RGC Ref. No.:
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(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

Seasonal Succession of Microalgae and Their Relationship with Environmental Factors in the Sources of Hong Kong Drinking Water

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

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	XU Jingliang, Associate Professor	School of Science and Technology, Hong Kong Metropolitan University

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	1 January 2019	N/A	
Project Completion Date	31 December 2020	31 December 2021	20 April 2021
Duration *(in month)*	24	36	20 April 2021
Deadline for Submission of Completion Report	31 December 2021	31 December 2022	20 April 2021

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. To investigate the annual and monthly microalgal diversity in the upper, middle, lower reaches of Dongjiang River and six reservoirs related to Hong Kong potable water supply
2. To monitor the in situ water quality parameters (flow rate, light penetration, water temperature, DO, pH, turbidity, etc.) in Dongjiang River and the six reservoirs
3. To examine the major contaminant parameters (BOD5, nitrogen and phosphorus nutrients, oil and grease, heavy metals and feacal coliform) in water samples
4. To compare the water quality and the composition of microalgal communities between reservoirs with different water sources (Dongjiang water or local rainwater)
5. To explore the major contributing environmental variables to the development of toxin and odor producing microalgal species

5.2 Revised objectives

Date of approval from the RGC: _____

Reasons for the change: _____

_____

1.

2.

3. ....

5.3 Realisation of the objectives
(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

A total of 33 microalgal genera from five phyla were identified in three sampling sites along the Dongjiang River during the sampling period, including 6 Cyanobacteria, 12 Diatom, 3 Dinoflagellate, 11 Chlorophyta and 1 Rhodophyta. The abundance of Cyanobacteria in Heyuan (HY, upper stream) was significantly higher than that in Huizhou (HZ, the middle stream) and Dongguan (DG, the lower stream), suggesting the water quality in HY favored the growth of Cyanobacteria. In Cyanobacteria phylum, six genera, namely *Anabaena*, *Oscillatoria*, *Microcystis*, *Aphanothece*, *Chroococcus*, and *Gloeocapsa*, were identified. *Oscillatoria* was the most dominated genus in this phylum in Dongjiang River, followed by Anabaena, while *Microcystis* and *Aphanothece* were only observed in July and August in DG. Four phytoplankton phyla, namely Bacillariophyta, Chlorophyta, Cyanophyta and Dinophyta, consisting of 36 genera were found in the five reservoirs. Commonly observed genera included diatoms (*Cymbella*, *Melosira*, *Neidium*, *Synedra* and *Thalassiosira*), green algae (*Scenedesmus* and *Staurastrum*), cyanobacteria (*Oscillatoria* and *Microcystis*) and dinoflagellate (*Peridinium*). Bacillariophyta (the diatoms) was generally abundant in all reservoirs, but the relative abundance of the other three phyla varied significantly among reservoirs. The dominant phylum was dinoflagellates (Dinophyta) in HIR, cyanobacteria (Cyanophyta) in PCR and TLC, and green algae (Chlorophyta) in SPR reservoir.

For water quality parameters in Dongjiang, some exceeded the level V of the Environmental Quality Standard for Surface Water of the People's Republic of China. They were TN (1.2 to 10.4, mg L^{-1}), TP (0.2 to 1.7, mg L^{-1}), BOD_5 (1.5 to 18.5, mg L^{-1}), COD (0.5 to 65.3, mg L^{-1}) and *E.coli* (1 $x10^3$ to 163x 10^3, CFU L^{-1}). The 17 water quality parameters exhibited diverse spatial and temporal trends. Both temporal and spatial variations of the physical parameters (water temperature, pH, EC, DO, Tur, and Lux) were significant, but significant temporal difference was not found in flow rate. Nutrients in the water, including TN, NH_4^+-N, NO_3^--N and TP, varied among sampling sites and months, but not OP and N:P ratio. The average TN concentration ranged from 1.01 to 9.6 mg L^{-1}. The temporal cyclic trends were comparable between sampling sites, with the lowest values in July, increased thereafter, reached the peak in October and decreased in the winter season (November to January) to the level similar to that in spring season. For the general water quality across reservoirs, the ranges of temperature, pH, DO and light intensity across reservoirs were 18.17-33.40°C, 5.62-9.48, 5.46-13.80 mg L^{-1}, 24.1-1699 x 100 lux, respectively. Turbidity and conductivity, ranging between 0 to 31.90 NTU and 0.001 to 0.15 mS cm^{-1} respectively, were significantly higher in PCR and TLC than the other three reservoirs, HIR, SMR and SPR.

Results of microalgal diversity suggested that the pollution level of Dongjiang water varied from slight to moderate. The total cell density of cyanobacterial species in the River was far below the margin of harmful algal bloom, however, some toxin producing Cyanobacteria, including *Anabaena*, *Oscillatoria*, *Microcystis*, *Aphanothece* and *Chroococcus*, were detected in some sample. Diatoms were the dominant species in the more polluted areas, while cyanobacteria were dominated in less polluted areas of the River. The relative abundance of Cyanobacteria was negatively correlated with TN, NH_4^+-N, NO_3^--N, TP and BOD_5, but positively correlated with Lux and TOC, indicating that low nutrient levels favored the occurrence of Cyanobacteria. For the five reservoirs, physical parameters and nutrient concentrations of surface waters explained 51.3% of the variance in phytoplankton dynamics based on multivariate analyses, and temperature and turbidity were the key factors influencing phytoplankton community and cyanobacterial abundance. HIR, PCR and TLC reservoirs shared the same water source (from Dongjiang River) but had different storage capacity, geographical location, water quality and phytoplankton composition, suggesting that these local drivers would have greater influence on phytoplankton dynamics in reservoirs than water source. Under predicted climate change with increases in temperature and rainfall, these conditions are likely to promote algal bloom in reservoirs, especially the proliferation of cyanobacteria, and pose public health risks.

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. To investigate the annual and monthly microalgal diversity in the upper, middle, lower reaches of Dongjiang River and six reservoirs related to Hong Kong potable water supply	✓	100%
2. To monitor the in situ water quality parameters (flow rate, light penetration, water temperature, DO, pH, turbidity, etc.) in Dongjiang River and the six reservoirs	✓	100%
3. To examine the major contaminant parameters (BOD_5, nitrogen and phosphorus nutrients, oil and grease, heavy metals and feacal coliform) in water samples	✓	100%
4. To compare the water quality and the composition of microalgal communities between reservoirs with different water sources (Dongjiang water or local rainwater)	✓	100%
5. To explore the major contributing environmental variables to the development of toxin and odor producing microalgal species	✓	100%

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

The present study monitors monthly changes of phytoplankton composition and water quality, including concentrations of nutrients and contaminants along the Dongjiang River and in five major reservoirs in Hong Kong.

For the Dongjiang River, TN, TP, BOD_5, COD and E.coli were the major parameters exceeded the Level V of the Standard for Surface Water in China (GB 3838-2002). Fecal pollution was serious in the upper, middle, lower reaches of Dongjiang River, but middle and lower reaches had significantly higher nutrient and organic pollution than upper reaches. Such spatial variation was probably due to the type of land use and human activities in different reaches. The water quality of Dongjiang River significantly affected the 32 genera of microalgae in five phylum, including Diatoms, Cyanobacteria, Dinoflagellate, Chlorophyta, and Rhodophyta. Diatoms dominant in the River were positively correlated with water nutrients and organic pollutants, including TN, NO_3^--N, TP, Fe, TOC and COD. Potential toxin-producing cyanobacterial species were also observed during the sampling period, including *Anabaena*, *Oscillatoria*, *Microcystis*, *Aphanothece* and *Chroococcus*. The relative abundance of Cyanobacteria was negatively correlated with TN, NH_4^+-N, NO_3^--N, TP and BOD_5, but positively correlated with light penetration and TOC, indicating that low nutrient levels favored the occurrence of Cyanobacteria. In spite of the presence of some toxin-producing Cyanobacteria, the cell density of total Cyanobacteria was far below the monitoring level, suggesting the risk posed by harmful cyanobacteria bloom in the water of Dongjiang River was low. Based on the microalgal diversity indices, the pollution level of Dongjiang River could be classified as light to moderate. Nevertheless, water pollution in the wet season (April to September) was more serious than in the dry season (October to March), continuous and routine monitoring of microalgal community and water quality is essential to ensure the drinking water safety of Dongjiang River.

The present study also revealed the monthly variation of water quality and phytoplankton composition in five reservoirs with different water sources, storage capacity and water quality in Hong Kong. Total 36 genera of phytoplankton were identified, and 46.6% of the variations in phytoplankton composition was explained by the abundance of *Oscillatoria*, *Neidium*, *Peridinium*, *Synedra* and *Staurastrum*. All reservoirs were generally abundant in diatoms, but the relative proportions of different phytoplankton phyla varied significantly among reservoirs, with high abundance of dinoflagellates in High Island Reservoir (HIR), cyanobacteria in Plover Cove Reservoir (PCR) and Tai Lam Chung Reservoir (TLC), and green algae in Shek Pik Reservoir (SPR) over the one year sampling period. Cyanobacteria were dominant in some reservoirs, especially in summer months. HIR, PCR and TLC reservoirs shared the same water source (from Dongjiang River) but had different storage capacity, geographical location, water quality and phytoplankton composition, suggesting that these local drivers would have greater influence on phytoplankton dynamics in reservoirs than water source. Physical parameters and nutrient concentrations of surface waters explained 51.3% of the variance in phytoplankton dynamics based on multivariate analyses, and temperature and turbidity were the key factors influencing phytoplankton community and cyanobacterial abundance. Under predicted climate change with increases in temperature and rainfall, these conditions are likely to promote algal bloom in reservoirs, especially the proliferation of cyanobacteria, and pose public health risks. The casual relationship between cyanobacterial abundance and toxin in water column, as well as the determining factor, in each reservoir shall be established and monitored for better management of drinking water reservoirs. Our work establishes a baseline reference of phytoplankton community in Dongjiang River and Hong Kong reservoirs and demonstrates the importance of continuous monitoring to minimize algal bloom risks.

Until October 2022, two peer-reviewed journal papers arising directly from this research project have been published. One more manuscript is about to be submitted. The PI also presented the research finding of the project in an international conference. Besides, total three bachelor degree theses were generated directly from the project and 11 undergraduates were trained.

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

In recent years the Dongjiang River has been facing increasingly severe water pollution problems due to the rapid economic development of Guangdong Province. The significant changes in land use in the Dongjiang River Basin have resulted in a significant decrease in the forested areas, a substantial increase in urbanisation and a moderate increase in farmland. The population growth and dramatic agricultural and industrial developments have increased the pollutant loadings in the river. This study provides a systematic research on the microalgal community in sources of Hong Kong drinking water from the upstream of the Dongjiang River to the local water reservoirs. The seasonal succession of microalgae in the Dongjiang River and two types reservoirs (mainly contains either Dongjiang water or local rainwater) in response to environmental variables has been examined. The results gained from this study also suggest the environmental variables which has the highest potential for the massive growth or blooms of toxin/odor producing microalgal species, so that the government agencies in Guangdong Province and Hong Kong can develop relevant risk assessment strategy, suitable control measures and sustainable usage plan on the crucial water resources in the region. The information is also important to the freshwater resources management agencies facing similar pollution issue throughout the world.

7. Layman's Summary

(Describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

The major source of drinking water in Hong Kong is the Dongjiang River in mainland China. Therefore, the quality of the drinking water is heavily determined by the water quality of the Dongjiang River. In recent years, the Dongjiang River has faced severe water pollution stresses due to the rapid development along its hinterland in Guangdong Province. Microalgae are deeply linked to water quality and serve as a biological indicator. The water quality, especially the nutrient levels, determines the variety and abundance of microalgae. Moreover, the dominance of certain toxin/odor-producing microalgae not only affects the quality of the raw water but also creates severe problems for subsequent water treatment. This study provides systematic research on the sources of Hong Kong drinking water from the upstream of the Dongjiang River to the local water reservoirs. The major environmental factors contributing to the development of toxin and odor-producing microalgal species have been examined. The results gained from this study can provide important information not only to the government agencies in both Guangdong and Hong Kong for better management of raw water resources but also to other freshwater resources management agencies who are facing similar water pollution problems all over the world.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the 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)** *(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 RGC** *(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)*						
2022				Steven Jing-Liang Xu, Sophie Cheuk-Yan Chan, Brian Yu-Keung Wong, Hai-Chao Zhou, Feng-Lan Li, Nora Fung-Yee Tam, Fred Wang-Fat Lee*	Relationship between phytoplankton community and water parameters in planted fringing mangrove area in South China / *Science of the Total Environment*	No	Yes [Attachment 1]	Yes	Yes
2022				Steven Jing-Liang Xu, Kam-Chau Wu, Winnie Lam, Fred Wang-Fat Lee*	Evaluation of a Causative Species of Harmful Algal Blooming, Prorocentrum triestinum, as a Sustainable Source of Biosorption on Cadmium / *Journal of Marine Science and Engineering*	No	Yes [Attachment 2]	Yes	Yes
		Yes		Sophie Cheuk-Yan Chan, Nora Fung-Yee Tam, Fred Wang-Fat Lee, Steven Jing-Liang Xu*	Cyanobacteria and other phytoplankton in drinking water reservoirs in South China and the significance of water quality / *Science of the Total Environment*	No	Yes [Attachment 3]	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 conference abstract)

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 RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
June/ 2019/ Hong Kong	Exploring the determinant for the dominance of cyanotoxins and odorous compound producing microalgae in Hong Kong drinking water sources	9th International Conference on Marine Pollution and Ecotoxicology	2019	Yes [Attachment 4]	Yes	Yes

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning

(Please elaborate)

The research findings and experience were shared to undergraduate and postgraduate students enrolled in environmental science and testing science related programmes of the University. Total three bachelor degree theses were generated directly from the project and 11 undergraduates were trained.

11. 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**
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

[redacted]	[redacted]	[redacted]	[redacted]

12. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

The project background and results have been utilized in three undergraduate courses: ENVRS374F Green Environmental Monitoring in Practice, SCIS463F Selected Topics in Food Safety, SCIS410F Science Research Project, and two postgraduate courses: TC S870F Environmental Protection Testing and Certification, and ENVR S888F Environmental Research Project to enhance students' understanding of the quality of the source of Hong Kong drinking water. Besides, two Mphil and eleven undergraduate students have been trained and have contributed to the information search, water sampling and water quality parameter measurement of the project.

13. Statistics on Research Outputs

	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	2 published 1 submitted	1 published			Type	No.

14. Public Access Of Completion Report

(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**