RGC Ref.: E-PolyU503/17

European Commission (EC) / Research Grants Council (RGC) Collaboration Scheme

Completion Report

(Please attach a copy of the completion report submitted to the European Commission by the project coordinator of the concerned Horizon 2020 project)

Part A: The Project and Investigator(s)

1. Project Title

Holistic Investigation of Fate and Behaviour of Emerging Contaminants in Complex Environmental Matrices

2. Investigator(s) and Academic Department/Units Involved

	Hong Kong Team	Europe Team
Name of Principal Investigator / Project Coordinator *(with title)*	Prof. Daniel Chiu Wa TSANG	Prof. Stuart HARRAD
Post	Professor	Professor
Unit / Department / University	Civil and Environmental Engineering / The Hong Kong Polytechnic University	Geography, Earth and Environmental Sciences / University of Birmingham
Contact Information	dan.tsang@polyu.edu.hk	s.j.harrad@bham.ac.uk

3. Project Duration

	Original	Revised	Date of RGC/ University Approval *(must be quoted)*
Project Start date	1 Apr 2018	N.A.	
Project Completion date	31 Dec 2020	N.A.	
Duration *(in month)*	33	N.A.	
Deadline for Submission of Completion Report	31 Dec 2021	N.A.	

Part B: The Completion Report

5. Project Objectives

5.1 Objectives as per original application

1) Establish comprehensive FRs/PPCPs distribution patterns in environments and waste streams (i.e., regional agricultural soils, local marine sediments, and incinerated ashes) by non-target analysis with the aid of ultra-high-resolution mass spectrometric techniques and statistical analysis;

2) Elucidate toxicity profiles of the environmental samples by rapid bioassay screening (e.g., DR-Luc bioassay, ER-Luc bioassay, AR-EcoScreen bioassay, and transthyretin (TTR) binding assay) for revealing spatial- and medium-wise toxicity response;

3) Unveil bioactive species of FRs/PPCPs in the environmental samples via effect-directed analysis (EDA);

4) Investigate the effect of physicochemical properties of environmental compartments (e.g., pH, organic carbon, cation exchange capacity, and particle size) on the behaviour and desorption dynamics of various emerging FRs/PPCPs.

5.2 Revised Objectives

N.A.

6. Research Outcome

Major findings and research outcome

(maximum 1 page; please make reference to Part C where necessary)

Major finding 1: Sediment samples exhibit the highest risk associated with dioxin-like toxicity

Soil and sediment samples exhibit significant dioxin-like activities compared to the carcinogenic reference compounds (**Figure 1a&b**). As for comparison among different environmental compartments, sediments tended to induce a higher DR-Luc response, which had a median value of 64.2% (with respect to TCDD) that exceeded 96% of the soil samples. In addition to the pollution sources, the environmental fate of pollutants is one of the critical determinants of the biological toxicity. While sediments are located in aqueous and anoxic environment, soils have a larger particle size and porosity and are more exposed to air, which can cause differences in the adsorption of pollutants on organic matter.

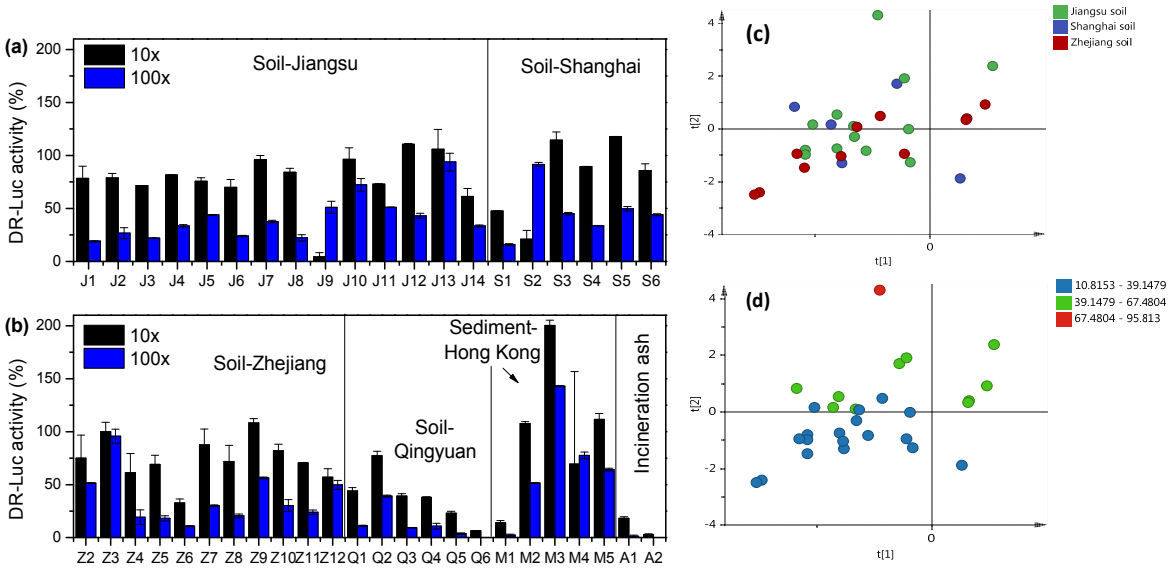

Figure 1. (a&b) DR-Luc activity (% with respect to the TCDD response) of different soil and sediment samples. J: Jiangsu, S: Shanghai, Z: Zhejiang, Q: Qingyuan. PLS score plots of dataset categorized by (c) soil location and (d) DR-Luc activity.

Major finding 2: Soils from Yangtze River Delta (YRD) region have similar chemical profile and biological response

The score plots show no clusters of the agricultural soil samples from Jiangsu, Shanghai, and Zhejiang, indicating that the sample characteristics may not be strongly correlated with the regions. Higher concentrations of PAEs, PBDEs, and OCPs were detected on the borders between Shanghai and Jiangsu and the borders between Shanghai and Zhejiang, implying a less obvious regional differences. This is probably because the major pollutant sources emitting from chemical factories were located near the borders to alleviate pollution in densely populated downtowns. Besides, a variety of naturally occurring and synthetic compounds of diverse structure and lipophility are able to bind AhR and induce DR-Luc activity, which may result in the observed scattering of the dataset when being categorized by locations (**Figure 1c**).

Major finding 3: Dioxin-like activity is positively correlated to the chemical profile

The partial least squares (PLS) regression suggests that the DR-Luc response can be partially explained by 90 contaminants, and samples exhibiting comparable DR-Luc activity are likely to share similar chemical profiles (**Figure 1d**). The regression model fitting had a R^2 value of 0.9113 for the observed DR-Luc activity versus the predicted DR-Luc activity. The revealed relationship between chemical properties and biological responses are important for understanding the actual impacts of contaminants of emerging concerns on ecosystem and human health for making adequate decision in risk control.

Potential for further development of the research and the proposed course of action *(maximum half a page)*

In this study a wide range of samples were analysed, including agricultural soils from polluted regions, marine sediments, and incineration ashes of sewage sludge and municipal solid waste. The DR-Luc bioassay revealed that the soil and sediment samples, which were contaminated by PAHs, PCBs, PBDEs, etc., exhibited significant dioxin-like activities. The sediment samples appear to induce a higher biological response, possibly due to the distinct environment of sediments (aquatic, anoxic) that could have promoted different transformation pathways of the organic contaminants. The DR-Luc activity exhibited insignificant correlation with the increase of contaminant concentrations, which was different from general observation of the single type of environmental samples. These results implied the potential significance of the environmental matrices in the biological toxicity patterns. The PLS regression model did not suggest definite regional differences while the samples exhibited a similar level of DR-Luc response clustered together. This study addressed the significance of biological implications in addition to chemical concentrations, which are important for understanding the actual impacts and devising adequate risk control of environmental contamination. Future research is required to examine the presence of a wider spectrum of dioxins (e.g., polychlorinated dibenzodioxins and polychlorinated dibenzofurans) through non-target analysis. The study of correlation between individual dioxin species and dioxin-related toxicity should also be verified in the environmental samples.

7. The Layman's Summary

(describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

There are growing concerns over environmental contamination by toxic and bioaccumulative organic chemicals in consumer products. Flame retardants (FRs) can be released to the environment upon disposal and recycling of waste electric and electronic equipment (e-waste). Chemicals in pharmaceutical and personal care products (PPCPs) such as antibiotics have been found persisting in various media, including treated effluents and sewage sludge from wastewater treatment plants, surface water, and marine sediment. Therefore, there is a pressing need to address these contaminants of emerging concerns for risk control. This project investigated FRs and PPCPs present in major waste streams in a holistic approach. A wide spectrum of environmental samples were analysed: (i) agricultural soils in densely populated region and e-waste recycling cities in China; (ii) marine sediments in Hong Kong; and (iii) incineration ashes of sewage sludge in Hong Kong and municipal solid waste in China, respectively. Comprehensive pollutant analyses and toxicity assessments were undertaken to detail the contamination at sampling areas and to offer scientific insights into the potential biological impacts. The research outcomes enable decision makers to prioritise the need for contaminant monitoring and regulation in major waste streams, and raise public awareness towards emerging contaminants and sustainable urban development.

Part C: Research Output

8. Peer-reviewed journal publication(s) arising directly from this research project

(Please attach a copy of each publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) *(**bold** the authors belonging to the project teams and denote the corresponding author with an asterisk*)*	Title and Journal/ Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this collaboration scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
Year of publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*						
2021				Mingjing He, Zhonghao Wan, **Daniel C.W. Tsang***, Yuqing Sun, Eakalak Khan, Deyi Hou, Nigel J.D. Graham	Performance indicators for a holistic evaluation of catalyst-based degradation—A case study of selected pharmaceuticals and personal care products (PPCPs). **Journal of Hazardous Materials**, 402, 123460. (Citations: 9)	No	Yes	Yes	Yes
2020				Md. Uzzal Hossain, Lei Wang*, Liang Chen, **Daniel C.W. Tsang***, S. Thomas Ng, Chi Sun Poon, Viktor Mechtcherine	Evaluating the environmental impacts of stabilization and solidification technologies for managing hazardous wastes through life cycle assessment: A case study of Hong Kong. **Environment International,** 145, 106139. (Citations: 6)	No	Yes	Yes	Yes
2020				Di Wang, Yuqing Sun, **Daniel C.W. Tsang***, Eakalak Khan, Dong-Wang Cho, Yaoyu Zhou, Fei Qi, Jianyu Gong, Linling Wang	Synergistic utilization of inherent halides and alcohols in hydraulic fracturing wastewater for radical-based treatment: A case study of di-(2-ethylhexyl) phthalate removal. **Journal of Hazardous Materials**, 384, 121321. (Citations: 22)	No	Yes	Yes	Yes

2019				Lei Wang, Liang Chen, **Daniel C.W. Tsang*,** Yaoyu Zhou, Jörg Rinklebe, Hocheol Song, Eilhann E. Kwon, Kitae Baek, Yong Sik Ok	Mechanistic insights into red mud, blast furnace slag, or metakaolin-assisted stabilization/solidification of arsenic-contaminated sediment. **Environment International**, 133, 105247. (Citations: 50)	No	Yes	Yes	Yes
2019				Xinni Xiong, Xueming Liu, Iris K.M. Yu, Lei Wang, Jin Zhou, Xin Sun, Jörg Rinklebe, Sabry M. Shaheen, Yong Sik Ok, Zhang Lin, **Daniel C.W. Tsang***	Potentially toxic elements in solid waste streams: Fate and management approaches. **Environmental Pollution**, 253, 680-707. (Citations: 32)	No	Yes	Yes	Yes
2019				Yuqing Sun, Dong-Wan Cho, Nigel J.D. Graham, Deyi Hou, Alex C.K. Yip, Eakalak Khan, Hocheol Song, Yaru Li, **Daniel C.W. Tsang***	Degradation of antibiotics by modified vacuum-UV based processes: Mechanistic consequences of H_2O_2 and $K_2S_2O_8$ in the presence of halide ions. **Science of The Total Environment.** 664, 312-321. (Citations: 66)	No	Yes	Yes	Yes
2019				Dong-Wan Cho, Kwangsuk Yoon. Yongtae Ahn, Yuqing Sun, **Daniel C.W. Tsang***, Deyi Hou, Yong Sik Ok, Hocheol Song	Fabrication and environmental applications of multifunctional mixed metal-biochar composites (MMBC) from red mud and lignin wastes. **Journal of Hazardous Materials**. 374, 412-419. ***(Highly Cited Paper)*** (Citations: 95)	No	Yes	Yes	Yes
2019				Lei Wang Dong-Wan Cho, **Daniel C.W. Tsang***, Xinde Cao, Deyi Hou, Zhengtao Shen, Daniel S. Alessi, Yong Sik Ok, Chi Sun Poon	Green Remediation of As and Pb Contaminated Soil using Cement-free Clay-based Stabilization/Solidification. **Environment International**, 126, 336-345. ***(Highly Cited Paper)*** (Citations: 145)	Yes (2019)	No	Yes	Yes

2019				Liang Chen, Lei Wang, Dong-Wan Cho, **Daniel C.W. Tsang**[*], Lizhi Tong, Yaoyu Zhou, Jian Yang, Qing Hu, Chi Sun Poon	Sustainable stabilization/solidification of municipal solid waste incinerator fly ash by incorporation of green materials. **Journal of Cleaner Production**, 222, 335-343. ***(Highly Cited Paper)*** (Citations: 85)	Yes (2019)	No	Yes	Yes
2019				Yuqing Sun, Di Wang, **Daniel C.W. Tsang**[*], Linling Wang, Yong Sik Ok, Yujie Feng	A Critical Review of Risks, Characteristics, and Treatment Strategies for Potentially Toxic Elements in Wastewater from Shale Gas Extraction. **Environment International**, 125, 452-469. (Citations: 60)	Yes (2019)	No	Yes	Yes
2019				Yuqing Sun, Iris K.M. Yu, **Daniel C.W. Tsang**[*], Xinde Cao, Daohui Lin, Linling Wang, Nigel J.D. Graham, Daniel S. Alessi, Michael Komárek, Yong Sik Ok, Yujie Feng, Xiang-Dong Li	Multifunctional Iron-Biochar Composites for the Removal of Potentially Toxic Elements, Inherent Cations, and Hetero-chloride from Hydraulic Fracturing Wastewater. **Environment International**, 124, 521-532. ***(Highly Cited Paper)*** (Citations: 240)	Yes (2019)	No	Yes	Yes
2019				Lei Wang, Liang Chen, **Daniel C.W. Tsang**[*], Harn Wei Kua, Jian Yang, Yong Sik Ok, Shiming Ding, Deyi Hou, Chi Sun Poon	The roles of biochar as green admixture for sediment-based construction Products. **Cement and Concrete Composites**, 104, 103348. ***(Highly Cited Paper)*** (Citations: 87)	Yes (2019)	No	Yes	Yes
2019				Lei Wang, Liang Chen, Dong-Wan Cho, **Daniel C.W. Tsang**[*], Jian Yang, Deyi Hou, Kitae Baek, Harn Wei Kua, Chi-Sun Poon	Novel Synergy of Si-rich minerals and Reactive MgO for Stabilisation/Solidification of Contaminated Sediment. **Journal of Hazardous Materials**, 365, 695-706. ***(Highly Cited Paper)*** (Citations: 100)	Yes (2019)	No	Yes	Yes

9. Recognized international conference(s) in which paper(s) related to this research project was/were delivered *(Please attach a copy of each delivered paper. All listed papers must acknowledge RGC's funding support by quoting the specific grant reference.)*

Month/Year/ Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this collaboration scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
5-6 December, 2019, Seoul, Korea	Risk-based management and remediation of arsenic-containing soils (Keynote)	CleanUp Korea 2019 Conference	No	Yes	Yes	No
1-5 December, 2019, Ho Chih Ming City, Vietnam	Novel and green biochar catalysts for advanced oxidation of environmental pollutants (Invited)	Green Technologies for Sustainable Water Conference	No	Yes	Yes	No
4-6 August, 2019, Harbin, China	Advanced wastewater treatment by designing sustainable biochar catalysts (Keynote)	5th International Conference on Environmental Pollution and Health	No	Yes	Yes	No
1-3 July, 2019, Fort Collins, USA	Biochar-mineral composites for catalytic degradation of environmental pollutants (Invited)	US Biochar Initiative Conference	No	Yes	Yes	No
6-9 May, 2019, Yangling, China	Biochar-supported catalysts for biorefinery and pollution control (Invited)	International Conference on Sustainable Solid Waste Treatment and Management	No	Yes	Yes	No
10-13 June, 2018, Hongcheon, Korea	Technical and economic assessment of green remediation and recycling of dredged sediment (Keynote)	2nd International Conference on Bioresources, Energy, Environment, and Materials Technology	Yes (2019)	No	Yes	No
19-23 August, 2018, Boston, USA	Engineered biochar for contaminant adsorption and reduction (Keynote)	256th American Chemical Society National Meeting	Yes (2019)	No	Yes	No
26-28 November, Seoul, Korea	Fate of metals in solid waste streams (Invited)	1st Asia Resilience Center Conference	Yes (2019)	No	Yes	No

10. Student(s) trained *(Please attach a copy of the title page of the thesis.)*

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation
Xinni Xiong	PhD	2016	Jul 2021
Season S. Chen	PhD	2014	Mar 2019
Yuqing Sun	PhD	2014	Aug 2018

11. Other impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, etc.)*

N/A

12. Statistics on Research Outputs

(Please ensure the summary statistics below are consistent with the information presented in other parts of this report.)

	Peer-reviewed journal publications	Conference papers	Scholarly books, monographs and chapters	Patents awarded	Other research outputs (Please specify)
No. of outputs arising directly from this research project	13	8	-	-	-