Research Assessment Exercise 2020
Impact Case Study

University: The Education University of Hong Kong
Unit of Assessment (UoA): 10 Earth sciences (incl. oceanography, meteorology) and other physical sciences (incl. environmental science)

Title of case study: Pollution control through novel practices for wastewater treatment

(1) Summary of the impact

Endocrine disrupting chemicals (EDCs)/pharmaceuticals and personal care products (PPCPs) are extensively used in industrial and consumer applications and widely recognised as typical contaminants of emerging concern because of their persistence and bioaccumulative properties. Even in very low concentration, they can disturb the hormonal balance, leading to reproductive impairment, abnormal development, and growth retardation. Much effort has been focused on investigating their occurrence, fate, and elimination efficiencies. However, water and sewage treatment systems worldwide face the challenge of how to effectively remove these emerging contaminants. Dr TSANG Yiu Fai has developed a novel approach to adapting existing systems by using mixed culture and other materials, such as biochars. Since 2016, this has been piloted in China, benefiting 200,000 people. It is also having a wider impact in the community by generating new understanding of water pollution and potential solutions and contributed to STEM education through the use of his teaching resources in more than 300 local schools (150,000 students).

(2) Underpinning research

Since joining EdUHK in 2013, Dr Tsang, an environmental engineer by training and associate professor in the Department of Science and Environmental Studies (SES), has conducted extensive research that furthers understanding of the novel solutions for EDCs/PPCPs and their removal mechanisms in biological wastewater treatment processes.

Dr Tsang, leading a collaborative team with South China University of Technology (SCUT) and University of Strathclyde (UoS), built on his earlier studies on wastewater treatment technology to investigate the occurrence, fate, and removal mechanisms of EDCs/PPCPs in biological sewage treatment plants (STPs) in Hong Kong, China, and Scotland. The research also involved 5 PhD, 5 master's and 5 bachelor students, 1 Hong Kong Scholar Post-doc and 1 Croucher Visiting Scholar. In China (SCUT), 18 antibiotics were found in the STPs and the receiving waters in Guizhou, affirming the seriousness of growing EDC/PPCP accumulation in drinking water sources in China as the country develops **[See Section 3, R1]**. In Scotland (UoS), the presence of EDCs/PPCPs, mainly from pharmaceuticals, detergents, and beverages, in biologically treated effluent discharged from two STPs in Glasgow was detected. Their mass balance was obtained and the analytical results were then compared with previous works found in literature **[R2]**. In Hong Kong, three EDCs were found in two major STPs and their removal mechanisms in biological and chemical STPs were clarified and evaluated **[R3]**. The results showed the treatment performance of EDCs/PPCPs in conventional STPs is not satisfactory. These findings can also provide a theoretical and practical basis to design, develop, and optimise new methods/processes/systems for realising stable and efficient EDC/PPCP removal for real applications in water purification and sewage treatment facilities. Through laboratory- and pilot-scale studies, Dr Tsang has pioneered a solution, by integrating microorganisms and biowaste-derived materials, such as coal slag, biogenic flocs, and biochars, to design and develop novel bioreactors that improve the efficiency of wastewater treatment and odour removal. The EdUHK team's unique contribution, in collaboration with other members of State Key Laboratory of Marine Pollution, has been to devise models that can modify conventional

treatment processes, an approach that is environmentally friendly and cost effective, to enable rapid adaptation of existing infrastructure to the new threat **[R4-R6]**. This contrasts with more costly tertiary treatment alternatives that may generate secondary pollutants. The team's technologies have been evaluated in the laboratory-scale systems at EdUHK **[R4]**, pilot-scale bioreactors at SCUT, and in a full-scale STP in Guizhou Province **[R5]** since 2013, 2015, and 2016, respectively, and also tested in a constructed wetland system in the Eco-garden at EdUHK.

Dr Tsang has also led closely-connected research on resources recovery - the retrieval of useful materials, engineered biochars and biogenic flocs for environmental remediation from waste sludge, a secondary pollutant in the wastewater treatment process **[R5-R6]**.

His work has been widely published, in more than 100 journal articles (~35% top 5% journals) and two teaching resources for primary and secondary schools, and shared his research in major international conferences for academics and practitioners, paving the way for its longer term impact.

(3) References to the research

[R1] Hu, J., Zhou, J., Zhou, S., Wu, P., & Tsang, Y.F.* (2018). Occurrence and fate of antibiotics in a wastewater treatment plant and their biological effects on receiving waters in Guizhou. Process Safety and Environmental Protection, 113, 483-490.

[R2] Yang, Y., Ok, Y.S., Kim, K.H., Kwon, E.E., & Tsang, Y.F.* (2017). Occurrences and removal of pharmaceuticals and personal care products (PPCPs) in drinking water and water/sewage treatment plants: A review. Science of the Total Environment, 596-597, 303-320. [The most cited article published in Science of the Total Environment since 2016, extracted from Scopus https://www.journals.elsevier.com/science-of-the-total-environment/most-cited-articles]

[R3] Man, Y.B., Chow, K.L., Tsang, Y.F., Lau, F.T.K., Fung, W.C., & Wong, M.H.* (2018). Fate of bisphenol A, perfluorooctanoic acid and perfluorooctanesulfonate in two different types of sewage treatment works in Hong Kong. Chemosphere, 190, 358-367.

[R4] Tsang, Y.F.*, Wang, L., & Chua, H. (2015). Simultaneous hydrogen sulphide and ammonia removal in a biotrickling filter: Crossed inhibitory effects among selected pollutants and microbial community change. Chemical Engineering Journal, 281, 389-396.

[R5] Wang, H.W., Liang, D.D., Wang, Y.N., Sun, Y.J.*, Li, W.H., Zhang, D.Y., Tsang, Y.F.*, & Pan, X.L. (2019). Fabricating biogenic Fe(III) flocs from municipal sewage sludge using NAFO processes: Characterization and arsenic removal ability. Journal of Environmental Management, 231, 268-274.

[R6] Rajapaksha, A.U., Ok, Y.S., El-Naggar, A., Kim, H., Song, F., Kang, S.*, & Tsang, Y.F.* (2019). Dissolved organic matter characterization of biochars produced from different feedstock materials. Journal of Environmental Management, 233, 393-399.

Funding sources: since joined EdUHK in 2013, Dr Tsang secured eight external and 14 internal research grants in the capacity of Principal Investigator, totalling over HK$5.5 million. These include Early Career Scheme (ECS) in 2015/16 for work on bioremediation (2016-18); a Dean's Strategic Research Area Fund project for work on EDC removal (2016-present); a GRF grant in 2016/17 for research on PPCP removal (2017-19); Research Cluster Fund project for research on resource recovery from biowaste (2017-present); a Croucher Chinese Visitorship project for research on biochar-enhanced EDC removal (2018-19); and a Dean's Research Fund project for work on biochar-enhanced bioremediation (2019-present).

(4) Details of the impact

Dr Tsang's research has had impacts on i.) water quality, biowaste, human health, and the environment; ii.) schools in their development of STEM education, and student learning; and iii.) community understanding of pollution issues.

Impact on water quality, biowaste, human health, and the environment: The innovative biological treatment processes using microorganisms and biowaste-derived materials to target EDCs/PPCPs devised by Dr Tsang is being piloted in one STP, in Guizhou China, in collaboration with Guizhou Academy of Sciences and SCUT. Early sampling from the Guizhou plant, serving a population of 200,000, has indicated enhanced removal of EDCs/PPCPs, which is improving the drinking water quality and community health. The technology will now be used more widely in Guizhou Province to safeguard the water sources, with Prof Shaoqi Zhou, Guizhou Academy of Sciences affirming that "the proposed system has been redesigned under the supervision of Dr Tsang, which has greatly improved the efficiency, stability and the reliability of treatment systems and reduced the cost" . This "greatly promoted the environmental pollution control in China". **[Section 5, C1]**

Dr Tsang's work has also contributed to industry understanding of the novel application of biowaste for effective removal of EDCs/PPCPs, having been shared with policy makers and water engineers at The International Conference on Biological Waste as Resource (BWR series) in 2014, 2017, 2018, and 2019. BWR in 2018 and 2019 were organised in collaboration with the Chartered Institution of Water and Environmental Management and Hong Kong Waste Management Association, Korea University, Sejong University, and Korean Society of Environmental Engineers **[C2-3]**. Industry and public service professionals attended, including from Hong Kong's Drainage Services Department and Water Supplies Department (WSD).

Dr Tsang's research on resource recovery of sludge collected from drinking water treatment plants has attracted the interest of the WSD, which invited him to conduct a pilot project (HK$600,000-750,000) to turn sludge into eco-construction materials through special appointment.

Impact on STEM education and student learning: Dr Tsang's insight on wastewater management, the treatment options he has devised, and links with broader issues related to water conservation have had impacts through teaching and learning resources that equip students with current knowledge and relevant problem-solving techniques, and cultivate their scientific investigation skills. In 2015, he was commissioned by the WSD to develop the teaching resources: "Integrated Education Programme on Water Conservation" as part of WSD's Cherish Water Campus water conservation campaign **[C4]**. The resources are being used by 296 primary schools **[C5]** to enhance teachers' and students' understanding towards knowledge of water resources and conservation through interesting and interactive activates. Teacher training workshops were also provided to facilitate effective implementation of the use of the resources. More than 200 General Studies teachers from at least 50 primary schools attended the workshops from 8 to 10 June 2015. These built on Tsang's 10 Environmental Campaign Committee Training Workshops for Teachers, reaching more than 200 teachers and 100 primary and secondary schools since 2009. Following these workshops, interactive teaching kits and a STEM-based prototype of a water treatment system were shared with Liberal Studies teachers at Lee Kau Yan Memorial School, reaching around 316 secondary students in 2014 **[C6]** and with around 50 secondary school teachers in 2015 and 2016 . The idea was also included in the STEM Olympiad 2016 in July by around 700 secondary students and teachers from 100 schools **[C7]**.

Dr Tsang's work on sewage treatment was relayed to all primary and secondary schools in 2017 in the publication: STEM Education: From Theory to Practice **[C8]**. Inspired by Dr Tsang, Tai Po Old Market Public School (Plover Cove) focused on removing microfibers from sewage in their FLL Creative Robot Competition entry, winning the overall championship in Hong Kong and research award in the international finals in Hungary. Principal Dr CC Tsui said that Dr Tsang's curriculum development materials enriched the design of school-based curriculum in general studies and allowed teachers to master enough new knowledge for designing STEM education and interdisciplinary teaching activities". **[C9]**.

Impact on public perceptions: Dr Tsang also shares his expertise as an advisory committee member to the Environmental Association's Fung Yuen Butterfly Reserve, and as the Technical Consultant (Sewage Treatment Plant) of Hong Kong Federation of Youth Groups. The Chief Executive Officer of Environmental Association, Dr WK Yau, shared that Dr Tsang's research had "greatly helped" the association devise "effective strategic plans for environmental protection and water conservation", was used for environmental monitoring and water reuse, and had raised public awareness "about the relationship between pollution and health" **[C10]**.

(5) Sources to corroborate the impact

[C1] Prof Shaoqi Zhou, Deputy Director, Guizhou Academy of Sciences

[C2] The 3rd International Conference on Biological Waste as Resource 2018, Hong Kong. http://www.bwr2018.org/

[C3] The 4th International Conference on Biological Waste as Resource 2019, Korea. http://www.bwr2019.org/

[C4] Water Supplies Department Cherish Water Campus Integrated Education Programme https://www.wsd.gov.hk/en/water-conservation/education/primary-school/index.html

[C5] Name of School participating the "Cherish Water Campus" Intergrated Education Programme (IEP)
https://www.wsd.gov.hk/filemanager/en/content_1386/IEP-Participating-Schools.pdf

[C6] Small Research Grant Scheme (SRGS) Final Report, Federation for Self-financing Tertiary Education (FSTE)
https://www.fste.edu.hk/files/Final%20report%20(2014-4-8).pdf

[C7] The summary of Hong Kong STEM Olympiad
https://www.eduhk.hk/stemo/view.php?secid=50709&u=u

[C8] Department of Science and Environmental Studies & Department of Mathematics and Information Technology (2017). STEM Education: From Theory to Practice https://repository.eduhk.hk/en/publications/stem%E6%95%99%E8%82%B2%E5%BE%9E%E7%90%86%E8%AB%96%E5%88%B0%E5%AF%A6%E8%B8%90

[C9] Letter, Dr Chun Cheung Tsui, Principal, Tai Po Old Market Public School (Plover Cove)

[C10] Letter, Dr Wing Kwong Yau, Chief Executive Officer, Environmental Association