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HEAVY METAL BIOACCUMULATION IN DUCKS AND POSSIBLE RISKS TO HUMAN HEALTH

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ABSTRACT

Meat is part of duck carcass mostly consumed by humans compared to other parts. This study aimed to analyze the heavy metal bioaccumulation factor (BAF) of duck meat and its possible risks to human health. A total of 25 duck samples with their drinking water and feed were taken from five intensive duck farms in Central Java Province, i.e., Semarang (A), Temanggung (B), Magelang (C), Pati (D) and Salatiga (E). Heavy metals concentration (As, Cd, Hg, and Pb) were measured following the ICP-OES method. Heavy metals concentration data obtained were then compared with the quality standard. The BAF value was calculated and the risks to human health were assessed. Our study found that drinking water provided for ducks in all farms contained heavy metals (As, Cd, Hg, and Pb) concentrations exceeding the quality standards. Hg concentration of 0.089 - 5.01 ppm in duck feed exceeded the quality standard. Concentrations of Cd (0.0713 - 0.075 ppm) and Hg (3.1 - 4.84 ppm) in duck meat exceeded the quality standard. The average of $BAF_{duck\ meat}$ values was in the range of 0.443 - 0.955. The EDI value of heavy metals (As, Cd, Hg, and Pb) for adults and children through consumption of duck meat in the Central Java region was lower than RfD. This study showed that the health risk parameters (EDI, HQ, and HI) were within safe limits. Exposure to heavy metals through duck meat consumption both in adults and children was unlikely to cause adverse health effects.

Keywords: bioaccumulation, duck, estimated daily intake, heavy metals, human health

INTRODUCTION

Indonesia is an agricultural country where most of the population work as farmers and breeders. Ducks are among the leading livestock commodities in Indonesia. The duck population in Indonesia ranks third in the world after China and Vietnam (Ismoyowati & Sumarmono 2019). In 2018, Indonesia's duck population was recorded to reach 51,239,185 (Department of Livestock and Animal Health 2019). The duck population in Central Java Province ranks fourth after East Java Province, with a population of more than 5 million (The Central Statistics Agency of Central Java Province 2018).

In the last decade, duck meat has been favored by many people. Duck meat also determines the agricultural economy. Based on the total production of duck meat in the world, Asian countries contributed 84.2%. The muscle fiber content of duck breast is higher than chicken meat, so it is often referred to as red meat (Biswas *et al.* 2019). Duck meat contains essential amino acids, vitamins, and minerals (Reis *et al.* 2010) and it tastes very delicious and is favored by most people. Based on those reasons there has been quite an increase in duck farming. In general, however, the quality of the foodstuff is not only determined by its nutritional content, but also by the safety of the food itself. Foodstuff must be free from harmful substances. The public's concern about the importance of food safety has increased.

Some cases related to food safety occur due to contamination of microorganisms, pesticides, hormones, antibiotics, and heavy metals. The consumption of foodstuffs is considered to be one of the main routes of heavy metal exposure to the human population. Heavy metal contamination is a major problem because it affects the structural and functional integrity of the ecosystem. Heavy metal contamination of

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meat, vegetables, and fish is a serious problem for food safety and a threat to human health (Bortey-Sam *et al.* 2015) as most of these metals are toxic even at very low concentration levels.

Dietary intake accounts for more than 90% of heavy metal exposure compared to other routes such as inhalation and dermal absorption (Loufty *et al.* 2006). Likewise, the source of heavy metal contamination in duck meat is most likely from its feed and drinking water. Abdulkhaliq *et al.* (2012) suggested that the accumulation of heavy metal in ducks is caused by contamination at every point of duck production, sources of nutrition, drinking water, and the environment. Faten *et al.* (2014) also suggested that the heavy metal accumulation in ducks' bodies can come from water, feed, air, and the environment contaminated with these metals. Meat is the part of duck carcass that is most consumed by humans compared to other parts such as the brain, lungs, liver, kidney, etc. Therefore, this study aimed to analyze the levels of heavy metal bioaccumulation factor (BAF) in duck meat and to assess the possible risks to human health.

MATERIALS AND METHODS

This research is an exploratory observational study. A total of 25 duck samples were taken from five intensive duck farms in Central Java Province, i.e., Semarang (A), Temanggung (B), Magelang (C), Pati (D), and Salatiga (E). The criteria for selecting duck farms were laying ducks with an intensive care system (ducks were kept in cages, not released from the cage), 18 months years old, and the total number of ducks in a cage was 200 - 500 ducks. Samples of ducks, drinking water, and feed were taken from each duck farm to be analyzed for heavy metal contents and concentrations.

Sample Preparations

Meat samples

Five ducks, duck feed, and duck drinking water were randomly taken from each intensive duck farm. Each duck was slaughtered. The thigh and breast meat were cut into sizes of 2 x 2 x 3 cm. Furthermore, the meat was weighed and dried in an oven for > 72 hours at 70 °C. A total of 6 g of dry meat was added with 2 mL of 65% HNO_3 (Merck) and then ashed using a furnace (Nabertherm L3/C6) at 500 °C for 2 hours (Demirel *et al.* 2008). Subsequently, the ashed meat was dissolved with distilled water (Merck) to a volume of 50 mL, to be analyzed for the heavy metal contents and concentrations.

Drinking water samples

As much as 100 mL of duck drinking water was acidified with 65% HNO_3 until the water pH became 2 (Demirel *et al.* 2008). After that, distilled water was added to the sample until the volume reached 200 mL, to be analyzed for the heavy metal contents and concentrations.

Feed samples

As much as 1,500 g of duck feed was dried in an oven at 70 °C for > 48 hours. After being dried, the feed sample was mashed in a blender. A total of 6 g of feed sample was added with 2 mL 65% HNO_3 (Merck) and mixed until homogeneous. Then, feed samples were ashed using a furnace (Nabertherm L3/C6) at 500 °C for 2 hours (Demirel *et al.* 2008). The ashed feed was dissolved in 50 mL of distilled water (Merck), to be analyzed for heavy metal contents and concentrations.

Quantification of Heavy Metals

Each sample of drinking water, feed, and duck meat was analyzed for heavy metal contents and concentrations following the ICP-OES method (Perkin Elmer Optima 8300) following the procedure of Naschan *et al.* (2017). Sample solutions and standard solutions of As, Cd, Hg, and Pb were prepared and injected into the ICP-OES equipment. The analytical wavelengths of investigated heavy metals were 546.074 nm for Hg, 193.696 nm for As, 220.353 nm for Pb, and 226.506 nm for Cd. Each heavy metal measurement of each sample was repeated 3 times.

Data of As, Cd, Hg, and Pb contents in the samples of drinking water, feed, and duck meat were compared with the determined quality standards (GoI 2001; SNI 2009; FAO 2017).

Bioaccumulation Factor (BAF)

Bioaccumulation factor (BAF) was calculated according to Wang *et al.* (2017), with the following equation:

$$BAF = \frac{\text{Concentration in organism (Ci)}}{\text{Concentration in ingested food and/or water (C0)}} \quad \ldots\ldots\ldots\ldots (1),$$

where:

C0 = concentration of heavy metals in drinking water and or feed;

Ci = concentration of heavy metals in duck meat.

Thus, there were 3 types of BAF calculated in this study, i.e., BAF_{water}, BAF_{feed}, and $BAF_{duck\ meat}$. BAF values were categorized according to Arnot and Gobas (2006), i.e., 1) BAF < 1,000: no possibility of accumulation; 2) 1,000 < BAF < 5,000: bioaccumulative; and 3) BAF > 5, 000: highly bioaccumulative.

Potential Health Risk Assessment

Non-carcinogenic risk to humans in the Central Java Province in relation to the consumption of duck meat contaminated with heavy metals was assessed following the USEPA (2000) method. Heavy metal (As, Cd, Hg, and Pb) accumulation in duck meat can cause adverse effects on human health. The Estimated Daily Intake (EDI) value through consumption of duck meat was calculated from the average concentration of heavy metals observed in duck meat samples and the average daily consumption of duck meat in Indonesia.

The EDI (mg/kg/day) was estimated using the following equation (USEPA 1989):

$$EDI = \frac{Cm \times ADC}{BW} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2),$$

where:

ADC = average daily consumption of duck meat in Indonesia, determined to be 0.0225 kg/person/day (Ministry of Trade of the Republic of Indonesia 2014);

BW = body weight, determined to be 70 kg for adults (USEPA 1989) and 30 kg for children (Bortey-Sam *et al.* 2015);

C_m = average heavy metal concentrations in duck samples (mg/kg).

The non-carcinogenic risk due to the consumption of duck meat containing heavy metals by the population of Central Java Province was called HQ (Hazard Quotient). The HQ is calculated using the following formula (USEPA 1989):

$$HQ = \frac{Cm \times EF \times ADC \times ED}{RfD \times BW \times At \times 1000} \times 10^{-3} \quad \ldots\ldots\ldots\ldots (3),$$

where:

C_m = average heavy metal concentrations in duck samples (mg/kg);

EF = exposure frequency (365 days/year);

ADC = average daily consumption of duck meat in Indonesia, determined to be 0.0225 kg/person/day (Ministry of Trade of the Republic of Indonesia 2014);

ED = exposure duration (70 years);

RfD = an estimate of the number of contaminants per day that a human can tolerate over their Lifetime. The RfD (oral) values used in this assessment were 3.00E-04 (for As), 5.00E-04 (for Cd), 3.50E-03 (for Pb), and 3.00E-04 (for Hg) (Tay *et al.* 2019);

BW = body weight, determined to be 70 kg for adults (USEPA 1989) and 30 kg for children (Bortey-Sam *et al.* 2015);

At = average exposure time (ED x 356 days).

If the HQ value is less than one (< 1), pollutant exposure to the population does not cause adverse effects on human health.

Duck meat contained more than one type of heavy metal. Therefore, the level of adverse effects on the exposed population is called Hazard Index (HI), which is the sum of all calculated HQs of all heavy metals found in the sample (USEPA 1989):

$$HI = HQ_{As} + HQ_{Cd} + HQ_{Hg} + HQ_{Pb} \quad \ldots\ldots\ldots (4)$$

HI is considered to be a potential risk estimated from exposure to some heavy metals (USEPA 1989).

Data Analysis

Heavy metal concentration data, BAF, EDI, HQ, and HI values were analyzed descriptively.

RESULTS AND DISCUSSION

Heavy metal toxicity can cause teratogenic, mutagenic, and carcinogenic effects in biological organisms including poultry (Hashmi *et al.* 2013). In ecosystems, metal contamination can also affect the habitat, food chain, and community structure of organisms in an environment (Kim & Oh 2013). Drinking water for ducks in all sampled intensive farms in this study contains heavy metals of As, Cd, Hg, and Pb which exceeded the determined quality standards (GoI 2001; SNI 2009; FAO 2017).

The concentrations of heavy metals in duck drinking water were 0.0513 - 0.081 ppm (for As), 0.07 - 0.08 ppm (for Cd), 1.74 - 2.4 ppm (for Hg), and 0.06 - 0.07 ppm (for Pb). The order of heavy metal concentrations in the drinking water of ducks from the highest to the lowest in Temanggung, Magelang, and Salatiga was Hg > Cd > As > Pb. On the other hand, the order of heavy metal concentrations in the drinking water of ducks from the highest to the lowest in Semarang was Hg > Cd > Pb > As; while in Pati was Hg > As > Cd > Pb (Table 1).

Table 1 Heavy metal content in drinking water and feed for ducks, and duck meat

Heavy Metals		Water	Feed	Duck meat
As	Standard			
	FAO 2017	0.01	0.5	0.5
	SNI 2009	0.05	0.5	0.5
	PP No 82 year 2001	0.01	0.25	0.25
	Samples from:			
	Semarang (A)	0.0513[abc]	0.0750	0.0700
	Temanggung (B)	0.0773[abc]	0.0800	0.0770
	Magelang (C)	0.0797[abc]	0.1097	0.0770
	Pati (D)	0.0810[abc]	0.0987	0.0770
	Salatiga (E)	0.0710[abc]	0.1003	0.0700
Cd	Standard			
	FAO 2017	0.003	0.5	0.5
	SNI 2009	0.003	0.1	0.3
	PP No 82 year 2001	0.003	0.1	0.05
	Samples from:			
	Semarang (A)	0.0700[abc]	0.0760	0.0740[abc]
	Temanggung (B)	0.0800[abc]	0.0750	0.0713[abc]
	Magelang (C)	0.0800[abc]	0.0787	0.0750[abc]
	Pati (D)	0.0800[abc]	0.0783	0.0740[abc]
	Salatiga (E)	0.0800[abc]	0.0783	0.0740[abc]
Hg	Standard			
	FAO 2017	0.001	0.1	0.1
	SNI 2009	0.001	0.05	0.03
	PP No 82 year 2001	0.001	0.06	0.03
	Samples from:			
	Semarang (A)	1.740[abc]	2.000[abc]	6.000[abc]
	Temanggung (B)	2.400[abc]	0.089[abc]	3.100[abc]
	Magelang (C)	2.380[abc]	4.420[abc]	4.840[abc]
	Pati (D)	2.260[abc]	5.010[abc]	4.220[abc]
	Salatiga (E)	2.380[abc]	4.560[abc]	4.400[abc]
Pb	Standard			
	FAO 2017	0.01	0.3	0.1
	SNI 2009	0.01	0.3	0.3
	PP No 82 year 2001	0.01	0.2	0.5
	Samples from:			
	Semarang (A)	0.0600[abc]	0.0740	0.0640
	Temanggung (B)	0.0700[abc]	0.0730	0.0690
	Magelang (C)	0.0700[abc]	0.0780	0.0670
	Pati (D)	0.0700[abc]	0.0730	0.0460
	Salatiga (E)	0.0700[abc]	0.0650	0.0650

Notes: [a] = The data exceed the quality standards set by FAO 2017 (FAO 2017); [b] = The data exceeds the quality standards set by Indonesian National Standard year 2009 (SNI 2009); [c] = The data exceeds the quality standards set by Indonesian Government Regulation No 82 year 2001/PP No. 82 year 2001 (GoI 2001).

The source of drinking water for the sampled intensive duck farms in Semarang, Pati, and Salatiga is groundwater, while in Temanggung and Magelang, the source is ponds. The high concentration of heavy metals in drinking water for ducks in this study was probably related to the timing of conducting the water sampling, which was during the dry season (May - June). The concentration of chemicals in groundwater is greatly influenced by the season. The seasonal analysis report from Obasi and Akudinobi (2020) showed a relative decrease in chemical concentration in groundwater during the rainy season compared to that during the dry season. Although heavy metal levels in drinking water for ducks increased relatively during the dry season, analysis of heavy metal concentrations in groundwater in various regions of Central Java Province and Indonesia is still required, both during dry and rainy seasons. The analysis is essential because groundwater is a source of drinking water for most livestock and humans. Accumulation of heavy metals in the body of animals and humans will cause an adverse impact on health, especially arsenic, cadmium, lead, and mercury which are reported of having high toxicity. Exposure to heavy metals in humans can increase the risk of cancer and other health problems such as anemia, liver and kidney damage (Malik & Khan 2016), decreased intelligence, decreased function of various organs, and even death (Kulkarni & Kaware 2013).

The variation of heavy metal concentrations in water is influenced by water pH, temperature, dissolved oxygen, and water flow rate (Li *et al.* 2013). The lower value of water pH causes higher metal solubility. Water pH can convert carbonate (CO_3) into hydroxide (OH) forming bonds with particles on the water surface (Palar *et al.* 2008). Heavy metal solubility of Zn, Cu, Cd, Cr, and Pb is greater at low pH conditions (4 - 7) than that at high pH conditions (8 - 10) (Li *et al.* 2013). The amount of Cd released from polluted sediment will decrease with increasing pH value (Zhang *et al.* 2018). In this study, the results of water and soil pH measurements in the five samples of intensive duck farms were in the range of 6 - 7 and 6.9 - 7, respectively. These pH values were within the pH range of 6 - 9 which is a safe pH value based on Indonesian Government Regulation No. 82 of 2001 (GoI 2001).

Temperature also has an important effect on heavy metal solubility. At higher temperatures (30 - 35 °C), the release rate of metals (Zn, Cu, Cd, Cr, and Pb) becomes faster than that at low temperatures (Li *et al.* 2013). The temperature at each location of the sampled intensive duck farms in this study was in the range of 25.6 - 34.6 ºC. This temperature was in the range of 27 - 35 °C which is a safe temperature per determination from the Indonesian Government Regulation No. 82 of 2001 (GoI 2001).

In duck feed, Hg was found in the concentration range of 0.089 - 5.01 ppm. This Hg concentration exceeded the determined quality standards (GoI 2001; SNI 2009; FAO 2017).

Meanwhile, the levels of other heavy metals (As, Cd, and Pb) were recorded as still under the determined quality standard. The range of As concentration detected in duck feed was 0.075 - 0.1097 ppm. Meanwhile, the concentration range of Cd, Hg, and Pb were 0.075 - 0.0787 ppm, 0.089 - 5.01 ppm, and 0.065 - 0.078 ppm, respectively (Table 1). A study by Ukpe and Chokor (2018) also showed that there was heavy metal contamination of Ni (1.71 g/kg), Co (0.39 g/kg), Pb (1.17 g/kg), Cr (0.529 g/kg) and Cd (0.031 g/kg) sourced from poultry feed. Poultry feed has the potential to pollute the environment through the fecal matter of cultivated poultry. A large-scale duck farm produces large amounts of fecal matter. Compost made from poultry fecal matter may still contain a lot of heavy metals (Alvarenga *et al.* 2015). Apart from being used as compost, fecal matter can be digested by maggots and the harvested maggots can be used as animal feed (Wang *et al.* 2017).

Heavy metals in manure will contaminate the soil, then from the soil, heavy metals can be transferred to plants and animals. In turn, humans can also be exposed to heavy metals if they consume the contaminated plants and animals. Heavy metals can contaminate various organisms in the ecosystem, through the food chain cycle. Poultry feed is made from plant material, thus, if plants are contaminated, the feed will also be contaminated. The raw materials of duck feed in this study varied, i.e., concentrate feed (commercial), rice bran, leftover vegetables, dry rice, trash fish, shrimp waste, and fish waste. Concentrate feed may also contribute to heavy metal contamination in duck feed. A study by Okoye *et al* (2011) showed that some concentrate feeds in Nigeria contained 50.575 - 170.075 mg/kg of iron, 6.52 - 14.20 mg/kg of copper, 1.10 - 7.85 mg/kg of lead, and 0.038 - 0.463 mg/kg of cadmium. Wang *et al.* (2013) also reported that several animal feeds in China contained several heavy metals with an average of 15.9 - 2,041.8 mg/kg of Zn, 0 - 392.1 mg/kg of Cu, and < 10 mg/kg of Hg, As, Pb, Cd, and Cr.

The concentrations of Cd (0.0713 - 0.075 ppm) and Hg (3.1 - 4.84 ppm) in duck meat were identified to exceed the determined quality standards (GoI 2001; SNI 2009; FAO 2017). Meanwhile, As and Pb concentrations were still under the determined quality standards. Analysis of heavy metals in Mallard ducks (*Anas platyrhynchos*) in Iran showed that the lowest concentrations of Pb, Cd, and Zn metals were found in muscle (meat) and the highest concentration was found in the liver (Alipour *et al.* 2016). Some previous studies also revealed heavy metal contamination in the meat of ducks and other livestock. A study by Widayanti and Widwiastuti (2018) showed that duck meat in Malang City contained 0.37 ppm of cadmium (Cd). Poultry meat in Egypt contained 0.086 ppm of Cd, 6.092 ppm of Cu, 0.136 ppm of Sn, and 1.280 ppm of Zn (Ali *et al.* 2017). Heavy metal Cd was detected at 0.003 ppm in poultry meat in Ghana (Nesta *et al.* 2015). Heavy metals of As, Cd, and Hg were also detected in duck meat products in Argentina (Hyun *et al.* 2018). Study results of Islam (2018) showed that beef, goat, chicken, and duck meat in Bangladesh contained 0.533 - 6.55 mg/kg of chromium (Cr), 0.005 - 7.70 mg/kg of Nickel (Ni), 0.581 - 15.99 mg/kg of copper (Cu), 0.080 - 11.34 mg/kg of Arsenic (As), 0.001 - 0.22 mg/kg of Cadmium (Cd), and 0.061 - 13.52 mg/kg of Lead (Pb).

Bioaccumulation is the absorption process of chemicals by an organism through all exposure routes, such as those that occur in the natural environment, i.e., food sources, drinks, and surrounding environment. The bioaccumulation factor (BAF) is a value to measure the bioaccumulation rate. BAF is calculated based on the ratio of metal concentration in an organism to metal concentration in water and feed. BAF value is influenced by several factors such as sex, reproductive status, age, body size, and lipid content of an organism. Organisms having a lot of lipids have a greater capacity to store hydrophobic organic chemicals, so their BAF values are higher (Arnot & Gobas 2006). In this study, the BAF value in duck meat was analyzed based on the accumulation of water, feed, and the total of water and feed. The BAF value of all heavy metals in duck meat was in the range of 0.065 - 5.01. According to Arnot and Gobas (2006), a BAF value < 1,000 means that accumulation is not possible.

The average values of BAF_{water} for As and Pb were greater than those of BAF_{feed}. On the other hand, the average values of BAF_{feed} for Cd and Hg were greater than those of BAF_{water} (Table 2). The BAF_{water} value of As, Cd, Hg, and Pb in duck meat in Semarang was the highest compared to the values calculated in other locations. Meanwhile, the highest BAF_{feed} value of As was found in Temanggung (0.962) followed by Semarang (0.933) and Pati (0.78). The highest BAF_{feed} value of Cd was found in Semarang (0.973) followed by Magelang (0.952) and Temanggung (0.95). The highest BAF_{feed} value of Hg was found in Pati (5.01) followed by Magelang (4.42) and Temanggung (3.48). The highest BAF_{feed} value of Pb was found in Temanggung (0.945) followed by Semarang (0.864) and Magelang (0.858) (Table 2). The average of $BAF_{duck\ meat}$ values was in the range of 0.443 - 0.955, with the details of 0.443 for Pb; 0.457 for As; 0.475 for Cd, and 0.955 for Hg. The highest $BAF_{duck\ meat}$ values of As, Cd, and Hg were found in Semarang. Meanwhile, the highest $BAF_{duck\ meat}$ value of Pb was found in Temanggung. The lowest $BAF_{duck\ meat}$ values of As, Cd, Hg, and Pb were found in Magelang, Temanggung, and Pati, respectively (Table 2).

Table 2 BAF values of heavy metals in drinking water and feed for ducks, and duck meat

Heavy metals		Location of duck farm					Average
		A	B	C	D	E	
As	Water	1.364	0.966	0.966	0.950	0.985	1.046
	Feed	0.933	0.962	0.701	0.780	0.697	0.815
	Duck meat	0.554	0.490	0.407	0.428	0.409	0.457
Cd	Water	1.054	0.891	0.937	0.925	0.925	0.946
	Feed	0.973	0.950	0.952	0.945	0.945	0.953
	Duck meat	0.507	0.460	0.473	0.467	0.467	0.475
Hg	Water	3.448	1.291	2.034	1.870	1.849	2.098
	Feed	3.000	3.483	4.420	5.010	0.964	3.375
	Duck meat	1.604	1.245	0.712	0.580	0.634	0.955
Pb	Water	1.066	0.985	0.957	0.657	0.928	0.919
	Feed	0.864	0.945	0.858	0.630	0.065	0.672
	Duck meat	0.478	0.483	0.453	0.322	0.481	0.443

Notes: A = Semarang; B = Temanggung; C = Magelang; D = Pati; E = Salatiga.

There have not been many studies related to BAF values of heavy metals in terrestrial animals. Research results by Wang *et al.* (2017) showed that younger maggot larvae had a higher BAF value of heavy metal than older larvae. The BAF value of Cd in 3-day-old larvae was 1.20, while the BAF value of Cd in 4-day-old larvae was 1.10. This comparison showed that as the maggots grow, heavy metals are released from the maggots' bodies. A study conducted in Gadani shipbreaking Pakistan to find out heavy metal BAF values in the gills and muscles of seven fish species showed that the BAF values found were in the order of Mn > Cd > Ni > Pb (Kakar *et al.* 2020).

Estimated Daily Intake (EDI) values of heavy metals (As, Cd, Hg, and Pb) for adults and children through the consumption of duck meat in the Central Java Province were calculated and presented in Table 3. Our study showed that children are more susceptible to the acute and chronic effects of a chemical contaminant because children consume more food per unit of body weight compared to adults (ENHIS 2007). Therefore, toxic contamination by means of food consumption is higher in children than that in adults, leading to higher EDI scores in children compared to that in adults for all heavy metals. The EDI values calculated for As, Cd, and Pb in our study were lower than the oral reference dose (RfD) of each metal. However, the EDI value for Hg metal was higher than the oral RfD. This result may be caused by the high concentrations of Hg in water, feed, and duck meat, which were above the determined quality standards (GoI 2001; SNI 2009; FAO 2017). High concentrations of Hg had also been reported in water at the ports of Mayangan, Kenjeran, and Gresik, East Java, Indonesia (Hertika *et al.* 2018).

Table 3 Estimated daily intake (mg/kg/day) values of heavy metals (As, Cd, Hg, and Pb) for adults and children through duck meat consumption

Heavy metals		Location of duck farm					Average
		A	B	C	D	E	
As	Adults	2.25E-05	2.47E-05	2.47E-05	2.47E-05	2.25E-05	2.38E-05
	Children	5.25E-05	5.77E-05	5.77E-05	5.77E-05	5.25E-05	5.56E-05
Cd	Adults	2.38E-05	2.29E-05	2.41E-05	2.38E-05	2.38E-05	2.37E-05
	Children	5.55E-05	5.35E-05	5.63E-05	5.55E-05	5.55E-05	5.53E-05
Hg	Adults	1.93E-03	0.99E-03	1.56E-03	1.36E-03	1.41E-03	1.45E-03
	Children	4.50E-03	2.33E-03	3.63E-03	3.12E-03	3.30E-03	3.38E-03
Pb	Adults	2.06E-05	2.22E-05	2.15E-05	1.48E-05	2.09E-05	2.00E-05
	Children	4.80E-05	5.18E-05	5.03E-05	3.45E-05	4.88E-05	4.67E-05

Notes: A = Semarang; B = Temanggung; C = Magelang; D = Pati; E = Salatiga.

Table 4 Hazard Quotient (HQ) values

Hazard Quotient		Location of duck farm					Average
		A	B	C	D	E	
As	Adults	7.50E-05	8.25E-05	8.25E-05	8.25E-05	7.50E-05	7.95E-05
	Children	1.75E-04	1.92E-04	1.92E-04	1.92E-04	1.75E-04	1.85E-05
Cd	Adults	4.76E-06	4.58E-05	4.82E-05	4.75E-05	4.75E-05	4.73E-05
	Children	1.11E-04	1.07E-04	1.12E-04	1.11E-04	1.11E-04	1.10E-05
Hg	Adults	6.43E-03	3.32E-03	5.19E-03	4.52E-03	4.71E-03	4.83E-03
	Children	15.00E-03	7.75E-03	12.10E-03	10.55E-03	11.00E-03	11.28E-03
Pb	Adults	5.88E-06	6.34E-06	6.15E-06	4.22E-06	5.97E-06	5.71E-05
	Children	1.37E-05	1.48E-05	1.44E-05	0.98E-05	1.39E-05	1.33E-05

Notes: A = Semarang; B = Temanggung; C = Magelang; D = Pati; E = Salatiga.

The non-carcinogenic risk of heavy metals through the consumption of duck meat was evaluated based on the value of the Hazard Quotient (HQ). The estimated HQ value of all heavy metals in this study was < 1 (Table 4). The HQ values indicate that the people in Central Java Province who consume duck meat are unlikely to suffer adverse health effects due to heavy metal contamination in the duck meat. The highest average of HQ values for adults and children were recorded at Hg intake (4.83E-03 and 11.28E-03, respectively) followed by As (7.95E-05 and 1.85E-05, respectively). The lowest averages of HQ values were recorded at Cd intake, i.e. 4.73E-05 in adults and 1.10E-05 in children. In this study, the order of HQ values from the highest was Hg > As > Pb > Cd.

Hazard Index (HI) is a parameter to assess the cumulative risk due to exposure to several heavy metals. The average of HI values of our study showed a number of < 1 for both adults (4.97E-03) and children (9.41E-03) (Table 5), which indicated that there was no significant health risk due to cumulative exposure to heavy metals (As, Cd, Hg, and Pb) in duck meat. A study by Kakar *et al.* (2020) showed that the HQ values of seven fish species in Gadani shipbreaking Pakistan were safe with regard to Pb and Mn (HQ < 1), but may cause potential risk with regard to Cd and Ni (HQ > 1). Estimated values of HQ and HI of heavy metals (Cd, Cr, Cu, Fe, Ni, Pb, and Zn) through consumption of Baladi chickens were < 1, indicating that chicken consumption did not have the potential to cause health risks for consumers in the Jazan Region of Saudi Arabia (Al Bratty *et al.* 2018).

Table 5 Hazard Index (HI) values

Ducks farm location	Adults	Children
Semarang (A)	6.56E-03	15.29E-03
Temanggung (B)	3.46E-03	8.06E-03
Magelang (C)	5.32E-03	12.42E-03
Pati (D)	4.66E-03	10.86E-03
Salatiga (E)	4.84E-03	11.29E-03
Average	4.97E-03	9.41E-03

All of the risk parameters (EDI, HQ, and HI) calculated in this study were within safe limits. Exposure to heavy metals through duck meat consumption, both in adults and children in Central Java Province, was not potential to present an adverse health risk. However, exposure to heavy metals contained in duck meat cannot be underestimated because it will accumulate in the human body. Exposure to heavy metals from other foodstuffs, dermal absorption, urban air inhalation, etc, which were not studied in this study, can increase the collective risk of heavy metal contamination in the human body.

CONCLUSION

Drinking water for ducks in all sampled intensive duck farms contained heavy metals of As, Cd, Hg, and Pb which exceeded the determined quality standards. All health risk parameters (EDI, HQ, and HI) were within safe limits. Exposure to heavy metals through duck meat consumption, both in adults and children, was unlikely to cause adverse health effects.

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