supporting the circular economy by reusing waste material. Anaerobic digestion was suggested as an effective technique for remediation of wastewater pollutants. This process could be utilized to remediate industrial waste or other pollution impacts such as water hyacinth biomass. Finally, **Mr Mohanty** (CEO, Phycolinc Technologies Pvt. Ltd) gave several practical case studies of integrated wastewater treatment from the textile industry and domestic sources in India. One plant in Malegan, Maharashtra, which was mercerizing and desizing textiles, was releasing untreated effluent into the local Mausam river. Microlagae were used treat the effluent, reducing the pH from 13 to 8 plus COD levels, before being discharged to the environment. Cost effectiveness and scale up potential of techniques were also discussed.



4.2 Parallel panels

Three parallel panels were staged in the afternoon of the workshop, with participants divided into socio-economic, bioremediation and solar PV groups. Panels were given three questions to consider concerning their main research priorities Indian river pollution, challenges to such research and potential collaborations that could be developed around these priorities.

Panel 1 considered these questions, identifying several areas of potential research collaboration. From the discussions, data deficiencies presented an evident constraint on addressing water pollution. More specifically, participants identified clear data gaps around health impacts, basin water quality and quantitative aspects of water management. Climate change is already exacerbating flood risks in the river basin. Data are also limited on the toxicity of dye effluents and the epidemiological effects on local populations. However, the lack of robust data on water quality, pollution sources and pollution 'hotspots' is particularly significant, since this evidence base could be considered critical to the preparation of a Detailed Project Report (DPR) – which in turn is necessary for requesting government funding for pollution remediation. A point forwarded was that such actions are currently underfunded, representing a major constraint on affirmative action. NGOs (OSAI) also stated that lack of funding was inhibiting their activities, suggesting that they could work with the KASC to hold further collaborative events if properly resourced. Finally, more specific needs were identified in valuing environmental resources to determine ecosystems services from water and associated biodiversity. The discussion also focused around how academic partners such as the University of Exeter could supply research expertise to meet such stakeholder demand, with data collection singled out as a key focus.



Panel 2 considered the lack of data on composition of waste streams and the fate of pollutants as a starting point. While some bioremediation technologies have been trialed in other sites by companies such as Phycolinc, a detailed understanding of mechanism and metabolism, including the fate of dye waste intermediates is currently missing. A key challenge for any treatment technology is the presence of a mixture of compounds, including pesticides from cotton substrate, dyes, salt, along with many unknowns including pollutants already in water abstracted. However, as the treatment plants pool waste from a number of facilities the industry association stated that there is a relative overall homogeneity in terms of the nature of the effluent. The industry association identified a number of recalcitrant issues with operation of CETP for dye waste. At present, there is not a method for dealing with non-biodegradable organics. There are 10 tons/day ASP sludge generated, and at the moment this is supplied dry and mixed with lime to be sold at a nearby cement factory. The burden of salt was stated as a particular problem, as neutralization processes lead to a net increase in salt. Detection and monitoring was also identified as a challenge, both for regulators seeking to implement stricter controls and for bioremediation practitioners wishing to establish the effectiveness of waste treatment. Cost effective, reliable and responsive on-line sensor systems for key pollution indicators are needed. In terms of remediation technologies, constructed wetlands have been implemented in other areas for salt management. However, due to the large volumes of water processed on a daily basis, and the footprint, the industry representatives questioned if this could be viable. Combining waste management with energy production could also contribute to plant efficiency. If biogas could be generated from anaerobic digestion of sludge, then energy could be recovered. At present, CETP operation uses coal, and thermal evaporation this has been identified as a significant cost. Potential routes for collaboration included the characterization and scale up of lab-based remediation experiments (Delhi and UCL, with pilot trials in collaboration with Phycolinc). It was recognized that integration of several systems may be required e.g. a hybridised process - algal and bacterial, using algae and ASP, or a sequential process dealing with different aspects of the waste treatment.

Panel 3 examined wastewater and solar engineering research on industrial wastewater pollution. Significant potential exists, as outlined in the workshop presentations to link solar energy technologies (concentrated, PV) to wastewater pollution remediation. The previous IAA workshop, held by the organisers in 2016, discussed the potential of solar technologies for powering water purification, primarily for desalination via reverse osmosis membrane technology. Such research is already being scaled up for commercial use elsewhere and has evident applications for addressing water pollution problems. Here, solar electrodialysis, using membrane systems, could be applied to industrial wastewater for dye removal. Significant scope exists for collaborations between UK and Indian researchers to develop technologies for use in India but also other ODA compliant countries, where innovative ‘off-grid’ solutions can support water-energy-food nexus development. As discussed in the workshop presentations, caveats to operationalising this purification technology include its accessibility and affordability, since cost efficiencies may restrict commercial scale up. Ongoing collaborations between the University of Exeter and ITTM could support such research.

5. Conclusions – meeting the aims and objectives

In conclusion, several research objectives were met in support of the project aim (see above). The workshop synthesised pre-existing research on innovative wastewater remediation technologies, presenting it to a range of academic and non-academic partners. Research was presented covering the use of inter alia constructed wetland remediation, algal bioremediation, anaerobic digestion, nanoparticles and innovative solar PV approaches. The workshop adopted a collaborative approach to knowledge transfer, involving different stakeholders: scientists; practitioners; industry; NGOs; and civil society. It was particularly important to include the views of the industry association, to demonstrate that solutions are not only a shared responsibility but also that addressing problems can present potential commercial opportunities or 'win-wins'.

This point then relates to the third workshop objective. Although the workshop process only initiated a broad dialogue, nascent recommendations for industrial scaling up of these technologies to support disruption of current unsustainable activities can still be forwarded. Industry actors themselves identified the need for technological solutions that are cost-effective and financially incentivising. In this respect, the workshop could help discursively 'reframe' the problem within the broader goal of sustainable development, particularly SDG 12, and the circular economy. Here, technological recovery of pollutants, both organic and inorganic, could add value to dyeing industry production chains, domestic wastewater remediation and agricultural water uses, thereby enhancing long term commercial profitability. Several technologies presented could provide an excellent fit with this issue reframing, most notably algal bioremediation, biological methods, anaerobic digestion, nanoparticles and solar technologies.

Finally, an additional output of the workshop was to identify research priorities. Lack of data on pollution sources and effects, for example, was considered a significant constraint to resolving issues. Research into health impacts, collaborative governance [8], valuing natural resources and climate change would have additional value. In particular, establishing a long-term collaborative process involving key stakeholders (NGOs, industry, citizen groups, academic, government agencies) is a priority. In terms of bioremediation, the industry association would like to understand how they can move from zero liquid to zero solid discharge at CETP. Data sharing was identified as an important first step towards the development of effective technologies. While laboratory bioremediation studies on defined compounds are important for R&D, there is a need for access to industrial samples. Research priorities included understanding the mechanism of dye detoxification in mixed consortia of microorganisms and scale up of sequential/hybridised systems. The emphasis was also on partnering with companies who could operate pilot sites in the field to ensure in-situ performance. Solar engineering research also has evident potential for addressing water pollution issues in the river basin and in other contexts. Here, research priorities include examining the commercial potential for scaling up solar electrodialysis for dye removal from wastewaters, and the development of solar technologies (PV, concentrated) for powering pollution remediation techniques, for example heavy metals or biological remediation. While such future research can help with countering chronic industrial wastewater pollution at this river basin scale, given the parlous state of major rivers across India and access to clean water issues on a global scale, this combined research agenda could prove significant in future.

References

1. Kulinkina, A.V. (2016) 'Seasonality of water quality and diarrheal disease counts in urban and rural settings in south India.' *Nature*. DOI: 10.1038/srep20521
2. UNICEF (2015) *Water in India: Situation and Prospects*. New Delhi: UNICEF.

3. Nair, K.S. (2016) 'Impact of Climate Change and Anthropogenic Pressure on the Water Resources of India: Challenges in Management'. Water Resources Assessment and Seasonal Prediction Conference, *Proceedings of the International Association of Hydrological Sciences (PIAHS)* 374: 63-67.
4. United Nations (2016) *Water Facts*. New York: UN. http://www.unwater.org/topics/water-quality/en/
5. United Nations (2015) *Sustainable Development Goals*. New York: UN.
6. United Nations (2015) *Sustainable Development Goals*. New York: UN.
7. Winans, K., Kendall, A. and Deng, H. (2017) 'The history and current applications of the circular economy concept.' *Renewable and Sustainable Energy Reviews* 68: 825-833.
8. Benson, D., Jordan, A., Smith, L. (2013) 'Is environmental management really more collaborative? A comparative analysis of putative 'paradigm shifts' in Europe, Australia and the USA.' *Environment and Planning A* 45 (7): 1695-712.

Appendix 1 – Workshop schedule

Day 1

Agenda

Introduction

08.30 Arrival/Registration – Tea & Coffee
09:00 Inauguration -
09.10 Introductions – Dr. Senthilarasu Sundaram, UoE, UK
09:20 Overview of the Project and Workshop Aims – Dr. David Benson, UoE, UK

Session – I Chair Prof. Tapas Mallick, University of Exeter, UK

09.40 Noyyal River History and Cultural practices – Mr. Perur Jeyaraman, Coimbatore
10.00 Noyyal River pollution and Dyeing Industry in the river basin – Mr. Kalidassan, OSAI, Environmental Agency
10.20 Scientific studies on the Noyyal by TNAU, Prof.S.Avudainayagam, Professor and Head, Dept. of Environmental Sciences, TNAU, Coimbatore
10.40 Tamil Nadu Government Policies and Practices in the Noyyal Basin – Dr. R. Ilangovan, PWD, Tamil Nadu, India

11:10 Tea and coffee

Session – II Chair Dr. Brenda Parker, University College London, UK

11.20 Wastewater treatment practices in Textile Industries -Prof S.Karthikeyan, Professor (Microbiology), Dept of bioenergy, TNAU
11.50 Best Possible Wastewater Treatment by Dyeing Industry – Mr. S. Nagarajan, President, Dyers Association of Tirupur, Tirupur
12.10 Socio-economic and Health issues from Dye Pollutants – Dr. K. Muthukumar, Kongunadu Arts and Science College, Coimbatore.
12.30 Wastewater Engineering Solutions for the Dyeing Industry – Prof Srinivas Reddy, IIT-M, Chennai, India

13:00-14:00 Lunch

Session – III Chair Prof. K. Srinivas Reddy, Indian Institute of Technology-Madras, Chennai

14:00 Algal Bioremediation and the Circular Economy – Dr. Brenda Parker, UCL, UK
14.20 Bioremediation Practices for Sustainable Dye Industry: An Environmental Perspective– Dr. Vandana Mishra, University of Delhi, India

14.40 Solar Technology Solutions for Water Treatment – Prof. Tapas Mallick, UoE, UK.
15:00 Purification of Noyyal River water using nano particles- Dr. V. Bhuvaneshwari, Kongunadu Arts and Science College, Coimbatore
15:20 Bioenergy solutions from waste slurry – Dr. Chris Mann, Bennamann Ltd UK.
15:40 Integrated effluent treatment and water body restoration using micro-algae - An Industrial case study – Mr. Sumeet Mohanty, CEO, Phycolinc Technologies Pvt. Ltd

16.00 Coffee/Tea

Session – IV Chair Prof. K. Srinivas Reddy, Indian Institute of Technology-Madras, Chennai

16.00 Round Table Discussion – Three parallel panels

- *Socio-economic and governance research on industrial wastewater pollution* – Dr. David Benson to lead
- *Bioremediation research on industrial wastewater pollution* – Prof. Karthikeyan to Lead
- *Wastewater and solar engineering research on industrial wastewater pollution* – Prof. Srinivas Reddy & Prof. Tapas Mallick to lead.

17:00 Summary and Further Actions
17:30 Finish and Early Departure

19:00 Dinner (All the participants)

Day 2:

08:00 TNAU Lab visits

10:00 Travel to Mercury Processing, Tirupur.