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Review Article

Selected Organs of Marine Mussels as Accurate Biomonitors of Metal Bioavailability and Contamination in the Coastal Waters: Challenges

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Abstract

The use of selected organ such as crystalline style, gills and byssus of marine mussels can be more accurately reflective of bioavailability and contamination of heavy metals in the contaminated coastal waters. However, there are challenges in using the selected organs. First, more time is needed to separate the organs of mussels when Mussel Watch is employed for biomonitoring of chemical pollutants in the coastal waters. Second, from human health point of view, total soft tissues of mussels are preferred in the consumption rather than selected organs. Third, currently, there are still uncertainties of added decrease the non-carcinogenic risk of metal exposure after the highly metal accumulated organs/parts are discarded, which is safer for the human consumption.

Keywords: *Mussel Watch; Selected Organs; Coastal Waters*

Introduction

It is nothing new when a mussel is used for the biomonitoring of chemical pollutants in the aquatic ecosystem. It is also of less novelty when selected organ/part of mussel is being used for the biomonitoring purpose of a particular chemical (e.g. heavy metal). However, the endeavors should be continued to find out a better way to increase the accuracy of the biomonitoring data by using Mussel Watch Concept (MWC).

When MWC was firstly proposed by Goldberg [1], total soft tissues (TST) were used for the monitoring of four major collective pollutants in the coastal waters, namely trace metals, artificial radioactives, petroleum hydrocarbons, and chlorinated hydrocarbons. Recently, Farrington., *et al*. [2] chronicled the extensive influence over the past forty years of Professor Edward D. Goldberg and his call in 1975 for a "Mussel Watch" or bivalve sentinel organism approach to assess geographic status and temporal trends of several chemicals of environmental concern in the coastal ocean. Examples of local, regional, national and international programs are discussed briefly as are examples of interesting useful findings and limitations to the MWC (Table 1). Monitoring bioavailable contaminants and determining baseline conditions in aquatic environments has become important aspects of ecology and ecotoxicology. Mussel Watch continues to provide useful data about status and trends of chemical contamination in coastal ecosystems. One the latest studies on MWC was reported by Ruiz., *et al*. [3] on ribbed mussel *Aulacomya atra*.

Table 1: *Limitations to the Mussel Watch concept [2].*

No.	Limitations
1	Not all chemicals of environmental concern are best addressed by the MWC because those chemicals have appreciable solubility in seawater and/or are not bioconcentrated to a large extent by bivalves.
2	Differences between species in bioconcentration of many analytes are not well documented at present and constrain larger scale geographic data comparisons in some geographic regions.
3	Chemical measurements in bivalves or biological effects measurements at the bivalve organismal level cannot be easily extrapolated, if at all, to the health of entire ecosystems.
4	Extrapolations from body burdens of chemicals in bivalves to human health risks associated with seafood consumption from the locations sampled must be done with great care. Bivalve body burdens cannot be extrapolated to other organisms in the location.
5	Bivalves are not always found in locations where measurements are required, and, if found, stable populations are needed.
6	The relationship between concentrations of chemicals in water and chemicals in bivalves can be influenced by several factors.

Previously, Farrington., *et al.* [4] presented one of the best comprehensive monitoring data on trace metals, DDE, polychlorinated biphenyls (PCBs), aromatic hydrocarbons, and artificial radionuclide ($^{239, 240}$Pu), in two marine mussel species (*Mytilus edulis,* and *M. californianus*) and one marine oyster species (*Crassostrea* sp.), under the U.S. Mussel Watch program in 1976 - 1978 from 62 locations on the U.S. east and west coasts. They used TST of the bivalves in their biomonitoring studies.

According to a review by Schöne and Krause [5], the US NOAA comprehensive study of coastal pollutants also used TST of marine mussels for the MWC. Since the mid-1970s and the initiation of the Mussel Watch program, this has been successfully accomplished with bivalves. These sedentary organisms reliably and proportionately record changes of a range of organic and inorganic pollutants occurring in the water, food or sediment [5].

Limitations to the 'Mussel Watch' concept

Briefly, there are six identified limitations (LM)s to the MWC, that have been deliberately reviewed by Farrington., *et al*. [2], as cited in table 1.

For LM no. 1, it is acceptable that the marine mussels can reliably monitor the heavy metals, PAH, and PCB considerable confidence. These common chemical pollutants have been released into the marine ecosystem in the past, in the present days and are expectedly to gain public concerns in the future. Therefore, this LM should not be regarded as a major problem in the use of MWC because 'Nothing is perfect', and the benefits gaining from MWC will reach a wider public health well-being with a cost-effective budget outweigh this single LM.

For LM no. 2, it is not valid to compare the chemical pollutant levels of different mussel species even though they are concurrently collected from the same sampling sites. From genetic differentiation point of view, different species possess different strategies of chemical sequestration and regulations. If two species are compared, the validity is low [6,7]. The genetic differentiation that occurs because of constant adaptation to the local changes in terms of chemical pollution, is ecologically and evolutionally acceptable. Therefore, LM is not a major problem in the use of MWC unless the supposedly a single mussel species is confirmed as a genetically different species.

For LM no. 3, if we are looking at the overall and holistic understanding of the whole aquatic ecosystem, this LM would discourage of use of MWC at the local scale. Everything should start at home. Researchers from Malaysia will start to monitor a single geographical population in the west coast of Peninsular Malaysia, expanding to monitor the while coast of Peninsular Malaysia. This involved perspective of ecology, ecotoxicology and ecotoxicological genetics [8]. As a biologist, we would be interested to study the factors (the reasons why) that influences the abundance and distribution of an array of plants and animals in the coastal waters. To study one single species of animal will take untold time to set the baseline understanding. To study two species would better improve our understanding on the chemical behaviours induced by humans into the coastal waters. To study many organisms in a coastal water, would be most interesting but involving man power and budget and time. Sometimes, extrapolation of a well-studied species to another new species of the same ecosystem is theoretically valid but low realism could result in wrong interpretation. Therefore, different species should be regarded an interesting unknown knowledge to be investigated with a new funding allocation.

For LM no. 4, it is always true not to compare a mussel with a fish or crustacean. However, the human health risk assessment of a chemical is challenged with the validity of oral reference dose (RfD) for the particular chemical (eg. heavy metals). Currently, the values RfD of Cd, Cu, Ni and Zn for marine mussels are based on those recommended by IRIS (2015). I am not in position to comment on the validity of the RfD values of the metals. However, I question on the validity and health risk of heavy metals to the mussel consumers because the sources of heavy metals to the consumers are many and the actual uptake and assimilation of the metals into the human body is still unsure.

For LM no. 5, as said, this problem can be reduced with transplantation of mussels to the coastal waters with absence of indigenous mussel pollution. If mussels are considered invasive species, the transplantation would be regarded as biologically acceptable or ecologically threatening to the indigenous populations.

For LM no.6, this is always a challenge to make valid spatial and temporal comparison of chemical pollutants of a single mussel species from different broad geographical areas. Biotic (such as reproductive status, nutrition and interactions with predators/preys) and abiotic factors (such as temperature, salinity, interactive effects among chemicals, and particulate matter concentrations in the water column) do influence the uptake, regulation and accumulation of chemicals into the mussel body. However, it is always difficult to collect mussel populations with similar maturity status, exact sizes and from the same salinity seawater levels due to mixture of freshwater in the estuary. This has been a reason why most researchers tend to forget this confounding factors and still comparing the chemical levels in the mussel populations from different locations, countries and regions. From ecotoxicological point of view, it is always welcome to have the baseline information for future comparison. On the other hand, it is acceptable from biologically point of view when all the biotic and abiotic factors must be taken into serious considerations.

Schöne and Krause [5] reviewed that the great majority of studies have measured the concentration of pollutants in soft tissues and, to a much lesser extent, in whole shells or fractions thereof. Both approaches come with several drawbacks. Neither soft tissues nor whole shells can resolve temporal changes of the pollution history, except through the analysis of multiple specimens collected at different times. Soft tissues and shell fractions provide time-averaged data spanning months or years, and whole shells time-averaged data over the entire lifespan of the animal. Even with regular sampling of multiple specimens over long intervals of time, the resulting chronology may not faithfully resolve short-term changes of water quality. Compounding the problem, whole shell averages tend to be non-arithmetic and non-linear, because shell growth rate varies through seasons and lifetime, and different shell layers often vary ultrastructurally and can thus be chemically different from each other.

The use of selected organs for Mussel Watch monitoring

The use of total soft tissues (TST) has been widely reported in the literature [9-13]. The idea of using different parts or a single organ in marine mussels as a better biomonitoring tool of chemical pollutants was best proposed on the selected byssus part of marine mussels namely *Mytilus edulis* from Kyushu Island (Japan) [14,15], *Perna perna* from the Gulf of Aden (Yemen) [16,17] and *Mytella strigata* from Mexico [15] Later, selected part/organ of *Perna viridis* has been proposed on the mussel byssus [11,18], crystalline styles [19-21] gills [22], total shells [23,24] and shell periostracum [8,25] for shell periostracum. Besides, the use of the selected organs/part of marine mussels has been constantly reported since 1999 [15,18-22,26-33].

The main reason why the use of selected organs/part is that there is more accuracy in the biomonitoring of heavy metal bioavailability and contamination in the coastal waters [15]. According to Yap., *et al*. [19-22] the use of different soft tissues of green-lipped mussel *P. viridis* as biomonitors of bioavailability and contamination by Cd, Cu, Fe, Pb, Ni, and Zn in the coastal waters is proposed. This is due to the fact that erroneous results due to spawning and the problem of defecation before dissection could be overcome. It is, therefore, a more accurate interpretation of the bioavailability and contamination by heavy metals in coastal waters could be obtained based on the MWC.

The latest publication on metal in mussels was that reported by Nagarjuna., *et al*. [34] who studied the effects selenium on the enzymatic activities and histopathological changes in *P. viridis*. They revealed that cellular anomalies in the foot tissues of *P. viridis* would influence the byssus thread formation in the green mussel. When it is observed closely, foot of mussel was the selected organ in the above study. Ruiz., *et al*. [3] investigated metal accumulation and oxidative effects in mantle, gill and digestive gland of the ribbed mussel *A. atra* from the Argentinean North Patagonian coastline. Mussels were transplanted over an 18-month period from a site with low anthropogenic impact to a harbour site with higher seawater concentration of Al, Cr, Cu, Mn, Ni and Zn. They found that *A. atra* selectively accumulated metals from the water column and depended on the tissue antioxidant defences and the exposure time. This study clearly used the selected parts, namely mantle, gill and digestive gland of the ribbed mussel *A. atra*, in the study of metal accumulation and oxidative effects.

Based on Scopus database searched on 25 April 2018, with the keyword 'Mussel Watch' to be found in the article title, there is a total of 87 papers indexed in Scopus database from 1975 until 2017. When the keywords were refined with 'metal mussel', it was found that a total of 556 papers indexed in Scopus database from 1973 until 2018. Later, it was narrowed down to 'distribution organ', there are 54 papers published about chemical pollutant levels in the different tissues in the bivalves.

In my opinion, there are three main logical reasons to explain the slow progress, problems and limitations behind the research activities about the use of selected organs/part in Mussel Watch biomonitoring. These are interpreted as future challenges as to be discussed in the following section.

Future Challenges

There are definite challenges in the future in using the selected organs of marine mussels. First, more time is needed to separate the organs of mussels when Mussel Watch is employed for biomonitoring of chemical pollutants in the coastal waters. The use of International Mussel Watch Programe, first recommended by Goldberg [1] was and is still a classic one because the same methodology using the total soft tissues of mussels, is still employed until today based on the papers published indexed in Scopus database as searched on 25 April 2018. Furthermore, if more time is needed, more manpower or research assistants are needed which would involve more research funding eventually. This factor could potentially create unpleasant image to the funding agencies in making their final decision on the grant application on the Mussel Watch title.

Second, from human health point of view, total soft tissues of mussels are preferred in the consumption rather than selected organs. There is hardly any human consumption that is only based on crystalline style, foot or muscle parts of the mussels. Separation of these parts is tedious and time consuming. Furthermore, the different parts of the mussels such as CS, foot and mussels are less of 20% of the total soft tissues. If these parts are to be separated for human consumption, the cost of mussel consumption will be significantly increased with the time and cost of employing workers to separate the parts.

Third, currently, there are still uncertainties of added decrease the non-carcinogenic risk of metal exposure after the highly metal accumulated organs/parts are discarded, which is safer for the human consumption. On the other hand, there are still uncertainties of added nutritional values of these selected parts of mussels. Information of such nutritional values are still lacking in the literature. Perhaps, if there is any of such beneficial value, it might take some time or years to develop such food technology for the selected organs of marine mussels for human consumption.

Conclusion

Nevertheless, all the above challenges can be tackled with available research funding to increase the scope of research activities within this topic. In practice, when a funding has come to an end, the whole research activity could possibly come to a standstill or would never be continued. In conclusion, the benefits of using MWC can outweigh the six reported limitations of using MWC. Future studies are needed to overcome the above three challenges so as to practically use the selected organs/parts of marine mussels to be more effectively and accurately monitor the contamination of bioavailability of chemicals in the coastal waters by using MWC.

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Bibliography

1. Goldberg ED. "The Mussel Watch - A first step in global marine monitoring". *Marine Pollution Bulletin* 6 (1975): 111-114.
2. Farrington JW., *et al*. "Edward D. Goldberg's proposal of "the Mussel Watch": Reflections after 40 years". *Marine Pollution Bulletin* 110.1 (2016): 501-510.
3. Ruiz MD., *et al*. "Trace metals and oxidative status in soft tissues of caged mussels (Aulacomya atra) on the North Patagonian coastline". *Ecotoxicology and Environmental Safety* 155 (2018): 152-161.
4. Farrington JW., *et al*. "U.S. 'Mussel Watch' 1976-1978: An Overview of the Trace-Metal, DDE, PCB, Hydrocarbon, and Artificial Radionuclide Data". *Environmental Science and Technology* 17.8 (1983): 490-496.
5. Schöne BR and Krause RA Jr. "Retrospective environmental biomonitoring - Mussel Watch expanded. Global Planet". *Change* 144 (2016): 228-251.
6. Yap C.K., *et al*. "Genetic variation of green-lipped mussel Perna viridis (Linnaeus) from the west coast of Peninsular Malaysia". *Zoological Studies* 41.4 (2002): 376-387.
7. Yap CK., *et al*. "Heavy metal contamination and physical barrier are main causal agents for the genetic differentiation of Perna viridis populations in Peninsular Malaysia". *Sains Malaysia* 42.11 (2013): 1557-1564.
8. Yap CK and Tan SG. "A study on the potential of the periostracum of Perna viridis as a biomonitoring material for Pb in tropical coastal waters based on correlation analysis". *Sains Malaysia* 40.8 (2011): 809-819.
9. Apeti DA., *et al*. "A historical assessment of coastal contamination in Birch Harbor, Maine based on the analysis of mussels collected in the 1940s and the Mussel Watch Program". *Marine Pollution Bulletin* 60.5 (2010): 732-742.
10. Yap CK., *et al*. "Studies on heavy metal accumulations in green-lipped mussel Perna viridis by using multiple linear stepwise regression analysis". *Pertanika Journal of Tropical Agricultural Science* 11.1 (2003a): 43-55.
11. Yap CK., *et al*. "Background concentrations of Cd, Cu, Pb and Zn in the green-lipped mussel Perna viridis (Linnaeus) from Peninsular Malaysia". *Marine Pollution Bulletin* 46.8 (2003b): 1043-1048.
12. Yap CK., *et al*. "Heavy metal (Cd, Cu, Pb and Zn) concentrations in the green-lipped mussel Perna viridis (Linnaeus) collected from some wild and aquacultural sites in the west coast of Peninsular Malaysia". *Food Chemistry* 84 (2004a): 569-575.

13. Yap CK., *et al*. "Cadmium, copper, lead and zinc levels in the green-lipped mussel Perna viridis (L) from the west coast of Peninsular Malaysia: Safe as food?" *Pertanika Journal of Tropical Agricultural Science* 28.1 (2005a): 41-47.

14. Szefer P., *et al*. "Distribution and association of trace metals in soft tissue and byssus of Mytilus edulis from the east coast of Kyushu Island, Japan". *Archives of Environmental Contamination and Toxicology* 32.2 (1997a): 184-190.

15. Szefer P., *et al*. "Mercury and other trace metals (Ag, Cr, Co, and Ni) in soft tissue and byssus of Mytilus edulis from the east coast of Kyushu Island, Japan". *Science of the Total Environment* 229.3 (1999): 227-234.

16. Szefer P., *et al*. "Distribution and association of trace metals in soft tissue and byssus of mollusc Perna perna from the Gulf of Aden, Yemen". *Environment International* 23.1 (1997b): 53-61.

17. Szefer P., *et al*. "Distribution and association of trace metals in soft tissue and byssus of Mytella strigata and other benthal organisms from Mazatlan harbour, mangrove lagoon of the northwest coast of Mexico". *Environment International* 24.3 (1997b): 359-374.

18. Yap CK and Tan SG. "Iron (Fe) concentrations in the byssus and soft tissues of the green-lipped mussel Perna viridis (L.): Byssus as an excretion route of Fe and Fe bioavailability in the coastal waters". *Indian Journal of Geo-Marine Sciences* 36.3 (2007): 227-234.

19. Yap CK., *et al*. "Crystalline style and tissue redistribution in Perna viridis as indicators of Cu and Pb bioavailabilities and contamination in coastal waters". *Ecotoxicology and Environmental Safety* 63.3 (2006a): 413-423.

20. Yap CK., *et al*. "Crystalline style and byssus of Perna viridis as indicators of Ni bioavailabilities and contamination in coastal waters of Peninsular Malaysia". *Malaysian Applied Biology Journal* 35.1 (2006b): 7-13.

21. Yap CK., *et al*. "Use of different soft tissues of Perna viridis as biomonitors of bioavailability and contamination by heavy metals (Cd, Cu, Fe, Pb, Ni and Zn) in a semi-enclosed intertidal water, the Johore Straits". *Toxicological and Environmental Chemistry* 88.4 (2006c): 683-695.

22. Yap CK., *et al*. "Biomonitoring of ambient concentrations of Cd, Cu, Pb and Zn in the coastal wetland water by using gills of the green-lipped mussel Perna viridis". *Wetland Science* 4.4 (2006d): 247-252.

23. Yap CK., *et al*. "Can the byssus of green-lipped mussel Perna viridis (Linnaeus) from the west coast of Peninsular Malaysia be a biomonitoring organ for Cd, Pb and Zn? Field and laboratory studies". *Environment International* 29.4 (2003c): 521-528.

24. Yap CK., *et al*. "The shell of the green-lipped mussel Perna viridis as a biomonitoring material for Zn: Correlations of shells and geochemical fractions of surface sediments". *Malaysian Applied Biology Journal* 33.1 (2004b): 79-88.

25. Yap CK. "Distribution of Cu and Zn in the shell lipped part periostracum and soft tissues of Perna viridis: The potential of periostracum as a biomonitoring material for Cu". *Pertanika Journal of Tropical Agricultural Science* 35.3 (2012): 413-426.

26. Yap CK., *et al*. "Can the shell of the green-lipped mussel Perna viridis (Linnaeus) from the west coast of Peninsular Malaysia be a potential biomonitoring material for Cd, Pb and Zn?" *Estuarine Coastal and Shelf Science* 57.4 (2003d): 623-630.

27. Yap C.K., *et al*. "Mercury levels in the green-lipped mussel Perna viridis (Linnaeus) from the west coast of Peninsular Malaysia". *Bulletin of Environmental Contamination and Toxicology* 71.3 (2003e): 570-576.

28. Yap CK., *et al*. "Accumulation, depuration and distribution of cadmium and zinc in the green-lipped mussel Perna viridis (Linnaeus) under laboratory conditions". *Hydrobiologia* 498.1-3 (2003f): 151-160.

29. Yap CK., *et al*. "Different soft tissues of the green-lipped mussel Perna viridis (Linnaeus) as biomonitoring agents of copper: Field and laboratory studies". *Malaysian Applied Biology Journal* 32.2 (2003g): 9-18.

30. Yap CK., *et al*. "Assessment of different soft tissues of the green-lipped mussel Perna viridis (Linnaeus) as biomonitoring agents of Pb: Field and laboratory studies". *Water Air and Soil Pollution* 153.1-2 (2004c): 253-268.

31. Yap CK., *et al*. "Tissue distribution of heavy metals (Cd, Cu, Pb and Zn) in the green-lipped mussel Perna viridis from Nenasi and Kuala Pontian, east coast of Peninsular Malaysia". *Pertanika Journal of Tropical Agricultural Science* 28.1 (2005b): 13-22.

32. Yap CK., *et al*. "Determination of heavy metal distributions in the green-lipped mussel Perna viridis as bioindicators of heavy metal contamination in the Johore Straits and Senggarang, Peninsular Malaysia". *Trends in Applied Sciences Research* 2.4 (2007): 284-294.

33. Yap CK., *et al*. "Distribution of heavy metal concentrations (Cd, Cu, Ni, Fe and Zn) in the different soft tissues and shells of wild mussels Perna viridis collected from Bagan Tiang, Perak. Malays". *Applied Biological* 37.2 (2008): 1-10.

34. Nagarjuna A., *et al*. "Effect of selenium on Penaeus monodon and Perna viridis: Enzyme activities and histopathological responses". *Chemosphere* 199 (2018): 340-350.

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