NUS National University of Singapore | NUS Environmental Research Institute

Climate & Water Quality

What, Who, When, Where and How?

RESEARCH AT NERI

PG. 2

ENGINEERING NATURE FOR ON-SITE SURFACE RUNOFF MANAGEMENT

PG. 3

CONTROLLING THE "BLOOM" IN RESERVOIRS

PG. 5

CLIMATE RESILIENCE APPROACH TO TAPPING SEAWATER

CLIMATE & WATER QUALITY

The distribution of water on Earth has been well documented over centuries. Freshwater only makes up to 2.5% of the total water, whereby the bulk is in the form of glaciers and ice caps, while the remaining is saline water (USGS, 1993). Climate change has led to increasing glacier melting, sea level rise, and intense and more frequent storm and drought events. This is changing the accessibility to fresh water in terms of quantity and quality which would impact water security and quality of life.

In preparedness for climate change effects on water, NUS Environmental Research Institute (NERI) has embarked on research to address "***What, Who, When, Where & How***" to manage water quality sustainably.

Below are the selected highlights of this research at NERI.

ENGINEERING NATURE FOR ON-SITE SURFACE RUNOFF MANAGEMENT

A pilot bioretention system using engineered soil developed by NERI research team

Urbanization and climate effect increases the pollutants in the surface runoff during storm events. Novel Bioretention systems comprised of selected vegetation and engineered soil mixes are designed with green features that help to slow down and cleanse the runoff before it enters nearby reservoirs or lakes.

Guo et al. 2015, "Soil column studies on the performance evaluation of engineered soil mixes for bioretention systems". Desalination And Water Treatment 54(13): 3661-3667. [Abstract]

Li et al. 2022, "Field study of the road stormwater runoff bioretention system with combined soil filter media and soil moisture conservation ropes in North China". Water, 14, 3, 10.3390/w14030415 [Abstract]

“SUSTAINABLE MANAGEMENT OF SURFACE RUNOFF COUNTS ON EFFICIENT POLLUTANT REMOVAL, IN WHICH NOVEL GREEN FEATURES PLAY A KEY ROLE.”

PROF HU JIANGYONG

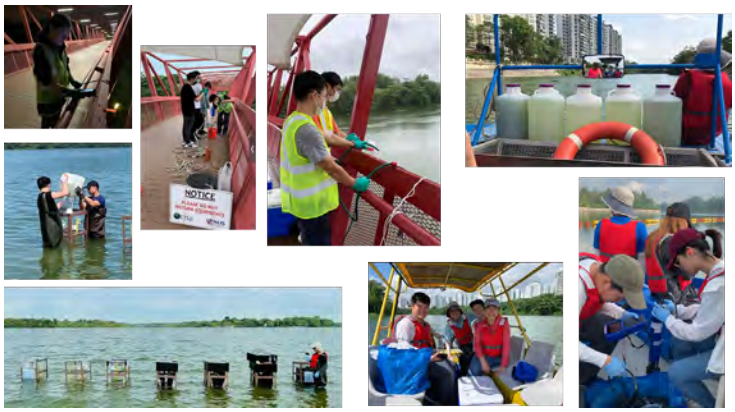
At NERI, researchers have formulated engineered soil mixes of novel Bioretention system development using locally available materials and selected plant species for tropical climate conditions. The local materials in the soil mix comprised different percentages of compost, coconut fibre, and water treatment residues (WTR) homogenously mixed with sand were shown to satisfy the pollutant removal objectives stipulated by Singapore’s Active Beautiful Clean Waters (ABC Waters) programme (PUB, 2018 “Engineering Procedures for ABC Waters Design Features, 2018 ed”). The bioretention systems were developed and pilot-tested at the NUS campus and various schools around Singapore. The knowledge and findings from the study were shared through workshops and conferences with various stakeholders for full-scale implementation.

Modification with soil moisture conservation ropes (known as modified Bioretention facility (MBF)) was further made to develop novel Bioretention systems for implementation in dry-cold regions. The development and test-bedding of the MBF were conducted in collaboration with Tsinghua University and North China Municipal Engineering Design & Research Institute Co., Ltd. from China and Ngee Ann Polytechnic, Singapore. MBFs implemented for on-site road runoff treatment in Tianjin Eco-city, China successfully demonstrated the adaptation of novel Bioretention systems for sustainable stormwater management in other urban regions.

CONTROLLING *the "BLOOM"* IN RESERVOIR

Water from local catchments collected in the reservoirs is a major tap water source for Singapore. Change in climatic conditions entails a strong impact on the reservoirs' water quality, besides the challenges in sustaining quantity in the event of a prolonged drought period. Algal bloom in freshwater bodies is a concern in particular to those that serve as the source of potable water supply. Adverse effects of the algal bloom could lead to potential taste and odor issues, and toxin production, a phenomenon known as ***Harmful Algal Bloom (HAB)***.

Understanding ***What*** are the influencing factors, identifying (***Who)*** the algae species that cause adverse water quality issues, predicting ***Where*** and ***When*** the algal bloom may occur and ***How*** to control the HAB incidences (i.e. putting in place the appropriate control measure) would be essential to enhance sustainable water supply.



In-situ experiment and field sampling from tropical freshwater lakes

What *- Environmental Factors Influencing Algal Blooms*

Temperature and light irradiance are key factors influencing the occurrence of algal blooms and major off-flavors generation. NERI researchers are filling the knowledge gap in understanding how these factors are regulating the growth and metabolism of both benthic and planktonic cyanobacteria collected from a freshwater reservoir in Singapore.

Mohanty et al. 2022, "Effects of Light and Temperature on the Metabolic Profiling of Two Habitat-Dependent Bloom-Forming Cyanobacteria". Metabolites, 12(5), 406 [Abstract]

Who *– Algae Species in the Reservoir*

Studies on the prevalence of algal species found in tropical reservoirs and characterizing their effects on the environment would be crucial to understanding and managing potential risks of this freshwater source for the drinking water supply. NERI researchers reported the discovery of novel cyanotoxin-producing *Synechococcus* sp., a type of picocyanobacteria (about the size of 0.8 – 1.5 μm), in the inland tropical freshwater lake during a prolonged bloom in a recent study. This strain was found to have the ability to produce cylindrospermopsin (CYN) and anatoxin-a (ATX) which had never been reported previously by this species. Climate change and urbanization leading to increase temperature and nutrient loads would exacerbate the proliferation of *Synehococcus* HAB. More sensitive monitoring and effective control approaches are needed to enhance preparedness for sustainable water supply.

Gin et al. 2021, "Novel cyanotoxin-producing Synechococcus in tropical lakes" Water Research, 192, 116828 [Abstract]

When, Where & How

- Predict Occurrence and Control

The prior research has generated essential information that are useful to predict the potential bloom and algal toxin (microcystin) production, as well as to formulate the measures to control their harmful effects on human health and environment.

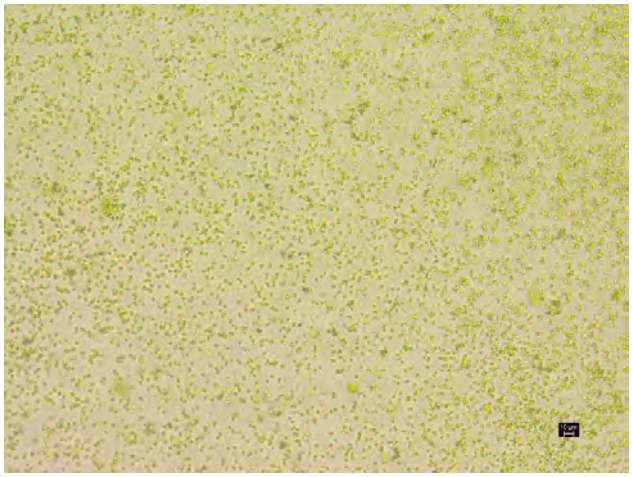
Common local algae species

NERI researchers applied the mechanistic model built on STELLA, a dynamic modelling software, to predict the microcystin production by microcystis in lab cultures and tropical lake. The model was based on constitutive cell quota that varies with nitrogen, phosphorus, and temperature. The model predicted most of the observations with a model efficiency that was >0.72 and >0.45 for the lab and field conditions respectively. Some observed discrepancies in the model were identified in the study.

Sukarji et al. 2022, "Application of a mechanistic model for the prediction of microcystin production by microcystis in lab cultures and tropical lake". Toxins, 14 (2), 103 [Abstract]

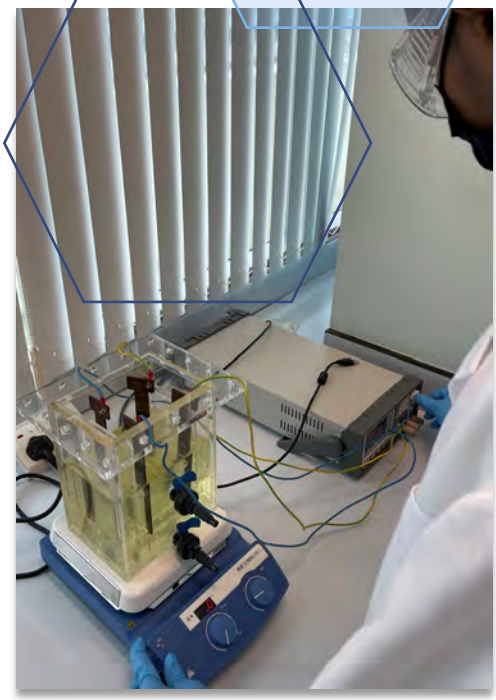
NERI researchers developed a novel approach to remove the blue-green algae of Microcystis aeruginosa using solid oxidants, namely, peroxymonosulfate (PMS) and peroxydisulfate (PDS). These oxidants offer ease of transportation, handling, and applications compared with their liquid counterpart, H_2O_2. The operating conditions and effectiveness of PMS and PDS as compared with H_2O_2 were determined in the study. PMS effectiveness lasted 5 times longer compared with H_2O_2 for treating algae-contaminated natural water. The PMS could degrade microcystin-LR and phycobiliproteins, and the mechanisms leading to cell inactivation were also elucidated in the study. The findings from this research provide useful design and application parameters for the use of PMS as a control of harmful algal bloom (HAB).

Chen et al. 2021, "Microcystis aeruginosa removal by peroxides of hydrogen peroxide peroxymonosulfate and peroxydisulfate without additional activators". Water Research, 201, 117263 [Abstract]



Novel off-flavor-producing cyanobacteria (Microcystis) capable of producing 2-MIB (2-methylisoborneol) isolated from tropical freshwater lake

CLIMATE RESILIENCE APPROACH TO TAPPING SEAWATER



Lab-scale Electrocoagulation System

NERI has embarked on projects to develop low-chemical-energy pre-treatment processes in seawater desalination to overcome potential issues in fluctuations of seawater quality at the intake to the desalination process. Innovations of the projects involved the development of a robust, integrated and cost-effective electrocoagulation (EC) pre-treatment platform, and process optimization of new ceramic ultrafiltration membrane (UF) for seawater desalination.

Pre-treatment using EC offers the potential of better chemical control, more energy efficient, smaller footprints, and less maintenance, while ceramic UF membrane is robust and more fouling resistant leading to reduced cleaning frequency, and hence, higher productivity.

Validation of lab-scale findings is being conducted at pilot systems to determine the long-term feasibility and cost-effectiveness of the process developed from the studies.

For further details: https://nus.edu.sg/neri/sustainable-climate-resilience-seawater-desalination-with-low-chemical-energy-pre-treatment-processes/

Please click here for the full list of NERI publications.

For more details on the following topics, please contact:

Engineering Nature for On-site Surface Water Runoff Treatment

Professor HU Jiangyong
E-mail: ceehujy@nus.edu.sg

Controlling the "Bloom" in Reservoir

Associate Professor Karina GIN Yew-Hoong
E-mail: ceeginyh@nus.edu.sg

Climate Resilience Approach to Tapping Seawater

Assistant Prof BAE Sung Woo
E-mail: ceebsw@nus.edu.sg

Associate Prof Olivier Patrick LEFEBVRE
E-mail: ceelop@nus.edu.sg

For more information on NUS Environmental Research Institute, please visit https://nus.edu.sg/neri/