Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 09, Issue, 10, pp. 30181-30186, October, 2019

RESEARCH ARTICLE

OPEN ACCESS

EVALUATION OF THE CONCENTRATION OF HEAVY METALS IN FILLETS OF PANGASIUS HYPOPHTHALMUS (SAUVAGE, 1878), PANGA, IMPORTED FROM VIETNAM

Gisele Silva Costa Duarte, Ricardo Massato Takemoto, Mirian Ueda Yamaguchi, Liliane Stedile de Matos and Gilberto Cezar Pavanelli

[1]Universidade Estadual de Maringá, Programa de Pós-Graduação em Biologia Comparada, Maringá – PR, Brazil
[2]Universidade Estadual de Maringá, Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura - Nupélia, Maringá – PR, Brazil
[3]UniCesumar, Programa de Pós Graduação em Promoção da Saúde, Pesquisador do Instituto Cesumar de Ciência, Tecnologia e Inovação (ICETI), Maringá – PR, Brazil
[4]Universidade do Estado de Mato Grosso – UNEMAT, Campus Universitário de Alta Floresta, Ciências Biológicas, Campus II – Mato Grosso, Brazil

ARTICLE INFO

Article History:

Received 19th July, 2019
Received in revised form
23rd August, 2019
Accepted 06th September, 2019
Published online 16th October, 2019

Key Words:

Panga,
Contamination,
Aluminum,
Zinc.

***Corresponding author:** Gisele Silva Costa Duarte

ABSTRACT

Studies in several countries have warned on the contamination of fish by heavy metals, especially *Pangasius hypophthalmus*, farmed in the Mekong river, Vietnam, one of the most polluted rivers in the world, and exported to all countries. Current paper quantifies the concentrations of heavy metals in samples of frozen panga fillets. Risk to human health associated to the consumption of fillets was calculated according to heavy metal levels. Two batches of panga from Vietnam were acquired, each batch was ground and homogenized, a single sample of fillets was prepared and analyses were performed from the sample. Panga samples in current analysis did not contain any detectable rates for contaminants Cd, Cr, Ni and Hg, with rates below detection limit. Al and Zn were detected in the two samples. Zn rates were below limits permitted by Brazilian legislation. Risk Index (RI) for consumption of panga fillets was below 1.0 for the studied metals, except Al. When fish consumption at 0.030 kg / day for sporadic consuming adults was used as a reference, the RI of Al varied between 2,557 (1st batch of steaks) and 3,928 (2nd batch of steaks). In the case of fish consumption at 0.142 kg / day by habitual consuming adults, such as fishermen and riverine people, RI ranged between 12,103 (1st batch of steaks) and 18,595 (2nd batch of steaks), with adverse effects on human health. Results reinforce the relevance of greater monitoring of imported fish and the risk of human exposure to heavy metals.

Citation: ***Gisele Silva Costa Duarte, Ricardo Massato Takemoto, Mirian Ueda Yamaguchi, Liliane Stedile de Matos and Gilberto Cezar Pavanelli*, 2019.** "Evaluation of the Concentration of Heavy Metals in Fillets of *Pangasius hypophthalmus* (Sauvage, 1878), Panga, Imported From Vietnam", *International Journal of Development Research*, 09, (10), 30181-30186.

INTRODUCTION

Since fish is one of the most important foods consumed by humans, assessment of its quality is paramount. Due to concern on food safety, zoonoses, bacteria-caused diseases, the accumulation of heavy metals should be taken into account when fish is included in human diet (Pavanelli *et al*., 2015). Pb, Cu, Hg and Cd may be underscored as the most relevant metals related to human health (Chen *et al*., 2007; Bhouri *et al*., 2010; Elnimir 2011). Since biomagnification of metals throughout the trophic chain mainly occurs by ingestion of fish, the panga may contain toxic elements such as arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd) and chromium (Cr). These elements may have originated from pollution sources of surface waters caused by discharges of industrial effluents, depositions from the atmosphere and accidents involving toxic chemical compound (Ikem, 2005). The concentration of heavy metals in eatable fish species has been recently focused upon and studied since food is the main vector of contaminants in humans (Castro-Gonzeza *et al*., 2008; Guimarães *et al*., 2016; Molognoni *et al*., 2016). In fact, there is evidence that industrial and domestic effluents, released into streams and rivers which receive production systems for aquaculture, pollute water bodies. It is the case of the Mekong Delta in Vietnam where potentially toxic elements to the biota have been frequently detected, with the consequent contamination of fish in fish farms or otherwise and of people that consume them (Hoang 2010; Berg, 2007). Several studies in different countries have pointed out contamination by heavy metals in several fish species, with special reference to *Pangasius hypophthalmus* (Elnimir 2011; Morgano *et al*., 2011; Popa *et al*., 2012; Trojnar *et al*., 2015; Ullah *et al*., 2017; Das*et al*., 2017). Farmed in the Mekong River, perhaps one of the most polluted rivers in the world according to several scientific journals (Chea *et al*., 2016; Le Trinh, 2017), the panga has been targeted for its highly questionable quality and origin, causing serious risks to consumers due to its high rate of heavy metals and other chemical products that accumulate in its muscles (Popa *et al*., 2012; Ullah *et al*., 2017; Rodriguez *et al*., 2018). *Pangasius hypophthalmus* (panga), a catfish imported from Vietnam, is widely consumed in Brazil. The species has been highly underscored in the media due to its low commercialization costs and to misleading advertisements by which it is sold as the much more expensive flounder (Carvalho *et al*., 2015).Imported panga from Vietnam has risen from 3,280 to 54,700 tons between 2009 and 2013 (Scorvo Filho, 2014).Since *Pangasius hypophthalmus* is already being farmed in Brazilian experimental research stations, it is prudent and necessary to assess specimens from Vietnam for eventual comparisons between the panga produced in Brazil and the imported one. It is also highly relevant to define whether fish sold on the Brazilian market have the quality expected of the product. This is especially urgent since several schools have introduced the species in their lunch diet for students, due to low costs. Extractive fishing in the Mekong River has been lately compounded by the development of fish farming by Chinese in healthier environments, even though there are still doubts on the origin of imported panga, whether they come from fish farms, extractive sources or both. There is still great health risk associated with the consumption of the species which must be thoroughly investigated to detect any danger for human health (Begum *et al*., 2005; Molognoni *et al*., 2016; Guimarães *et al*., 2015). Scanty information is available in Brazil on heavy metals in panga. The few extant publications deal with bacteriological analyses and chemical quality (Guimarães *et al*., 2015; Molognoni *et al*., 2016). Current assay evaluates concentrations of Al, Cd, Pb, Cr, Hg, Ni and Zn in samples of Vietnamese frozen panga (*P. hypophthalmus*) fillets for possible contamination by heavy metals. Risk to human health associated with the consumption of panga fillet may be calculated by evaluating the amounts of metals present.

MATERIALS AND METHODS

Samples

Twenty-five samples of frozen fillets of *Pangasius hypophthalmus*, weighing 3.2 kg, from two different batches, were bought in a supermarket network in Maringá, Brazil, in December 2017 and March 2018. Package label showed that the fish were imported from Vietnam. The frozen fillets were analyzed in the Bioagri Ambiental laboratory, specialized in biological analyses, following assay reports 368328/2017-0 and 47676/2018-0. Each panga fillet lot, ground and homogenized, became a single fillet sample. Metals were analyzed from the sample produced. Samples were prepared in ICP-MS by digestion with nitric acid and hydrogen peroxide at temperatures ranging between 70°C and 120°C. Metal counts were done in triplicate by Inductively Coupled Plasma Mass Spectrometry.

Estimating risks to human health

Human health risks were determined according to requirements by the US Environmental Protection Agency (NAS, 1991; USEPA, 2009). So that the exposure level resulting from the consumption of heavy metal in any eatable tissue of fish (muscles) may be calculated, the equation for a daily mean dose (DMD=mean daily ingestion of a specific heavy metal throughout a life time) may be estimated by:

DMD (mg/kg/d) = (C*TI*FE*DE)/(PC*TV)

where: C is the mean concentration of heavy metals in fish eatable tissues (mg/kg); TI is the mean ingestion rate (0.030 kg/day for sporadic adult consumers of fish and 0.142 kg/day for habitual adult consumers of fish); FE is exposure frequency (365 days/year); DE is the duration of exposure throughout a life span (70 years); PC is body weight (70 kg for normal adults); TV is mean life time (70 years x 365 days/year). Risk evaluation was measured by calculating the Risk Index (RI) which is the index of non-development of cancer due to the effects on health by heavy metals in food. It may be expressed as the ratio between DMD and DRf (reference dose given by mouth) of the specific heavy metal, according to the equation:

RI = IMD/ DRf, where, DRf is the heavy metal reference dose given by mouth (mg/kg/day), based on the highest ingestion rate of a determined metal for a human adult with a mean body weight of 70 kg. Oral DRf for Hg, Zn, Al, Ni, Cd, Cr and Pb is that suggested by FAO and WHO (WHO, 2008; USEPA, 2009). RI rates <1.0 show no susceptibility of developing cancer. However, if the concentration of a specific heavy metal exceeds its oral DRf and, thus, RI is ≥1.0, it may be presumed that negative health effects will ensue.

RESULTS

Table 1 shows results from analyses of Vietnam-importedpanga fillet samples, bought between December 2017 and March 2018. RI rates for the consumption of *Pangasius hypophthalmus* fillets imported from Vietnam were below 1.0 for the metal under analysis, with the exception of Aluminum (Table 1). When reference was the consumption of 0.030 kg/day of fish by sporadic adult consumers, the RI of Aluminum ranged between 2.557 (1st lot of fillets) and 3.928 (2nd lot of fillets); in the case of consumption of 0.142 kg/day of fish by habitual adult consumers, such as fishermen and riverine people, RI ranged between 12.103 (1st lot of fillets) and 18.595 (2ndlot of fillets) with negative health risk (Table 2).

DISCUSSION

Panga samples analyzed for Al, Zn and Pb revealed the presence of these elements, with 3.58 mg.kg^{-1} for Al in the first sample and 5.5 mg.kg^{-1} in the second sample; 17.3 mg.kg^{-1} for Zn in the first sample and 9.02 mg.kg^{-1} in the second sample; 0.166 mg.kg^{-1} for Pb in the first sample; Pb was not detected in the second sample. Although present in the samples analyzed, Zn and Pb had lower rates than those permitted in Brazilian and International legislation (FAO/WHO, 1984).In the case of Al, concentrations were above those allowed by international legislation, or rather, 1.0 mg.kg^{-1} (FAO/WHO, 2007) Zn and Pb concentrations in panga fillets did not present any health risk for humans. Moreover, panga fillet samples did not show any traces of the heavy metals Cadmium, Chromium, Nickel (<0.05 mg.kg^{-1}) and Hg (<0.025 mg.kg^{-1}). They were below the method´s detection limits.

Table 1. Results by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to determine metals in 25 samples of *Pangasius hypophthalmus* fillets imported from Vietnam. Results (mg.kg-¹)

Metals	LQ	1st lot	2nd lot
Aluminum	0.05	3.58	5.50
Cadmium	0.05	< 0.05	< 0.05
Chromium	0.05	< 0.05	< 0.05
Lead	0.05	0.166	< 0.05
Mercury	0.025	< 0.025	< 0.025
Nickel	0.05	< 0.05	< 0.05
Zinc	0.05	17.3	9.02

Quantity Limits (LQ): 0.05 mg.kg-1 (Aluminum), 0.05 mg.kg-1 (Cadmium), 0.05 mg.kg- (Chromium), 0.05 mg.kg-1(Lead), 0.025 mg kg-1 (Mercury), 0.05 mg kg-1 (Nickel) e 0.05 mg kg-1 (Zinc).

Table 2. Concentration of heavy metals in *Pangasius hypophthalmus* fillets imported from Vietnam, DRf (dose of heavy metal by mouth) and RI (risk index of negative health effects) rates

Heavy metals	Mean concentration in muscles (mg.kg^{-1})	RfD (mg/kg/d)	RI – sporadic adult consumers	RI – habitual adult consumers
Hg	<0.025	0.0003	<0.036	<0.169
Zn	9.02 - 17.30	0.2600	0.014 - 0.028	0.070 - 0.135
Al	3.58 - 5.50	0.0006	2.557 – 3.928	12.103 – 18.595
Ni	<0.05	0.0090	<0.002	<0.011
Cd	<0.05	0.0010	<0.021	<0.101
Cr	<0.05	0.0006	<0.035	<0.169
Pb	0.05 - 0.166	0.0036	0.006 - 0.019	0.028 - 0.094

The inorganic elements Cu and Zn are necessary for the physiological regulation of vertebrates (Hogstrand *et al*., 1991), even though they may bio-accumulate and reach more toxic levels.28 In fact, they may contaminate human beings and cause lung diseases, gastroenteritis, fever, vomits, deficiency in muscle coordination and dehydration (Rietzler*et al*., 2001). The concentration of heavy metals in imported *P. hypophthalmus* on the Brazilian market has still to be assessed. Guimarães *et al*. (2015)evaluated the parameters of chemical quality in Vietnamese fish fillets of the same species and determined its pH, ammonia, biogenic amino acids, Hg, malondialdehyde and polyphosphate. Further, Molognoni *et al*. (2016) assessed As, Cd, Pb, Cu and Cr levels in Vietnam-imported panga fillets and reported that 80% of the 20 samples under analysis had Cd levels above the maximum concentration allowed. The authors also registered that Cr concentrations were below detection limits, corroborating results in current study. Further, Molognoni *et al*. (2016) detected low Cu concentrations, ranging between 0.0127 and 0.0366 mg.kg-¹. However, the panga is capable of gradually accumulating Cr and Cu after experimental exposure to high concentrations of the elements (Fauziah *et al*., 2013). Although Cu is an essential trace element for the organism, its accumulation in the blood causes pain in the muscles and joints, learning disorder, depression and fatigue. Moreover, accumulation of Cu in the liver causes irreversible brain and hepatic alterations (Baierle *et al*., 2010). According to Brasil (2013), Resolution 42 of the Anvisa, maximum limit for contaminating elements in raw fish, frozen or refrigerated, for Zn is 30 mg.kg-¹;for Pb is 0.30 mg.kg-¹;for Cd is 0.05 mg.kg-¹;for Cr is 0.10 mg.kg-¹; for Ni is 5.0 mg.kg-¹ and for As is 1.00 mg.kg-¹. In the case of Al, no reference rates for maximum concentrations in fish are extant in Brazilian legislation. However, international legislation put the limit 1.0 mg.kg-¹ for Al (FAO/WHO, 2007). Excess of Al in the human body may cause toxic effects, such as hypochromic and microcyte anemia, a risk factor for Alzheimer´s disease, and acute neurotoxicity. Further, gait and speech disturbances may occur, coupled to hearing and visual hallucinations and bone diseases (Barreto *et al*., 2011). If all the metals analyzed in current study were below the established limits for human consumption, the calculation for RI for sporadic and habitual adult consumers is high in the case of Al.

Ingestion limits by WHO are based on the maximum limit of a specific metal that one may ingest so that no significant risk of health deleterious effects may occur. However, body weight and amount of fish ingested per day are important. Limits suggested by legislation were calculated for a person weighing approximately 60 kg, who ingests approximately 250 g of fish per week. However, in the case of sensitive groups of people (children, breast-fed children and breast-feeding women), the ingestion of metals should be low due to risks to children´s neurological system and developing fetuses. On the other hand, studies on risks by contaminants and benefits provided by the consumption of fatty acids Omega 3 have demonstrated that benefits exceed risks implied (Mozaffarian *et al*., 2006; Mahaffey *et al*., 2011).Frequency of consumption and size of the fish portion are relevant to balance benefits and risks in the regular consumption of fish (Domingo, 2007). According to Brasil (2013), levels of inorganic contaminants in food should be the lowest possible and all available technology should be employed to avoid the contamination, commercialization or consumption of a specific type of food. Although Zn and Pb occurred in the samples, their rates were below limits permitted by Brazilian legislation, and thus, concentration would not put health to risk when fish is ingested. Several international studies have been published on variations of metal contamination levels among fish species (Legorburu *et al*., 1988; Begum *et al*., 2005; Velcheva 2006; Priprem *et al*., 2007). Srivastava *et al*. (2014) evaluated Cu, Pb, Ni, Cd, Cr and Zn levels in the muscles of *P. hypophthalmus* available on the fish market in Utter Pradesh, India. They compared results with metal accumulation in the same species bred on the local farms. Results by Srivastava *et al*. (2014) demonstrated that farmed fish were safer for consumption than fish sold on the market since cancer risks in the latter were higher. Moreover, Pb, Cd, Cr and Znconcentrations were greater than the limit imposed by WHO (2007)in market fish when compared to farmed ones. Studies by Grudpan *et al*. (2016) also assessed contamination by Cd, Cr, Cu, Pb, Mn and Zn in the liver, kidney and muscle of the catfish *Helicophagus leptorhynchus* from the Mun River, the large affluent of the Mekong River in Thailand. The authors reported that Zn had the greatest concentration level in all samples, or rather, two or three times the level permitted for the element in eatable fish (FAO, 1983 and FDA, 2011). Further, Mortuza *et al*. (2015) analyzed several fish species harvested in Bangladesh and discovered that mean metal concentrations in fish muscles varied according to a decreasing order: Zn> Fe> As> Cu> Sr> Mn> Cr> Se>Ni> Co> Pb> Mo> Cd> Sb> Be. Results corroborated those in current study for highest Zn concentration rates in frozen fillets of *P. hypophthalmus.* Concentrations of Ni and Cr in panga fillets were below detection levels, contrastingly to results by Kulawik *et al*. (2016) who reported significant differences in Ni concentration in panga and a greater amount of Crwhen compared to elements in the Nile tilapia. Although Cr is an essential trace element, it may be toxic due to oxidation. Cr VI is the most dangerous since it is cancerigenous. It is produced by industrial processes and affects the human immunological system (Gomes *et al*., 2005).

The Hg element in the samples under analysis was below detection limits. However, results differ from those by Reham (2011) who investigated heavy metal rates in panga and sardine fillets on different fish markets in Qalyubia and Gharbia, Egypt. Hg rates were higher in the panga than in sardines, with limits beyond the 0.50 mg.kg-^{1} recommended by the Egyptian Organization for Standardization and Quality Control (EOS, 2005). Excessive Ni in the organism has toxic effects and generally causes gastrointestinal pain, apathy, diarrhea, fever, insomnia and nauseas. It is also toxic and cancerigenous to humans (Gonzalez, 2016). Hg in the samples was below detection limit, different from results by Amin (2011) who analyzed heavy metal rates in frozen panga and sardine fillets from different fish markets in the provinces of Qalyubia and Gharbia, Egypt. Hg rates were higher in panga than in sardines, exceeding limit (0.50 mg.kg-^{1}) recommended by (EOS, 2005).When Guimarães *et al*. (2015) investigated safety aspects based on several chemical quality parameters of *P. hypophthalmus* fillet from Vietnam, they reported that 50% of samples featured Hg rates higher than limits (0.51-1.31 mg.kg-^{1}) recommended by (FAO, 2007).Moreover, Ferrantelli *et al*.(2012)evaluated Hg rates in panga and cod fillets commercialized in Sicily, Italy, and detected mercury in all samples analyzed. Further, Hg levels in panga (0.41±0.08 mg.kg-^{1}) were higher than those in cod (0.11± 0.004 mg.kg-^{1}), with statistically significant differences at $p \leq 0.001$. The presence of Hg in low concentrations may cause chronic intoxication, bronchitis, lung edema, excessive salivation, kidney lesions, trembling, convulsions, bellyache, vomits, diarrhea, hallucinations, irritability, memory loss, mental confusion, abnormal reflexes, coma and even death (Zavariz *et al*., 1993). Molognoni *et al*. (2016) assessed As, Cd, Pb, Cu and Cr rates in panga fillets from the provinces of Dong Thap and Can Tho, Vietnam, and exported to Brazil. Although they did not detect As, Cr, Cu and Pb in the samples, Cd did not comply with legal levels. Once more, the importance of monitoring imported panga quality should be underscored.

Trojnar *et al*. (2015) compared Cd, Zn, Mn and Ni concentrations in fillets from four fish species on the Polish market, namely, Nile tilapia, panga imported from Asian fish farms, Alaska pollock and rainbow trout, and reported greater Cd levels in the muscles of panga and tilapia. Current results corroborate those by Molognoni *et al*. (2016) who did not report any detectible traces for As, Cr, Cu and Ni. Results differed in the case of Pb (0.166 mg.kg-^{1}) found in the sample, even though rates were within Brazilian and international level ranges. The main clinical effects from Pb exposure are gastrointestinal, renal, reproductive, hematological, neurological and carcinogenic diseases (Schifer *et al*. 2005). Studies on the rates and bioaccumulation of metals in *P. hipophthalmus* from fish farms in Bangladesh by Das *et al*. (2017) revealed that Cu concentration was higher than all international standards, with Pb and Cr slightly higher than established parameters. They also reported that concentration of metals in fish muscles indicated a certain bioaccumulation degree. Results corroborate those in current assay with regard to Pb in panga. Although they are within the limits allowed by Brazilian legislation. Costa *et al*. (2001) evaluated Aland Hglevels in *Colossoma macropomum* (known as tambaqui in Brazil) from the cold waters of the igarapes of Parauapebas PA Brazil. Al rates reached 213.27±98.68 mg.kg-^{1}, above legal limits. In current assay, Al rates for the frozen panga samples were (3.58 mg.kg-^{1}; 5.50 mg.kg-^{1}). However, reference rates for Al are not extant for maximum concentrations in fish according to Brazilian legislation, contrastingly, international legislation (FAO/WHO, 2007) marked the limit of 1 mg.kg^{-1}of Al for human consumption. Aluminum is a more abundant metal and ranks third on the Earth surface (Exley, 2003). However, the geochemical cycle of aluminum became a biogeochemical cycle due to human activities, indirectly (e.g. the acidification of water basins by anthropic acid deposits) or directly (e.g. extraction of aluminum from its inert minerals) (Hachez-Leroy, 2013). As remarked above, the Mekong river, from where the samples in current studies originated, is a highly polluted river and its fish may be thereby also contaminated. It should be underscored that, the detection of heavy metals in the samples is a warning for health authorities. Further studies must be undertaken with more diversified samples, or rather, with a greater number of samples, different trademarks and from different supermarkets). Contamination by heavy metals in species reared in fish farms should be regularly monitored against possible risks in human health. Public policies should also be defined to protect populations from ingesting contaminated products.

Conclusion

Data reveal that, although *Pangasius hypophthalmus* is highly consumed by Brazilian people, samples commercialized in a supermarket network in Maringá, Brazil, contained Pb and Zn within rates permitted by Brazilian and international limits, with the exception of Al which presented above-permitted levels and high values of risk index for human consumption. However, it should be underscored that ANVISA always warns that inorganic elements in food should be at the lowest levels possible. Public health care and environmental concerns with regard to the consumption of fish should be in the limelight. Data reinforce the importance of more effective monitoring with regard to imported fish prior to commercialization to better evaluate contamination risk by heavy metals resulting from the accumulation or bioaccumulation of metals especially in regions where fish is daily consumed. Further in-depth investigation on the matter is required not only on *Pangasius hypophthalmus* but on all fish species consumed by humans.

Declaration of conflicting interests: The authors declare that they have no conflicts of interest.

REFERENCES

Baierle M, Valentini J, Paniz C, Moro A, Barbosa Junior F and Garcia SC. 2010. Possible effects of blood copper on hematological parameters in elderly. *J Bras Patol Med Lab,* 46(6):463-70.

Barreto FC, Araújo SMHA. 2011. Intoxicação alumínica na doença renal crônica. *J Bras Nefrol,* 33(suppl 1):21-25.

Begum A, Amin MN, Kaneco S, Ohta K. 2005. Selected elemental consumption of the muscle tissue of three species of fish, *Tilapia nilotica*, *Cirrhina mrigala* and *Clarius batrachus*, from the fresh water Dhanmondi Lake in Bangladesh. *Food Chemistry*, 93:439-443.

Berg M, Stengel C, Trang PTK, Viet PH, Sampson ML, Leng M. 2007. Magnitude of arsenic pollution in the Mekong and Red River Deltas: Cambodia and Vietnam. *Sci Total Environ,* 372(2-3):413-25.

Bhouri AM, Bouhlel IL, Chouba M, Hammami CE and Chaouch A. 2010. Total lipid content, fatty acid and mineral compositions of muscles and liver in wild and farmed sea bass (Dicentrarchuslabrax). *African J Food Sci,* 4:522-530.

Brasil. Ministério da Saúde, 2013. Agência Nacional de Vigilância Sanitária. *Resolução-RDC n. 42, de 29/08/2013* – Regulamento Técnico Mercosul sobre Limites Máximos de Contaminantes Inorgânicos em Alimentos. Brasília: Diário Oficial da União.

Carvalho Filho J. 2010. Panga: um peixe bom de cultivo e de polêmica. *Rev Panorama da Aquicultura,* 20:57-61.

Castro-Gonzeza MI, Mendez-Armentab M. 2008. Heavy metals: implications associated to fish consumption. Environ. *Toxicol Pharmacol*, 26(3):263-271.

Chea R, Grenouillet G, Lek S. 2016. Evidence of Water Quality Degradation in Lower Mekong Basin Revealed by Self-Organizing Map. *PLoS ONE*, 11(1):e0145527.

Chen YQ, Edwards JJ, Kridel SJ, Thornburg T, Berquin IM. 2007. Dietary fat gene interactions in cancer. *Cancer metastasis Reviews*, 26(3-4):535-551.

Costa DA, Palheta DC, Nascimento Junior AS, Sousa MSD, Pereira SFP. 2011. Avaliação dos níveis de alumínio e mercúrio em tecidos e conteúdo estomacal de *Colossoma macropomum* (tambaqui) da área de preservação ambiental do igarapé gelado no município de Parauapebas-Pará. In: *Anais do 38º Congresso Brasileiro de Medicina Veterinária*, 2011; Florianópolis. Florianópolis: Soc Bras de Med Vet.

Das PR, Hossain MK, Sarker BS, Parvin A, Das SS. 2017. Heavy Metals in Farm Sediments, Feeds and Bioaccumulation of Some Selected Heavy Metals in Various Tissues of Farmed *Pangasius hypophthalmus* in Bangladesh. *Fish Aqua J*, 8(3):1-8.

Domingo JL. 2007. Omega-3 fatty acids and the benefits of fish consumption: is all that glitters gold? *Environ Int,* 33(3):993-998.

Egyptian Organization for Standardization and Quality Control (EOS), 2005. *Maximum level for heavy metal contaminants in foods*. Es nº. 2360.

Elnimir T. 2011. Evaluation of some heavy metals in Pangasius hypothalmus and Tilapia nilotica and the role of acetic acid in lowering their levels. *Int J Fish Aquac*, 3(8):151-157.

Environmental Protection Agency, U.S. EPA. 2009. EPA Order 5360: *The EPA Quality Manual for Environmental Programs*. Washington, DC.

Exley C. 2003. A biogeochemical cycle for aluminium? *J Inorg Biochem*, 97(1):1-7.

FAO/WHO Expert Committee on Food Additives, 2007. *Evaluation of certain food additives and contaminants*. WHO Tech Rep Ser 940:33-44.

Fauziah SH, Emenike CU, Agamuthu P. 2013. Leachate risk and identification of accumulated heavy metals in *Pangasius sutchi*. *Waste Manage Res*, 31(suppl 10):75-80.

FDA, 2011. Title 21: Food and drugs. Chapter I: Food and drug administration. Department of Health and Human Services. U.S. Food and Drug Administration. Available: http://www.gpo.gov/fdsys/pkg/CFR-2011-title21-vol3/pdf/CFR-2011-title21-vol3chapI.pdf

Ferrantelli V, Giangrosso G, Cicero A, Naccari C, Macaluso A, Galvano F, D'orazio N, Arcadipane GE, Naccari F. 2012. Evaluation of mercury levels in Pangasius and Cod fillets traded in Sicily (Italy). *Food Add e Cont,* 29(7):1046-1051.

Food and Agriculture Organization of the United Nations, 1983. *Manual of methods in aquatic environment research* [Part 9 Analyses of metals and organochorines in fish]. FAO Fish Tech Pap 212:33.

Food and Agriculture Organization/World Health Organization - FAO/WHO, 1983. *Food consumption and exposure assessment of chemicals*. Geneva, Switzerland: Report of FAO/WHO Consultation.

Gomes MR, Rogero MM, Tirapegui J. 2005. Considerações sobre cromo, insulina e exercício físico. *Rev Bras Med Esporte,* 11(5):262-266.

Gonzalez KR. 2016. Toxicologia do Níquel. *Revinter*, 9(2):30-54.

Grudpan J, Pradermwong KP. 2016. Heavy Metal Contamination in Indochinese Molluscivorous Catfish (*Helicophagus leptorhynchus* Ng & Kottelat, 2000) from Mun River Basin, *Ubon Ratchathani Province*, 40(1).

Guimarães CFM, Mársico ET, Monteiro MLG, Lemos M, Mano SB, Conte Junior CA. 2015. The chemical quality of frozen Vietnamese *Pangasius hypophthalmus* fillets. *Food Sci Nutr,*4(3):398-408.

Hachez-Leroy F. 2013. Aluminium in health and food: a gradual global approach. *European Review of History: Revue européenne d'histoire,* 20(2):217-236.

Hoang TH, Bang S, Kim KW, Nguyen MH, Dang DM. 2016. Arsenic in groundwater and sediment in the Mekong River delta, Vietnam. *Environ Pollut*, 158(8):2648-2658.

Hogstrand C, Haux C. 2001. Binding and detoxifcation of heavy metals in lower vertebrates with reference to metallothionein. *Compd Biochem Physiol*, 100(1-2):137-141.

Ikem A, Egiebor NO. 2005. Assessment of trace elements in canned fshes (mackerel, tuna, salmon, sardines and herrings) marketed in Georgia and Alabama (United States of America). *J Food Comp Anal,* 18(8):771-787.

Kulawik P, Migdał W, Tkaczewska J, Gambuś F, Szczurowska K, Özoğul F. 2016. Nutritional Composition of Frozen Fillets from Pangasius Catfish (Pangasius hypophthalmus) and Nile Tilapia (*Oreochromis nilotcus*) Imported to European Countries. *Annals of Animal Sci,* 16(3):931-950.

Le Trinh, 2017. *Water pollution in the Mekong Delta*: sources, present, future, ecological impacts and mitigation. Institute for Environmental Science and Development (VESDEC), prepared for the International Water Forum. Chungnam, Korea.

Legorburu I, Canton L, Millan E, Casado A, 1988. Trace Metal Levels in Fish from Unda River (Spain) Anguillidae, Mugilidae and Salmonidae. *J Environ Technol Lett,* 9(12):1373-1378.

Mafra D, Cozzolino SMF, 2004. Importância do zinco na nutrição humana. *Rev Nutr,* 17(1):79-87.

Mahaffey KR, Sunderland EM, Chan HM, Choi AL, Grandjean P, Mariën K, *et al*. 2011. Balancing the benefits of n-3 polyunsaturated fatty acids and the risks of methylmercury exposure from fish consumption. *Nutr Rev* 69(9):493-508.

Molognoni L, Vitali L, Ploencio LAS, Santos JN, Daguer H. 2016. Determining the arsenic, cadmium, lead, copper and chromium contents by atomic absorption spectrometry in Pangasius fillets from Vietnam. *J Sci Food Agric*, 96(9):3109-3113.

Morgano MA, Oliveira APF, Rabonato LC, Milani RF, Vasconcellos JP, Martins CN. 2011. Avaliação de contaminantes inorgânicos (As, Cd, Cr, Hg e Pb) em espécies de peixes. *Rev Inst Adolfo Lutz*70(4):497-506.

Mortuza MG, Al-Misned FA. 2015. Trace elements and heavy metals in five cultured and captured fishes from Rajshahi City, Bangladesh. *Biomed Sciences Today*, 1:1-10.

Mozaffarian D, Rimm EB. 2006. Fish intake, contaminants, and human health: evaluating the risks and the benefits. *JAMA*. 296(15):1885-1899.

National Academy of Sciences. *Seafood safety* (1991). Washington, DC: Committee on Evaluation of the Safety of Fishing Products, National Academy of Sciences.

Pavanelli GC, Eiras JC, Yamaguchi MU, Takemoto RM. 2015. Zoonoses *Humanas Transmissíveis por Peixes no Brasil*. Maringá, Paraná: UniCesumar.

Popa C, Bulai P. 2012. Fish pollution with heavy metals. *Food and Environ Safety J,* 11.

Priprem A, Sripanidkulchai B, Wirojanagud W, Chalorpunrut P. 2007. Heavy metals in freshwater fish along Pong and Chi rivers. *KKU Research J,* 420-430.

Reham RAA. 2011. Heavy metal residues in imported frozen fish and *Pangasius hypophthalmus* (Basa) fish fillets. *Benha Vet Med J*, 2:13-21.

Rietzler AC, Fonseca AL, Lopes GP. 2001. Heavy metals in tributaries of Pampulha reservoir, Minas Gerais. *Braz J. Biol,* 61(3):363-370.

Rodríguez M, Gutiérrez ÁJ, Rodríguez N, Rubio C, Paz S, Martín V *et al*. 2018. Assessment of mercury content in Panga (*Pangasius hypophthalmus*). *Chemosphere,* 196:53-57.

Schifer TS, Bogusz Junior S, Montano MAE. 2005. Aspectos toxicológicos do chumbo. *Infarma,* 17(5-6):67-72.

Scorvo Filho JD. 2014. Panga "Made in Brasil"! Além de importar o país também já cria o peixe vietnamita. *Rev Panorama da Aquic,* 24:30-33.

Srivastava SC, Verma P, Verma AK, Singh AK. 2014. Assessment for possible metal contamination and human health risk of Pangasianodon hypophthalmus (Sauvage, 1878) farming, India. *Int J Fisheries and Aquatic Stud*, 1(5):176-181.

Trojnar EL, Bloniarz P, Winiarski B, Kozak ED, Popek W. 2015. Comparison of cadmium, zinc, manganese and nickel concentrations in fllets of selected species of food fish.*Sci Annals of Polish Soc of Animal Prod*, 11(1):75-84.

Ullah AKMA, Maksud MA, Khan SR, Lutfa LN, Quraishi SB. 2017. Dietary intake of heavy metals from eight highly consumed species of cultured fish and possible human health risk implications in Bangladesh. *Toxicol Rep*, 4:574-579.

Velcheva IG. 2006. Zinc Content in the Organs and Tissues of Freshwater Fish from the Kardjali and Studen Kladenets Dam Lakes in Bulgaria. *Turk. J. Zool*, 30:1-7.

World Health Organization – WHO, 2007. Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization,* Geneve, 85:660-667.

World Health Organization – WHO, 2008. United Nations Environment Programme. *Guidance for identifying populations at risk from mercury exposure*. Geneva: World Health Organization.

Zavariz C, Glina DMR. 1993. Effects of Occupational Exposure to Mercury in Workers at a Light Bulb Factory in Santo Amaro, São Paulo, Brazil. *Cad. Saúde Pública,* 9(2):117-129.

****