International Specialised Skills Institute

State Government Victoria Department of Education & Training

ENERGY EXTRACTION

from domestic wastewater and municipal solid waste

An International Specialised Skills Institute Fellowship.

PHILLIP BELL

Sponsored by the Higher Education and Skills Group, Department of Education and Training (Victorian Government)

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i. Executive Summary

The decreasing amount of fossil fuels coupled with the current push for societies to move toward alternate and renewable energy sources has prompted research into contemporary wastewater sludge treatment processes. The use of wastewater sludge treatment processes that incorporate wet municipal solid waste is a new technology that not only solves the problem of wet municipal solid waste disposal but delivers significant commercial bio-fuel recovery. To this end, research into the use of sludge and wet municipal waste as a bio-fuel to run critical processes in the treatment of wastewater is being undertaken in several overseas locations, predominantly Europe and Asia.

While wastewater treatment on a large scale is primarily the domain of municipal / community collection infrastructure treatment plants, environmental concerns for the quality of discharge from general manufacturing and food manufacturing industries has also provided an imperative for wastewater discharge to meet these environmental standards.

Despite considerable global research projects focused on the use of wastewater sludge and wet municipal solid waste as sources of biofuels, there is a noticeable gap in the Australian industry and operator skill levels. As a result, wastewater sludge and wet municipal solid waste continues to be administered as a final treatment process whereby, in many cases, the waste is buried in landfill causing grave concern for other environmental factors such as groundwater quality.

This Fellowship has resulted in the formation of strong connections between industry and education providers in Australia and India. A framework for skills transfer and training has been developed. To that end, the development of the Certificate III and Certificate IV in Water Operations, which incorporates the skills necessary to run the process of biofuel recovery, is well underway. Accreditations are scheduled for completion in 2017 with the inaugural courses commencing in 2018.

ii. Abbreviations and Definitions

AIWS	Australian Institute of Water Sciences
Mld	Million litres per day
WWTP	Wastewater Treatment Plant
WMSW	Wet Municipal Solid Waste

Definitions

Biofuels
Biofuels are fuels produced directly or indirectly from organic material (biomass) including plant materials and animal waste. In this context biofuels include the components of sludge and wet municipal solid waste that is able to be used to extract energy

Recognition of Prior Learning (RPL)
The acknowledgment of a person's skills and knowledge acquired through previous training, work or life experience, which may be used to grant status or credit in a subject or module.

Sludge
Sludge includes material that is produced in various industrial processes (such as in the treatment of sewage). Sludge is generally the intermediary and/or final product of the wastewater treatment process

Treatment
Wastewater treatment is a process to convert wastewater - which is water no longer needed or suitable for its most recent use - into an effluent that can be either returned to the water cycle with minimal environmental issues or reused.

Wastewater
Wastewater is any water that has been adversely affected in quality by anthropogenic influence. Wastewater can originate from a combination of domestic, industrial, commercial or agricultural activities, surface runoff or stormwater, and from sewer inflow or infiltration.

Wet Municipal Solid Waste
Wet municipal solid waste incudes domestic waste such as food waste of meat, fats, oils and vegetable waste, as well as trade waste including food and meat processors, kitchens and fast food retail outlets

Unit of Competency
A component of a competency standard. A unit of competency is a statement of a key function or role in a job or occupation. See also element of competency, performance criteria, range of variables.

Training Package
An integrated set of nationally endorsed standards, guidelines and qualifications for training, assessing and recognising people's skills, developed by industry to meet the training needs of an industry or group of industries. Training packages

consist of core endorsed components of competency standards, assessment guidelines and qualifications, and optional non-endorsed components of support materials such as learning strategies, assessment resources and professional development materials.

1. About the Fellow

» Trainer in Water Operations at Australian Institute of Water Sciences.

» Professor of Water Science at Trinity Academy of Water Science, Pune, India.

» Qualified chemist with a bachelor's degree in Applied Science.

» Forty-two years of industry experience in water and wastewater analysis and treatment.

» Interested in researching and implementing new technologies that improve treatment processes and save on energy costs.

Phillip Bell, Fellow, ISSI, Adjunct Professor and Co-Chair, Trinity Academy of Water Sciences, Pune, India

2. Aims of the Fellowship Program

The goals of the fellowship program were to:

» Study new methods of sludge and municipal solid waste treatment that enables this waste to be converted to biofuels.

» Identify and record specific skills required by the wastewater operators to facilitate the process of converting wastewater sludge to biofuel.

» Form relationships with overseas stakeholders who are already involved in the extraction of biofuels from wastewater sludge.

» Share and compare information from the Australian context and the overseas experience with stakeholders overseas in order to identify key technologies and skills required to enable the advancement of these skills and technologies in Australia.

» Produce a working roadmap that incorporates strategies to adopt new technologies that enable wastewater sludge to be converted to biofuels as well as strategies to ensure that the relevant skills are incorporated in wastewater treatment training programs.

3. The Australian Context

The wastewater industry in Australia is predominantly involved in treating wastewater from both domestic and industrial sources. While the technology and skill levels are developing with respect to the main treatment methods, the processes involved are expensive due to energy and labour costs. In the primary treatment process such as removing solids from wastewater, energy costs are particularly high. In winter months and in colder climates, energy is required to maintain an even, moderate temperature to allow aerobic and anaerobic digesters, membrane bioreactors and other biological processes involved in wastewater treatment to function properly. Other significant costs involve the transportation of large amounts of sludge during the final disposal. Wet municipal solid waste disposal remains a significant problem in Australia with much of it being sent to landfill, ultimately causing environmental issues such as underground gas build up and leakages leading to detrimental effects on shallow aquifers.

New technologies currently successfully operating internationally enable the majority of the sludge to be converted into biofuels which are then used as energy sources to run the treatment process itself. This includes technical equipment such as water pumps and temperature monitoring equipment necessary in the biological treatment process.

The increasing demand for wastewater treatment and disposal of wet municipal solid waste, fuelled by increasing populations, provides an imperative to not only reign-in energy and processing costs but to be conscious of the environmental impact of these processes. While the technology and skill required to achieve both volume and energy efficiencies is available overseas, this technology has not been widely adopted in Australia.

SWOT analysis

Strengths

» New technologies reduce the volume of sludge and hence reduces transport and disposal costs.

» Sludge conversion to biofuels provides energy to run the treatment processes, thus saving on a major cost centre.

» Biofuels could be exported to other industries and processes.

» Wastewater process costs can be partially mitigated by selling excess biofuels.

» Industry can be created around the collection and conversion of sludge to biofuels.

Weaknesses

» Building of sludge to biofuels conversion infrastructure required. The initial costs might be an impediment to some treatment operators.

» Little or no research in the Australian context. Very little local research is being done that specifically looks at Australian conditions.

» Lack of knowledge of the processes involved.

» Many small treatment plants mean that there is insufficient scale.

» Lack of skills involved in the process.

» Lack of training in Australia.

» Reluctance of industry to make changes to current practices.

» Availability of land for landfill means that Australian treatment operators find it convenient to simply bury their sludge, particularly in rural settings.

Opportunities

» Better efficiencies in energy use during treatment processes.

» Provision of new skills for operators.

» Export of sludge treatment creating new energy industries.

» Smaller carbon footprint.

» Improvements to groundwater resources (less impact from sludge burial).

» Less need for land to create landfill areas for sludge disposal.

Threats

» Reluctance of stakeholders to invest in and / or adopt new technologies.

» Temporary reduction in cost of fuel such as oil and gas makes biofuels less cost effective.

» Expensive intellectual property acquisition costs where technology is imported directly.

» Little or no support for renewable technologies from government stakeholders.

4. Identifying Skills Deficiencies

4.1 Initial preparation of sludge

» Dewatering techniques to remove excess water.

» Developing heating infrastructure to break down sludge particles.

» Transferring of treated sludge to bioreactor vessels.

4.2 Extraction of energy from the sludge

» Development of suitable bacteria to break down waste and produce fuel gas.

» Maintaining conditions of temperature and pressure to facilitate micro-biological activity.

» Separation of fuel gasses from unwanted gasses such as hydrogen sulphide.

» Monitoring of biological activity.

» Collection and storage of fuel gasses.

4.3 Collection and disposal of de-energised sludge

» Analysis of calorific value of sludge and wet municipal solid waste during and after the biological process.

» Further treatment of sludge wet municipal solid waste to extract any remaining energy.

» Further dewatering of sludge.

» Handling of sludge and wet municipal solid waste and OHS / environmental concerns.

Outcome of result statement

The outcome of this study is to investigate and introduce new skills and technologies in the Australian wastewater and wet municipal solid waste treatment context, with respect to waste treatment, with the express aim of accessing the energy inherent in wastewater and wet municipal solid waste.

5. The International Experience

5.1 Experience 1.

The Fellow met with a consortium from the Trinity College of Engineering and Research where he was introduced to Professor Vijay Whadi and Professor Satish Deshmukh from the Civil Engineering Faculty.

Professor Vijay Whadi

The district of Pune has 411 public operational wastewater treatment facilities. Overall, the current Pune residential water supply is 794 million litres per day (mld), despite that, the current government mandated allocation of 459 mld (58 %), based on a population of 3.4 million at 135 litres per capita per day.

Household deposits are about 70 - 100g per capita per day of solids into wastewater. The impurities present in the wastewater must either be transformed into innocuous end-products or be effectively separated from the effluent stream. Impurities which are removed are drawn off as side-streams to the main flow and partially converted into gaseous products like methane. Treatment and disposal of side-streams is an essential part of the overall treatment process and they frequently contribute significantly to the total cost of treatment.

It should be appreciated that the sludge consists mainly of water and that dewatering is the first and most important requirement in sludge processing. The cost of treating the sludge, particularly for wastewaters, is a major component of the total cost of treatment, and the effects of the final disposal methods and return flows from sludge treatment can have significant implications for the environment.

The Pune urban circle faced a power shortage of about 90 MW, which would have resulted in the distribution utility, Maharashtra State Electricity Distribution Co Ltd, switching off power for about three hours daily. But this has been largely avoided thanks to initiatives that use biofuels to generate the electricity to run energy-hungry waste treatment plants. Energy in terms of electricity is rationed throughout Pune with load-shedding occurring for each district in turn throughout the week for 3 hours once per week.

The Fellow was introduced to various parliamentarians including the chairman of the Maharashtra Legislative Council The Hon. Ramraje Naik Nimbalkar, deputy chairman Shri Manikrao Thakre. leader of the House, Shri Chandrakant Patil and leader of the Opposition, Dhananjay Munde. Everyone agreed that Maharashtra was the leading state in India in the production and adoption of bio-fuel technologies.

The Fellow was invited to address a forum of dignitaries and university students at Trinity Academy of Engineering to describe the Australian context and the way in which advancements in Indian technologies and skills can be transported to Australia.

After the formalities, the Fellow was invited to participate in workshops led by Dr. Vijay Whadi. During these workshops discussions took place on the progress of biofuels technology, the training of operators, creation of specific training modules, and competencies and methods of streamlining processes. Strategies for rolling out the technology and training to other parts of the Indian sub-continent were also discussed.

Trinity College of Engineering and Research, Pune, India

Objectives

To become familiarised with bio-fuel technologies in the Indian context with the aim of learning about those parts of the technology not available in Australia.

Outcomes

The workshops over seven working days were instrumental in the sharing of experiences from operators of different wastewater facilities throughout the Pune district. Participants could describe their situations and share common problems and successes. Items discussed were:

» Newly acquired knowledge about process constraints such as temperature and chemistry

» Methods of producing various biofuels including methane and bio-diesel

» Problems and solutions to process problems including fat and energy content

» Networking opportunities for participants to be able to share resources and knowledge

Key Learnings

Municipal wastewater is a valuable source of energy that can now be exploited to create biofuels like methane and bio-diesel.

Major obstacles such as moisture content that have made extraction of biofuels such as bio-diesel from sewage sludge have largely been overcome.

Production of methane from sludge is vastly superior to Australian methods due to the process of “cooking” which allows the particles of sludge to become finer, providing the biology with greater surface area, hence greater output per kilogram of sludge.

Pre-treatment of sludge to provide optimum conditions for lipid (bio-diesel)

extraction which includes initial dewatering, cooking to decrease particle size, extraction and conversion of fatty acids and finally extraction of bio-diesel

5.2 Experience 2

The Fellow met with Mr. Umesh Panse from Panse Consultants Pvt. Ltd, a civil engineering consulting firm responsible for a considerable number of the wastewater treatment plants in the Maharashtra and particularly the Pune district. The Fellow was invited by Mr. Panse to spend several weeks visiting eight (8) wastewater treatment plants in and around Maharashtra where sludge is being converted to biofuels and / or where works are in progress to install equipment and processes to extract biofuels from municipal wastewater.

Pre-treatment of wastewater for Bio-fuel extraction

The Fellow was invited to be one on the Pense Consulting team responsible for the management of these plants. At three of the plants visited, the process of creating biofuels was well established, however they were not meeting their targets for energy generation. The investigation team of which the Fellow was a member, concluded the following.

- Lack of training in general wastewater treatment processes resulting in low levels of sludge and elevated levels of solids in the final effluent.
- Plant facilities were not properly maintained and were inefficient
- Flow rates had exceeded the plant design and therefore not operating to specification

For each of the above indicators of failure, training was identified as the problem.

Objectives

To get firsthand experience working at various wastewater treatment plants to learn how the process of creating biofuels work in the Indian context, with the aim of adopting practices that can be applied in Australia.

Bio-gas Storage

Outcomes

The key outcome was establishing the knowledge that the fundemental determinant of success in the conversion of sewage to biofuels is the reliable operation of the facility. Underpinning this reliability is adequate operator training. The Fellow is acutely mindful of the necessity for sound operator training and documentation of standard operating procedures.

Key Learnings

» The importance of operator training and documentation

» The importance of maintenance

» That plant design must adequately consider future growth

» The process is successful when the technology is correctly applied

» There are several opportunities for learning in the Australian context, particularly in relation to preparation of sludge for both biological digestion to create methane or adequate dewatering for the purposes of extracting bio-diesel

5.3 Experience 3

On the following trip to India in June 2017 the fellow was accompanied by Mr. Atul Bhaktar and Mr. Puruchottum Chhatre from the energy and commodities consortium Reya Group Pty Ltd., the water science training organisation, Australian Institute of Water Sciences and the Maharashtra Skills Development & Entrepreneurship Minister, Mr. Diliprao Patil. The purpose of the meeting was to create lines of co-operation between Indian and Australian industry and skills training providers with the aim of creating a path for skills transfer in the wastewater treatment space in either direction.

One of the major initiatives from the Indian perspective was to solve the problem of accumulating, rotting wet municipal solid waste stored in 5 locations around the district of Pune and replicated at the majority of major population centres around India. While the Indian plant operators had the technology to solve this problem, it was made clear that they generally lacked proper skills due to a lack of formalised skills training.

In contrast, the Australian delegation made it clear that skills training in Australia is widespread and expected in order to operate wastewater treatment facilities. The benefits gained from formalised skills training was outlined by the Australian delegation as follows:

Longevity of plant assets - It has been well established that WWTP asset life is prolonged by the establishment and adherence to sound operating procedures and practices. This includes identifying proper operating parameters and recognising situations where processes are failing that will have future negative impacts on WWTP assets.

Meeting EPA licence requirements - Failure to meet Australia EPA discharge licences as described above results in prosecutions under the Environmental Protection Act. In most proven cases, this will mean substantial fines up to several million dollars depending on the severity of the breech. In all cases WWTP operating entities are required to make good the damage caused by non-compliance.

Ongoing / Recurring costs / Efficiency - The cost of maintaining and running WWTP facilities involves maintenance, labour and consumables such as chemicals. Inadequate training leads to overuse of chemicals and other consumables adding to the running costs of wastewater treatment. This also extends to processes such as sludge treatment and dewatering both of which incur high costs. The standard Australian practice is to train operators to manage and optimise chemical dosing as well as undergo training in the proper management of sludge.

Occupational health and safety - Before the various Workplace State Safety Acts were updated in Australia, there was little operator training specific to workplace safety. World's Best Practice now dictates that operators are training in the safe management of each process in the wastewater treatment cycle. This not only

reduces immediate and long-term injury to operators and other workers but reduces overall running costs by reducing operator absences.

Environment - World's Best Practice involves consideration of the environment. This includes the broader environment that extends to waterways and rivers, coastal areas for recreation and ports, parks and gardens and urban amenities. Wastewater directly impacts these environments. To that end, training of WWTP operators has a direct beneficial effect on protecting these environments.

Objectives

To create a framework for a skills training course that combines the units of competency available in Australian accredited wastewater treatment courses, with the skills required to run wastewater plants that treat wet municipal solid waste and produce biofuels.

Outcomes

The key outcome from this experience was formalising a relationship between key engineering colleges and universities, Skill Development & Entrepreneurship Ministry, Reya Group Australia and the Australian Institute of Water Sciences.

Considerable effort from all parties that has produced an accredited course that will not only benefit Indian operators but Australian companies in the water and energy space considering producing energy from waste sludge and wet municipal solid waste.

Key Learnings

Synergies between the skills training needs of Indian and Australian wastewater and bio-fuel interests.

Development of Certificate III and Certificate IV courses that will be delivered in India and Australia covering the essential skills to run effective wastewater treatment, WSMW and bio-fuel recovery.

Joint facilities between Indian education institutes and Australian Institute of Water Sciences to conduct research programs to improve wastewater treatment methods and bio-fuel recovery.

6. Knowledge Transfer: Applying the Outcomes

Knowledge transfer is best achieved by educating Australian wastewater and municipal solid waste collectors on the benefits of investing in the technology to turn waste into biofuels. Such waste that would otherwise be relegated to landfill can now be used to produce biofuels that run the treatment plant.

In the Indian context, this is done by feeding the energy produced by the biofuels into the public electricity grid. The permanent connection to the public grid also enables the plant to use electricity when biofuel generation is not working at full capacity.

As of this writing, projects that involve the cooking of sludge to affect improved bio-fuel outcomes are happening in several countries including one wastewater treatment plant in Queensland, Australia.

Trinity Academy of Water Sciences Biofuels inaugural education team

7. Recommendations

1. Education on the processes outlined in this report by addressing seminars and industry group meetings.

2. Research on the viability of transferring these technologies and skills to Australia.

3. Approaches to government and industry stakeholders to establish a framework for obtaining research funding.

4. Collaboration between RTO's and Industry to formulate specific skills training courses and /or units of competency that would fit into existing courses such as NWP30215 Certificate III in Water Industry Operations.

5. Collaboration between Indian and Australian government, industry and skills education providers to share specific knowledge and skills.

6. Introduction of Certificate III and Certificate IV courses including units of competency specific to biofuel recovery from wastewater treatment sludge and wet municipal solid waste

8. References

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9. Acknowledgements

The Fellow would like to thank the following individuals and organisations who have generously given their time and their expertise to assist, advise and guide him throughout the Fellowship program.

Awarding Body – International Specialised Skills Institute (ISS Institute)

The ISS Institute exists to foster an aspirational, skilled and smart Australia by cultivating the mastery and knowledge of talented Australians through international research Fellowships. The International Specialised Skills Institute (ISS Institute) is proud of its heritage.

The organisation was founded over 25 years ago by Sir James Gobbo AC CVO QC, former Governor of Victoria, to encourage investment in the development of Australia's specialised skills. Its international Fellowship program supports many Australians and international leaders across a broad cross-section of industries to undertake applied research that will benefit economic development through vocational training, industry innovation and advancement.

To date, over 350 Australian and international Fellows have undertaken Fellowships facilitated through ISS Institute. The program encourages mutual and shared learning, leadership and communities of practice. At the heart of the ISS Institute are our individual Fellows. Under the International Applied Research Fellowship Program the Fellows travel overseas and upon their return, they are required to pass on what they have learnt by; Preparing a detailed report for distribution to government departments, industry and educational institutions; Recommending improvements to accredited educational courses; Delivering training activities including workshops, conferences and forums.

The organisation plays a pivotal role in creating value and opportunity, encouraging new thinking and early adoption of ideas and practice. By working with others, ISS Institute invests in individuals who wish to create an aspirational, skilled and smart Australia through innovation, mastery and knowledge cultivation. For further information on ISS Institute Fellows, refer to www.issinstitute.org.au

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Personal Acknowledgements

Trinity College of Engineering and Research

Considered throughout India to be leaders in innovation and research, Trinity College of Engineering and Research was established June 2008 offers courses in Electronics & Telecommunication, Mechanical Engineering, Computer Engineering, Information Technology, Civil & Electrical Engineering.

Trinity Academy of Water Sciences

Established in 2017 in a partnership with the Australian Institute of Water Sciences, in response to the need to establish an accredited training package specifically to enhance the skills of operators in India and Australia.

Panse Consultants PVT LTD

Established in 2004, Panse Consultants, with founder and CEO Mr. Umesh Panse is considered to be the premier manufacturers and service provider of wastewater and munincipal solid waste bio gas plant and associated technology in India

Parliament of Maharashtra

» The Hon. Ramraje Naik Nimbalkar - Chairman of the Maharashtra Legislative Council

» Shri Manikrao Thakre - Deputy chairman of the Maharashtra Legislative Council

» Shri Chandrakant Patil - Leader of the House and Leader of the Opposition.

Inauguration of Trinity Academy of Water Sciences

Australian Institute of Water Sciences

The Australian Institute of Water Sciences established in 2016 has as its mission the establishment of quality skills training and research in potable water and wastewater treatment as well as using wet waste to recover biofuels. Although the AIWS was only recently established, it has forged ahead in leaps and bounds forming valuable relationships thanks to the work of the fellow and the International Specialist Skills Institute. The efforts of the Fellow in the performance of this Fellowship, together with the government of Maharashtra, the Trinity Academy of

Water Sciences, the Trinity College of Engineering and Research and the Australian Institute of Water Sciences has resulted in the building of the framework for skills transfer in the wastewater treatment and bio-recovery space between India and Australia.

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