Project number: T21-711/16-R

RESEARCH GRANTS COUNCIL
THEME-BASED RESEARCH SCHEME (TRS)

Completion Report on Funded Project

Project start date: *1 November 2016*
Project completion date: *31 October 2022*

1. Project Title:

Enhanced Separation and Sludge Refinery for Wastewater Treatment – Solving the Nexus of Pollution Control and Resource Recovery in Mega Cities

2. Names and Academic Affiliations of Project Team Members#

Project team member	Name / Post	Unit / Department / Institution	Average number of hours per week spent on this project in the whole project period
Project Coordinator (PC)	Li Xiao-yan / Chair Professor [1]	Dept of Civil Eng, The Univ of Hong Kong (HKU)	12
Co-Principal Investigators	Zhang Tong / Chair Professor [2]	Dept of Civil Eng, HKU	8
	Shih Kaimin [3] / Professor		6
	Chui May T.F. [4] / Associate Professor		6
	Gu Ji-dong [5] / Associate Professor	School of Biological Sciences, HKU	6

	Li Xiang-dong / Chair Professor	Dept of Civil & Environ Eng, Hong Kong Polytechnic Univ (PolyU)	6
	Lee Henry P.H. [6] / Associate Professor		6
	Jiang Yi [7] / Assistant Professor		6
	Lo Irene M.C. [8] / Chair Professor	Dept of Civil & Environ Eng, Hong Kong Univ of Sci & Tech (HKUST)	6
	Zhang Xiang-ru [9] / Professor		6
	Leung Kenneth M.Y. [10] / Chair Professor	Dept of Chemistry, City University of Hong Kong (CityU)	6
Collaborators	Hu Hong-ying / Professor	Graduate School at Shenzhen, Tsinghua Univ, Shenzhen, China (THU-Shenzhen)	N.A.
	Zhang Jian-jun / Director	Shenzhen Municipal Design & Research Institute, Shenzhen, China (Shenzhen MDRI)	N.A.
	Leckie James O. / Chair Professor	Dept of Civil & Environ Eng, Stanford University, USA	N.A.
	Rittmann Bruce E. / Chair Professor	Dept of Civil & Environ Eng, Arizona State University, USA	N.A.

 # Please highlight the approved changes in the project team composition and quote the date when the RGC granted approval of such changes. For changes in the project team composition, please submit a separate request, together with the justification and the curriculum vitae of the new member(s), to the RGC three months prior to the intended effective date of the change.

1. Professor Li X.Y. was promoted to Chair Professor effective from July 1, 2021.
2. Professor Zhang T. was promoted to Chair Professor effective from July 1, 2021.
3. Professor Shih K. was promoted to Professor effective from March 1, 2018.
4. Professor Chui May T.F. was promoted to Associate Professor effective from January 2, 2019.
5. Dr. Gu Ji-dong has retired from The University of Hong Kong since July 2020.
6. Dr. Lee Henry P.H. has departed from the Hong Kong Polytechnic University to join Imperial College London, UK, since January 2019.
7. Dr. Jiang Yi from the Hong Kong Polytechnic University has joined the TRS team as a Co-PI to carry out the research tasks left by Dr Lee Henry P.H effective from September 2019 (RGC approval was granted on September 17, 2019).
8. Professor Lo Irene M.C. was promoted to Chair Professor effective from July 1, 2017.
9. Professor Zhang X.R. was promoted to Professor effective from July 1, 2017.
10. Professor Leung Kenneth M.Y. has moved from The University of Hong Kong to the City University of Hong Kong since August 2020, and he is appointed as a Chair Professor at CityU.

3. Project Objectives

Summary of objectives addressed/achieved:

Objectives*	Percentage achieved	Remarks**
1. To develop a new wastewater treatment process aiming for effective and energy-saving treatment, sufficient nutrient removal and high-quality effluent	100%	
2. To create the capabilities of recovering resources and energy from municipal wastewater, achieving sludge minimization together with the production of value-added products	100%	
3. To present an advanced urban water pollution control system with a sound integration of wastewater treatment, resource recovery and minimization of sludge and food wastes	100%	

* *Please highlight the approved changes in objectives and quote the date when the RGC granted approval of such changes.*

****** *Please provide reasons for significantly slower rate of progress than originally planned.*

6. Research Highlights and Outputs

6.1 What are the most exciting research accomplishments of the project?
(Please list five or more of the team's best research accomplishments, such as journal and conference papers, software codes, research infrastructure, etc. For each item, please clearly justify how it has achieved international excellence (e.g. best paper award, invited presentation, citations, product licensed to industry, etc.))

#	Item	Type Year	Excellence and accomplishment
1	I. Gravity-driven chitosan-enhanced melamine sponge for stable ultrafast filtration, **Li X.Y.** and Li H.B., PCT/CN2019/105893, 2019. II. Spiral-structured 3D porous graphene oxide based membrane for stable ultrafast filtration, **Li X.Y.** and Li H.B., PCT/CN2019/091259, 2019.	Patents 2020	Patents licensed to industry: Patent exclusive licensing to VCG Green (Beijing) Environmental Technology Ltd., 2020 Upfront fee: US$320,000 (paid) Annual loyalties:5% of gross sales
2	Pilot-scale plant of the integrated enhanced separation and sludge refinery (ESSR) system for advanced wastewater treatment and resource recovery at Nanshan Wastewater Treatment Plant, Shenzhen. 	Technology 2020	Fabarication and demonstration of a pilot sytem with a capacity of 10 m^3/d for advanced wastewater treatment with resource recovery. It is the first of such innovative and compact wastewater treatment technology in the world, with the integration of chemically-enhanced seperation, acidogenic sludge fermenation and the biofilm-based biological treatment, capable of enhanced removals of organic and nutrient pollutants and recovery of organic and P resources from municipal wastewater.
3	Pilot-scale fix bed adsorption reactor for the polishing removal of phosphorus (P) from water using the lanthanum-based polymeric nanocomposite La@201 in Hong Kong. 	Technology 2019	Fabrication and demonstration of a pilot-scale fix bed adsorption reactor for the polishing removal of P from the water of Lam Tsuen River in Hong Kong using the lanthanum-based polymeric nanocomposite La@201. The pilot reactor has an average treatment capacity of 10 m^3/d. It is the first of such P removal and recovery technologies in the world.
4	Yang Y., **Zhang X.R.**, Jiang J.Y., Han J.R., Li W.X., **Li X.Y.**, **Leung K.M.Y.**, Snyder S.A., Alvarez P.J. (2022) Which micropollutants in water environments deserve more attention globally? Environmental Science & Technology, 56(1), 13-29, doi.org/10.1021/acs.est.1c04250.	Journal Paper 2022	Highly Cited Paper by Clarivate, 92 citations by October 2023 (Web of Science).

- s c h e m a t i c	5	Wu B., Wan J., Zhang Y., Pan B., and **Lo I.M.C.** (2020) Selective phosphate removal from water and wastewater using sorption: Process fundamentals and removal mechanisms. Environmental Science & Technology, 54(1), 50-66, doi.org/10.1021/acs.est.9b05569.	Journal Paper 2020	2020 ES&T Best Paper Awards-Best Features/Critical Review Paper; 393 citations by October 2023 (Web of Science).
	6	Wu B., Fang L.P., Fortner J.D., Guan X.H., and **Lo I.M.C.** (2017). Highly efficient and selective phosphate removal from wastewater by magnetically recoverable $La(OH)_3/Fe_3O_4$ nanocomposites. Water Research, 126, 179-188, doi.org/10.1016/j.watres.2017.09.034.	Journal Paper 2017	Published in Water Research, the leading journal in water science and technology (IF: 12.9 in 2023); 262 citations by October 2023 (Web of Science).
i s s u e - n e w s	7	Dong C.C., Wang Z.Q., Yang C., Hu X.M., Wang P., Gong X.Q., Lin L., **Li X.Y.** (2023) Dual-functional single-atomic Mo/Fe clusters–decorated C_3N_5 via three electron-pathway in oxygen reduction reaction for tandemly removing contaminants from water. Proceedings of the National Academy of Sciences (PNAS), 120(39), e2305883120, doi.org/10.1073/pnas.2305883120.	Journal Paper 2023	Published in PNAS, one of most prestigious journals on multidisciplinary scientific research (IF: 11.1 in 2023).
r e p o r t	8	Liang J.J., Li B., Wen L., Li R.H., **Li, X.Y.** (2021) Thermal hydrolysis of wastewater sludge followed by fungal fermentation for organic recovery and hyphae fiber production. Engineering, 7(2), 203-211, doi.org/10.1016/j.eng.2020.09.002.	Journal Paper/ Technology 2021	Published in Engineering, one of the leading journals in engineering and technology (IF: 12.8 in 2023); It reports our novel technology that turns sewage sludge to papers and other fibrous materials.
	9	**Lo I.M.C.** (2021) Selective phosphate removal from water and wastewater using sorption: process fundamentals and removal mechanisms. The 4th International Caparica Conference on Pollutant Toxic Ions and Molecules, May 2021, Capuchos, Portugal.	Conference Presentation 2021	Invited Keynote Speaker: online Plenary Presentation to over 500 delegates.
	10	**Li X.Y.** (2019) A membrane bioreactor with iron dosing and acidogenic co-fermentation for enhanced phosphorus removal and recovery in wastewater treatment. 2019 IWA Innovation Conference on Sustainable Wastewater Treatment and Resource Recovery (2019 IWA SWTRR), November 2019, Shanghai, China.	Conference Presentation 2019	Invited Keynote Speaker for the 2019 IWA-SWTRR Conference with over 600 delegates.

6.2 What was the added value of the TRS funding, rather than standard project grant funding?
(For example, could this work have been achieved with other funding scheme, such as the General Research Fund or Collaborative Research Fund? If not, why?)

The TRS project provided a unique platform for exchange of ideas and development of research collaborations among members from different universities in Hong Kong and our international advisors. The project also fostered translational research to turn fundamental research ideas into practical solutions for advancing the current wastewater treatment technologies by enhancing resource recovery, removing more pollutants and reducing energy consumption. Thanks to the substantial funding received from this TRS project, our research team was able to build the costly pilot-scale wastewater and sludge treatment system in Shenzhen as well as the pilot-scale adsorption systems for in-situ P removal from Lam Tsuen River in Hong Kong, to verify and demonstrate the feasibility of scaling up the innovative treatment technologies from lab-scale research to industrial applications. The TRS funding model also encourages the participation of multiple co-Principal Investigators (co-PIs) in theme-based research activities, fostering a collaborative environment that facilitates regular interactions among Ph.D. students and Postdoctoral fellows from various universities and research groups. This platform not only enlarges the scale of the research but also promotes multidisciplinary learning and networking, contributing to a richer educational and research experience for all members of different parties involved. All of these cannot be fully achieved with other funding schemes, such as GRF and CRF, in Hong Kong

6.3 If the project has not met its original objectives, why?

Nil

6.4 (a) Please provide details of each peer-reviewed journal publication arising directly from this project by completing the table at **Annex** *(one for each publication)*.

123 peer-reviewed journal articles have been generated directly from this project, in the field of environmental engineering and science, civil engineering, chemical engineering, environmental biotechnology, microbial ecology, marine science and toxicology. Please refer to the list in ***Appendix I***.

(b) Please provide details of recognised international conference(s) in which paper(s) related to this project was/were delivered by completing the following table:
(Please attach a copy of each conference abstract)

The PC, Co-PIs, post-doctoral fellows and research postgraduate students have attended more than **47 international conferences** on cutting-edge research and advancement in the fields of wastewater treatment technology, water resources and sustainable water pollution control, to present research findings from this project. Please refer to the list in ***Appendix II***.

(c) RGC funding should have been acknowledged in all publication(s)/conference papers listed in (a) and (b) above. If no acknowledgement has been made in any of the publications/ papers, please indicate and provide explanations.

Nil

6.5 To what extent this project has strengthened inter-institutional collaborations and other partnerships?

The TRS project team combines the multidisciplinary strength of 10 members from 4 Hong Kong universities and 4 collaborators with different and complementary expertise (in wastewater engineering, hydraulics and water system, environmental biotechnology, chemistry, materials, ecotoxicology, and molecular techniques). The project has greatly strengthened inter-institution collaborations and other partnerships.

The complementary expertise of the project team is critical for delivering high quality research outputs from this multidisciplinary project. Research staff and students has been sharing equipment and resources in different institutions regularly and using online platform to exchange ideas and discuss about research findings. To achieve Objective #1, XY Li and Irene MC Lo continued their collaboration to enhance the removal of low concentration phosphate from wastewater using new iron composite materials, while XD Li and XY Li applied XANES spectroscopy to investigate P removal and recovery from the wastewater and sludge. Kenneth MY Leung continued to work with XY Li to study the removals of endocrine disrupting chemicals (EDCs) and retinoic acids (RAs, including their metabolites) from municipal wastewater in several sewage treatment works in Hong Kong and by the innovative treatment system that couples chemically-enhanced primary sedimentation (CEPS) with acidogenic fermentation of the sludge in side-stream. For Objective #2, K Shih worked with XY Li to develop methods for stabilizing inorganic and toxic compounds in the residual sludge solids through ceramic production processing. T Zhang and JD Gu applied their expertise in microbial community analysis to further investigate the key microbial players in nitrogen removal, sludge and food waste co-fermentation and fungus cultivation process to optimize the system operation for sludge reduction, nitrogen removal and resource recovery. For Objective #3, XR Zhang and XY Li worked together to prioritize emerging contaminants and assess the potential ecological impact of the effluent from the new wastewater treatment system. With the support from our collaborators, HY Hu and JJ Zhang, in Shenzhen, the pilot integrated wastewater system has been developed and operated in Nanshan Wastewater Treatment Plant in Shenzhen to evaluate and demonstrate the performance and effectiveness of innovative wastewater treatment technologies. In addition, the team was also able to extend the partnerships with the governmental departments in Hong Kong, such as Drainage Services Department, Water Supplies Department and Environmental Protection Department, as well as Tsinghua Shenzhen International Graduate School and Shenzhen Water Group in Shenzhen, China.

The project has significantly bolstered inter-institutional collaborations and fostered a variety of partnerships, creating a robust network of shared knowledge, resources, and expertise. One of the most notable examples of strengthened collaboration is seen in our joint publications and co-supervision of postdocs and PhD students. Teams from different institutions have worked seamlessly together, conducting laboratory experiments and field studies, sharing data, and co-authoring publications. This has not only expedited the research process but also enriched the quality of research findings, as diverse viewpoints and skills were pooled together. In particular, the project facilitated regular workshops and meetings, where researchers, Ph.D. students, and Postdoctoral fellows from all participating institutions had the opportunity to interact, exchange ideas, and forge connections. The group meetings and workshops have provided great opportunities for all team members with each other and frequently discuss research findings and progress. These interactions have gone a long way in building a sense of research community and shared purpose among the different institutions. Besides, our project international advisors, Prof. Bruce Rittmann from Arizona State University and Prof. James Leckie from Stanford University have visited HKU to attend our project meetings, reviewed the research progress, and advised the team on on-going and future

project work.

6.6 Research students trained (registration/awards):

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation
MI Wenkui	PhD	1 September 2019	30 November 2023
TEE Aaron Kendric	MPhil	1 September 2019	30 April 2022
WAN Zhishang	PhD	1 September 2018	31 October 2023
YANG Chao	PhD	1 September 2018	1 June 2022
PENG Bo	PhD	1 September 2018	30 April 2023
YEUNG W.Y. Katie	PhD	1 September 2017	31 August 2023
WEN Lei	PhD	1 September 2017	07 December 2021
BADSHA Mohammad Abu Hashnat	PhD	1 September 2017	31 August 2021
CHEN Yiqiang	PhD	1 September 2017	31 August 2021
HUANG Qi	PhD	1 September 2017	31 August 2021
FAN Yiang	PhD	1 September 2017	31 August 2021
LI Pu	PhD	1 September 2016	1 December 2020
LI Yingyu	PhD	1 September 2016	1 December 2020
CHE You	PhD	1 September 2016	31 August 2020
WANG Chunxiao	PhD	1 September 2016	31 August 2020
ZHOU Ying	PhD	1 September 2015	31 August 2019
YANG Yuchun	PhD	1 November 2015	31 August 2019
WU Baile	PhD	1 September 2015	31 August 2018
YU Yue	MPhil	1 September 2015	31 December 2017
LI Wanxin	MPhil	1 September 2015	31 August 2017
YANG Yang	PhD	1 January 2015	31 December 2018
FENG Yong	PhD	1 September 2014	31 August 2018
LIN Lin	PhD	1 September 2014	31 August 2018
YANG Peixian	PhD	28 August 2014	30 June 2018
LENG Ling	PhD	2 December 2013	31 December 2017
LI Ruohong	PhD	1 September 2013	31 August 2017
Total number	**26**		

6.7 Specific products (e.g. software or netware, instruments or equipment developed):

(I) Fabrication of a pilot-scale system of the integrated enhanced separation and sludge refinery (ESSR) for advanced wastewater treatment and resource recovery at Nanshan Wastewater Treatment Plant, Shenzhen. The pilot system has a wastewater treatment capacity of 10 m^3/d, for evaluation and demonstration of the innovative wastewater and resource recovery technologies.

(II) Fabrication of a pilot-scale fix bed adsorption reactor for the polishing removal of

phosphorus (P) from water of Lam Tsuen River in Hong Kong using the lanthanum-based polymeric nanocomposite La@201. The pilot reactor has an average treatment capacity of 10 m^3/d, for evaluation and demonstration of the novel P removal and recovery technology.

6.8 Other education activities and/or training programmes developed:

Nil

6.9 Please highlight any deliverables indicated in the project implementation timetable endorsed by the RGC which have not been covered or achieved as per sections 6.1 to 6.8 above, and explain/ elaborate.

Nil

Project Management

6.10 Please elaborate how the PC has played his/her role in coordinating and managing the project.

The PC has been playing a critical role in leading and managing the TRS project, given the high complexity and connectivity of various components. His main duties and responsibilities include: (i) dividing the research tasks to the members and allocating the resources accordingly, based on the co-PIs' expertise and project workloads, (ii) monitoring and coordinating the research progress and project activities by face-to-face meeting, email and other means with co-PIs, to ensure satisfactory project progress, (iii) organizing regular group meetings to provide opportunities for all team members to communicate with each other, discuss the progress and share research findings, (iv) facilitating collaborations and encouraging team members to share research facilities and resources, organizing annual workshops for the project team, (v) making arrangement and supervising the field trials of the pilot system at Nanshan Wastewater Treatment Plant, Shenzhen, China, and (vi) liaising with different organizations for knowledge exchange activities.

Moreover, the TRS project consists of three research programs. Each program is led by a Program Leader (PL) whose main responsibility is to coordinate the research activities of the team members to achieve the goals set for each stage. The PC and 3 PLs form the management committee of the TRS project to oversee and monitor the project progress and address issues promptly. The PC regularly communicated with all co-PIs and the collaborators in Shenzhen to ensure that the project is on track. The management committee also regularly reported the project progress to the International Advisors (IAs) and invited them to provide valuable feedbacks on the project.

Due to the social unrest in 2019 and the COVID-19 pandemic during 2020-2022, research activities of the project were impacted to various extents. During the social unrest in Hong Kong, the laboratories were closed and research students had to stay away from the campus for a period of from 1 to 3 months in all universities. This disruption and the re-start of the laboratory work have caused the delay of the experimental research, especially biological experiments and microbiological investigations, for up to 6 months. Owing to the COVID-19 outbreak in 2021, the start-up and operation of the pilot system were suspended for more than 6 months because of the restrictions in both Nanshan wastewater treatment plant and the district where the treatment plant is located in Shenzhen. Because the above unforeseeable difficulties, the progress of the TRS project has been seriously affected. In view of the special circumstance and the resulting delay of the proposed laboratory investigations and field trials, the PC, on behalf of the team, had applied and obtained a

period of 12-month extension for the TRS project. With the extended project duration, the laboratory research and pilot study of the project have been completed with more high-quality deliverables.

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7. Awards and Recognition

7.1 Have any research grants been awarded that are directly attributable to the results obtained from this project?

The project team members have obtained **17 research grants with a total funding of over HK$58.1M**.

PI	Project Title	Funding Source	Amount (HK$)	Project Period
Irene M.C. LO	Removal/Recovery of Phosphorus from Water by Using $La_2(CO_3)_3$-Loaded Anion Exchange Resin in a Semi-fluidized Bed Reactor	ECF	496,000	06/2023 – 05/2025
Yi JIANG	Polyelectrolyte Nanofiltration Membranes via Aerosol-assisted Printing: Establishing Fabrication-Structure-Performance Relationships towards Scalable Manufacturing and Applications in Advanced Water and Wastewater Treatment	RGC-GRF	1,115,452	01/2023 – 12/2025
Yi JIANG	Development and Application of Nanocomposite Membranes via 3D Printing for Water Treatment	Shenzhen Science and Technology Innovation Commission	1,170,000	04/2022 – /04/2024
Xiao-yan LI	Pilot Study of the Innovative CeFSCM-CfSBBR System for Advanced Wastewater Treatment	ITF	8,899,980	07/2021 – 12/2023
Xiao-yan LI	Evaluation of Wastewater Reuse in Hong Kong Using an Integrated Framework for Life-cycle Economic, Environmental and Public Health Impact Assessment	PPR	998,315	02/2021 – 01/2023
Tong ZHANG	Assess antibiotic resistome flows from pollution hotspots to environments and explore the control strategies	RGC-TRS	34,213,000	11/2020 – 09/2025
Xiao-yan LI	Impact assessment of mosquito-repellent softener on conventional wastewater treatment processes and development of advanced technologies for pyrethroids removal	ITF-PRP	898,150	08/2020 – 07/2022
Xiao-yan LI	LCA-based evaluation of the sustainability of urban water facilities	Guangdong GDH Water Company, Shenzhen, China	900,000	01/2020 – 12/2022

Xiao-yan LI	Recovery of organic, nutrient and metal resources from wastewater sludge by co-fermentation and capacitive deionization	RGC-GRF	748,300	01/2020 – 12/2022
Tong ZHANG	Codigestion for enhanced energy production and metagenomic analysis of the key microbial players in codigestion.	DSD/HKSAR	1,350,000	12/2019 – 06/2021
Kaimin SHIH	Advanced treatment of electroplating wastewater for water pollution control and resource recovery	Kimou Environmental Holding Ltd., Hong Kong	2,400,000	10/2019 – 20/2022
Irene M.C. LO	Pilot-scale study on phosphate removal in river water by nanocomposite particles in Hong Kong	WSD/HKSAR	1,400,000	06/2019 – 12/2020
Xiang-dong LI	Study of super-fast large-area economical marine reclamations for housing and infrastructural developments in the Guangdong-Hong Kong-Macau Greater Bay Area (CEE-3)	RGC-RIF Subproject	1,136,036	06/2019 – 06/2024
Xiang-dong LI	Sustainable marine infrastructure enabled by the innovative use of seawater sea-sand concrete and fibre-reinforced polymer composites	RGC-TRS Subproject	610,948	01/2019 – 12/2023
Kenneth M.Y. LEUNG	Ecological risk assessment of retinoic acids in urbanized coastal marine ecosystems	RGC-GRF	733,240	09/2017 – 03/2021
Xiao-yan LI	Study on use of colourants and anti-ingestants in reclaimed water	WSD/HKSAR	420,000	03/2017 – 02/2018
Xiao-yan LI	Enhanced sedimentation and hydrolysis of solid organics for biological denitrification in wastewater treatment	RGC-GRF	675,647	01/2017 – 12/2019
Total number	**17**			
Total amount (HKD)	**58,165,068**			

7.2 Have any project team members participated as invited speakers in or organisers of international conferences as a result of this project?

The project team members have been invited to more than **32 conferences as keynote speakers** and involved as **key organisers in 5 international conferences**.

PI	Title of Presentation	Conference Name	Date and Venue of the Conference	Invited / keynote / Others

Kenneth M.Y. LEUNG	Global initiatives for monitoring and combating water pollution	International Conference on Seas and Oceans' Health and their role on the Present and Future of Humanity Scientific: Perspective and Future Scenarios for a Sustainable Coexistence between Humanity and Oceans	06/2022, Rome, Italy	Invited Speaker
Kenneth M.Y. LEUNG	Global initiatives for monitoring and combating water pollution	The franc. Sydney 2022 Conference	03/2022, Sydney, Australia	Invited Keynote Speaker
Kenneth M.Y. LEUNG	The Global Estuaries Monitoring (GEM) Programme	The Third Ocean Decade Laboratory 'A Clean Ocean'	11/2021, online	Invited Keynote Speaker
Irene M.C. LO	Selective Phosphate Removal from Water and Wastewater using Sorption: Process Fundamentals and Removal Mechanisms. The 4th International Caparica Conference on Pollutant Toxic Ions and Molecules	The 4th International Caparica Conference on Pollutant Toxic Ions and Molecules	05/2021 Capuchos, Portugal	Keynote Speaker
Kaimin SHIH	Persistent Perfluorochemical Pollutants in the Environment and Thermal Treatment Processes	The 3rd International Conference on Resources and Environment Sciences (ICRES 2021)	04/2021, Bangkok, Thailand (& online)	Keynote Speaker
Ji-dong GU	Active Anammox bacteria in full-scale WWTPs by metagenomics, transcriptomics and N-15 stable isotope	2nd International Conference on Bioprocess for Sustainable Environment and Energy (ICBSEE-2020)	03/2020 Rourkela, Odisha, India	Keynote Speaker & Scientific Committee
Ji-dong GU	N Transformation in full-scale WWTPs with active Anammox bacteria by metagenomics, transcriptomics and N-15 stable isotope	De-ammonification and Environmental Technology and Management 2019	12/2019 Bangkok, Thailand	Keynote Speaker
Xiao-yan LI	A membrane bioreactor with iron dosing and acidogenic co-fermentation for enhanced phosphorus removal and recovery in wastewater treatment	2019 IWA Innovation Conference on Sustainable Wastewater Treatment and Resource Recovery (IWA-WSWTRR 2019)	11/2019 Shanghai, China	Keynote Speaker

Tong ZHANG	Antibiotics resistance genes as biological pollutants from WWTPs	8th IWA Microbial Ecology and Water Engineering Specialist Conference	11/2019 Hiroshima, Japan	Keynote Speaker
Xiao-yan LI	Direct filtration of municipal wastewater using flat-sheet ceramic membrane for pollutant removal and resource recovery	The 8th IWA-ASPIRE Conference and Exhibition (ASPIRE 2019)	10/2019 Hong Kong, China	Keynote Speaker
Kenneth M.Y. LEUNG	Environmental rate and ecological risks of retinoic acids and their metabolites in highly urbanised coastal city	The 11th International Water Association (IWA) Micropol & Ecohazard Conference 2019	10/2019 Seoul, South Korea	Keynote Speaker
Xiang-dong LI	Publishing your best research in Environmental Science & Technology (ES&T) and Environmental Science & Technology Letters (ES&TL)	The 8th IWA-ASPIRE Conference and Exhibition	10/2019 / Hong Kong, China	Invited Speaker
Ji-dong GU	Microbial members responsible for N transformation in full-scale WWTPs with active Anammox bacteria by DNA and RNA sequencing and N-15 stable isotope	The 5th International Water Industry Conference – New Paradigm of Water Industry	09/2019 Daegu, South Korea	Keynote Speaker
Kenneth M.Y. LEUNG	Ecologically engineered shorelines for enhancing marine biodiversity and ecological conservation	NSFC-RGC Young Scholars Forum on Frontiers in Ecology and Environmental Science and Green Development	09/2019 Guangxi, China	Keynote Speaker
Irene M.C. LO	Fe^0/Fe_3O_4 activated by Fe^{2+} for low concentration phosphate removal	The 10th National Conference on Environmental Chemistry	08/2019/ Tianjin, China	Keynote Speaker
Tong ZHANG	Wastewater resistome revealed by metagenomics approaches	Gordon Research Conference “Applied and Environmental Microbiology”	07/2019 South Hadley, MA, USA	Invited Speaker
Irene M.C. LO	Selective phosphate removal from water and wastewater using sorption: Process fundamentals, removal mechanisms, and practical applications	The 3rd International Conference Bioresources, Energy, Environment and Material Technology	06/2019 Hong Kong, China	Keynote Speaker
Irene M.C. LO	Application of Nanotechnology with Environmental Implications	The Gordon Research Conference (GRC) on Environmental Nanotechnology	06/2019 ME, USA	Invited Discussion Leader

Kenneth M.Y. LEUNG	Putting 'eco' into ecotoxicology: A revisit	The 9th International Conference on Marine Pollution and Ecotoxicology (ICMPE-9)	06/2019 Hong Kong, China	Keynote Speaker
Kaimin SHIH	Material mineralogical technology for pollution prevention and resource recovery	The 19th Mainland-Taiwan Environmental Protection Conference (MTEPC)	05/2019 Tianjin, China	Keynote Speaker
Kaimin SHIH	Sludge management in urban environment – taking Hong Kong as an example	Symposium on Urban mining and Waste Management (SUMEast 2019)	05/2019 Suzhou, China	Keynote Speaker
Kenneth M.Y. LEUNG	Putting 'eco' into ecotoxicology: A revisit	2019 International Symposium on Chemical Risk Prediction and Management	04/2019 Guangzhou, China	Keynote Speaker
Xiao-yan LI	Enhanced separation and sludge refinery for wastewater treatment – Solving the nexus of pollution control and resource recovery in mega cities	The 4th International Conference on Contaminated Land, Ecological Assessment and Remediation 2018 (CLEAR2018)	08/2018 Hong Kong	Keynote Speaker
Tong ZHANG	Metagenomic insights into antibiotic resistance genes in environments	Gordon Research Conference "Environmental Sciences: Water"	06/2018 Holderness, New Hampshire, USA	Invited Speaker
Tong ZHANG	-	The 15th IWA Leading Edge Conference on Water and Wastewater Technologies	05/2018, Nanjing, China	
Kenneth M.Y. LEUNG	Joining the dots between omics and environmental management	The 4th Conference on Environmental Pollution and Health	05/2018, Tianjin, China	Keynote Speaker
Xiao-yan LI	-	The 1st international Symposium on Novel Technologies for Enhanced Wastewater Treatment	05/2018 Changsha, China	Keynote Speaker
Xiao-yan LI	-	The 14th Symposium of Chinese Chemical Society on Water Treatment	05/2018 Shanghai, China	Keynote Speaker

Xiao-yan LI	Chemically enhanced primary sedimentation and acidogenic sludge fermentation for resource recovery in wastewater treatment	IWA Conference on Sustainable Wastewater Treatment and Resource Recovery	11/2017 Chongqing, China	Keynote Speaker
Tong ZHANG	-	4th International Symposium on the Environmental Dimension of Antibiotic Resistance	08/2017 East Lansing, Michigan, USA	Organizing Committee & Invited Speaker
Xiao-yan LI	In-situ investigation of membrane fouling during membrane filtration using micro-particle image velocimetry (MicroPIV)	The 7th International Multidisciplinary Conference on Optofluidics	07/2017 Singapore	Keynote Speaker
Kenneth M.Y. LEUNG	Removal of endocrine disrupting chemicals and retinoic acids from wastewater by novel chemically-enhanced primary sedimentation processes.	The 3rd International Conference on Environmental Pollution and Health	05/2017, Guangzhou, China	Keynote Speaker

Organizers of international conferences:

PI	Conference Name	Date	Venue	Role
Ji-dong GU	De-ammonification and Environmental Technology and Management 2019	12/2019	Bangkok, Thailand	Organizing Committee, Scientific Committee & Programme Committee
Kenneth M.Y. LEUNG	NSFC-RGC Young Scholars Forum on Frontiers in Ecology and Environmental Science and Green Development	09/2019	Guangxi, China	Co-chairman of Organizing Committee
Kenneth M.Y. LEUNG	The 9th International Conference on Marine Pollution and Ecotoxicology (ICMPE-9)	06/2019	Hong Kong, China	Co-chairman of Organizing Committee
Tong ZHANG	5th International Symposium on the Environmental Dimension of Antibiotic Resistance	06/2019	Hong Kong, China	Chairman of Organizing Committee
Tong ZHANG	4th International Symposium on the Environmental Dimension of Antibiotic Resistance	08/2017	East Lansing, Michigan, USA	Organizing Committee

7.3 Have any project team members taken leadership positions in editorial boards, scientific and professional organisations?

The team members are taking more than **15 leadership positions** as detailed below.

PI	Journal or Professional Organisation	Role / Position	Duration
Irene M.C. LO	Special issue entitled "Post-Global Pandemic Challenges and improvements in advanced detection and removal processes of toxic pollutants", Journal Hazardous Materials	Co-guest Editor	2022
Kenneth M.Y. LEUNG	Water Biology and Security (NSFC/ KeAi Journal)	Editorial Board Member	2021-
Kenneth M.Y. LEUNG	Fundamental Research (NSFC/ KeAi Journal	Editorial Board Member	2021-
Yi JIANG	ACS Environmental Au	Member, Editorial Board	2021-
Kaimin SHIH	Journal of Environmental Chemical Engineering	Executive Editor	2021 -
Kenneth M.Y. LEUNG	Journal of Hazardous Materials Letters	Editorial Board Member	2020 -
Yi JIANG	Chemical Engineering Journal Advances	Member, Editorial Board	2020 -
Xiang-ru ZHANG	Environmental Science & Technology Water	Editorial Advisory Board (EAB) Member	2020-
Kaimin SHIH	Hong Kong Waste Management Association	Chairman	2019 - 2021
Kaimin SHIH	American Society of Civil Engineers (ASCE) – Greater China Section	President-Elect	2019 - 2020
Xiang-dong LI	National Science Review	Member, Editorial Board	2018 -
Ji-dong GU	International Society for Subsurface Microbiology	International Board Member	2017 -
Irene M.C. LO	Environmental Science: Water Research & Technology	Advisory Board	2017-
Tong ZHANG	Applied Microbiology and Biotechnology	Associate Editor	2017 - 2023
Tong ZHANG	Microbiome	Associate Editor	2017 -

7.4 Any documentary proof of the application of technologies arising directly from this project?

Nil

7.5 Other awards and recognitions as a result of this project (please specify):

The team members have received more than **21 awards and recognitions** as a result of this project.

PI	Type	Description	Society or Organisation	Country or Region	Date Awarded
Xiao-yan LI	Awardee's supervisor	Outstanding Research Postgraduate Student 2022-23 (to Yang Chao, PhD student)	The University of Hong Kong	Hong Kong	2023

Xiao-yan LI	Awardee's supervisor	Best presentation award for Y.Y. Wang, X.M. Hu, J. Yeung & X.Y. Li for "Development of an Integrated Framework for Life-Cycle Economic, Environmental and Human Health Impact Assessment for Reclaimed Water Use in Water Systems of Various Scales"	ICUSLCA 2022, London, United Kingdom	United Kingdom	2022
Kenneth M.Y. LEUNG	Awardee	Fellow of the Royal Society of Biology	The Royal Society of Biology	United Kingdom	2022
Kenneth M.Y. LEUNG	Awardee	Fellow of the Royal Society of Chemistry	The Royal Society of Chemistry	United Kingdom	2022
Kenneth M.Y. LEUNG	Awardee	Top 2% Most Cited Scientists by the Stanford-Elsevier Indicators	Stanford University	Global	2021
Irene M.C. LO	Awardee	The 110th Global Outstanding Overseas Student Alumni Award Overseas Community Affairs Council	Overseas Community Affairs Council, Taiwan	Taiwan	2021
Xiao-yan LI	Awardee	HKIE Best Transactions Paper Prize 2020 to R.H. Li & X.Y. Li for "*Acidogenic phosphorus recovery from iron-facilitated primary sedimentation sludge in wastewater treatment*", *HKIE Transactions. Vol 26 No 2*	The Hong Kong Institution of Engineers (HKIE)	Hong Kong	2020
Irene M.C. LO	Awardee	2020 ES&T Best Paper Awards- Best Features/Critical Review Paper	Environmental Science & Technology, American Chemistry Society	USA	2020
Xiang-ru ZHANG	Awardee	Best Poster Award for Yang, Y. & Zhang, X.R. for "*Which micropollutants in water environments deserve more attention globally?*"	The 7th National Symposium on Disinfection and DBPs. Xi'an, China	China	2020
Xiao-yan LI	Awardee	Second-class Award in Environmental Science and Technology: Membrane technology for water purification and wastewater reuse	Chinese Society for Environmental Sciences, Ministry of Ecology and Environment	China	2019
Kenneth M.Y. LEUNG	Awardee	Certificate for Top Downloaded Article in *Environmental Toxicology and Chemistry* [2017-2018]	Wiley Publisher	Global	2019
Irene M.C. LO	Awardee	2019 Higher Education Outstanding Scientific Research Output Award	Ministry of Education	China	2019

		(Science and Technology)			
Kaimin SHIH	Awardee	Second-class Award in Environmental Science and Technology: Membrane technology for water purification and wastewater reuse	Chinese Society for Environmental Sciences, Ministry of Ecology and Environment	China	2019
Kaimin SHIH	Awardee's supervisor	Best Final Year Project Award 2019	American Society of Civil Engineers – Hong Kong Chapter	Hong Kong	2019
Xiang-ru ZHANG	Awardee	Best Poster Award for Li, W.X., Zhang, X.R., Li, X. Y. and Lee, J.H.W *"Mystery of the high chlorine consumption in disinfecting a chemically enhanced primary saline sewage*"	The 8th IWA–Aspire Conference and Exhibition: Smart Solutions for Water Resilience	Hong Kong	2019
Xiao-yan LI	Awardee's supervisor	Outstanding Research Postgraduate Student 2017-18 (to Lin Lin, PhD student)	The University of Hong Kong	Hong Kong	2018
Kenneth M.Y. LEUNG	Awardee	Top 100 Asian Scientists	Asian Scientist Magazine [The Asian Scientist 100 – 2018 Edition]	Asia	2018
Kenneth M.Y. LEUNG	Awardee	SETAC Fellows Award	Society of Environmental Toxicology and Chemistry (SETAC)	Global	2017
Kenneth M.Y. LEUNG	Awardee	19th Biwako Prize for Ecology	Ecological Society of Japan	Japan	2017
Kenneth M.Y. LEUNG	Awardee	Justice of the Peace	HKSAR Government	Hong Kong	2017
Tong ZHANG	Awardee	Outstanding Research Student Supervisor Award 2016-2017	The University of Hong Kong	Hong Kong	2017

8. Impacts

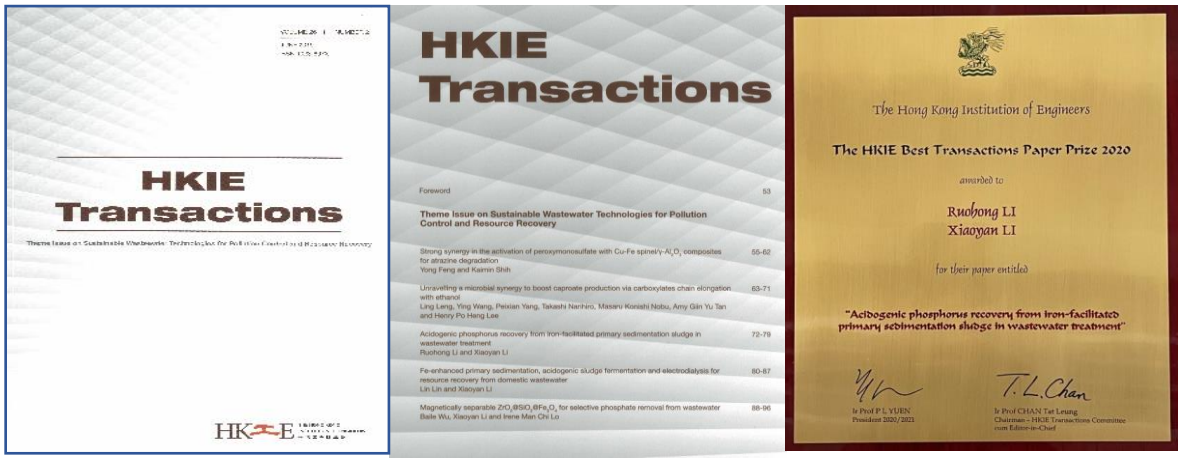
8.1 What are the current and expected impacts of the project on the long-term development of Hong Kong (social or economic development, e.g. patent, technology transfer, collaboration with external organisations, etc.)?

The novel wastewater treatment system developed in this project can effectively remove conventional pollutants, and recover valuable resources such as phosphorus and organics from wastewater. Moreover, compared with the conventional sewage treatment plants, the novel system that integrates CEPS of sewage with acidogenic sludge fermentation is more effective in removing emerging chemical contaminants from wastewater. Furthermore, the extended operation of the pilot wastewater system in Shenzhen has demonstrated the benefits

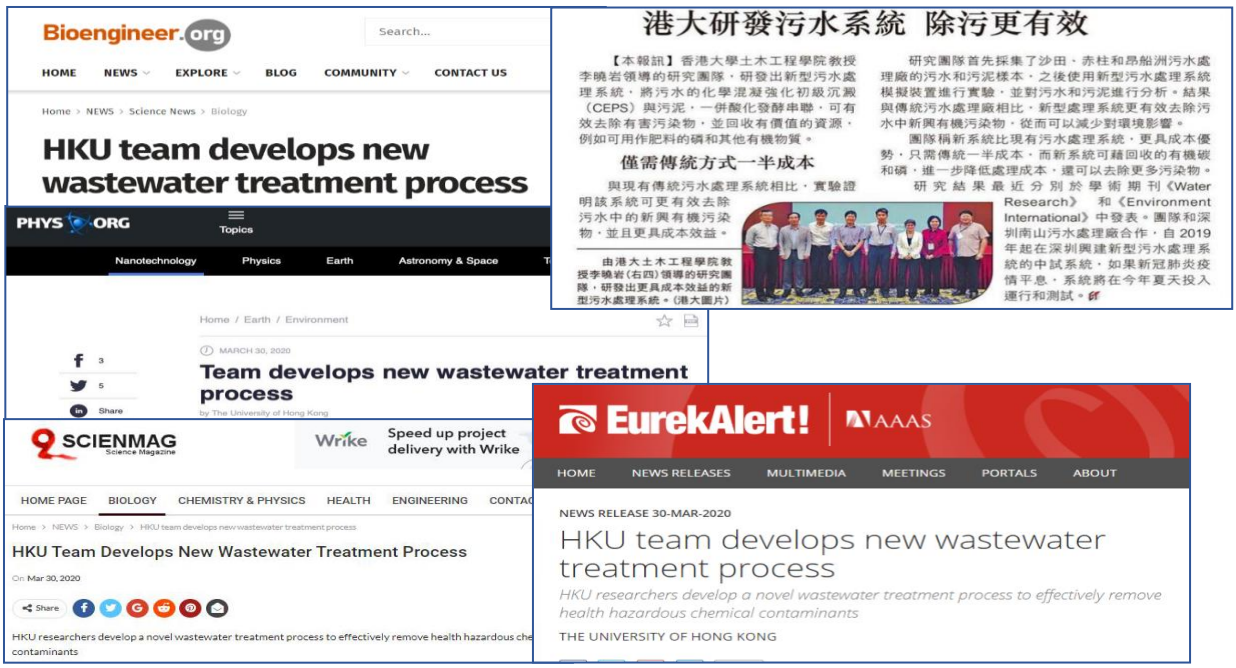
and advantages of the new ESSR system that is more compact, uses less energy, generates cleaner effluent and recovers more useful materials (VFAs and P) from the sludge than the conventional treatment system. In the long term, the novel system will contribute to the advancement of waste-to-resource technologies and can be applied in Hong Kong and other places for the upgrading of existing wastewater treatment facilities.

The project has yielded a number of patents for our technological development. Technology transfer has been achieved for 2 patents: (i) Gravity-driven chitosan-enhanced melamine sponge for stable ultrafast filtration, Li X.Y. and Li H.B., PCT/CN2019/105893, 2019, and (ii) Spiral-structured 3D porous graphene oxide based membrane for stable ultrafast filtration, Li X.Y. and Li H.B., PCT/CN2019/091259, 2019. The IPs of the new membrane filter materials for wastewater reuse and water purification have been licensed to VCG Green (Beijing) Environmental Technology Ltd. in 2020, with a upfront fee of US$320,000 (paid) and an annual loyalty of 5% of the gross sales. The products are in the final phase of development and commercialization by the company.

Due to the such significance of this project, the TRS project team was invited to prepare a special issue in *HKIE Transactions*, "**Theme Issue on Sustainable Wastewater Technologies for Pollution Control and Resource Recovery**" (June 2019, https://doi.org/10.33430/V26N2). This is the 5th theme issue of HKIE (Hong Kong Institution of Engineers) Transactions in its 26 years of publication, and is a great opportunity for promoting our R&D outcomes to the industry professionals in Hong Kong and abroad.



Moreover, in March 2020, HKU publicized our project work and research findings via a press release (https://www.hku.hk/press/press-releases/detail/20830.html), and a number of local newspapers (e.g. HKET, Oriental Daily, Sing Tao, ToPick, on.cc) and international digital media reported our impactful research work. These reports of this project and its R&D outputs have received broad attentions from a wide range of researchers and professionals in the field of water pollution control and urban sustainability in Hong Kong, China and elsewhere.



Overall, with the ESSR-based system, the main function of wastewater treatment will shift from pollutant degradation and removal to the enhanced material separation and sludge refinery for value-added products. As a result, the new technology will transform the current wastewater treatment into a more sustainable and resource-mining operation. Furthermore, the novel ESSR process will help resolve the difficult sludge and food waste problems in mega cities. Besides, the novel process can be readily modularized and used to improve existing treatment facilities. Its scientific merits will contribute to environmental technology advancement, and the new process can be immediately used to upgrade the chemically-enhanced primary treatment in Hong Kong to the level of advanced secondary biological treatment. These innovations also will have a profound impact on the development of water pollution control technology in Hong Kong, which help provide a sustainable wastewater and food waste management model for the massive urbanization in China and elsewhere.

8.2 Others (please specify):

Nil

9. Sustainability of the Project

9.1 Whether there are new ideas evolved directly from this project?

Yes, some of new ideas evolved from this project include: (i) treatment of CEPS effluent by the Anammox process for cost-effective nitrogen removal from saline wastewater, (ii) advanced treatment for enhanced removals of emerging pollutants, such as antibiotics, ARGs, EDCs, PFAS, microplastics, etc., from municipal wastewater, (iii) continuous development and application of new water pollutant control and water reuse technologies, such as aerobic granular sludge (AGS), enhanced P removal and recovery, and electrocatalytic treatment, and (iv) in-depth techno-economic analysis and life-cycle assessment of the technological development for water pollution control and wastewater treatment.

9.2 Whether there are new projects evolved directly from this project?

Yes, there are several new projects evolved directly from this project. Some examples are as follows:

PI	Project Title	Funding Source	Amount (HK$)	Project Period
Irene M.C. LO	Removal/recovery of phosphorus from water by using $La_2(CO_3)_3$-loaded anion exchange resin in a semi-fluidized bed reactor	ECF	496,000	06/2023 – 05/2025
Xiao-yan LI	Pilot study of the innovative CeFSCM-CfSBBR system for advanced wastewater treatment	ITF	8,899,980	07/2021 – 12/2023
Xiao-yan LI	LCA-based evaluation of the sustainability of urban water facilities	Guangdong GDH Water Company, Shenzhen, China	900,000	01/2020 – 12/2022
Tong ZHANG	Codigestion for enhanced energy production and metagenomic analysis of the key microbial players in codigestion.	DSD/HKSAR	1,350,000	12/2019 – 06/2021
Irene M.C. LO	Pilot-scale study on phosphate removal in river water by nanocomposite particles in Hong Kong	WSD/HKSAR	1,400,000	06/2019 – 12/2020
Kenneth M.Y. LEUNG	Ecological risk assessment of retinoic acids in urbanized coastal marine ecosystems	RGC-GRF	733,240	09/2017 – 03/2021

9.3 Whether there are new collaborations developed directly from this project?

Yes, during the project work, the team has developed new collaborations with the Drainage Services Department and Water Supplies Department, HKSAR, Hong Kong Productivity Council, several environmental companies in Hong Kong and Shenzhen, Shenzhen Water Group, etc. on the development and application of the innovative wastewater treatment technologies. In addition, the team members have developed new collaborations with a wide range of universities in mainland China and overseas on fundamental and applied research on water pollution control, advanced wastewater treatment with resource recovery, carbon neutrality and urban sustainability.

9.4 Please give details on how much money and from which sources has been obtained/requested for the specific purpose of continuing the work started under this project.

Refer to 9.2 for details.

10. Statistics on Research Outputs

(Please ensure the statistics in this section are consistent with the information presented in other sections of this report.)

	Peer-reviewed journal publications	Conference papers	Scholarly, books, monographs and chapters	Patents awarded	Other research outputs (please specify)	
					Type	No.
No. of outputs arising directly from this research project	123	47	1	5		

11. Public Access of Completion Report

(PCs of projects funded in 2010/11 academic year or onwards are required to release the completion reports to the public through the RGC website. Completion reports containing information such as abstracts in non-technical terms, objectives, research output including the list of conference papers / publications / journals and research findings and contact information of PCs should be open to public access.)

Please specify the information, if any, that cannot be provided for public access and give the reasons.

Information that cannot be provided for public access	Reasons

12. The Layman's Summary

(describe in layman's language the abstracts and research impact of the project.)

Many forms of development threaten the environment, causing serious water pollution in Hong Kong, mainland China and many other regions of the world. Most core wastewater treatment technologies were developed about half a century ago and thus they are no longer capable of accommodating the fast population growth, industrialization and urbanization. A city like Hong Kong discharges more than 2 million tons of municipal wastewater every day. Removal of pollutants in wastewater treatment is not only difficult and costly, but also produces a large amount of sludge (~1 ton dewatered sludge per 1000 ton wastewater). Disposal of sewage sludge is one of the most challenging and expensive environmental problems for large cities. On the other hand, major pollutants (organics and nutrients) in wastewater are valuable resources that should be recovered instead of being degraded or wasted with the sludge. As a mega city with 7.2 million people, Hong Kong is a typical urban environment that needs such a technological breakthrough for its planned wastewater treatment upgrading from the current primary level to the secondary level.

In this TRS project, novel technologies, namely Enhanced Separation and Sludge Refinery (ESSR), have been developed for advanced wastewater treatment, together with effective resource recovery. The project team has been at the forefront in global research on advanced wastewater treatment with resource recovery. The 6-year research work has succeeded in the following technological development: (a) Chemically-enhanced Membrane Filtration (CeMF) replacing the conventional primary sedimentation, together with the side-stream Acidogenic sludge and food waste Co-Fermentation (sACF), for phosphorus recovery and organic hydrolysis for use in denitrification and biosynthesis of polyhydroxyalkanoates (PHAs); (b) treatment of the waste sludge by thermal Sludge Hydrolysis followed by fungal Fermentation and Refinery (SHFR) for waste minimization and production of ethanol, biodiesel, and hyphae fibres for papers and biofibre materials; and (c) integration and pilot demonstration of the novel CeMF-sACF and SHFR modules for advanced wastewater treatment with improved nutrient removal, energy saving, resource recovery and sludge reduction, together with the assessment of the effluent quality and its impact on the receiving aquatic ecosystem.

The innovative technological development will improve the wastewater treatment efficiency and reduce its footprint, energy consumption and carbon emission. With the resource recovery-minded wastewater treatment technologies, it is estimated that over 30% organic carbon and 50% P resources can be recovered from municipal wastewater, the footprint of the treatment works will decrease by 30%, and the electricity consumption and the treatment cost can be reduced by more than 25%, while the sludge production is decreased by 30% and the enhanced nutrient (N & P) removal can be achieved. The new wastewater treatment system will not only resolve the sludge problems for large cities but also enable effective resource recovery from municipal wastewater for the production of significant amounts of value-added products, including fertilizers, organic acids, bio-plastics, and biofibre sheets. The advanced technology will fundamentally transform wastewater treatment from an end-of-the-pipe purification to a resource-mining practice. Besides the design of new wastewater treatment plants, the novel processes can also be used as add-on modules to retrofit existing facilities. Towards the end, the innovative wastewater treatment system will set a model with its both environmental and economic benefits for sustainable water pollution control in Hong Kong and other mega cities.