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Assessment of metal and bacterial contamination in cultivated fish and impact on human health for residents living in the Mekong Delta

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HIGHLIGHTS

- There were metals and microbial contaminations in fish in the southern Vietnam.
- Different methods of aquaculture cultivations affect metal concentrations in fish.
- Health impacts of Zn, As, and Cu are expected from daily fish consumption.
- Low infection risks of *Listeria* spp. and *Escherichia coli* in cooked fish (<2 log/g).
- Processing methods may cause higher microbial contamination in market fish.

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ABSTRACT

Fish is the main source of animal protein and micronutrients for inhabitants in the lower Mekong River basin. Consumption of fish in the basin ranges from 41 to 51 kg capita^{-1} year^{-1}. Thus, concerns of human health impacts caused by daily intake of metals contained in fish, and the incidence of bacterial contamination from *Listeria* and *Escherichia coli* have been raised. This study was conducted to 1) determine concentrations of metals, fecal indicator organisms, and *Listeria* spp. in cultivated common diet fish, and 2) assess human health risks as results of fish consumption on a daily basis. The results showed significant impacts of metal accumulation in fish especially from the intensive aquaculture. Chemical use to promote the rapid allometric growth of fish was expected to be the explanation for this finding. Concentrations of metals contained in different fish species were not statistically different with the exceptions of Na, Mn, and Zn. This might be due to the mobility of elements in aquaculture farms. *Listeria* and *E. coli* log CFU/g were 1.36 $\pm$ 0.11 (standard error) and 1.57 $\pm$ 0.1 s.e., respectively with higher counts observed in samples collected in market sites. Lastly, for human health risk assessment via fish consumption, it was found that hazard quotients of consuming As, Cu, and Zn contained in all fish species could contribute adverse health effects to the local residents (hazard quotients higher than 1). Therefore, risk management measures must be promoted and implemented in all study areas to reduce potential risks to local Vietnamese residents.

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1. Introduction

As a valuable source of a wide range of essential micronutrients, minerals, high quality of protein, as well as high content of unsaturated fatty acids, fish is a common food throughout the world (FAO

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Fisheries and Aquaculture Department, 2012; Jiang et al., 2014). For the Southeast Asia region, in particular, fish play an important role in staple diets in which annual consumption ranges from 6.1 kg capita^{-1} to 15.3 kg capita^{-1} (FAO Fisheries and Aquaculture Department, 2014). As clearly seen, the consumption levels vary considerably within the region. Consumption levels are generally high in countries located within the Mekong Delta such as Cambodia, Lao People's Democratic Republic, and Vietnam (FAO Fisheries and Aquaculture Department, 2014). The Mekong Delta is the most productive inland fisheries in the world with a total production of about 3.9 million tons in 2008, in which the amount of capture fisheries and aquaculture productions occupied about 1.9 and 2 million tons, respectively (Mekong River Commission, 2010). The Mekong Delta in Vietnam covering an area of 3300 km^2 has the largest aquaculture area in the basin. In addition, about 5000 cages ranging from 50 to 400 m^2 in size can be found in the delta (Mekong River Commission, 2002). The most commonly cultured species include pangasiid catfish, hybrid catfish, silver barbs, common carps, silver carps, Indian carps, snakehead, tilapia, giant gouramis, sand juveniles, sand goby, and shrimp (Sverdrup-Jensen, 2002; Mekong River Commission, 2010). About one million tons per year of cultured fish are exported and dominate sales in city markets for Thailand and Lao PDR (Mekong River Commission, 2010).

Recently, a few studies reported about metal contamination through the food chain within the Lower Mekong Basin (LMB). Food stuffs such as fish and rice collected from areas along Mekong River of Cambodia were found with high concentrations of arsenic (0.256 μg g^{-1} in rice, 0.178 μg g^{-1} in fish, and 0.062 μg g^{-1} in vegetable) and mercury in fish (642 ng g^{-1}) (Murphy et al., 2009; Phan et al., 2013). Food stuffs collected from the Mekong Delta of Vietnam were reported to have arsenic contamination in rice (0.471 μg g^{-1}), and several other trace metals (including copper, zinc, selenium, molybdenum, silver, cadmium, tin, manganese, selenium, barium and mercury) in aquatic food webs such as octopus and fish (Hanh et al., 2011; Tu et al., 2012). Though trace element concentrations measured in aquatic food webs were within safe levels for human consumption according to criteria established by the Ministry of Agriculture, Fisheries and Food in the UK, metals such as zinc, selenium, and mercury were found to be biomagnified. As humans are at the highest consumer level of the food web, concerns of the health importance of metals in the diet and food chain have been raised. Results of Murphy et al. (2009) and Hanh et al. (2011) showed elevated levels of mercury and arsenic in human hair for study areas in the LMB of Vietnam. Hanh et al. (2011) also found a significant correlation between daily arsenic intake through rice and drinking water determined by total arsenic concentrations in human hair. However reports of the impact of metal concentrations in fish to human health have not been sufficiently studied (Tu et al., 2012).

Consumption of fish and fish products can also be associated in outbreaks of foodborne illness where pathogenic *Escherichia coli* (Mitsuda et al., 1998) and *Listeria monocytogenes* (Tham et al., 2000) have been determined to be causes of infections (Novotny et al., 2004). Although *Listeria* spp. can survive in a wide variety of temperatures and be isolated readily from the environment, food is still a common source for human infections (McLauchlin et al., 2004) and this organism has been detected in fish and fish products (Karunasagar and Karunasagar, 2000; Jeyasekaran et al., 1996; Destro, 2000; Yücel and Balcienay, 2010). *E. coli* is an opportunistic pathogen and is also a classic indicator for fecal contamination, as it is a common organism within the gut of warm-blooded mammals (Nataro and Kaper, 1998). Despite being commonly associated with foodborne illness from contaminated meat, *E. coli* has also been isolated from seafood and fish products (Thampuran et al., 2005; Atanassova et al., 2008). Additionally published studies on the incidence and relative risk of bacterial pathogens in fish, and fecal contamination of fish within Southeast Asia is also limited.

Therefore, the objectives of this study were to 1) determine the concentrations of metals, fecal indicator organisms, and *Listeria* spp. in cultivated common diet fish, and 2) assess the human health risks of fish consumption on a daily basis.

2. Materials and methods

2.1. Study areas

Due to intensive aquaculture activities within the region, three sites located at the lower Mekong river basin of Vietnam including An Giang, Can Tho, and Hau Giang were selected as the study areas (Fig. 1). It is highly expected that, by 2020, Can Tho will have 26,000 ha for aquaculture which will be doubling the current area. With the expanded area, fishery production is expected to reach 335,000 metric tons valued at $1 billion. From its total production, 160,000 tons will be exported (Vietnam Association of Seafood Exporter and Producers (2013)). In the case of the An Giang Province, another famous area for cultivated fish seedlings, a total aquaculture area of 331 ha is expected to be reached by late 2016. In addition comparing to 2012, about a 30% increase in the value of each hectare is also estimated by 2020 (Invivo NSA Vietnam, 2016). Hau Giang is also known as one of the provinces with recent growth of export-oriented aquaculture cultivation, especially catfish (Ikeguchi et al., 2008). It was reported by the Hau Giang Provincial Department of Agriculture and Rural Development that the province is expected to expand its aquaculture area to 11 thousand hectares as well as fisheries production of 206 thousand tons by 2020 (Hau Giang Provincial Department of Agriculture and Rural Development, 2014; 2016).

2.2. Samples collection

Samplings were conducted during August 2013. Fish were collected by a grab sampling method from three different types of fish pond production operations including industrialized farms (intensive yields), reduced production farms with mid to high yields, and smaller production farms with low yield.

Various species of fish cultivated in these different types of aquaculture operations were collected. The fish species (indicated as common names) focused on in this present study were catfish, climbing perch, common carp, and snapper. Total number of fish collected from aquaculture ponds were 39 samples. Moreover, another 36 fish samples were also purchased from local markets (1 super market and 2 open air markets) located within the study areas. It was expected that market sources of fish were from local production sources within the provinces of interest. To confirm, prior to sample collection from local markets, sources and methods of cultivation of fish were determined using a questionnaire. Only fish of interested species indicated above that were cultivated from aquaculture systems in the study areas were collected. Once collected, fish samples were kept in polyethylene bags to minimize contamination by handling, and maintained at 4 °C in a cooler with blue ice. Processing of fish samples was done within 8 h of sampling in the field.

2.3. Chemical sample preparation and analysis

Acid digestion was performed for all fish samples. Briefly, about 0.10 g of fish were weighed and transferred into a 15 mL polyethylene tube. Then, 1 mL of the concentrated HNO_3 was added into each tube. The tube was capped and left in a hood at room

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