Research Assessment Exercise 2020
Impact Case Study

University: The Hong Kong University of Science and Technology
Unit of Assessment (UoA): 1 - Biological Sciences
Title of case study: Addressing water pollution and food safety through new understanding of accumulation and transfer of metals in the marine environment

(1) Summary of the impact

Metal pollution is a significant environmental problem in the marine waters of China and other regions. Marine biologist Prof Wenxiong Wang, Director of HKUST's Coastal Marine Laboratory, has been leading research to address this challenge by generating new understanding of the biogeochemistry involved in the accumulation and transfer of metal pollutants through the marine ecosystem and food chain. His research has contributed to shaping public policy and practice, benefiting the environment, public health, the economy, and public understanding. It has directly resulted in new protocols for water pollution monitoring by the Environmental Protection Department (EPD) of the Government of the Hong Kong SAR and informed marine water quality guidelines, assisting professional practice and protecting the marine ecology, with longer-term benefits for public health through the reduction of excessive metals in seafood. His expertise in metal ecotoxicity has also had impact on policy, public health, and professional practitioners in the US and Hong Kong by informing policy frameworks for and control of metals transferred through the food chain to humans, and his direct contributions to public policy in Hong Kong as a key member of the government's Expert Committee on Food Safety. Further impact on public policy, health, and the environment has been achieved from contracts to monitor sewage effluent for the Drainage Services Department.

(2) Underpinning research

As in many parts of the world, industrialization and development in Hong Kong and the wider Pearl River Delta have resulted in widespread marine pollution, prompting public concern and a policy need to monitor and clean up the marine environment. Basic and applied research on the increasing prevalence and effect of metal pollutants on dynamic marine ecosystems, led by Wang (joined HKUST in 1997) has created important new understanding of environmental toxicology for water quality management and seafood safety in China coastal areas and beyond.

From 2000-09, Wang carried out research that for the first time quantified how heavy metals transfer along the food chain in the marine ecosystem, and affirmed the main route for uptake of metal contaminants in marine organisms is through the food chain rather than their water and sediment habitats **[R1]**. He received China's Ministry of Education Higher Education Outstanding Scientific Research Output Award (Science and Technology): Natural Science, First Class (2009) for his work. He also developed a bioavailability and trophic transfer model, now used globally, to estimate metal concentration within marine organisms. This considers the geochemical properties of metals (e.g. composition of a metal and its environmental concentration) and biological process (e.g. absorption and assimilation) for a more accurate estimation of the process of bioaccumulation **[R1, R2]**.

Wang's toxicology work has been conducted in HKUST's state-of-the-art marine laboratory and its gamma radioisotope laboratory (one of the few in the world) that he leads. In carrying out his work, he has made innovative use of the newly developed technologies available in these two facilities, with the radioisotopes used to quantify both the rates of metal contamination and where it goes in the cellular structure of an organism, a technique subsequently applied in his research related to water quality standards and monitoring, and food safety. Typical aquatic toxicological studies simply expose marine organisms to toxicants in the water for a period of time under different conditions. Wang developed protocols that seek to understand the toxicology under more realistic and changing environmental conditions, especially under the conditions of dietary exposure due to trophic transfer of metals. His extensive work involves three basic frameworks: environmental behavior/transport, bioavailability/bio accumulation (exposure), and toxicity at different biological levels. This, he

demonstrated, enhanced understanding of the impacts of toxicants on living environments, and could better inform environmental risk assessments needed for public health and environmental management and policies **[R2]**. Between 2010-11, he led the first comprehensive review and mapping of sediments and marine organisms in Chinese coastal environments, which demonstrated the link between increased metal contamination and economic development and indicated the urgent need for more stringent control of discharge of metals into the environment **[R3, R4]**.

Wang's monitoring of metal pollution in the Pearl River Delta also led to research that solved the long-standing mystery as to why South China estuary oysters carry unacceptably high levels of cadmium (Cd). The country is the biggest producer of oysters (>80% of world market), but most can only be consumed locally, having failed to be accepted internationally due to cadmium contamination. Paradoxically, these coastal waters contain relatively low levels of this pollutant. Research led by Wang showed that the abnormally high levels of Cd were mainly caused by cross-contamination by other metals, such as zinc **[R5]**, and that at regional level can be caused by low salinity in estuarine waters when overflows of freshwater come into the delta, particularly in the summer, and the increased bioavailability that results **[R6]**.

(3) References to the research

[R1] Wang WX*. 2002. Interactions of trace metals and different marine food chains. Mar. Ecol. Prog. Ser. 243: 295-309.

[R2] Wang WX*. 2011. Incorporating exposure into aquatic toxicological studies: An imperative. Aquat. Toxicol. 105S: 9-15.

[R3] Pan K, **Wang WX***. 2012. Trace metal contamination in estuarine and coastal environments in China. Sci. Total Environ. 421/422: 3–16.

[R4] Wang WX*, Pan K, Tan QG, Guo L, Simpson SL. 2014. Estuarine pollution of metals in China: Science and mitigation. Environ. Sci. Technol. 48: 9975-9976.

[R5] Liu F, **Wang WX***. 2013. Facilitated bioaccumulation of cadmium and copper in the oyster *Crassostrea hongkongensis* solely exposed to zinc. Environ. Sci. Technol. 46: 1670-1677.

[R6] Yin Q, **Wang WX***. 2017. Relating metals with major cations in oyster *Crassostrea hongkongensis*: A novel approach to calibrate metals against salinity. Sci. Total. Environ. 577: 299-307.

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4. Details of the impact

Research by Wang and the HKUST Coastal Marine Laboratory has had direct impact on *public policy*, *professional practice*, *marine ecology* and *environment*, *public health* and *economy*, as well as *societal impact* through *public understanding* in the US and Hong Kong. It has achieved this by informing the revision of government regulations on metal contamination in foods and water quality standards that can help protect human health and the marine environment, and facilitate the sale of safe food to local consumers, tourists, for export, and through its on-going monitoring of effluent.

Wang's extensive research on eco-toxicology, recognized internationally, was used by the United States Environmental Protection Agency (EPA) to inform new guidelines on dietary-borne exposure to metal contaminants, which continue to have *impact on policy, public health, professional practice,* and *public understanding* in the US, having remained in force since 2007. **[See Section 5**, **S1**, EPA's "Framework for Metals Risk Assessment", which cites Wang's research 22 times.] The significance and use of this framework for monitoring foods is summarized in the EPA's introduction, which describes it as "*a science-based document that addresses the special attributes and behaviors of metals and metal compounds to be considered when assessing their human health and ecological risks. The document describes basic principles to be considered in assessing risks posed by metals*

and is intended to foster consistency in how these principles are applied across the Agency's programs and regions when conducting these assessments" **[S1]**.

Wang's knowledge and expertise subsequently resulted in him being awarded a contract to lead a series of Hong Kong government projects with the Environmental Protection Department (EPD) to conduct eco-toxicity tests focused on heavy metals in Hong Kong waters. [Text removed for publication] **[S2]**

[Paragraph removed for publication].

Further impact on *public policy*, the *economy*, and *public health* has been achieved from Wang's discovery that cadmium contamination in oysters in Pearl River Delta waters resulted from cross-contamination of other metal pollutants and freshwater input in the estuarine area. [Text removed for publication] **[S2]**. This paves the way for longer-term beneficial effects on the seafood industry and public health.

Wang's expertise in trophic transfer is also used by the Drainage Services Department (DSD), Government of the HKSAR, in on-going contracts, the first in 2009, for toxicity tests of effluent samples from the Stonecutters Island Sewage Treatment Works, which has been treating two million cubic meters of sewage daily and is the largest treatment facility in Hong Kong. [Text removed for publication] [see **S3** for example of report and contract details]. The Whole Effluent Toxicity Tests (WETT), initially conducted monthly and now every three months, in partnership with [redacted], ensure that effluent released from the facility meets all water quality standards, with important *impacts for public policy, protecting public health,* and *the environment.* [Text removed for publication] [**S4]**

Wang's research leadership on metal contamination and other pollution in the marine environment has also contributed to *impacts on public policy, public health* and *public understanding* through his appointment, by Hong Kong's Secretary for Food and Health, as Vice-Chairman of the Expert Committee on Food Safety in 2018 and as a member since 2012 **[S5]**. The committee advises the Director of Food and Environmental Hygiene on existing or new food safety operational strategies and measures to protect public health, and on standards or guidelines relating to food safety and food composition, according to a 2018 press release from the government's Information Services Department announcing his new appointment [**S5**].

Wang's research on trophic transfer informed the Centre for Food Safety's research and preparations of the Food Adulteration (Metallic Contamination) (Amendment) Regulation 2018, enacted by the Legislative Council in October 2018 and implemented for food testing from November 2019 **[S6]**. In testimony, Dr Ho Yuk-yin, Head of the Centre for Food Safety, affirmed the importance of Wang's insight for the tightened standards: *"For the amended regulation, Professor Wang contributed significantly to discussions, including identification of metals of concern; the scope of the revisions; the standards to be set; and the scientific justification for our recommendations, which has been informed by his expertise and research related to metallic contamination in the marine ecosystem."* **[S7]** The tightened regulation, he added, "*is an important piece of legislation that serves two main purposes: to safeguard food safety and public health and facilitate fair trade practices in international trade*", indicating its impact for public health and the economy. Ho added that Wang had "*made significant contributions to our food safety work, and to improved public health associated with this*". He had made valuable contributions to the Committee, which he described as *"one of the most important expert committees"* under the FEHD. *"It has done much to ensure that food safety in Hong Kong has continuously improved in recent years."* Food safety in Hong Kong is now *"one of the best in the region"*, measured by *"high satisfaction of our foods tested under our surveillance programme, and decreasing incidents of food poisoning over the last twelve years. It also contributes to the increase in life expectancy in Hong Kong, which is now the longest in the world"* **[S7]**.

The unique contribution of Wang and the HKUST Coastal Marine Laboratory to addressing metal pollution in aquatic ecosystems was relayed to the wider public in a short documentary broadcast on TVB Jade, Hong Kong's most popular TV channel, now available on YouTube **[S8]**.

This has achieved *societal impact* by facilitating greater public understanding of the issues, need for public effort to address them, and the role of his laboratory.

5. Sources to corroborate the impact

[S1] United States Environmental Protection Agency. Framework for Metals Risk Assessment 2007. [Wang cited 22 times, as Wang W-X and Wang XL] https://www.epa.gov/risk/framework-metals-risk-assessment [active report, accessed 11 September 2019].
[S2] Letter, [redacted] Environmental Protection Department, HKSAR Government. [on file]
[S3] R&D Corp, HKUST. Final Laboratory Testing Report for Operation Phase Whole Effluent Toxicity Test for Advance Disinfection Facilities at Stonecutters Island Sewage Treatment Works (Contract No. DE/2012/08), for Drainage Services Department. Report for the Month of July 2014
[S4] Letter, [redacted], Drainage Services Department, HKSAR Government. [on file]
[S5] HKSAR Government Press Release, "Appointments to Expert Committee on Food Safety", 14 September 2018. www.info.gov.hk/gia/general/201809/14/P2018091400235.htm
[S6] Centre for Food Safety, HKSAR Government. Food Adulteration (Metallic Contamination) Regulations.www.cfs.gov.hk/english/whatsnew/whatsnew_fstr/whatsnew_fstr_PA_Food_Adulteration_Metallic_Contamination.html
[S7] Letter, Dr Ho Yuk-yin, Head, Centre for Food Safety, FEHD, HKSAR Government. [on file]
[S8] TVB Documentary www.youtube.com/watch?v=o48gBIPywOo&list=PL9WlaJHtZ5WPVsZNnYPgSYHEhfn7HSyPt