Completion Report

Effects of heavy metals and antibiotic pollution to the mangrove sediment microbiome and their functional diversities in western waters of Hong Kong

MCEF21103

Date Submitted: 21/4/2025

Executive Summary

Project Overview

Mangrove ecosystems are vital coastal habitats that deliver essential ecological services, including shoreline stabilization, carbon sequestration, and nutrient cycling. Central to these functions is the mangrove sediment microbiome, a complex community of microorganisms highly sensitive to environmental stressors such as heavy metals and antibiotics. In Hong Kong, mangroves are particularly vulnerable due to their location at the Pearl River Estuary, where upstream discharge carries both heavy metals and antibiotics, posing risks to the sediment microbiome and, consequently, ecosystem health.

This funded project aimed to elucidate the impacts of heavy metal and antibiotic pollution on the mangrove sediment microbiome in Hong Kong. By integrating fieldwork, laboratory analyses, metagenomics, and stakeholder engagement, the project sought to enhance scientific understanding and raise awareness of the critical role played by sediment microbiomes in coastal ecosystem resilience.

Project Activities and Achievements

The project was implemented through a series of structured activities:

- **Staff Recruitment and Training:** Research assistants were recruited and trained to support field sampling, laboratory analyses, and data management.
- **Field Sampling:** Systematic sampling was conducted at five mangrove sites (Tai O, Shui Hau, Pak Lai, Tung Chung, and Yan O) across wet (June–August 2023) and dry (November 2023–February 2024) seasons. Surface and core sediment samples were collected to assess both horizontal and vertical pollutant distributions.
- **Laboratory Analyses:** Sediment samples underwent comprehensive testing for physicochemical properties, heavy metals (As, Cd, Cr, Cu, Pb, Zn), and antibiotics (20 compounds across tetracyclines, quinolones, macrolides, and sulfonamides). DNA extraction and metagenomic sequencing were performed to profile microbial communities.
- **Knowledge Dissemination:** Three seminars were held for students and stakeholders, and results were presented at two international conferences. Educational materials were developed for integration into university curricula.

Key Findings

1. Sediment Nutrients and Pollution Patterns

- Sites near dense human settlement and tourism (Tai O and Tung Chung) exhibited elevated levels of total organic matter, nitrogen, and phosphorus, reflecting anthropogenic influence—particularly from unregulated sewage and runoff.
- Nitrate levels showed marked seasonal variation, likely driven by rainfall and associated runoff patterns.

2. Heavy Metal Distribution

- Surface sediment layers at human-impacted sites showed elevated Zn, Cu, and Pb, with concentrations declining at greater depths—indicative of ongoing maritime and urban pollution (notably from antifouling paints on vessels).

- As (arsenic) was detected at higher concentrations in deeper sediments at Tai O, likely due to historical use of arsenic-based wood preservatives.
- All measured heavy metals were below probable effect levels (PEL), indicating low immediate ecological risk, though some surface concentrations exceeded threshold effect levels (TEL), warranting continued monitoring.

3. Antibiotic Contamination

- Six out of twenty antibiotics were detected, with tetracycline and oxytetracycline most prevalent. Notably high oxytetracycline levels in Pak Lai were linked to adjacent aquaculture activities.
- Antibiotic concentrations varied significantly across sites and seasons, with wet season samples showing higher tetracycline levels and dry season samples dominated by oxytetracycline, highlighting the influence of both local activities and seasonal runoff.

4. Microbial Community Dynamics and Functional Diversity

- Metagenomic analysis revealed that over 98% of classified reads belonged to prokaryotes, with dominant taxa including Pseudomonadota, Actinomycetota, and Cyanobacteriota.
- Microbial diversity and composition varied distinctly by site, season, and local pollution levels. Sites with higher nitrogen content (Tai O, Tung Chung) supported greater abundance of microorganisms involved in the nitrogen cycle (e.g., Nitrospinia, Nitrososphaeria).
- Heatmaps showed that less polluted sites (e.g., Shui Hau) harbored unique microbial communities compared to more impacted sites, indicating that pollution gradients shape microbiome structure and function.
- Functional gene analysis of nitrogen cycling (including nitrogen fixation, ammonification, denitrification, nitrification, anammox, and assimilation) revealed notable differences among sites. Tai O exhibited the highest activity in denitrification, nitrogen fixation, and assimilation processes, likely driven by high organic matter and nitrate availability, while other sites showed minimal or stable activity. This suggests that environmental conditions and pollutant levels not only shift community composition but also significantly influence key ecosystem functions such as nitrogen cycling.

5. Stakeholder Engagement and Impact

- Seminars and sharing sessions reached students, government agencies, NGOs, and the public, fostering awareness of mangrove sediment microbiome functions and pollution risks.
- Preliminary findings have informed curriculum enhancements at HKMU and contributed to discussions on policy and management strategies for mangrove conservation.

Conclusions and Recommendations

The project successfully advanced understanding of how heavy metals and antibiotics affect mangrove sediment microbiomes in Hong Kong. Key conclusions include:

- **Pollution hotspots** are associated with human activities, with both heavy metals and antibiotics present at levels that, while generally below acute toxicity thresholds, indicate chronic pollution and potential long-term impacts on ecosystem function.
- **Microbial communities** are sensitive bioindicators, with shifts in composition and nitrogen cycling functions reflecting both pollution levels and nutrient availability.
- **Integrated monitoring** and targeted management are essential to safeguard mangrove ecosystem functions, particularly in the face of ongoing coastal development and aquaculture expansion.

Recommendations:

- Establish regular monitoring of both chemical pollutants and microbiome health in mangroves.
- Strengthen regulations and best practices to reduce pollutant inputs from maritime, urban, and aquaculture sources.
- Expand educational outreach to raise public and stakeholder awareness of the importance of sediment microbiomes in ecosystem services and coastal resilience.