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# Heavy Metals in the Farming Environment and in some Selected Aquaculture Species in the Van Phong Bay and Nha Trang Bay of the Khanh Hoa Province in Vietnam

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**Abstract** Aquaculture is currently one of the most rapidly growing production sectors in Vietnam. This publication describes the concentrations of heavy metals in the farming environment and some aquaculture species in the Khanh Hoa Province in Vietnam. The concentration of total As in the sediments ranged from 0.07 to 0.64 mg/kg, whereas the concentration of Hg varied from <0.0005 to 0.56 mg/kg. The corresponding concentration span for Cd and Pb, were 0.001–0.069 and 0.016–0.078 mg/kg, respectively. The concentrations of As in the aquaculture organisms spanned from 0.14 to 1.03 mg/kg. For Hg the concentrations varied from 0.1 to 0.45 mg/kg, for Cd from 0.02 to 0.10 mg/kg and for Pb from 0.07 to 0.37 mg/kg.

**Keywords** Heavy metals · Aquaculture · Vietnam

The Vietnamese aquaculture production has had a substantial growth during the latest decades, and reached a total estimated production of 1.7 million tons in 2006 (FAO 2007) getting close to the Vietnamese volume of wild catch of seafood organisms at 2 million tons.

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Aquaculture products increasingly contribute to the food supply of the Vietnamese people. The per capita consumption of fishery products in Vietnam increased from 13.2 kg in 1990 to 18.7 kg in 2000 and 19.4 kg in 2002 which represents more than half of their animal protein intake (WHO 2007). Seafood has also become an important export product from Vietnam, measuring over 820,000 tons in 2006. The total export income from seafood products this year was over 3.3 billion of USD. In the Khanh Hoa province alone, the income from exported seafood reached 260 million USD this year (Statistics provided by Ministry of Fisheries, Hanoi).

There are several species of special interest Vietnamese aquaculture, such as Green mussels (*Perna viridis*), Babylonian snails (*Babylonia areolata*), Abalone snails (*Haliotis diversicolor*), Red snapper (*Sciaenops ocellatus*), Sea bass (*Lates calcarifer*), and Sea cucumber (*Sticophus japonicus selenka*).

The area for aquaculture in the Khanh Hoa province are calculated to be approximately 5,430 ha, in which the area for shrimp cultivation alone is about 4,100 ha, with the average annual yield per ha of over 1.5 tons. An important species in the Khanh Hoa aquaculture is the Green mussels, with a total production of 1,600 tons. In addition, the cultivation of lobster in captivity is developing with over 24,000 cages and a production of about 1,100 tons in 2005. The farmers in the Khanh Hoa province also cultivate Babylonia snails, reaching a production of about 30–50 tons annually. In addition Abalone, Sea cucumber, Red snapper and Sea bass are important species in aquaculture in this province.

The demand for fish and fish products in Vietnam is high, and many people consume aquaculture products on a daily basis. Thus, such products provide a main source of dietary protein. However, the fish consumption per capita

varies considerably throughout the country, from claims of 60 kg/capita in Long An to 30 kg/capita in the Mekong Delta to 12 kg/capita in the North of Vietnam (WHO 2007). Shrimp is the most favoured product, followed by squid and mackerel. However, consumers have a preference for fresh seafood rather than frozen products. As Vietnamese eat often out of home, restaurants have a big demand for seafood products. Domestic demand for aquatic products has grown rapidly in recent years in Vietnam.

Several factors influence the safety of seafoods. Such factors may be food borne infections by pathogenic bacteria, virus or parasites, residues of agrochemicals, veterinary drugs and heavy-metals, and have all been identified as possible health hazards associated with aquaculture products.

To document seafood safety, information on the status of undesired chemical elements, drug residues and infective organism is considered necessary. Such documentation is important in maintaining consumer reliance and may also facilitate export of seafood products. In this publication, we focus on the content of the heavy metals arsenic (As), mercury (Hg), cadmium (Cd) and lead (Pb) in sediments, feed and some selected aquaculture species. For three of the chosen elements studied upper limits for content in seafood have been established while arsenic is focussed on because of the interest about the inorganic form, rather than the total content.

The present study was undertaken to study whether the content of heavy metals in seafood products from Khan Hoa was in the safe range compared to limits set in important import countries. This applies especially to EU and the limits set in directive EU 466/2001 (Anon. 2001).

## Materials and Methods

Sampling for analyses was performed in the south-eastern costal part of Vietnam, in the Khanh Hoa Province. Samples of sediments, fish feed and cultured organisms were collected from several localities in Nha Trang Bay and the Van Phong Bay on four occasions between October 2005 and May 2007. The samples of sediments were collected at increasing distance from the cages. The location of Nha Trang Bay and the Van Phong Bay are shown in Fig. 1. The samples of sediments and feed organisms and seafood were collected in plastic bags and immediately transported in a chilled state to the laboratory. All analytical work was performed at the Institute of Biotechnology and Environment, University of Nha Trang, Vietnam.

Samples were digested before analyses of the elements As, Hg, Cd and Pb. Sediments, feed organisms and aquaculture products (1.0–2.0 g) were weighed into ceramic vessels, added 5 mL 10% $KNO_3$ (Merk p.a.) and dried at 110–120°C for 3 h. Vessels containing the dried sample were then placed in a cold furnace (Thermolyne 4700) and were deashed at a temperature of 500°C for 6–8 h, until the ash appeared white and essentially carbon free. After cooling to ambient room temperature, the sides of the vessels were washed by a minimum amount of deionised $H_2O$ and add 2 mL $HNO_3$ (Merk p.a.). The sample was then dried thoroughly on a hot plate at low setting for several minutes to ensure dryness. The vessels were then returned to the furnace at 500°C for 30 min. The latter step was repeated using 1 mL increments of 10% $HNO_3$, until the sample appeared white. Subsequently, 1 mL 10% $HNO_3$ and 10 mL $H_2O$ were added to the to vessel which were swirled to dissolve completely under heating to 80–90°C on a hot plate not longer 10 min. Afterwards the sample were cooled and transferred to a 25 mL volumetric flask with the aid of $H_2O$. Cd and Pb were analysed by graphite Furnace –AAS with Zeeman background (Thermo Element model Solaar M6, United Kingdom). The LOD's were determined to be 0.1 μg/kg for Cd and 0.2 μg/kg for Pb. Hg were analysed by cold Vapour –AAS with a LOD of 0.5 μg/kg. Arsenic were analysed by hydride generation AAS with a LOD of 1 μg/kg. All data are expressed on wet weight basis. To document the accuracy of the results, triplet analysis on a standard reference material were performed giving results within ±5.5% for Hg, ±4.3% for Pb, ±9.2% for Cd and ±5.3% for As, as compared to the certified concentrations. The reference materials were estuarine sediment No. 1646 a, obtained from National Institute of Standardization and Technology, New York, USA.

## Results and Discussion

The content of heavy metals in river and estuarine sediments at four locations in Vietnam has previously been examined by Nguyen and Nguyen (2007). The authors report the mean concentration of As to range from 0.25 to 16.1 mg/kg, the corresponding maximum values ranged from 0.46 to 37 mg/kg. For Cd the mean ranged from 0.29 to 0.47 mg/kg, and the maximum ranged from 0.38 to 0.86 mg/kg. For Pb the mean concentrations ranged from 29 to 46 mg/kg, and the maximum concentrations ranged from 45 to 132 mg/kg. The corresponding figures for copper were from 15.8 to 32.3 mg/kg (mean) and from 25.2 to 65.1 mg/kg (max).

In the present study (Table 1) the concentration of total As in sediments ranged from 0.07 to 0.64 mg/kg, whereas the concentration of Hg varied from <0.0005 to 0.56 mg/kg. The corresponding concentration span for Cd and Pb, were 0.001–0.069 mg/kg and 0.016–0.078 mg/kg, respectively.

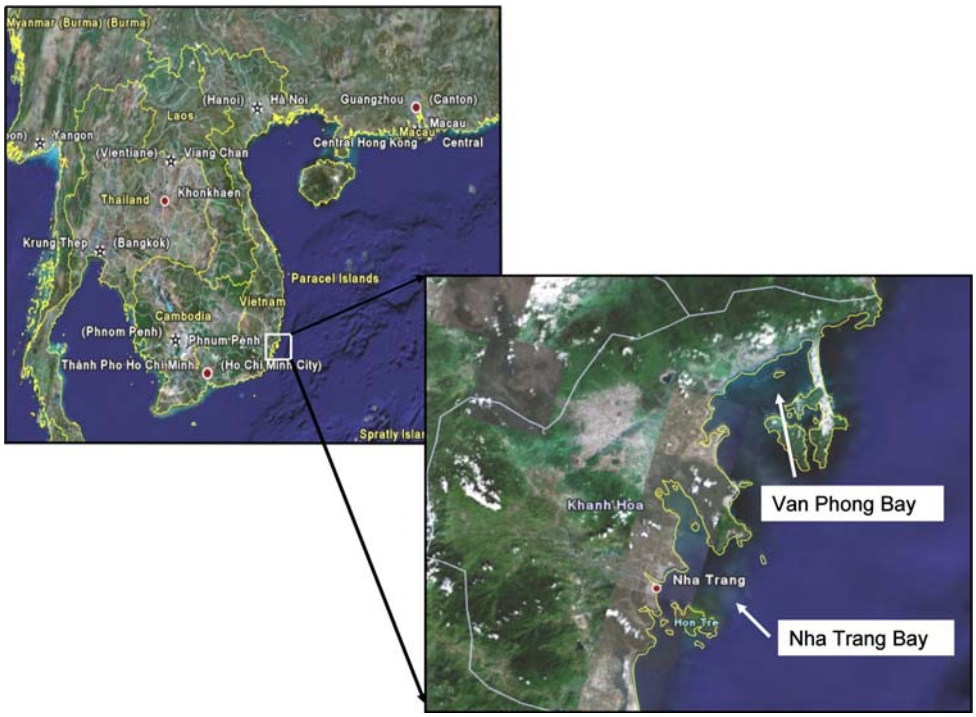


**Fig. 1** Samples were collected from aquaculture sites in the Van Phong Bay and Nha Trang Bay. All sites are situated at the South-eastern costal part of Vietnam, in the Khanh Hoa Province. The location of the two sampling sites is indicated on the present map. (Source: Google Earth at www.google.com)

As may be seen from Table 1, there seems to be a difference in the content of heavy metals in samples of sediments collected inside the cages, compared to sediment collected at a distance away from the cages. This effect was especially pronounced in the Van Phong Bay area. This indicates that aquaculture activity as performed in this case, in it self contributes with heavy metals.

The concentration of mercury in fish caught in the open sea is normally lower then from closed waters near shore. Heavily contaminated fish, as from the Minamata incidence, were reported to have concentrations of Hg from 50 to 250 mg/kg, and the corresponding concentration in molluscs was 50–200 mg/kg wet weight (Montoro and Vélez 2004), but normally fish is lower that the Codex limit of 0.5 mg Hg/kg w.w.

Cadmium is widely distributed in the marine environment and bioaccumulation of this metal in seafood organisms is well recognised. The cadmium content of the muscle of fish is generally low, while the deposits in the kidney and liver are much higher. The cadmium content of fish muscle in the North Atlantic, the Barents sea and around Greenland is about 0.5–5 μg/kg wet weight. Whereas in costal areas of the Baltic sea is may be higher reaching 10–20 μg/kg wet weight (Oehlenschläger 2002).

The legal limits for wet weight based cadmium content in the European Union is currently 0.05 mg/kg in the muscle of most fish species, 0.5 mg/kg in crustaceans, and 1 mg/kg in mussels and cephalopods without intestine (Anon. 2001).

In a publication by Marcussen et al. (2007) the food safety of fish from production systems in Hanoi feed with domestic and industrial wastewater with respect to the potentially toxic elements, such as arsenic (As), cadmium (Cd) and lead (Pb) were examined. In this study, common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*) and tilapia (*Oreochromis niloticus*) were examined with respect to total concentrations of As, Cd and Pb in skin, liver and muscle. The concentrations of As, Cd

**Table 1** Concentrations of Arsenic (As), Mercury (Hg), Cadmium (Cd) and Lead (Pb) in sediments collected in Nha Trang Bay and Van Phong Bay

| | Samples | As (mg/kg) | Hg (mg/kg) | Cd (mg/kg) | Pb (mg/kg) |
|---|---|---|---|---|---|
| Nha Trang Bay | Sediment inside cages | 0.16 ± 0.04 n = 6 | 0.12 ± 0.04 n = 6 | 0.069 ± 0.011 n = 6 | 0.078 ± 0.01 n = 6 |
| | Sediment outside cages | 0.15 ± 0.05 n = 3 | 0.07 ± 0.01 n = 3 | 0.056 ± 0.016 n = 3 | 0.078 ± 0.005 n = 3 |
| Van Phong Bay | Sediment inside cages | 0.64 ± 0.40 n = 11 | 0.56 ± 0.10 n = 4 | 0.028 ± 0.002 n = 11 | 0.048 ± 0.025 n = 11 |
| | Sediment outside cages | 0.07 ± 0.01 n = 3 | <0.0005 n = 3 | 0.001 ± 0.0002 n = 3 | 0.016 ± 0.005 n = 3 |

All concentrations are given on a wet weight basis

**Table 2** Concentrations of Arsenic (As), Mercury (Hg), Cadmium (Cd) and Lead (Pb) in feed organisms collected in Nha Trang Bay and Van Phong Bay

| | Samples | As (mg/kg) | Hg (mg/kg) | Cd (mg/kg) | Pb (mg/kg) |
|---|---|---|---|---|---|
| Nha Trang Bay | Seaweed (*Sargassum* sp.) | 0.080 n = 1 | 0.06 n = 1 | 0.09 ± 0.02 n = 2 | 0.12 n = 2 |
| | Seaweed (*Gracilaria verucosa*) | 0.74 ± 0.09 n = 2 | NA | 0.04 n = 2 | 0.24 ± 0.01 n = 2 |
| | Trash fish | 1.41 ± 0.42 n = 2 | 0.16 ± 0.13 n = 2 | 0.05 ± 0.01 n = 2 | 0.15 ± 0.10 n = 2 |
| Van Phong Bay | Seaweed (*Kappaphycus alvarezi*) | 0.85 ± 0.09 n = 8 | <0.0005 n = 8 | 0.06 ± 0.02 n = 8 | 0.17 ± 0.06 n = 8 |
| | Seaweed (*Gracilaria verucosa*) | 0.79 ± 0.11 n = 7 | <0.0005 n = 8 | 0.09 ± 0.01 n = 7 | 0.25 ± 0.07 n = 7 |
| | Sea crab | 1.88 ± 0.04 n = 2 | 0.24 ± 0.02 n = 2 | 0.07 ± 0.01 n = 2 | 0.20 ± 0.04 n = 2 |
| | Trash fish | 0.70 ± 0.03 n = 2 | 0.38 ± 0.19 n = 2 | 0.07 ± 0.01 n = 2 | 0.38 ± 0.05 n = 2 |

All concentrations are given on a wet weight basis

**Table 3** Concentrations of Arsenic (As), Mercury (Hg), Cadmium (Cd) and Lead (Pb) in aquaculture organisms collected in Nha Trang Bay and Van Phong Bay

| | Samples | As (mg/kg) | Hg (mg/kg) | Cd (mg/kg) | Pb (mg/kg) |
|---|---|---|---|---|---|
| Nha Trang Bay | Abalone (*Haliotis diversicolor*) | 0.43 ± 0.19 n = 3 | 0.17 ± 0.07 n = 3 | 0.08 ± 0.04 n = 3 | 0.16 ± 0.08 n = 3 |
| | Sea bass (*Lates calcarifer*) | 0.59 ± 0.29 n = 3 | 0.11 ± 0.03 n = 3 | 0.04 ± 0.03 n = 3 | 0.07 ± 0.01 n = 3 |
| | Red snapper (*Sciaenops ocellatus*) | 0.14 ± 0.099 n = 2 | 0.10 ± 0.01 n = 2 | 0.10 ± 0.01 n = 2 | 0.09 ± 0.01 n = 2 |
| Van Phong Bay | Babylonia (*Babylonia areolata*) | 2.12 ± 0.25 n = 9 | 0.45 ± 0.04 n = 6 | 0.04 ± 0.01 n = 9 | 0.25 ± 0.03 n = 9 |
| | Green mussel (*Perna viridis*) | 1.03 ± 0.08 n = 9 | 0.42 ± 0.08 n = 6 | 0.06 ± 0.01 n = 9 | 0.37 ± 0.03 n = 9 |
| | Sea cucumber (*Sticophus japonicus selenka*) | 0.77 ± 0.06 n = 7 | 0.21 ± 0.01 n = 7 | 0.02 ± 0.01 n = 5 | 0.23 ± 0.02 n = 7 |
| | Abalone (*Haliotis diversicolor*) | 0.91 ± 0.10 n = 5 | 0.21 ± 0.03 n = 5 | 0.07 ± 0.01 n = 5 | 0.21 ± 0.01 n = 5 |

All concentrations are given on a wet weight basis

and Pd were generally low. The highest concentrations of Cd and Pb were found in the liver of tilapia, and the highest As concentration in the skin of tilapia. Maximum concentrations in muscle tissue were 0.120, 0.079 and 0.082 mg/kg wet weight for As, Cd and Pb, respectively. Consumption of fish with maximum muscle tissue concentration as found in their study will result in a human intake corresponding to 6.2%, 8.7% and 2.5% of the tolerable intake of these elements set by Codex Alimentarius Commission. The authors conclude that consumption of the examined species produced in wastewater-fed ponds seems not to constitute a food safety problem with respect to As, Cd and Pb.

The Vietnamese National Fisheries Quality Assurance and Veterinary Directorate (NAFIQAVET) have reported on the wet weight mean concentration in 40 samples of some selected heavy metals in some species examined from November 2006 to February 2007 (Anon. 2007). For White leg shrimp *(Penaeus vannamei)* the concentration of Cd and Pb were 0.002 and 0.03 mg/kg, respectively. The mean concentrations in Black tiger shrimp (*Penaeus monodon*) were 0.013 for Hg, 0.003 for Cd and 0.018 mg/kg for Pb.

In Catfish (*Pangasius hypophthalmus*) Cd in a concentration of 0.003 and Pb 0.046 mg/kg were reported, whereas the corresponding concentrations in Scampi (*Macrobrachium rosenbergii)* were for Cd and 0.028 mg/kg for Pb.

In a study by Nguyen Van (2004) 15 samples of farmed Tiger shrimp (*Penaeus monodon*) were examined with respect to the concentration of Cd, Hg and Pb. The Cd concentration ranged from 0.002 to 0.047 mg/kg, Hg from 0.006 to 0.023 mg/kg and the Pb concentration was found to be 0.020 mg/kg.

In our study the concentration of heavy metals in feed organisms and aquaculture organisms are as shown in Tables 2 and 3. The concentrations of As in the aquaculture organisms spanned from 0.14 to 1.03 mg/kg. For Hg the concentrations varied from 0.1 to 0.45 mg/kg, and for Cd from 0.02 to 0.10 mg/kg. The corresponding value for Pb was 0.07 to 0.37 mg/kg.

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