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REVIEW ARTICLE

The Connections between Mussel Watch for Potentially Toxic Metals and Nexus Seafood-Water-Energy

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ABSTRACT

The previous assessment intends to support the inaugural International Mussel Watch program's use of marine mussels as biomonitors of potentially toxic metals in aquacultural areas has been considered of low novelty even though it is a necessary biomonitoring. When it is looked into the connections between Mussel Watch and Nexus seafood-water-energy, the questions can be raised up because there is apparently no such discussion in the literature. Therefore, the objective of this review is to discuss the connections between Mussel Watch for potentially toxic metals and Nexus seafood-water-energy, based on the topic reported in the literature separately. The current short review can act as a springboard for additional insights to offer fresh perspectives and original suggestions on using marine mussels more effectively in biomonitoring investigations in connections to Nexus seafood-water-energy. Nowadays, the biomonitoring by using Mussel Watch has remained effective and sustainable which further highlighted their importance in pollution monitoring. The likelihood of improved and wider-ranging molluscan uses in environmental monitoring in the future is almost inevitable. However, more research is still needed to address the rising demand in line with sustainable, attainable United Nation Sustainable Development Goals ("Responsible consumption and production", and 'Good Health and Well-beings'). This is surely a major player in the Nexus's seafood in cycle with water and energy that should be addressed in future biomonitoring studies.

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Introduction

The International Mussel Watch has held tenacious efforts to promote using marine mussels as biomonitors of Potentially Toxic Metals (PTMs) [1,2]. Since the beginning of the mussel watch project, which dated back to 1986, numerous studies on biomonitoring are focused on marine molluscs. From the commencement down to the completion, as first proposed by Goldberg ED [2], this mussel monitoring programme should be highly commended and promoted for educational purposes. This is because bivalves are ubiquitous in aquaculture areas, in which the levels of pollution in these areas greatly affect human health. However, with the advancement technologies and more sophisticated pollution monitoring methods, molluscs maybe considered by many as an old and ineffective method [3]. The question of 'What are the connections between Mussel Watch and Nexus seafood-water-energy?' is interesting since there are answers seekers. Therefore, the objective of this review is to discuss the connections between Mussel Watch for potentially toxic metals and Nexus seafood-water-energy.

The Uses of Bivalves as Biomonitors of Metal Bioavailability and Contamination

Since the 1970s, bivalves have been utilised in pollution studies, and this trend is anticipated to continue. According to the review by Yap CK, et al. [3], many comparable studies have been conducted in various countries around the world. Although using bivalves is a traditional biomonitoring approach that was first used in the 1970s, the value of these organisms for spatial distribution and comparability should be improved, and accuracy should be enhanced.

In their previous studies, Yap CK, et al. [3] and Boening DW [4] suggested using sea mussels in biomonitoring assays. Their studies have effectively illustrated the potential of molluscs as sentinels of potentially toxic metal contamination for future research. For instance, Yap CK, et al. [3] stated that by adopting the given criteria for sea mussels, different molluscs species might be established as efficient biomonitors of metal pollution. A review which was based on various literature on the utilization of bivalves' soft tissues for metal pollution studies has been comprehensively done by Yap CK, et al. [3].

The assessment of the body burden of toxic synthetic chemicals, elements, or their metabolites in bioorganic substances is known as biomonitoring in the discipline of analytical chemistry [4]. However, aquatic ecotoxicology's definition of biomonitoring, which is more accurate, is the "regular and systematic use of living organisms to evaluate changes in environmental or water quality that entails repetitive measurements of pollutants/chemicals."

It is believed that the current issues in biomonitoring studies are to improve the precision of the bivalves as biomonitors, whether in coastal or freshwater habitats, before we can evaluate the environmental quality. Several abiotic and biotic factors may impact the metal bioaccumulation findings in bivalves. For instance, the biotic and abiotic factors may only change the data of metal accumulation in the soft tissues of bivalves [5].

The majority of ecotoxicologists would agree that the use of bivalves for biomonitoring purposes is unique. However, as indicated in the Mussel Watch Program [2], bivalves have been highly employed and regarded as good biomonitors of four major pollutants, such as halogenated hydrocarbons, transuranics, heavy metals, and petroleum. This is because mussels possess several crucial traits for a reliable biomonitor [6,7] of coastal pollution. Bivalves can pose a risk to human health because they are extensively found in global coastal waters, are sedentary, tend to bioaccumulate high levels of pollutants but do not seem to be affected by these pollutants, and are famous seafood in certain areas of the world. Numerous investigations have been conducted on *Perna viridis*, particularly in the coastal areas of Asia-Pacific [8,9]. Therefore, although having traditional origins and concepts, the biomonitoring study employing mussels is a futuristic study with influence in many parts of the world.

Connections between Mussel Watch and Nexus Seafood-Water-Energy

When it is looked at the cycle of food-water-energy as dipicted in figure 1, three interpretations can be made. First, the Mussel Watch can act as a proxy to complement the Nexus seafood-water-energy. The good quality seafood product with unpolluted raw seafood materials from the coastal environment is sustainable through well-managed coastal aquacultural farmed mussels. Second, the Nexus seafood-water-energy is acting as an important proxy for United Nation's Sustainable Development Goals on a) 'Responsible consumption

and production', b) 'Good health and well-being', c) 'Zero hunger', and d) 'No poverty'. The a) and b) being the most relevant and almost directly connected to. Third, the sustainable coastal resources is a challenge. The well-balanced coastal ecosystem that should be protected, conserved, and upgraded in its environmental quality. It is believed that Mussel Watch could play an important policing job to monitor the coastal ecosystem quality before it is too late for recovery and its resilience is superceded with carrying capacity overloaded.

Worldwide, the public concerns over resource security have been increasing throughout the years [10]. By taking the mussel aquaculture in the Straits of Johore (SOJ) as an example. Continuous ecological-health risks of PTMs' to human health in the aquaculture-farmed mussels in the SOJ is necessary for mitigation strategies to lessen the severity of the depletion and its environmental implications. This is where the Nexus seafood-water-energy is connected to.

The Mussel Watch which is concentrated on the safety of mussels could be a key solution in the supply chain for sustainable and high-quality seafood products. It also considered biomonitoring and health risk assessments *via* assessments in terms of safety guidelines, target hazard quotient of PTMs, and comparison to provisional tolerable weekly intake of PTMs, of the mussel resources along the chain (Figure 1). This knowledge can help the mussel seafood industry supply chain attain sustainability *via* cogent policymaking and management with the concept of Nexus food-energy-water [10-13].

The main type of aquaculture products in the coastal water could face pollution problem. The risk assessment approach suggested by Bai X, et al. [14] should be expanded for aquaculture applications. The high bioaccumulation of contaminants in marine aquacultural mussels in the SOJ is caused by the presence of PTMs [15] and other organic and inorganic contaminants in the coastal areas [15-19]. These pollutants can all bioaccumulate in mussel tissues and enter the food chains. The Food Safety Objective approach is consistent with the core principles of process validation, according to Keener [20].

Conclusion

The International Mussel Watch program's utilization of marine mussels as biomonitors for hazardous metals in aquaculture areas is a valuable and efficient way to monitor pollution. The current research further emphasizes the success and sustainability of using molluscs for biomonitoring. Despite this, there is still a need for further research to meet the increasing demand for sustainable and achievable environmental monitoring goals. The current short review can serve as a jumping off point for further insights to provide novel views and innovative recommendations on how to use marine mussels more successfully in biomonitoring studies related to the Nexus seafood-water-energy. The fact that Mussel Watch biomonitoring

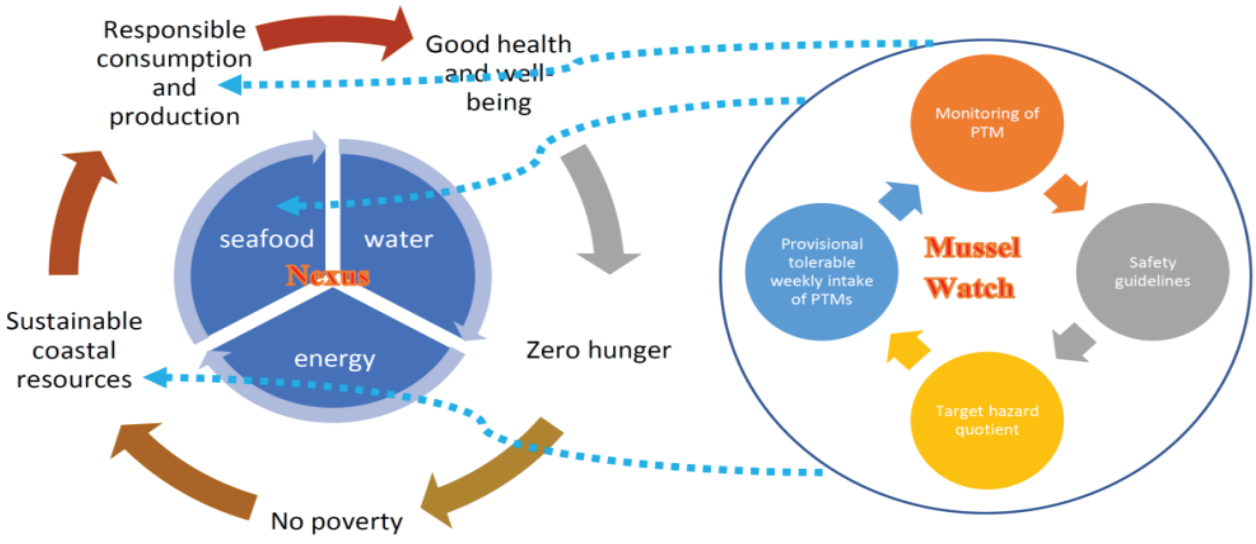

Figure 1 Overall concept of connections between Mussel Watch and Nexus seafood-water-energy.

is still effective and sustainable today emphasises its significance in monitoring pollution. Future molluscan environmental monitoring applications are probably certainly going to get better and more widespread. To satisfy the growing demand in line with the sustainable, achievable United Nations Sustainable Development Goals ('Responsible consumption and production', and 'Good Health and Well-beings'), additional research is still required. Future biomonitoring studies ought to take this important role in the seafood cycle in the Nexus, along with its interactions with energy and water, into consideration.

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