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Determination of Mercury Accumulation Factor in Hard Clam (*Meretrix lyrata*) at Bach Dang Estuary, Viet Nam

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Abstract

Bach Dang estuary (Hai Phong City) is one of the developed economic centers of Hai Phong city with abundance of natural resources. At the Bach Dang estuary, waste sources of mercury compounds discharge from the industrial sources, transportation sources, port, agricultural sources and living sources. Two forms of mercury: total mercury and methyl mercury in the water at the Bach Dang estuary are lower than the allowable limit. Bioaccumulation factor (BAF) of total mercury in hard clam *Meretrix lyrata* is 307 and that one of methyl mercury is 165,000.

Keywords: accumulation coefficient, hard clam (*Meretrix lyrata*), mercury

1. Introduction

Biological accumulation is defined as a biological process in which organism directly store chemicals from the abiotic environment (water, air and soil) and from food sources (food transmission). The chemicals in the environment are absorbed through passive diffusion process. The first organ for the absorption includes pleural, gills and intestines. The chemicals must penetrate the lipid bilayer of the membrane to enter the body. Potential bioaccumulation of the chemicals relates to the solubility of the substances in the lipid. Aquatic environment is the place that the affinity with lipid substances through barrier between the natural environment and living organisms. Because rivers, lakes and oceans as substances settling tank and aquatic organisms move large amounts of water through their respiratory membrane, allow a number of chemical separated from water in the body. Aquatic organisms can biologically accumulate chemicals and reach higher concentrations in the environment.

In the coastal environment, the bottom layer living molluscs group were selected by scientists to be the study subjects due to high bioaccumulation, sedentary life, organic humus filter eating, etc. It also comes with the risk of losing safe for humans to use them as food if the toxicity levels (eg heavy metal group, persistent organic group) accumulate in tissues and internal organ large enough. The bottom layer living molluscs group has met the conditions for studying, such as sedentary life, capable of accumulating pollutants, long life enough, sizes suitable to provide sufficient tissue for analysis service and easy sampling. In fact, it is hard to get any species that meets all the criteria. Bivalve mollusks have the ability to accumulate pollutants many times higher than in the water environment, food and sedentary filter, they are usually chosen as the indicator organisms, the study object in the field environmental toxicology.

Bach Dang estuary (Hai Phong City) is one of the developed economic centers of Hai Phong city with abundance natural resources (Thanh, An, & Trang, 2014). The tidal plains formed on both sides of the Bach Dang River area due to the interaction between flow in river and coastal river. There, the nutrients from the estuary are favorable conditions for aquaculture, especially clam aquaculture (Le Xuan, Duc, & Kim, 2011). At the Bach Dang estuary, the mercury discharge sources from the same industrial sources (power plants, steel plants, electronic plants and cement plants), traffic sources, port, agricultural sources and living sources (Le Xuan, 2015). Research mercury bioaccumulation factor of Ben Tre white clam species *(Meretrix lyrata)* helps assess the mercury accumulation process in the environment to go into the living organisms here.

2. Object and Method of Research

2.1 Research Object

- Sampling subject is Ben Tre hard clam *(Meretrix lyrata)* with commercial size (size may be sold on the market) in Dong Bai commune (Cat Hai district of Hai Phong city).

- Mercury total and Metyl Mercury in water and tissue of Meretrix lyrata at Bach Dang estuaty from July 27th, 2010 to May 6th, 2011.

Figure 1. Ben Tre hard clam (*Meretrix lyrata*)

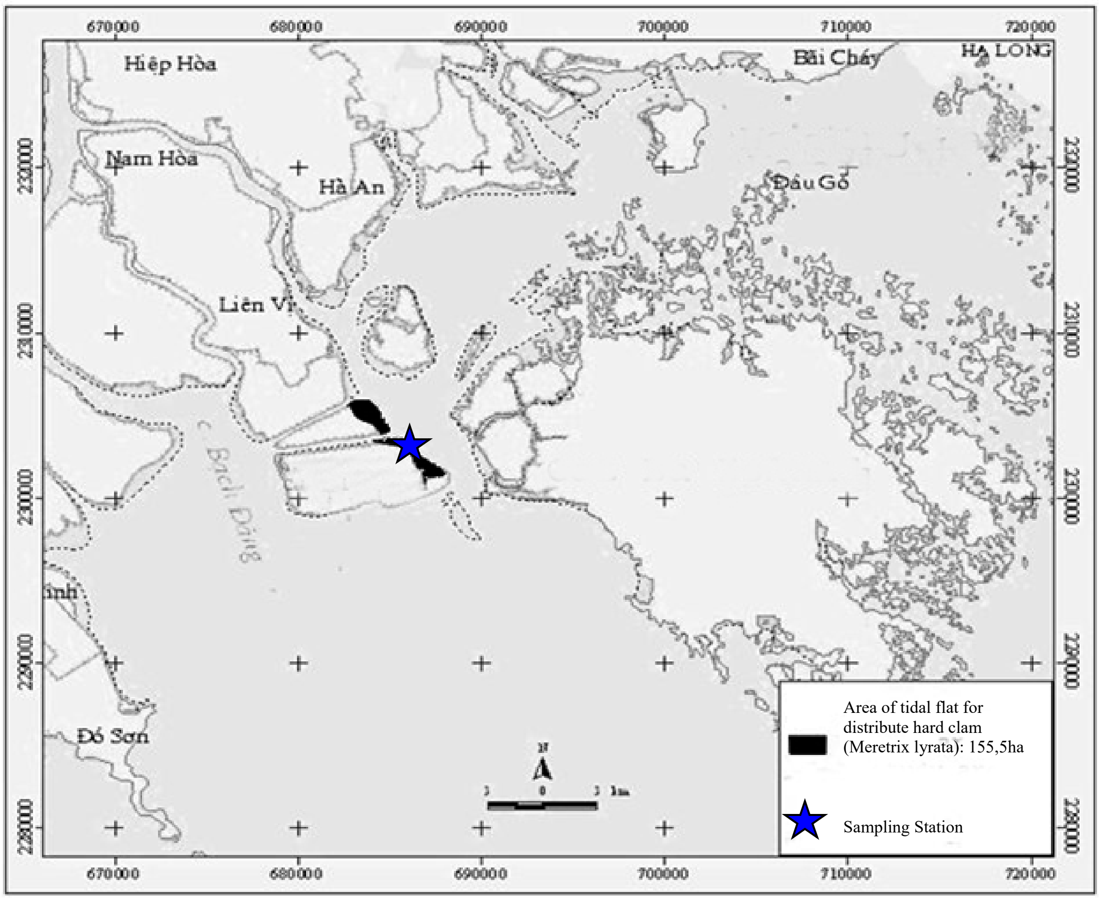

Figure 2. Diagram of onsite sampling

2.2 Research Method

Mercury analysis in water and organism

+ Analysis of total mercury in water by the method of EPA 1631e (EPA, 2002).

+ Total mercury concentration in biological tissue (EPA, 2002).

In this study, the detection limit of the method is determined according to 09 times repeat sample test results of standard solution at a concentration of 0.5µg/l. According to this result, the average measured result is 0.51µg/l, the standard deviation S is 0.03 µg/l, the recovery is 102%. It shows that the precision and focus of the analytical results. Ts value correspond to 99% probability measurement number (n = 9) is 3.36, which determine the method detection limit MDL = Sxts = 0.12 µg/l.

To assess the accuracy of the method, we had used the following standard samples: standard sample of sediment MESS-3 of Canadian with the determined concentration is 0,091 µg/g ± 0,009. The result of measuring MESS-3 sample in the laboratory of Institute of Marine Environment and Resources (n = 4) is 0,101 µg/g ± 0,012, analysis deviation compared with standard sample was 108%. It indicated that the analysis method of total inorganic mercury met the requirement for the analysis of environmental samples.

2.3 The Bioaccumulation Factor (BAF) Calculation Method

Bioaccumulation factor (BAF) is the ratio of substance concentration in tissues of living organisms to the concentration of the substance in the water environment (Arnot & Gobas, 2006).

$$BAF = \frac{C_t}{C_s} \tag{1.1}$$

In which:

- BAF is calculated by experimental data

- Ct is the pollutant concentration in biological tissues (mg/kg dry tissue)

- Cs is the pollutant concentration in water (mg/l)

3. Research Result and Discussion

Clam samples were collected 10 times per year to analyze total mercury and methyl mercury concentration in clam tissue. The water samples were collected 10 times and analyzed the concentration of total mercury and methyl mercury. The analytical result for the repeat sample (n = 5) has shown in Table 1.

Table 1. The results of the mercury analysis in water environment and clam tissue

Sample time	Total mercury		Methyl mercury	
	Hg_T in clam tissue (ng/g)	Hg_T in water (µg/l)	Hg_{Me} in clam tissue (ng/g)	Hg_{Me} in water (ng/l)
Series 1: 1st sampling (27 July, 2010) (n=5)	12.5	0.61	1.1	0.18
Series 2: 2nd sampling (29 August, 2010) (n=5)	24	0.52	7	0.16
Series 3: 3rd sampling (27 September, 2010) (n=5)	35	0.23	8.5	0.12
Series 4: 4th sampling (30 October, 2010) (n=5)	37.9	0.36	10.45	0.18
Series 5: 5th sampling (4 December, 2010) (n=5)	57.85	0.31	10.75	0.16
Series 6: 6th sampling (5 January, 2011) (n=5)	47.1	0.30	13.65	0.15
Series 7: 7th sampling (27 January, 2011) (n=5)	31.8	0.35	14.05	0.18
Series 8: 8th sampling (4 March, 2011) (n=5)	53.7	0.25	15.1	0.13
Series 9: 9th sampling (8 April, 2011) (n=5)	84.85	0.28	23.1	0.14
Series 10: 10th sampling (6 May, 2011) (n=5)	87.9	0.77	24.55	0.23

n: sample per time to survey.

3.1 Assessing the Evolution of Mercury Concentration in Water

According to the analysis result in Table 1, the concentration of total mercury and methyl mercury were shown in diagrams 3. Total mercury concentration fluctuated in the range of 0.25 ÷ 0.77 µg/l in 10 sampling times. It showed that the mercury concentration in the rainy season (June, July, August and next May) is higher than in the dry season (from September to next April). Methyl mercury concentration ranged in 0.12 ÷ 0.23 ng/l in 10 sampling times. The trend of methyl mercury was not clear as the trend of total mercury. The concentration of methyl mercury in seawater was small, get only 0.03 ÷ 0.05% of the mercury concentration. Although methyl mercury concentration in water environment was small in comparison with the total mercury concentration, its toxicity is very high if it enters the organism and human body. Methyl mercury is the most toxic form of mercury. Methyl mercury is soluble in fat or lipid component of the brain membranes, accumulates in cells with long life. Methyl mercury can be transported from mother to child when the mother poisoned. Methyl mercury accumulated in seafood because it can not be disposed in the seafood processing due to methyl mercury tightly bound to proteins in the cell. 95% of methyl mercury absorbed into the organs of the fish after 2 days and exist in the fish body from 70 ÷ 90 days (Eisler, 2006). Therefore, methyl mercury will go into the human body through eating fish, cause Minamata disease in Japan (lost control CNS) if the body absorbed an amount of methyl mercury higher than 0,1µg/kg/day (EPA, 1997b).

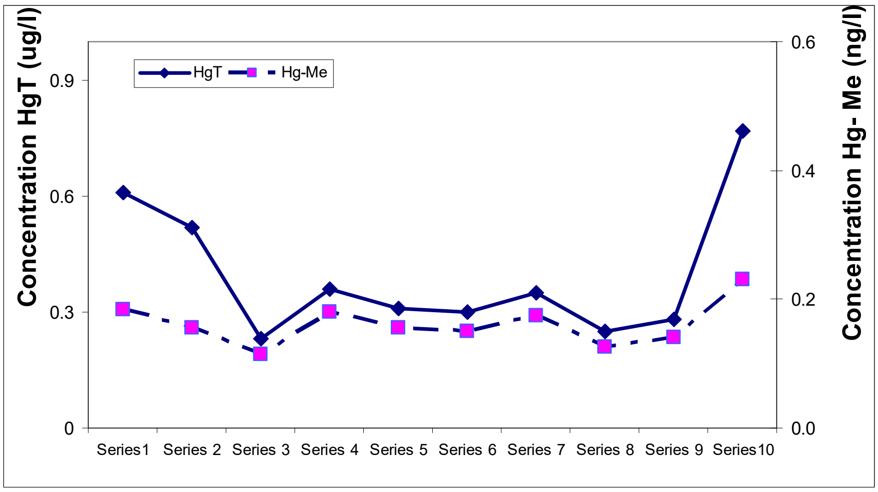

Figure 3. Performance of Hg_{Me} and Hg_T concentration over time

3.2 Assessing the Mercury Concentration Accumulated in Clam Meat Tissue

Mercury from the water accumulated in organisms in general and in particular white clam species. The mercury concentration accumulation in clam depends on the different times in a year. The data of total mercury and methyl mercury accumulated in clam meat tissue shown in Figure 4.

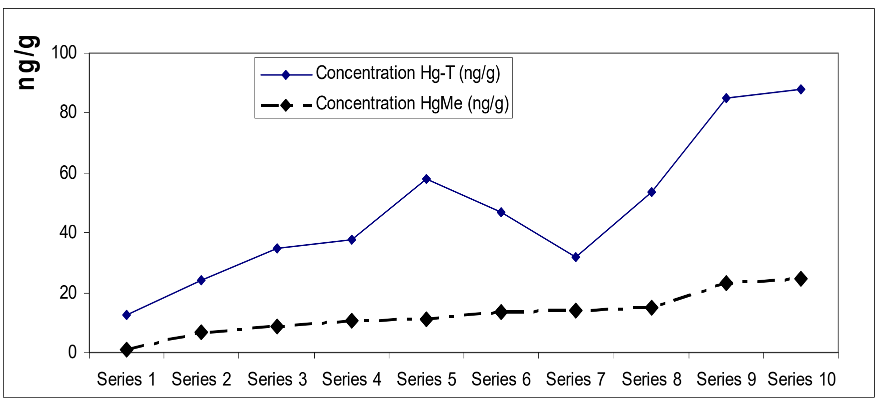

Figure 4. Performance of Hg_{Me} and Hg_T concentration in clam meat tissue over time

According to Figure 3, the trend of total mercury concentration accumulation in the meat tissue increased from the 1st sample to the 5th sample (from July to December), then reduced from the 5th sample to 7th sample. It was in January, the coldest month in the year. In this period, the total mercury accumulation in meat tissue decreased due to the elimination process larger than the accumulation process. In winter, temperatures are around 15°C, the wave and flow regime in clam aquaculture place is strong because it is affected by the northeast monsoon. Therefore, the clam should often bury themselves in the sand to cope with the extreme weather, clam fat is reduced due to the lack of food. At this time, because of strong sea waves, the clams must spend a portion of energy to fix on the sand by foot (Phu, 1999). When the clams bury themselves in the sand, they use the stored energy which accumulated in fat tissue, the analysis data showed that the lipid concentration in clam tissue in 6th and 7th sample decreased (Le Xuan, 2015). The loss of lipid can lead to release lipid soluble toxin and eliminate mercury mount accumulated in the fat tissue out (Tuan, 2008). Then, the total mercury accumulation in tissue increased from the 7th sample to 10th sample, corresponding to the period from March to May. It was the spring time, food abundant so the clam thrives. Spring is also time of recording the study result of mercury accumulation level increase gradually over time. The accumulation speed is different over time.

Hg_{Me} concentration accumulates much in adipose tissue. However, when reduce the amount of lipid content in tissue, Hg_{Me} still up, it showed that the sustainability of the mercury form as methyl mercury tightly bound to the protein in muscle cell in clam body and organism body in general (EPA, 1997a). Acccumulated methyl mercury concentration in clam meat tissue tended to rise. It increased from 106% ÷ 127%, particularly in the 2nd sample, it increased 636% in comparison with the 1st sample. The average proportion of methyl mercury accounted for 26%, similar to the study result of some bivalve molluscs distributed in Rio de Janeiro estuaries in Brazil (Kehrig, Costa, Moreira, & Malm, 2001). To assess the maximum mercury accumulation of clam through sampling times, it is necessary to be based on the bioaccumulative factor of mercury forms.

3.3 Bioaccumulation Factor of Total Mercury and Methyl Mercury

Calculating bioaccumulation factor is according to the formula 1.1, the result of bioaccumulation factor (BAF) of total mercury and methyl mercury are shown in Table 2.

Table 2. Bioaccumulation factor (BAF) of mercury forms

Series	BAF of Hg_T	BAF of Hg_{Me}
Series 1	21	6,011
Series 2	46	44,872
Series 3	149	73,913
Series 4	105	58,056
Series 5	185	69,355
Series 6	159	91,000
Series 7	90	80,286
Series 8	217	120,800
Series 9	307	165,000
Series 10	114	106,277

Bioccumulation factor of both types of mercury (methyl mercury and total mercury) in 9th sampling was very high. The BAF of total mercury was 307 and that one of methyl mercury was 165,000. The highest bioaccumulation factor (BAF) of two types of mercury is always in April - this is the time for clam harvest at Bach Dang estuary. Thus, the clam sampled was in the time when accumulated mercury was the highest. This is also the clam's fattest time in a year. Then, the clams are arrested for rehabilitating beach for the next season.

The BAF of clam and cockle *(Anadara granosa)* are equivalent because of their similarity of distribution, size and breeding process. BAF of Hg_T of cockle (BAF_T = 355, this is the research result of topic coded VAST06.07/11-12) is not much different in comparison with clam (BAF_T = 307).

Currently, the studies on mercury accumulation in the clam *Meretrix lyrata* tissue still lack, or have but the monitoring data on the clam and environment samples is heterogeneous. According to the data in March 2011 of the North coast station, the data on total mercury in the clam intestine and in the environment in Sam Sơn region (Thanh Hoa) and Cua Lo region (Nghe An) (Monitoring and environmental analysis stations in Coastal Northern Viet Nam, 2011). The monitoring data in March coincided with the time of clam harvesting in the Bach Dang estuary. BAF has been transformed in correspondence with the size of the clam collected at Sam Son and Cua Lo region, BAF of the clam farmed in the Bach Dang estuary has been calculated according to the mercury concentration of the stomach and tissue. After converted into the BAF of clam farmed in the Bach Dang estuary in correspondence with the size of clam farmed in the Sam Son and Cua Lo region, we recognize that BAF is different. BAF of the clam farmed in the Bach Dang estuary is higher than in Sam Son region 130% and lower than in Cua Lo region 76% (Figure 5).

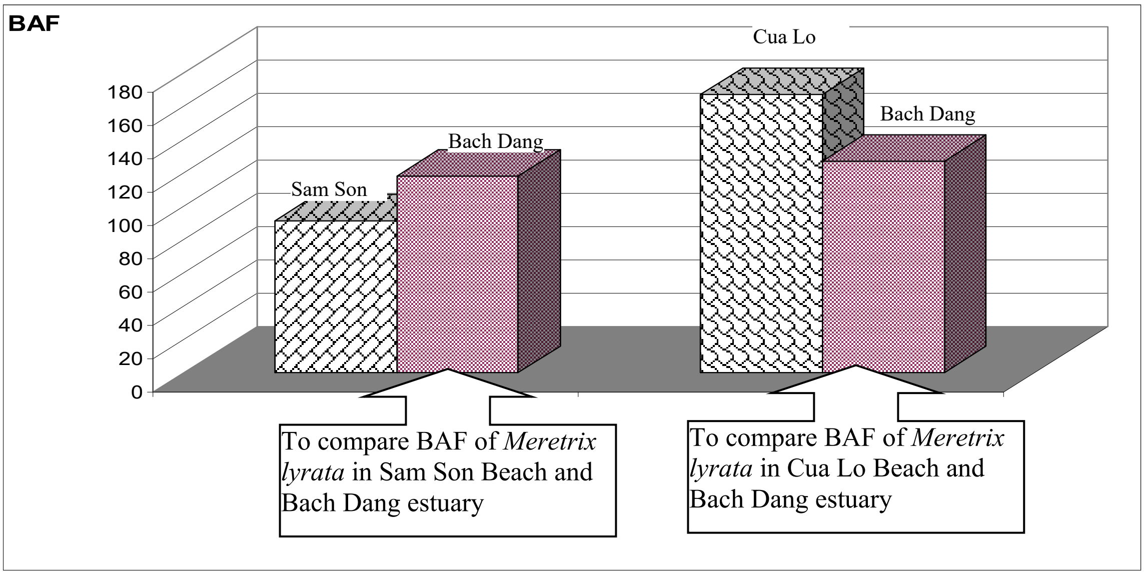

Figure 5. Comparison of the bioaccumulation factor BAF of clam in Bach Dang estuary, Sam Son and Cua Lo beach

Thus, the mercury accumulation of hard clam *Meretrix lyrata* in various areas is different. It depends on the geographic partition. Currently, the data for the comparison with clam mercury accumulation in the south is not enough. This is one of the contents that the author need to research more in the future.

4. Conclude

Two forms of mercury are defined as total mercury and methyl mercury in the water environment are lower than the allowable limit. In a clam meat tissue, total mercury accumulation ranged from 12.5 to 87.9 ng/g dry. Mercury concentration accumulation increased from feeding until December, then reduced in January and increased from harvesting in May. Methyl mercury accumulation increased from feeding until harvesting, fluctuated in the range of 1.1 to 24.6 ng/g dry. Bioaccumulation factor of total mercury of clam *Meretrix lyrata* is 307 and BAF of methyl mercury is 165,000. The mercury accumulation in hard clam *Meretrix lyrata* in the Bach Dang estuary, Sam Son and Cua Lo beach is different, so BAF is different, it depends on the environmental conditions of each region.

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