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# THE INTRODUCTION OF HALOPHYTES AS NATURE-BASED SOLUTIONS IN WASTEWATER TREATMENT FOR THE MALAYSIAN AQUACULTURE INDUSTRY

**Mariam MARIP[1,2], Juris BURLAKOVS[3], Mohamad Nor AZRA[2,4,5]**
[1] *Institute of Climate Adaptation and Marine Biotechnology (ICAMB),*
*Universiti Malaysia Terengganu (UMT)*
Kuala Nerus 21030, Terengganu, Malaysia
[2] *Department of Fisheries (Terengganu)*
Taman Perikanan Chendering, 21080 Kuala Terengganu, Terengganu, Malaysia
[3] *Riga Technical University*
Kipsalas 6A, LV-1048, Riga, Latvia
[4] *Research Center for Marine and Land Bioindustry, Earth Sciences and Maritime Organization,*
*National Research and Innovation Agency (BRIN)*
Lombok 83352, Indonesia
[5] *Jiangsu Key Laboratory of Marine Biotechnology, Jiangsu Ocean University*
No. 59 Cangwu Road, Haizhou District, Lianyungang City, Jiangsu, 222005, China
**e-mail**: mariam_marip@dof.gov.my

**Abstract**

*Aquaculture became very important in the seafood sector in recent times owing to the depletion of the wild stock, and it is recognized as a major contributor to seafood for human consumption. Meanwhile, halophytes, recognized for their extreme resilience to saline environments, have gained prominence as pivotal components in climate adaptation strategies, phytoremediation, and sustainable agriculture. However, the main sustainability issues associated with intense aquaculture, as exemplified by seafood products, are the large amounts of wastewater generated that are discharged with minimal treatment. The aim of the proposed presentation is to establish new innovation to address the above problems, using halophytes within a bespoke production system, the first of its kind in the Malaysian aquaculture industry. The findings from the proposed work will be timely given the increasing consequences of climate change and the drive towards sustainable solutions. It will enable the direct beneficiaries, such as Malaysia to accelerate sustainable aquaculture development and take a leading role in the wider SEA region in developing sustainable solutions for producing an important source of global food security. This will be an exemplary case to be followed elsewhere, globally.*

**Keywords**: *Climate adaptation; Ecophysiology; Food security; Sustainability; SDG-Life below water.*

**Introduction**

Halophytes, as highly salt-tolerant plants, offer a strong potential for tackling soil salinisation and climate adaptation challenges, particularly in salinity-vulnerable areas for agriculture. Halophytes, recognized for their extreme resilience to saline environments, have gained prominence as pivotal components in climate adaptation strategies, phytoremediation, and sustainable agriculture. Emerging applications in sustainable agriculture highlight their potential; *Salicornia europaea*, for example, improves soil nutrients and exhibits antimicrobial and anti-inflammatory properties, making it ideal for saline farming. Halophytes have also demonstrated significant potential in the phytoremediation of saline and contaminated soils, particularly in regions affected by anthropogenic activities that result in heavy metal contamination **[1]**. The introgression of salt tolerance genes from halophytes into glycophytes through breeding or genetic engineering has been proposed as a strategy to develop salt-tolerant crop varieties. The unique adaptations of halophytes to saline conditions make them ideal candidates for use in saline agriculture, particularly in regions where soil salinisation renders conventional crops unviable, and to produce better water quality management in shrimp aquaculture in the future.

Nowadays, numerous technologies available, from simple methods to complicated mechanical system that could be used for aquaculture wastewater treatment from conventional method such as physical, chemical and biological **[2]** to mechanical system such as activated sludge systems, biofiltration systems, oxidation ditches, rotating biodisc systems, and membrane **[3]**. Although, the basis of the consideration is aquaculture wastewater treatment that meets the recommended microbiological and chemical quality guidelines at low cost and minimal maintenance requirements. Specifically, certain halophytes possess antimicrobial properties and can influence rhizosphere microbial communities, thereby reducing the presence of pathogenic microorganisms. Thus, uncertainty the extent of its effectiveness in aquaculture wastewater treatment and retention times adequate to eliminate or reduce the huge amount of effluent and organic load before release to water bodies needs to be evaluated. Other than that, global not only faces the enormous challenge of providing food for a continuously growing population as mention in Blue Revolution, but withstanding the effects of climate change and widespread degradation of natural resources as a main agenda and defined in SDG 14 "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" [**4**] as discussed above. On the basis of these considerations, this study extends the reflection to the aquaculture sector as a whole and argues that policy coherence and benefit sharing should become key considerations in the planning and future development of sustainable and equitable aquaculture. To date, there are scarce data from journal publications on the aquaculture industry, especially regarding environmental impacts due to effluent from aquaculture farms; the regulated environmental acts governing the effluent; best practices adopted in the aquaculture industry; and the currently available treatment technologies for aquaculture effluent **[5]**.

**Objectives**

Addressing these issues is critical through the utilization of halophytes for sustainable food systems, improved aquaculture wastewater treatment, and soil reclamation which directly contribute to global efforts in combating food insecurity, restoring degraded ecosystems, and achieving climate resilience. Figure 1 shows the ability of certain halophytes to hyperaccumulate heavy metals (such as from agricultural activities such as aquaculture and coupled with their inherent salt tolerance, making them ideal candidates for the remediation of polluted soils as well as potential future application.

**Potential impacts of halophytes**

Maximizing Positive Impact: To ensure a lasting positive impact, our engagement plan is tailored to each stakeholder group. Measuring impact will combine quantitative and qualitative methods, including economic assessment, environmental monitoring, policy analysis, and stakeholder feedback. Online platforms, including the project website, will reach a broader audience, ensuring accessibility. Feedback loops will ensure alignment with stakeholder needs, enhancing our positive impact during and beyond the grant's lifetime. Aquaculture industry practitioners: Workshops, field demonstrations, and participatory research activities to showcase sustainable practices and technologies, disseminate research findings, and gather stakeholder feedback. Pre- and post-engagement surveys will assess changes in knowledge, attitudes, and practices among shrimp farmers and related stakeholders. Impact measures: Surveys to assess changes in practices, productivity, and environmental impact. Local communities and the aquaculture value chain: Engagement: Community meetings, educational programs, and involvement in research activities to ensure inclusive benefits and knowledge sharing. Impact measures: Livelihood assessments to gauge economic and social impacts, with a focus on improved living conditions and adaptation to climate change. Policymakers and regulatory bodies: Engagement: Policy briefs, roundtable discussions, and collaborative forums to share research findings and recommendations for sustainable aquaculture policies. Impact measures: Policy adoption rates and changes in regulatory frameworks as indicators of engagement effectiveness. Research communities: Engagement: Academic publications, conferences, and joint research initiatives to disseminate findings and foster collaborative research. Impact measures: Citation analysis and collaborative project counts to measure research influence and partnerships. Environmental impacts statement: Expected positive impacts: Reduced nutrient runoff: By absorbing excess nutrients, halophytes decrease risk of eutrophication or algal blooms in nearby water, promoting healthier aquatic ecosystems.

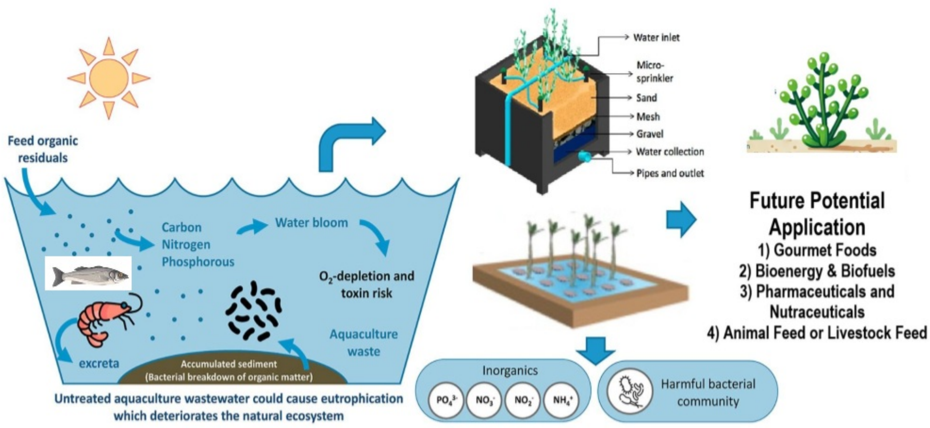


***Fig. 1.*** *Example of hyperaccumulation capacity of halophytes for heavy metals in fish or shellfish's aquaculture ponds and the future potential and application of halophytes Modification from Castagna et al. [6]*

Enhanced carbon sequestration: Halophytes can contribute to carbon sequestration, aiding climate change mitigation. Biodiversity enhancement: Halophytes can contribute to biodiversity conservation within aquaculture systems, offering habitats and resources for other potential aquatic species. Resource use: The project will ensure efficient use of water and land resources to prevent overexploitation, employing sustainable aquaculture practices in harmony with local environmental capacities. Mitigation of potential negative impacts: Habitat disturbance: Halophyte introduction could potentially disturb local flora and fauna. Native species will be selected (such as sea purslane and moras-bhaji) or those shown to integrate well with local ecosystems, minimizing ecological disruption. Expected societal benefits. Local communities in Malaysia & Indonesia: These are dependent on aquaculture for livelihoods, particularly in regions susceptible to disruption due to global change. They may additionally benefit from added-value products emerging from our project as well as environmental improvements brought by halophytes on water quality. Economic benefits. The proposed project targets the integration of halophytes with aquaculture to harness their synergistic potential to improve water quality and benefit farmers economically. Scientific benefits: Environmental and climate change research communities: Academics and researchers focusing on environmental sustainability and climate resilience in aquaculture. Policymakers and regulatory bodies: These key decision-makers influence aquaculture policies, regulations, and support mechanisms and will be an important part of encouraging technology uptake.

This study also supported the National Policy on Climate Change 2.0 (ST3S4KA2: Promote agricultural research and innovations to increase varieties of climate-resilient and disease-resistant food crops, commercial crops, livestock breeds, fish as well as technologies and practices for sustainable farming systems). The study will also collect some water quality data related parameters as in Table 1.

**Table 1.** Methods used for each parameter

| **Aquaculture Wastewater and Water Culture** | | |
|---|---|---|
| **Categories** | **Parameter** | **Methods / Instrument** |
| Physical | pH<br>Dissolved Oxygen<br>Salinity<br>Temperature<br>Total Dissolved Solids (TDS)<br>Conductivity | YSI Pro |
| Chemical | Biochemical Oxygen Demand | BOD5 (APHA, 1999) |
| | Chemical Oxygen Demand (COD) | Method 5220D Closed Reflux Method Colorimetric Method (APHA, 1992) |
| | Nitrogen (Ammonia – NH3) | Direct Nesslerization (ASTM, 2008) |
| | Total Suspended Solids | Photometric method (Krawczyk & Gonglewski, 1959) |
| | Nitrite | Diazotization Method (Federal Register, 1979) |
| | Nitrate | Method 4500-NO3 Cadmium Reduction Method (APHA, 1992) |
| | Total Nitrogen | Method 4500-N Persulfate Method (APHA, 2005) |
| | PO4 (Phosphate) | Method 4500-P Ascorbic Acid Method (APHA, 2005) |
| | Chlorine residue | APHA (Standard Methods for the Examination of Water and Wastewater, 23rd ed.) |
| | Oil & Grease | APHA (Standard Methods for the Examination of Water and Wastewater, 23rd ed.) |
| Bacteriology parameter | *Vibrio alginolyticus*<br>*Vibrio vulnificus*<br>*Vibrio parahaemolyticus* | |

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# ГАЛОФІТИ В ОЧИЩЕННІ СТІЧНИХ ВОД У АКВАКУЛЬТУРНІЙ ПРОМИСЛОВОСТІ: МАЛАЙЗІЙСЬКИЙ ПРИКЛАД ПРИРОДООРІЄНТОВАНИХ РІШЕНЬ

**Маріам МАРІП**
*Інститут адаптації до клімату та морської біотехнології (ICAMB), Університет Малайзії*
Kuala Nerus 21030, Terengganu, Малайзія
https://orcid.org/0009-0000-3662-0285

**Юріс БУРЛАКОВС**
*Ризький технічний університет*
Kipsalas 6A, LV-1048, Riga, Латвія
https://orcid.org/0000-0003-2607-6997

**Мохамад Нор АЗРА**
*Університет Малайзії Теренґгану*
Taman Perikanan Chendering,
21080 Kuala Terengganu, Terengganu, Malaysia
*National Research and Innovation Agency*
Lombok 83352, Indonesia
*Jiangsu Ocean University*
No. 59 Cangwu Road, Haizhou District,
Lianyungang City, Jiangsu, 222005, China
https://orcid.org/0000-0001-9333-9270

**Анотація**

Аквакультура останнім часом набула великого значення в секторі морепродуктів через виснаження природних запасів і визнана основним джерелом морської їжі для споживання людиною. У той же час галофіти, відомі своєю надзвичайною стійкістю до солоних середовищ, набули важливого значення як ключові елементи у стратегіях адаптації до кліматичних змін, фіторемедіації та сталого сільського господарства. Водночас основною проблемою сталості, пов'язаною з інтенсивною аквакультурою (зокрема при виробництві морепродуктів), залишається велика кількість стічних вод, що скидаються з мінімальним очищенням. Мета запропонованої презентації — представити новаторське рішення для подолання цих проблем шляхом використання галофітів у спеціально розробленій виробничій системі, яка є першою у своєму роді в аквакультурній промисловості Малайзії. Результати цієї роботи будуть своєчасними з огляду на посилення наслідків змін клімату та зростаючий попит на сталі рішення. Це дозволить безпосереднім бенефіціарам, зокрема Малайзії, пришвидшити сталий розвиток аквакультури та відігравати провідну роль у регіоні Південно-Східної Азії у впровадженні стійких рішень для виробництва важливого джерела глобальної продовольчої безпеки. Це стане зразковим прикладом для наслідування в інших частинах світу.

**Ключові слова:** адаптація до клімату, екофізіологія, продовольча безпека, сталий розвиток міста, життя під водою.