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Heavy metal concentration in the sediments in aquacultural areas in An Giang province, Vietnam

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Abstract

An Giang is an upstream province in the Mekong Delta, generating favorable conditions for aquaculture development. The area of aquaculture land in 2020 is 7,769 ha, accounting for 2.71% of the natural land area. Fishery production for the whole year reached 532.6 thousand tons, of which aquaculture reached 513 thousand tons. The study was carried out to determine the concentration of heavy metals (Cu, Zn, Pb, Cd, As) in the sediment of aquaculture ponds in the farming areas of Long Giang, Vinh Hoa and Vinh Thanh Trung, An Giang province. The results showed that the concentrations of heavy metals including Cu, Pb, Zn, Cd, As in the sediment samples were 19.81, 21.56, 15.12, 0,20.63 mg/kg; 68.91, 39.25, 69.99, 0, 0 mg/kg and 21.9, 13.5 , 23.68, 0, 0 mg/kg. Heavy metals in the sediment samples were all within the allowable limits of QCVN 03-MT: 2015/BTNMT, CCME (2007), except for As in Long Giang farming area, which exceeded the limit of QCVN 03-MT: 2015/BTNMT and CCME (2007). Initial research results showed that the sediment in the farming areas was contaminated with heavy metals. The ecological risk is low in the farming area. However, the presence of heavy metals can lead to bioaccumulation that affects ecosystem and human health. Future study should focus on speciation of heavy metals in the pond's sediment.

1. Introduction

Aquaculture has become a strong economic agricultural industry in freshwater aquaculture of the Mekong Delta provinces, ranking second after rice, especially An Giang is one of the provinces with the largest export turnover of freshwater seafood in the country, accounting for 30% of total export value. Exported seafood is mainly catfish such as pangasius and basa fish, which are very popular in the domestic market and especially in the international market. Aquaculture area is increasing due to its high commercial value. In 2019, the province's aquaculture area was 3,309 ha, in which, the concentrated areas for ponds had a large area such as Vinh Hoa farming area (153.2 ha) in Tan Chau town, adjacent to the Tien River; Long Giang farming area (112 ha) in Cho Moi district, adjacent to Hau river; Vinh Thanh Trung farming area (68.53 ha) in Chau Phu district,

adjacent to Vinh Tre canal and Muong Khai canal. The continuous increase in the size of the area in the province is a good sign because it contributes to creating jobs and increasing income for the household economy. However, the farming of pangasius, basa and giant freshwater shrimp has caused many environmental concerns, the amount of food lost to the aquatic environment accounts for about 15%. The amount of dry matter discharged into the environment is about 460 tons/ha. Each hectare of fishpond will accumulate about 1,000 cubic meters of sediment at the end of each crop. Most of the ponds have wastewater treatment systems (settling ponds, water treatment with chemicals, etc.) before discharging into rivers, but not thoroughly treated, of which about 33% - 40% of farming households discharged directly into rivers and canals, leading to the unavoidable pollution of surface water quality for rivers and canals. In the model of intensive catfish farming, homemade feed is used a lot, frequent water changes have released a large amount of untreated waste, potentially polluting the water environment [1]. When producing one ton of pangasius, 3.2-3.6 tons of homemade feed or 1.5-1.6 tons of industrial feed are needed [2]. Leftover food, fish waste and some drugs/chemicals used in the rearing process form a layer of sediment. This large amount of sediment affects pond water quality, fish health and impacts on the surrounding environment, affecting the sustainability of aquaculture. Nutrient composition of sediment in pangasius culture has 17.1% organic matters, 9.90% total carbon (TC), 2.04 mg/g total nitrogen (TN) and 0.96 mg/g total phosphorus (TN) [2]. Besides, heavy metal pollution is a threat to agricultural and industrial production areas [3]. Determination of heavy metal concentration in the environment is very necessary due to its toxicity, their sustainability and bioaccumulation [3-4]. According to research by [3], some heavy metals such as Fe, Zn, Cu, Mn, Ni are necessary for the body's biological metabolism in very small amounts, but in high doses, it causes toxicity to living organisms. Pb, Hg, Cd, As are very toxic to the body even at low doses. Sources of pollution include mining wastes, sewage, municipal wastewater, and industrial wastewater. The study also showed that the problem of heavy metals in wastewater is getting worse, because it tends to accumulate in the sediment. The accumulation of heavy metals will affect the life of aquatic organisms, affecting human health through the food chain [4]. Currently, there are not many studies on heavy metal concentration in the sediment in aquaculture ponds. Therefore, the study was conducted to evaluate the concentration of heavy metals in the sediment of aquaculture ponds and estimate the ecological risk. The results provide helpful information on the current state of the environment, especially the presence of heavy metals that can cause many harms to the health of ecosystems and local community.

2. Materials and methods

2.1 Sediment sampling and analysis

The study was carried out in three farming areas in An Giang province, soil sample data was collected from An Giang Department of Natural Resources and Environment in 2020. Samples were taken from January 6, 2020 to January 22, 2020 with 66 samples at a depth of no more than 30cm in three farming areas Long Giang, Cho Moi district (B1 – B22); Vinh Hoa farming area, Tan Chau town (B23 – B52) and Vinh Thanh Trung farming area, Chau Phu district (B53 – B66). The diagram of sampling locations of three farming areas is shown in Figure 1. Each soil sample for analysis is taken with sufficient weight from 1kg to 1.5kg, put in a separate bag, the outside of the bag must be labeled with full information, inside the bag labeled with information (location, sampling depth, date and soil sampling person). Soi sample is stored in clean plastic bags. Soil samples were dried at room temperature, ground and sieved through a mesh with the pore size of

0.5 mm. Heavy metals including Cu, Zn, Pb and Cd were determined using an atomic absorption spectrometer (AAS, Agilent, AA240). Measurement results of heavy metal concentration in soil are evaluated against the national technical regulation on permissible limits of some heavy metals in soil (QCVN 03-MT:2015/BTNMT)[5] and Canadian Council of Ministers of the Environment (CCME) [6].

Figure 1. Map of sampling locations in An Giang

2.2 Data analysis

The data on environmental quality of the sediment environment are presented as TB± SD. The difference in the mean values of the analytical parameters between the sediment sampling locations was checked by using the analysis of variance (Analysis of Variance or ANOVA) IBM SPSS statistics for Window software. Version 20.0 (IBM Corp., Armonk, NY, USA) at 5% significance level. The ecological potential risk index (RI) method was proposed by [4] to assess heavy metal pollution. RI can reflect the individual potential ecological risk level of a heavy metal as well as the overall risk level of an object [4]. The ecological potential risk index method is one of the methods that is considered on both factors that are the concentration of heavy metals in the environment and the toxicological response coefficient. According to [4], the toxicity coefficients of metals Cu, Zn, Pb, Cd and As were determined to be 5, 1, 5, 30 and 10, respectively. Ecological Potential Risk Index (RI) was determined according to Equation (1):

$$\mathbf{RI} = \sum_{\boldsymbol{p=1}}^{\boldsymbol{n}} \left(\boldsymbol{E}_{\boldsymbol{r}}^{\boldsymbol{p}} \right) \qquad E_r^p = CF^p \times T_r^p \qquad \mathrm{CF} = \frac{Cm}{Cb} \qquad (1)$$

In which: E^p_r is the potential ecological risk index for each metal; CF is the pollutant factor of each metal; T^p_r is the metal toxicity coefficient; Cm is the average concentration of metal observed; Cb is the corresponding background value of the metal.

Table 1. Assessment of potential ecological risk

Level of risk	Er	RI
Low	<40	RI < 150
Moderate	40 ≤ Er <80	150 ≤ RI <30
Worrisome	80 ≤ Er < 160	300 ≤ RI <600
High	160 ≤ Er < 320	-
Very high	≥ 320	RI ≥ 600

3. Results and discussion

3.1 Copper in the sediment in aquaculture ponds

The results of analysis of Cu metal concentration in pond sediment in three districts show that the Cu concentration in Long Giang ponds is quite low and there is not a large fluctuation between the sampling points, the point with the highest concentration reached 22.83 mg/kg and the lowest was 16.35 mg/kg. In Vinh Hoa farming area, the value of Cu metal indicator was relatively low, but there was a fluctuation in the value between the sampling points, ranging from 12.44 to 24.39 mg/kg. Vinh Thanh Trung farming area has low Cu value and little fluctuation between sampling points, reaching values from 11.54 to 17.31 mg/kg. In general, the sampling sites have mean values ranging from 15.12±1.66 – 21.56±2.39 mg/kg and there is a statistically significant difference between the sites ($p<0.05$). This result is consistent with the study of [7], the concentration of Cu present in alluvial soil in the Mekong Delta is 22.31 mg/kg. The highest average Cu concentration in Vinh Hoa farming area was 21.56±2.39 mg/kg, the lowest in Vinh Thanh Trung was 15.12±1.66 mg/kg and the average value was 19, 81±1.7 mg/kg in Long Giang farming area. Cu at the sampling locations are within the allowable limits of the standards (QCVN 03-MT: 2015/BTNMT) and CCME (2007). Through the results, it can be seen that the sediment in the pond bottom has a lower Cu concentration in the farming areas compared to the alluvial soil in the Mekong Delta, although farmers use $CuSO_4$ to kill algae, improve ponds [2]. $CuSO_4$ are soluble compounds, so it is less absorbed in the pond sediment. Copper plays a role in nitrogen exchange, photosynthesis, pollen formation and fertilization. When applying copper to the soil, a maximum of 2-3 kg Cu/ha is applied [8]. Once $CuSO_4$ compounds were used, after 12 days it was in soluble form and continued to persist in the medium until day 19 [9]. This study is also consistent with the evaluation of studies around the world with the average Cu concentration in soil in the range of 20 - 30mg/kg. The concentration of Cu in agricultural soils in the Mekong Delta (Vietnam), Samut Songkhram (Thailand) and Tanzania ranges from 15 - 18mg/kg, 17.01 - 19.02 mg/ kg; 15.5 - 20.13 mg/kg [10].

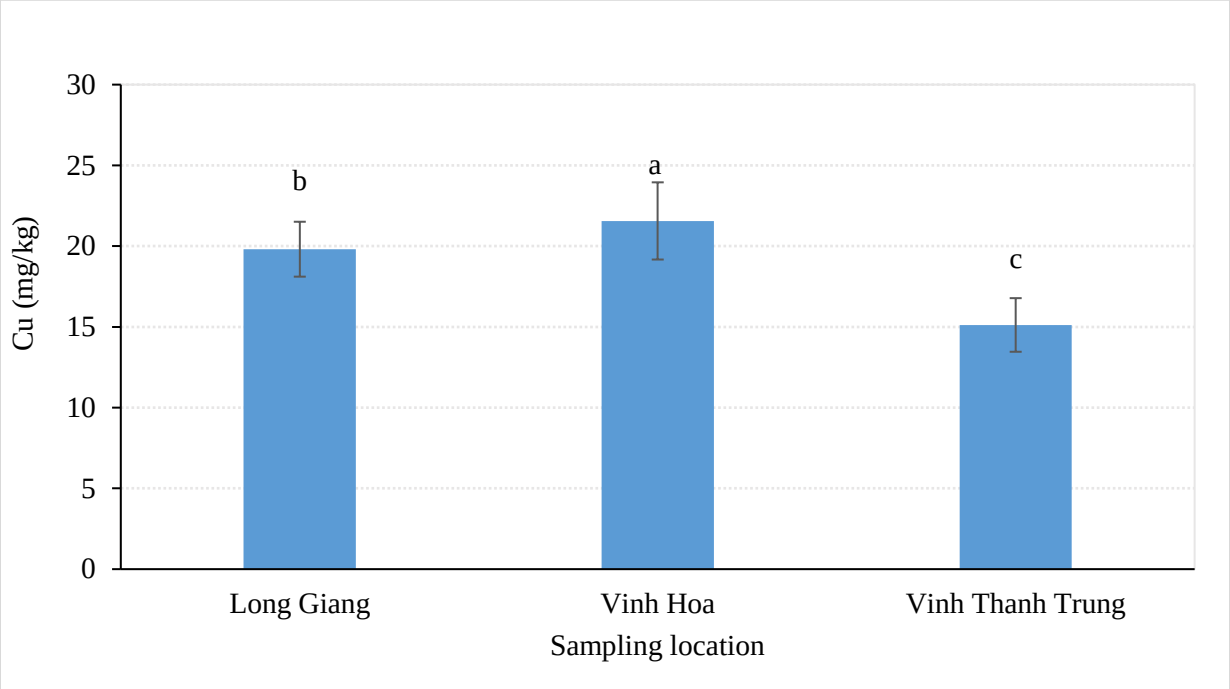

Figure 2. Cu in the sediment in aquaculture ponds

3.2. Zinc in the sediment in aquaculture ponds

The analysis results show that the Zn concentration in Long Giang is relatively high, there is a large variation in the value at the sampling points, ranging from 35.85 to 85.30 mg/kg. In Vinh Hoa farming area, the Zn concentration was relatively lower and fluctuated greatly with the highest value at 22.45 mg/kg and the lowest at 73.16 mg/kg. In the farming area of Vinh Thanh Trung, the Zn index reached a rather high value, there was a large variation in the value of the sample points, especially one sample point reached a very high value (Zn = 121.24 mg/kg) reached the contamination threshold, while other samples only ranged from 50.42 to 83.11 mg/kg. The results of Figure 3 show that the average concentration of Zn at the sampling locations fluctuates from 39.25±15.29 to 69.99±18.58 mg/kg. Zn in Long Giang and Vinh Thanh Trung had no significant difference but was significantly larger than in Vinh Hoa culture area ($p<0.05$). The sludge sample at Vinh Thanh Trung had the highest average Zn value of 69.99±18.58 mg/kg and the equivalent value of Long Giang was 68.91±12.87 mg/kg and the lowest value in Vinh Hoa at 39.25±15.29 mg/kg. This result is consistent with the previous study that Zn concentration present in the natural environment is about 17 - 150 ppm and in alluvial soil in the mekong delta is 76.64 mg/kg [7, 11]. The Zn concentration is within the allowable limits of the standards (QCVN 03-MT:2015/BTNMT) and CCME (2007).

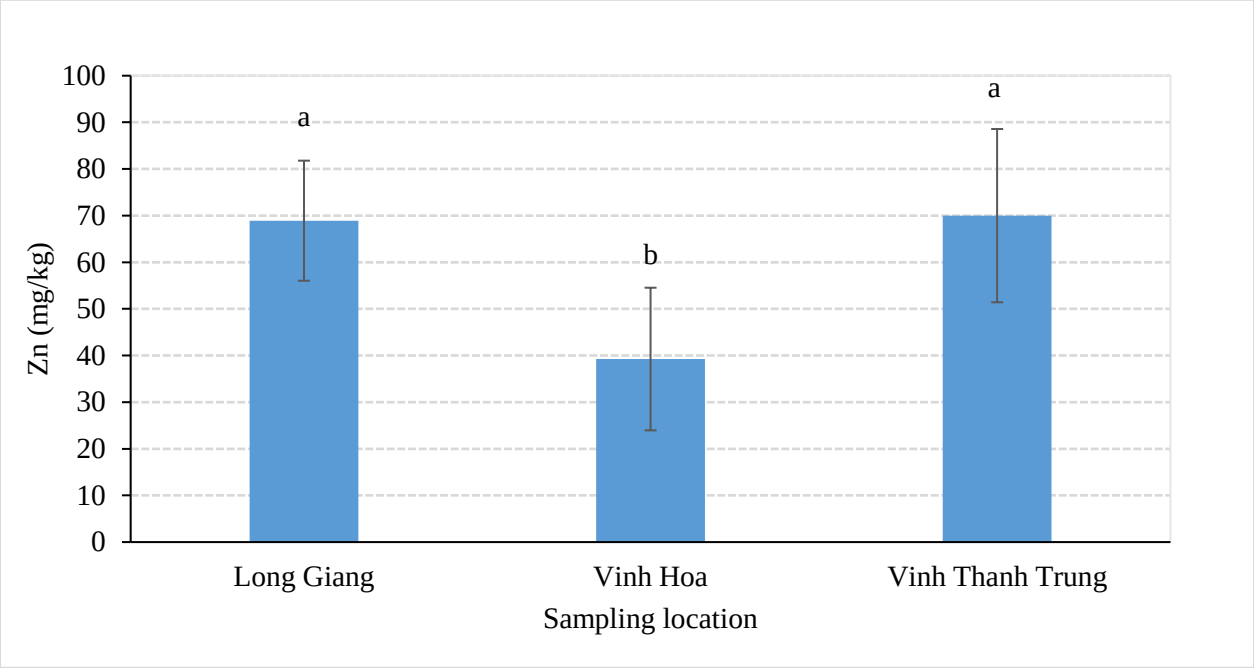

Figure 3. Zn in the sediment in aquaculture ponds

3.3 Lead in the sediment in aquaculture ponds

The results of analysis of Pb concentration showed that Pb in sediment samples in Long Giang culture area was relatively low, reaching an average value of 21.93 mg/kg and there was a fluctuation in the value in different locations. in the range from 11.30 to 30.98 mg/kg. In Vinh Hoa farming area, the concentration of Pb was also relatively low and there was a large variation in value at different locations, the highest value was 22.54 mg/kg and the lowest was 2.68 mg/kg. In the farming area of Vinh Thanh Trung, the highest value reached 28.68 mg/kg and the lowest was 19.52 mg/kg, the values fluctuated between the sampling points. The results of Figure 4 show that the Pb concentration in the sludge is relatively low, on average in soil ranges from 13.53±4.89 to 23.68±3.18 mg/kg, there is a fluctuation in the sampling points. The sediment in Vinh Thanh Trung pond area had the highest Pb of 23.68±3.18 mg/kg. Pb in Vinh Thanh Trung area was no difference with Long Giang culture area (21.9±5.39 mg/kg) but significant difference compared to Vinh Hoa culture area (13.5±4.89 mg/kg). Pb concentrations at all locations are within the allowable standards QCVN 03-MT:2015/BTNMT and CCME (2007). Pb concentration in some agricultural production areas in Vietnam ranges from 6.23 to 8.79 mg/kg; Pb concentration in the topsoil in alluvial soil in the Mekong Delta was 29.10 mg/kg, lower than that found in the present study [7]. The difference in Pb concentration is mainly due to geological differences [11].

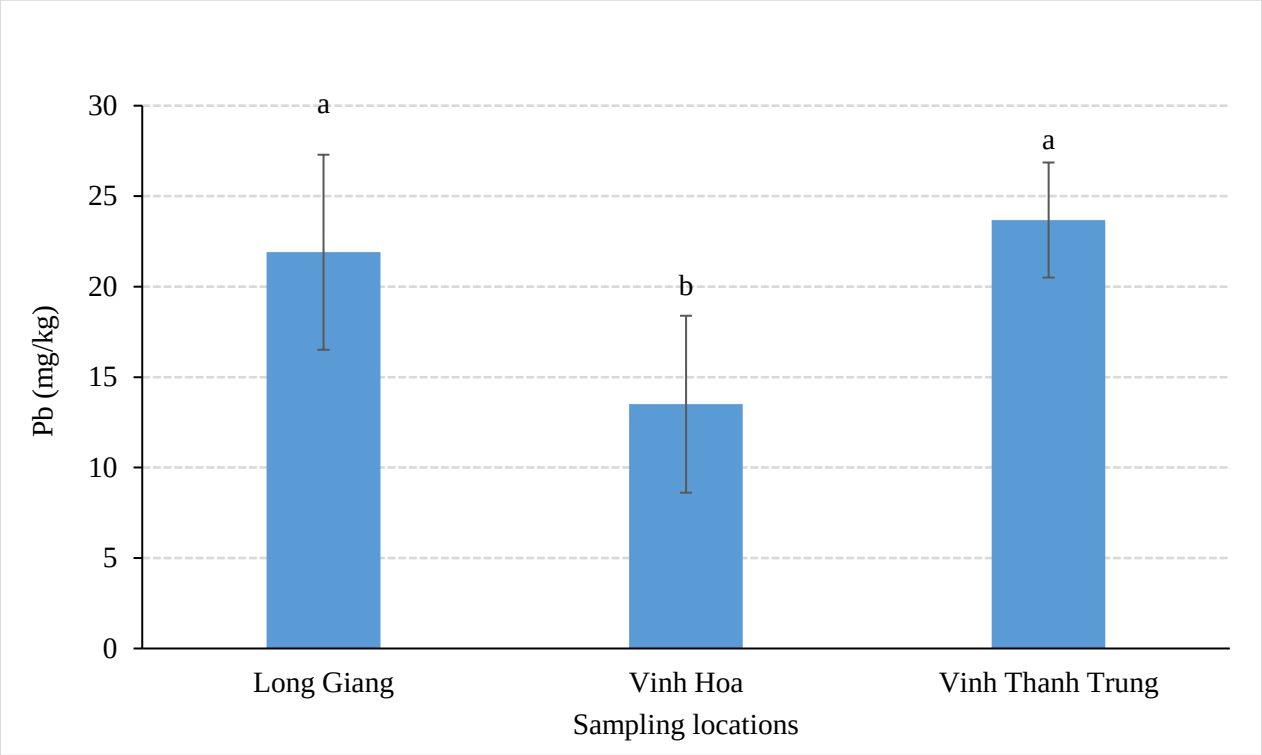

Figure 4. Pb in the sediment in aquaculture ponds

3.4 Cd in the sediment in aquaculture ponds

The results presented that Cd is the only metal below the detection threshold in all analyzed samples; Cd was not detected or significant in all soil samples [10]. In natural soil, the average Cd concentration is about 0.1 mg/kg [12].

3.5 As in the sediment in aquaculture ponds

The results of analysis of heavy metal concentration in pond bottom sediment samples in the farming area in An Giang showed that the As concentration in the Long Giang farming area was contaminated, reaching very high values with an average value of 20, 64±2.77 mg/kg. There is variation in As values between locations, ranging from 15.76 to 25.42 mg/kg, all samples in Long Giang exceeded the pollution threshold compared to with QCVN 03-MT:2015/BTNMT and CCME (2007), the analysis results have determined that the sediment samples in Long Giang exceed the pollution threshold 1.37 times higher than the allowable threshold. As was not detected in Vinh Hoa and Vinh Thanh Trung farming areas. This disparity can be attributed to the difference in values of different microbial and adsorbent reactions controlled by chemical processes occurring in the soil (pH, redox, clay and soil moisture) and the amount of organic matter. As concentration in Long Giang farming area exceeds the allowable threshold that may be the influence of the surrounding adjacent social economic activities, affecting the quality of the environment in the farming area. According to As analysis data in 2,699 samples of groundwater wells from the UNICEF project from November to December 2005 and 6,293 samples of groundwater wells across the province of An Giang Science and Technology from June 2006 to June 2007 showing that As commonly occurs in well water. This could lead to high As concentration in the environment.

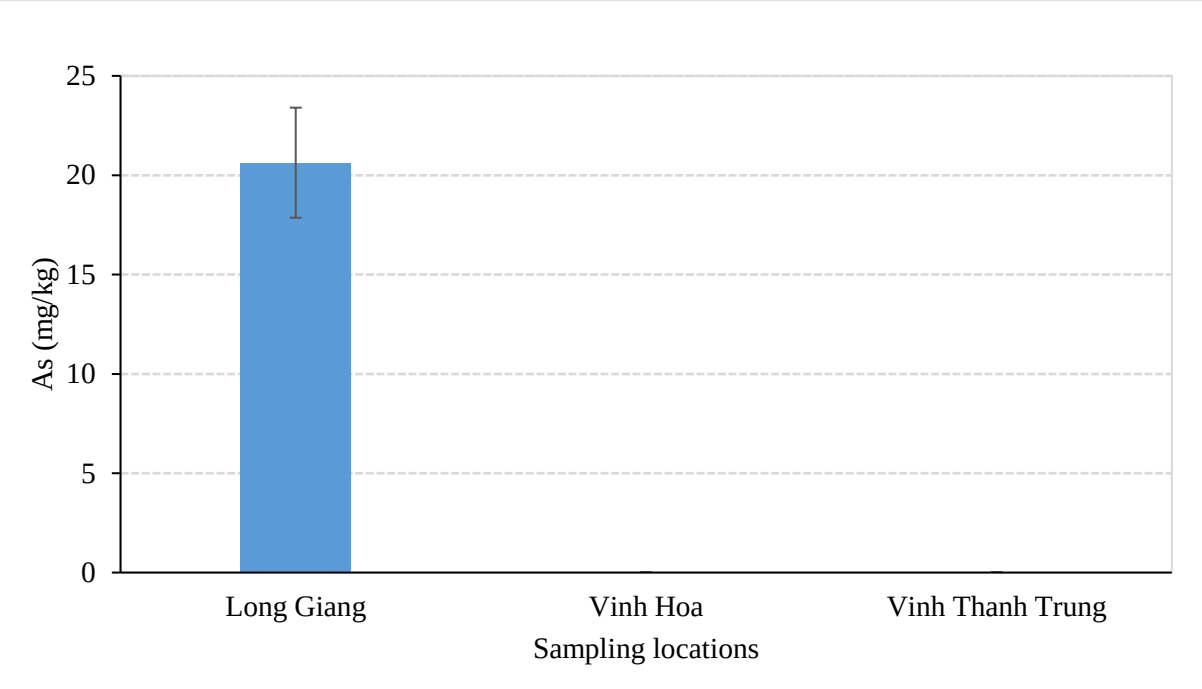

Figure 5. As in the sediment in aquaculture ponds

3.6 Assessment of potential ecological risks

The study conducted to calculate the risk factor of each heavy metal and the combined ecological potential risk factor in each aquaculture pond. Tables 2 and 3 show the calculation results of the coefficients.

Table 2. Potential ecological risk

Parameter	Long Giang	Vinh Hoa	Vinh Thanh Trung
Cu	0.99	1.08	0.76
Zn	0.34	0.20	0.35
Pb	1.56	0.96	1.70
Cd	0.00	0.00	0.00
As	13.75	0.00	0.00

From the results of Table 2 combined with the risk rating scale, the risk factor (Erp) of Cu in 3 farming areas ranges from 0.76 to 1.05; Zn ranges from 0.20 to 0.35; Pb fluctuates from 0.96 to 1.70; As only detected in Long Giang farming area was 13.75; Cd does not pose a risk to the culture area. Overall, As was the main ecological risk factor among the 5 metals studied.

Table 3. Overall potential ecological risk index for each farming area

Study areas	RI	Risk level
Long Giang	16.65	Low
Vinh Hoa	2.24	Low
Vinh Thanh Trung	2.80	Low

From Table 3 combined with the risk assessment scale, it shows that the composite potential ecological risk index of 5 heavy metal parameters in 3 farming areas are arranged Vinh Hoa < Vinh Thanh Trung < Long Giang, all at low risk. Thus, according to Hakanson's ecological risk assessment method, Cu, Zn, Pb, Cd and As metals all have low ecological risks. Heavy metals are usually low in concentration, but many elements can be toxic even at very low concentrations, elements such as Hokinson's, Cd, Zn, Pb are highly toxic. Although heavy metals are naturally present in soils, metal pollution occurs mainly due to human activities. Metals at appropriate concentrations will stimulate the respiration of microorganisms and increase the amount of CO_2 released. However, at high concentrations of Pb, Zn, Cu, Cd, the amount of CO_2 released will decrease. Many studies show a significant reduction in microbial biomass with increasing levels of toxic metals, some authors suggest that heavy metals have an effect on higher plants, such as causing leaf spot disease, reducing chlorophyll activity and reducing the products of photosynthesis. Humans can be directly affected by contact with contaminated soil. Besides, when the pollutant evaporates, if people inhale it, it will also be significantly affected. The threat becomes great when toxic substances through the soil seep into groundwater. Typical heavy metals that have an impact on human health are the concentration of Pb, As and Cu. and Pb are classified as human carcinogenic heavy metals [4] and it can lead to damage in many parts of the human body even when exposed to very low concentrations. The heavy metal accumulation in the food chain can lead to many unpredictable harms [3-4].

4. Conclusion

The results of heavy metals including Cu, Pb, Zn, in sediment samples in three farming areas Long Giang, Vinh Hoa and Vinh Thanh Trung, An Giang province, respectively, 19.81 - 21.56 - 15.12 mg/kg ; 68.91 – 39.25 – 69.99 mg/kg and 21.9 – 13.5 – 23.68 mg/kg both did not exceed the allowable threshold according to Vietnamese standards (QCVN 03:2015/BTNMT) and CCME (2007). Cd was not detected in the sediment samples at the three regions. As was also not detected in Vinh Hoa and Vinh Thanh Trung farming areas. In Long Giang farming areas, As concentration was 1.37 times higher than the allowable limit. The presence of heavy metals in the sediment of aquaculture ponds proves that the impacts of aquaculture activities on environment. Ecological risk assessment indicated that the risk is still low in the study area. Heavy metals may increase its concentrations through accumulation so it potentially pose a threat to health and the environment through the chain food in a longer time. Regularly monitor environmental quality in the farming areas is needed. The speciation of heavy metals in the study area should be focused in the future research.

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