List of EWI awarded projects for RFP 08/01 (Biological Processes) and RFP 08/02 (Chemical Redox)

Name of PI / Co-PI	Participating Organisations	Abstract of Project
Integration of Novel Forward Osmosis Membranes and Optimized Bioprocess for Water Reclamation		
Prof Anthony G Fane	NTU	The osmotic membrane bioreactor (OMBR) is a new type of the membrane bioreactor (MBR) technology, which combines two basic processes – biological degradation of organic wastes and membrane separation using forward osmosis (FO) – into a single process for various wastewater treatments. Compared with conventional MBRs, the OMBR offers potential advantages such as lower energy requirement and better water quality for water reclamation. However, a number of technical barriers impede OMBR industrial applications. Two major challenges are the lack of an ideal membrane that can produce a high water flux and poor optimization of bioprocess performance in the bioreactor. The proposed work aims to the development of novel FO membranes suitable for use in the OMBR systems for water reclamation. The membranes will be integrated with a biological process enhanced by system optimization, where the interaction between the bioprocess and the membrane process is taken into account, and made suitable for scale-up. Its application and commercial exploitation will have direct benefits for the water industry in terms of better water quality and lower production cost as well as more options for various types of used water treatment. It will also provide strategic benefits for Singapore by meeting the national goals in sustainability through water reclamation. Through R&D and manpower training it will provide skilled professionals for Singapore's water industry.
Low-temperature Solution-processed Protonated Titanium Oxides for Photocatalytic Applications		

Assoc Prof Chen Zhong	NTU	Titanium dioxide is ubiquitous in our daily life, e.g., in skin care products and as pigment in paints ("Titanium White"). Its presence in every sunscreen is due to its strong ability to absorb or deflect harmful UV light. The ability to convert light it into another form of energy (heat, electrical and chemical) make TiO_2 attractive for advanced applications such as solar-driven hydrogen and electricity production (clean energies), and waste degradation (environmental). The proposed research is to investigate a recently discovered family of titanates in protonated form for environmental applications. An interdisciplinary team of materials scientists and chemical engineers are joining forces to develop photocatalysts that are able to more efficiently degrade harmful organic pollutants in waste water streams, and detoxify the same, e.g., by transforming toxic metal ions into innocuous ions.
Material Engineering and Fabrication of High-Performance Nanofiltration-based FO Membranes for Water Reuses		
Prof Chung Tai-Shung Neal	NUS	Forward osmosis (FO) is an emerging new desalination technology. Driven by an osmotic pressure gradient, FO does not require significant energy input. FO also may offer the advantages of high rejection of a wide range of contaminants and lower membrane-fouling propensities than traditional pressure-driven membrane processes. The team aims to develop better nanofiltration-based FO membranes for water recycle aiming to greatly reduce energy costs in water production.
Assembling of Multifunctional TiO_2 Nanofiber Membrane for Water Treatment		
Assoc Prof Darren Sun	NTU	Progress has been made with regard to the use of MF/UF membranes as advanced water treatment process for producing high quality drinking water with small footprint size. However, the commercial filtration membranes have a high fouling tendency caused by the deposition of contaminants such as NOMs and microorganisms which is one of the major problem in using filtration

		membrane for producing high quality drinking water. There is need in search for new generation membranes whihc will be able to overcome the existing problems of membrane fouling and leaking of contaminants within the membrane pore. Dramatic effects haveen added in this area by A/P Darren Sun's group. Given the potential of nanofabricated membrane to advance molecular separation and photocatalytic oxidation, we proposed the project is to develop a robust and inexpensive free-standing TiO_2 nanofiber membrane. In the presence of UV light, the crystalline TiO_2 nanofiber is know to produce strong oxidant and exhibit quantum size effects at nanosize (<10nm). These unique properties flexible, concurrent filtration and photocatalytic oxidation give rise to various applications particularly in producing cost effective commercial filtration membrane that could dramatically reduce the cost of water production.
Silver-doped mesoporous titanium dioxide for water disinfection and detoxification		
Assoc Prof George Zhao	NUS	Among the various disinfection technologies, the ultraviolet technology is increasingly gaining popularity because of several advantages such as it is safe, easy to install and operate, and environmentally friendly. However, ultraviolet disinfection also presents some problems. For example, low ultraviolet dosage may not effectively inactivate some viruses, spores, and cysts. In addition, ultraviolet disinfection does not have a residual effect, which is required for long-time disinfection. This project proposes to exploit the advantages of nanostructured composite materials for total disinfection of virtually all microorganisms and complete mineralization of organic compounds including those untreatable by conventional technologies.
MBR Process Modeling and Optimization: Case Study of Ulu Pandan WRP		

Asst Prof Jim Chen	NTU	Within Ulu Pandan Water Reclamation Plant (WRP) is a demonstration scale MBR plant with a design flow rate of 23,000 m3/day. The cost for operating the MBR system stems predominantly from its overall power consumption. The owners and operators of the MBR system, Public Utilities Board (PUB) and Centre for Advanced Water Technology (CAWT), desires to reduce its overall power consumption by 27% to achieve directly correlated cost savings. The strategy for achieving the desired cost savings is to develop computational models of the MBR system that will: a) Identify optimal operating conditions from searching historical data of the system performance b) Describe the biological processes that are occurring within the MBR system. Item a will identify the optimal operating conditions that exist within the ranges of conditions that have been historically practiced. Item b will extend beyond the limits of historical range of operating conditions and identify biological conditions that will even further improve the cost savings of the MBR system below levels achievable by item a. The models of items a and b would then be packaged together to form an overall comprehensive model. The comprehensive model will then be adapted and transferred to a scale-up MBR system as identified by PUB and CAWT. The strategy for achieving cost savings through power consumption reduction would then be repeated at the new site.
Nitrogen-doped TiO2/AC composite for adsorptive-photocatalytic oxidation-reduction of refractory organic subs		
Assoc Prof Lim Teik Thye	NTU	This project integrates environmental process engineering, materials engineering and advanced materials characterization to develop a new generation of adsorptive photocatalyst, that is a composite of

		nitrogen-doped TiO2 supported on powdered activated carbon (N-TiO2/AC). The NTiO2/AC composite is photoactive in sunlight, and exhibits adsorptive properties inherited from the AC for a large variety of organic pollutants that are resistant to degradation by conventional chemical and biological redox processes. Thus, synergistic adsorptive-photooxidative degradation of adsorbed pollutants may occur on the surface of the N-TiO2/AC composite. The AC also functions as a stable support for the nanosized N-TiO2 particles, preventing aggregation or deposition on the photoreactor wall. The N-TiO2/AC composite will be tested for (i) its photocatalytic activity under visible light, (ii) mechanical stability, and (iii) adsorptivephotodegradation of some emerging organic pollutants including plasticizers, pharmaceuticals, estrogen, ingredients in personal care products, and disinfection-by-products. To evaluate the practical delivery of the N-TiO2/AC composite in a water treatment system, an experiment in a completely-mixed flow photoreactor with microfiltration system will be carried out. The exhausted N-TiO2/AC composite will be tested for its ability to self-regenerate on site. The outcomes of this study will demonstrate the prospects, as well as possible barriers, to commercial (large-scale) application in potable water treatment. Success of the project will enable a large-scale, economical, clean, and safe application of photocatalytic redox processes in water treatment for potable water reuse.
Development of Forward Osmosis Membrane Bioreactor (FO-MBR) for Water Reclamation		
A/Prof Ng How Yong	NUS	Technologies such as membrane bioreactor (MBR) are widely used to recycle wastewater into product water for indirect potable or direct non-portable use. However, widespread application of MBR process is constrained by high energy cost due to the intensive aeration required for control of

		membrane fouling. The study aims to further develop the new technology by coupling forward osmosis (FO) process with biological treatment, a process known as FO-MBR. This is achieved by incorporating new materials and process designs to alleviate high energy and fouling issue, leading to greater efficacy in producing clean water for our consumption and the environment.
Microbial Fuel Cell Technology for Wastewater Treatment and Alternative Clean Energy Production		
A/Prof Ng How Yong	NUS	Microbial fuel cell (MFC) is an innovative and attractive technology that can produce alternative clean energy from cheap or free organic compounds such as wastewater. In an MFC, bacteria extract the energy stored into the organic compound and release it directly into the form of electricity. For the case of wastewater, organic pollutant is being degraded in the process, resulting in treatment of wastewater. This is an enormous advantage in comparison to conventional treatment processes. This project proposes a multidisciplinary approach to study the various aspects of MFCs from the fundaments to applications.
Development of AOP Utilizing Persulfate Based Radical Generation		
Richard Woodling	Siemens Pte Ltd	The proposed research to study and develop an advanced oxidation process will utilize persulfate based radicals for removal of organic contaminants and disinfection enhancement. Sulphate radicals formed from persulfate or peroxymonosulphate behave similarly to hydroxyl radicals. They have improved quantum yield in the destruction of organic compounds due to the high absorptivity of the persulfate ion as compared to ozone or peroxide. This study aims to improve the understanding of the sulphate radical's reactivity, degradation pathway, kinetics, oxidation efficiency and byproducts. The catalytic effects of several transition metals will also be studied to examine their capability to enhance the

		oxidation process. Lastly, the disinfection capability of sulphate-radical processes will also be investigated.
Minimizing Energy Usage by Applying Hybrid Anaerobic Digestion for Water Reclamation		
Richard Woodling	Siemens Pte Ltd	Siemens will conduct both laboratory and pilot experiments to investigate the feasibility of a novel hybrid process, with which it is potentially feasible to retrofit large scale municipal WWTPs to approach zero energy consumption and significantly lower sludge production. This novel process overcomes the technical difficulties of using anaerobic processes to treat low strength wastewater. It utilizes bio-sorption and flocculation mechanisms to convert an anaerobic wastewater process into a high strength- low volume anaerobic sludge digestion process. The majority of the COD/BOD in the wastewater is biodegraded by the anaerobic process in this scheme. This process can provide additional advantages in comparison with conventional anaerobic processes to directly treat wastewater.
A Pilot Plant Study on a New Combined Upflow Anaerobic Sludge Blanket (UASB)/Membrane Bioreactor (MBR) Process for Treating Municipal Wastewater in Warm Climatic Conditions		
Dr Wong Fook-Sin	IESE	The aim of the research is to develop a novel technique in operating a combined biological / membrane filtration system for treating a low substrate wastewater. The method utilizes a 'shortcut' route in nitrogen removal. This reduces oxygen requirement (saving on energy with less aeration) and also carbon requirement (saving on carbon consumption which can be used for methane generation). This can be applied to the treatment of municipal wastewater more economically, with the methane produced used for power generation. Preliminary laboratory testwork has produced promising results. This proposal seeks to operate a pilot trial to prove up the process, which if successful, will provide significant advantages over currently used methods for

		treating municipal wastewater in warm climatic zones. The major advantages include reduced power usage, reduced green-house gas production, useful methane gas is produced that can be converted to power, the plant requires less space and produces almost zero sludge.
Novel Silver Nanoparticle/Multi-Walled Carbon Nanotube Nanohybrid Coating for Disinfection of Drinking Water Treatment		
Asst Prof Xu Rong	NTU	Water resources are highly precious to Singapore given the small land area and a high urban population. Over the past decades, tremendous efforts have been spent to build a secure, reliable, and diversified supply of water to sustain our city's growth. The water supply of Singapore comes from the so-called "four taps", which are water from our local catchments, imported water, NEWater and desalinized water. To produce clean water which meets the domestic drinking water quality and industry standards, the solid particles, various chemicals and pathogens have to be removed from water by separation processes. The most commonly used technologies are based on membrane separation where only water molecules, and not other components, are allowed to pass through the membranes. Pathogenic microorganisms present in natural and used water if not being removed during water treatment will pose a serious threat to public health. The currently applied disinfection methods, including chlorination and ozonation, provide effective solutions to kill pathogens. However, these processes generate toxic by-products which are required to be treated with additional efforts. We propose a new disinfection system based on the combination of carbon nanotubes and silver nanoparticles, both of which have good antimicrobial activities. This binary nanocomposite material will be applied as an integral coating on the existing purification membrane to achieve an added excellent

		barrier for killing of pathogens with minimal by-products. Our purification system will be designed to ensure the carbon nanotubes and silver nanoparticles will not cause contaminants to water. Hence, besides achieving good disinfection performance, we will also ensure that the water safety will not be compromised.