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Impacts of Marine Pollution and Toxicology: A Mussel Watch Experience in Peninsular Malaysia

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Abstract

Based on a well studied green lipped *Perna viridis*, the present review paper exemplified the impacts of marine pollution and toxicology in terms of a) chemicals/pollutant bioaccumulation, b) morphological and physiological responses and c) genetic polymorphism and differentiation. From the review based on Mussel Watch publications, three insights can be found. Firstly, the similar finding for both heavy metals and polycyclic aromatic hydrocarbons (PAHs) studies in the marine mussels was found in which elevated or higher levels (than the normal ranges) of the two types of pollutants in the mussels collected from anthropogenic receiving inputs areas. Secondly, the morphological response (shell deformities) and physiological responses (CI, FR and mortality) of mussels are results of heavy metal pollution in the marine coastal waters. Thirdly, the changes of genetic polymorphic loci in the polluted mussels were resulted from exposure to metal polluted coastal waters. Therefore, our Mussel Watch experience can be employed to understand the effects of marine pollution and toxicology.

Keywords: Marine pollution; Mussel watch; Physiological responses; Morphological response; Genetic polymorphism

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Aquatic Pollution

Water pollution is commonly defined as any changes in physical, chemical or biological parameters in water quality which are potentially harmful to living biota in the aquatic ecosystem. This could change the ecology of living biota of the aquatic ecosystem [1].

Marine pollution has been a hot issue since 1990s around the world. Chua discussed marine pollution prevention and management in the East Asian Seas, concentrating on pollution caused by land and sea based sources [2]. The land based sources included destruction of coastal habitats, urban effluents discharge and coastal sand mining has resulted in serious coastline erosion. Sea based sources included oil and chemical spills from ships, increased vessel traffic and port activities without adequate oil spill response system.

In Peninsular Malaysia (PM), marine pollution has been a research interest based on many reported studies in the literature. For example, pollution by heavy metals and polycyclic aromatic hydrocarbons (PAHs) in the coastal waters of PM has been documented [3-9].

Toxicology

Toxicology can be simply explained by the study of toxicity of environmental chemicals or pollutants. Rand and Petrocelli provided a comprehensive review of the fundamental aspects of aquatic toxicology [10]. Toxicity can be expressed in many ways. For instance, the nonessential Cd that is assimilated by marine mussels can be bioaccumulated in their different soft tissues especially in the crystalline style, interfering with essential Cu and Zn absorption and tissue development. The detoxified stored metals in metallothioneins may be released to the reproduction or formation of gonadal tissues during maturity or weight loss during spawning and the metals may be bioconcentrated or biomagnified to elevated levels through food chain transfer

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system. Toxic stress may influence growth and duration of development and may cause an increase of malformations and mortality [11].

The accumulation of non-essential element such as Cd in the human body may cause skeletal damage, kidney dysfunction, reproductive deficiencies and finally cancer, while Pb could cause a lot of adverse health effects including nephrotoxicity and neurotoxicity [12, 13].

Essential elements such as Ni, Cu and Zn are biologically important in the nutrition of humans [14]. However, there overdose is not. For example Ni is a carcinogenic metal and overexposure to it can trigger an array of pulmonary adverse human health effects, such as fibrosis, lung inflammation, emphysema and tumors in animals [15]. For Cu, the very elevated levels of Cu intake via the marine seafood consumption can initiate undesirable health troubles such as kidney and liver damage [16]. For Zn, high levels of dietary Zn intake can cause severe health implications, such as disturbances of protein metabolism and arteriosclerosis, pancreatic damage and poisoning, acute stomach pains, nausea, diarrhea and fever [17].

For PAHs, they can potentially cause serious major human health concerns once in the body [18]. The most serious toxic effect related to exposure to PAHs in humans is cancer. PAH exposure in animals is related with such toxic effects as immune system suppression, reproductive toxicity, liver toxicity and cardiovascular toxicity [19].

According to a review by Graff et al., bioavailability is one of the main factors governing the toxicity of chemicals to living species [20]. Bioavailability depends on the inherent properties of the chemical, such as its solubility in water, lipophilicity and molecular weight, as well as the physicochemical characteristics of the surrounding environment. According to Jonnalagadda and Prasada Rao, Cd salts such as sulphides, carbonates or oxides are practically insoluble in water. However, these can be converted to water soluble salts in nature under the influence of oxygen and acids. Chronic exposure to Cd is associated with renal toxicity in humans once a critical body burden is reached [21]. According to Rittschof and McClellan-Green, the prediction of the environmental impact of sublethal concentrations of chemical compounds or their mixtures is a major research challenge in environmental toxicology [22].

To understand aquatic pollution and toxicology, our experience on Mussel Watch study in PM can be used to exemplify the two specific terminologies. Therefore, the objective of this paper is to review the impacts of aquatic pollution and toxicity in terms of a) chemical bioaccumulation, b) morphological and physiological responses and c) genetic polymorphism and differentiation in the well studied green lipped mussel *Perna viridis*, which is under the umbrella of Mussel Watch program **(Figure 1)**.

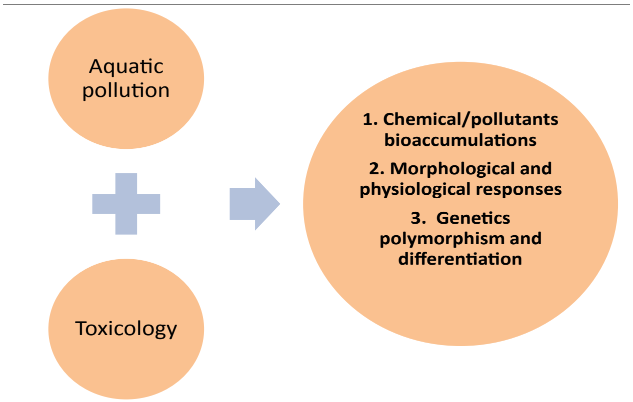

Figure 1 A diagram showing the additive effects as a result of aquatic pollution plus toxicology of the bioaccumulated chemicals/pollutants.

Chemical/Pollutants Bioaccumulations

Yap et al. indicated that heavy metal contamination in the coastal waters off PM (mainly the west coast) is not a serious threat [3]. The results of heavy metals recorded in *P. viridis* collected from 20 sites off PM served as background concentrations for future reference [4]. Since they are widely distributed in the west coast of PM, Yap et al. reported that the ranges of Hg in *P. viridis* from the west coast of PM was comparable to reported unpolluted studies in the literature. However, higher level of Hg was found at some sites supposedly to have received anthropogenic inputs besides natural origins.

Shahbazi et al. reported the distributions of PAHs in the different soft tissues of *P. viridis*, collected from eight geographic locations along the coastal waters of PM [9]. They found that mussels collected from the eastern part of the Johore Straits had higher bioavailability of and contamination by PAHs than from other areas. Higher levels of PAHs and heavy metals contamination in the eastern part of the cause way had been reported by several studies [5-7].

Overall, the similar finding for both heavy metals and PAHs studies in the marine mussels was found in which elevated or higher levels of the two types of pollutants in the mussels collected from anthropogenic receiving inputs areas including land based sources such as constructions, agricultural wastes or pesticides, industrial and domestics and sea based sources such as shipping, ports, boating, etc.

Morphological and Physiological Responses

Shell deformities in marine mussels had been found to be a morphological response to heavy metal pollution. Yap et al. reported the morphological shell deformities in *P. viridis* of 15 locations collected from PM [23]. The known unpolluted sites were found to record none cases of shell deformities while high frequency of shell deformities recorded in some sites could be attributable to contamination of heavy metals, hydrocarbons and tributyltins besides other unidentified pollutants and environmental factors. In short, the effect of heavy metal pollution was believed to cause the shell deformities in the mussels.

Changes in condition index (CI) of marine mussels had been proposed as an indicator of physiological response to heavy metal pollution. Yap et al. reported the relationships between CI and accumulated concentrations of Cd and Pb in the field samples of *P. viridis* and those under experimental conditions [24]. From the findings of both field and laboratory experimental samples, they confirmed that CI can be used to show that *P. viridis* was a sensitive organism to Cd and Pb. Although the CI results could also be due to variation in nutritional state and reproductive status of the mussels, the influences caused by the above two parameters would be masked by the ecotoxicological effects of heavy metal contamination, provided that mussels with similar size range were selected for the CI determination.

Later, Yap and Al-Barwani compared some allometric parameters (shell length, shell width, shell height, total dry weight of soft tissues, CI and heavy metals (Cd, Cu, Pb and Zn) in the different soft tissues of *P. viridis* collected from Sebatu and Muar estuary [25]. It was found that the total dry weight of soft tissues and CI of mussels collected from Sebatu were significantly ($p<0.05$) higher than those in Muar, correlating with the finding that a higher contamination and bioavailability of Cu and Cd at Muar than Sebatu. These results of field collected mussels again confirmed CI can be used to show that *P. viridis* is a sensitive organism to Cd, besides Pb and Cu [24].

By using filtration rate (FR) as a physiological response, Yap et al. reported the toxicity tests of the effects of Cd, Cu, Pb and Zn to *P. viridis* [26]. The results suggested that the mussels were most sensitive to Cu, followed by Cd, Zn and Pb. Therefore, the FR of *P. viridis* can be used as a quick and simple physiological index/response for the relative sensitivity of the mussels to the four metals. Later, by using mortality as physiological response to metal toxicity, Yap et al. investigated 24 h LC_{50} of these Cd, Cu, Pb and Zn in the mussel. They found that mussel was most sensitive to Cu, followed by Cd, Zn and Pb [27].

Besides the marine mussels, Yap et al. reported the studies on toxicities and tolerances of Cu in the blood cockle *Anadara granosa* by 48 h toxicity testing using endpoint mortality [28]. They found that CI reductions were positively related to increasing levels of Cu exposure. Therefore, similar to mussel study, this laboratory study suggested the potential of CI of *A. granosa* as a physiological indicator of Cu pollution.

Overall, the morphological response (shell deformities) and physiological responses (CI, FR and mortality) of mussels were results of heavy metal pollution in the marine coastal waters.

Genetics Polymorphisms and Differentiation

As a result of marine pollution, there is possibility of genetic changes in terms of genetic polymorphisms and differentiations in the marine mussels. Without knowledge of the genetic structure of the mussel populations, the biomonitor species is chosen solely based on its morphological characters which could be confusing. Therefore, biochemical and molecular studies are needed to validate the genetic similarity of the chosen biomonitor [29].

Yap et al. reviewed all the studies done on genetics and heavy metal ecotoxicology focussing on the green lipped mussel *P. viridis* from PM [30]. Based on the findings reported in 10 publications on the above topics, the genetic differentiation in *P. viridis* populations could be explained as being due to geographical factors, physical barriers and heavy metal contamination. All the studies were done using allozymes and DNA microsatellite markers. The results based on both the biochemical and the molecular markers were comparable and almost similar in their genetic distances and FST values. The genetic distances indicated that the mussel populations from PM were conspecific populations. While the FST values showed a moderate genetic differentiation. The results well supported the use of *P. viridis* as a good biomonitor in the coastal waters of PM since the various geographical populations in the region belong to the same species.

From another point of view, Yap et al. based on hierarchical F-statistics and cluster analysis, the physical barrier that blocked the gene flow (through the pelagic larvae swimmers) of *P. viridis*, and a distinct heavy metal contamination in a polluted population were identified as being the two main causal agents for the genetic differentiation of *P. viridis* populations, indicating that environmentally induced selection had happened [8]. All these conclusions could only be drawn when both the genetic and the ecotoxicological information were put together.

Overall, changes of genetic polymorphic loci in the polluted mussels were resulted from exposure to polluted environments due to local adaptations by the marine mussels.

Conclusion

To conclude, the implications of aquatic pollution by heavy metals in the marine mussels can be found in the a) bioaccumulation of the pollutants that were higher than the normal ranges, b) morphological and physiological changes when compared to the unstressed or unpolluted mussels and c) higher genetic polymorphism and differentiations in the polluted mussels. Therefore, our Mussel Watch experience can be employed to understand the effects of aquatic pollution and toxicology, which can shed more insights of understandings about our aquatic environment that become our natural resources supply.

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References

1 Laws EA (2000) Aquatic pollution: An introductory text. John Wiley and Sons, New York, p: 430.

2 Chua TE (1999) Marine pollution prevention and management in the East Asian Seas: A paradigm shift in concept, approach and methodology. Mar Poll Bull 39: 80-88.

3 Yap CK, Ismail A, Tan SG (2003a) Background concentrations of Cd, Cu, Pb and Zn in the green-lipped mussel *Perna viridis* (Linnaeus) from Peninsular Malaysia. Mar Poll Bull 46: 1043-1048.

4 Yap CK, Ismail A, Tan SG (2003b) Mercury levels in the green-lipped mussel *Perna viridis* (Linnaeus) from the west coast of Peninsular Malaysia. Bull Environ Contam Toxicol 71: 570-576.

5 Yap CK, Ismail A, Edward FB, Tan SG, Siraj SS (2006) 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 semi-enclosed intertidal water, The Johore Straits. Toxicol Environ Chem 88: 683-695.

6 Yap CK, Shahbazi A, Zakaria MP (2012a) Concentrations of heavy metals (Cu, Cd, Zn and Ni) and PAHs in *Perna viridis* collected from seaport and non-seaport waters in the Straits of Johore. Bull Environ Contam Toxicol 89: 1205-1210.

7 Yap CK, Nasir SM, Edward FB, Tan SG (2012b) Anthropogenic inputs of heavy metals in the east part of the Johore Straits as revealed by their concentrations in the different soft tissues of *Perna viridis* (L). Pertanika J Trop Agric Sci 35: 827-834.

8 Yap CK, Cheng WH, Ong CC, Tan SG (2013) Heavy metal contamination and physical barrier are main causal agents for the genetic differentiation of *Perna viridis* populations in Peninsular Malaysia. Sains Malay 42: 1557-1564.

9 Shahbazi A, Zakaria MP, Yap CK, Tan SG, Surif S, et al. (2010) Use of different tissues of *Perna viridis* as bio monitors of polycyclic aromatic hydrocarbons (PAHs) in the coastal waters of Peninsular Malaysia. Environ Forensics 11: 248-263.

10 Rand GM, Petrocelli SR (1985) Fundamentals of aquatic toxicology: Methods and applications, Hemisphere publishing, Washington, USA, p: 666.

11 McKim JM (1977) Evaluation of tests with early life stages of fish for predicting long-term toxicity. J Fish Res Bo Can 34: 1148-1154.

12 Zheng R, Peng X, Zeng H, Zhang S, Chen T, et al. (2015) Incidence, mortality and survival of childhood cancer in China during 2000–2010 periods: A population based study. Cancer Lett 363: 176-180.

13 Garcia-Leston J, Mendez J, Pasaro E, Laffon B (2010) Genotoxic effects of lead: An updated review. Environ Int 36: 623–636.

14 Mertz W (1981) The essential trace elements. Sci 213: 1332-1338.

15 Denkhaus E, Salnikow K (2002) Nickel essentiality, toxicity and carcinogenicity. Crit Rev Oncol Haematol 42: 35–56.

16 Gorell JM, Johnson CC, Rybicki BA, Peterson EL, Kortsha GX, et al. (1997) Occupational exposures to metals as risk factors for Parkinson's disease. Neurology 48: 650–658.

17 Bilandzic N, Sedak M, Đokic M, Varenina I, Kolanovic BS, et al. (2014) Determination of zinc concentrations in foods of animal origin, fish and shellfish from Croatia and assessment of their contribution to dietary intake. J Food Compos Anal 35: 61–66.

18 Shor LM, Kosson DS, Rockne KJ, Rockne LJ, Young LY (2004) Combined effect of contaminant desorption and toxicity on risk from PAH contaminated sediments. Risk Anal 24: 1109-1120.

19 Collins JF, Brown JP, Alexeeff GV, Salmon AG (1998) Potency equivalency factors for some polycyclic aromatic hydrocarbons and polycyclic aromatic hydrocarbon derivatives. Reg Toxicol Pharm 28: 45–54.

20 Graff L, Isnard P, Pierre C, Bastide J, Cambon JP, et al. (2003) Toxicity of chemicals to microalgae in river and in standard waters. Environ Toxicol Chem 22: 1368-1379.

21 Jonnalagadda SB, Prasada Rao PVV (1993) Toxicity, bioavailability and metal speciation. Comp Biochem Physiol 106: 585-595.

22 Rittschof D, McClellan-Green P (2005) Mollusks as multidisciplinary models in environment toxicology. Mar Pol Bull 50: 369-373.

23 Yap CK, Ismail A, Tan SG (2002a) Occurrence of shell deformities in green lipped mussel *Perna viridis* (Linnaeus) collected from Malaysian coastal waters. Bull Environ Contam Toxicol 69: 877-884.

24 Yap CK, Ismail A, Tan SG (2002b) Condition index of green-lipped mussel *Perna viridis* (Linnaeus) as a potential physiological indicator of ecotoxicological effects of heavy metals (Cd and Pb). Malays Appl Biol 31: 37-45.

25 Yap CK, Al-Barwani SM (2012) A comparative study of condition indices and heavy metals in *Perna viridis* populations at Sebatu and Muar, Peninsular Malaysia. Sains Malay 41: 1063-1069.

26 Yap CK, Ismail A, Tan SG, Omar H (2003c) Effects of heavy metals (Cd, Cu, Pb and Zn) on the filtration rate of the green lipped mussel *Perna viridis* (Linnaeus). Malays Appl Biol 32: 7-13.

27 Yap CK, Ismail A, Omar H, Tan SG (2004) Toxicities and tolerances of Cd, Cu, Pb and Zn in a primary producer (*Isochrysis galbana*) and in a primary consumer (*Perna viridis*). Environ Int 29: 1097-1104.

28 Yap CK, Azlan AGM, Cheng WH, Tan SG (2007) Toxicities and tolerances of Cu in the blood cockle *Anadara granosa* (Linnaeus) under laboratory conditions. Malays Appl Biol 36: 41-45.

29 Yap CK, Tan SG, Ismail A, Omar H (2002c) Genetic variation of green-lipped mussel *Perna viridis* (Linnaeus) from the west coast of Peninsular Malaysia. Zool Stud 41: 376-387.

30 Yap CK, Tan SG (2011) Ecotoxicological genetic studies on the green-lipped mussel *Perna viridis* in Malaysia. In: Mussels: Anatomy, habitat and environmental impact. LE McGevin (edtr), Nova Science Publishers, USA, pp: 221-244.