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Corresponding Author	FamilyName	**Ali**
	Particle	
	Given Name	**A. I. M.**
	Suffix	
	Division	Department of Animal Science, Faculty of Agriculture
	Organization	Universitas Sriwijaya
	Address	South Sumatra, Kota Palembang, Indonesia
	Phone	
	Fax	
	Email	asep_ali@fp.unsri.ac.id
	URL	
	ORCID	http://orcid.org/0000-0001-6330-8748
Author	FamilyName	**Imsya**
	Particle	
	Given Name	**A.**
	Suffix	
	Division	Department of Animal Science, Faculty of Agriculture
	Organization	Universitas Sriwijaya
	Address	South Sumatra, Kota Palembang, Indonesia
	Phone	
	Fax	
	Email	
	URL	
	ORCID	
Author	FamilyName	**Riswandi**
	Particle	
	Given Name	
	Suffix	
	Division	Department of Animal Science, Faculty of Agriculture
	Organization	Universitas Sriwijaya
	Address	South Sumatra, Kota Palembang, Indonesia
	Phone	
	Fax	
	Email	
	URL	
	ORCID	
Author	FamilyName	**Palupi**
	Particle	
	Given Name	**R.**
	Suffix	
	Division	Department of Animal Science, Faculty of Agriculture
	Organization	Universitas Sriwijaya
	Address	South Sumatra, Kota Palembang, Indonesia
	Phone	
	Fax	
	Email	
	URL	
	ORCID	

Author	FamilyName	**Muhakka**
	Particle	
	Given Name	
	Suffix	
	Division	Department of Animal Science, Faculty of Agriculture
	Organization	Universitas Sriwijaya
	Address	South Sumatra, Kota Palembang, Indonesia
	Phone	
	Fax	
	Email	
	URL	
	ORCID	

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Abstract

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Keywords (separated by '-'): Backyard poultry - Heavy metal - Household waste - Lowland farming

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SHORT COMMUNICATION

Free-range poultry farming in a lowland suburban area increased the health risk of heavy metal contamination

A. I. M. Ali[1] · A. Imsya[1] · Riswandi[1] · R. Palupi[1] · Muhakka[1]

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Abstract

Uncontrolled waste disposal allows the release of various contaminants into the local environment and food chain. The purpose of this study was to assess lead (Pb) and cadmium (Cd) contamination in backyard poultry reared in a suburban area of Palembang, Indonesia. Meat, liver, and feathers from broiler chickens, backyard chickens and ducks (*Anas platyrhynchos* f. domestica), as well as feed and water samples, were subjected to Pb and Cd analysis by an atomic absorption spectrophotometer. The heavy metal levels in meat, liver, feed, and water samples were lower than tolerable maximum limits, and health risk assessment did not indicate harm for consumption. Only one duck had a higher Pb level in the liver than the permissible limit. The Pb and Cd levels in the meat samples did not differ between the poultry species ($P > 0.05$), whereas Pb levels in feathers were highest in backyard ducks and lowest in broiler chickens. ($P < 0.05$). In the liver, Pb and Cd levels were higher in backyard chickens and ducks than in broiler chickens ($P < 0.01$). The higher heavy metal concentrations in the backyard poultry might relate to the age of the animals and the contaminated household area.

Keywords Backyard poultry · Heavy metal · Household waste · Lowland farming

Introduction

Sumatra's lowland area in Indonesia is a catchment area of rivers in the northeastern part of the island, distinguished by the high acidity of soil and water and periodic flooding during the rainy season. Environmental management and sustainable agriculture are critical challenges in this region, which is the primary location for food production and the final destination for industrial and urban waste streams and other anthropogenic sources of contamination (World Bank 2021). On the other hand, increased residential areas, as well as inadequate waste management services and infrastructure, may lead to the discharge of hazardous contaminants into the environment and food chain (Guerrero et al. 2013).

The elevated availability and uptake of lead (Pb) and cadmium (Cd) by plants in the acid soil (Bang and Hesterberg 2004; Mühlbachová et al. 2005; Zeng et al. 2011) could relate to the higher levels of the metals in the forage and buffalo hair (Ebrahimpour and Mushrifah 2008; Ali et al. 2021). The Pb concentrations in the forages exceeded the permissible limit (EC 2013), while the Pb level in the buffalo's hair was higher than that in other studies (Gabryszuk et al. 2010; Miroshnikov et al. 2019). However, no available data in the literature on Pb and Cd accumulation in food originates from livestock reared in the area.

Backyard poultry, particularly in developing nations, is an essential sector of livestock, characterized by indigenous breeds and low investments, and contributes significantly to incomes and home food consumption. Backyard chickens and ducks are reared in free-range systems throughout the year. The chickens are dual-purpose breeds for meat and egg production, while the ducks are mainly reared for egg production and usually allowed to scavenge in the backyard and swamp area (Barua and Yoshimura 1997; Rajkumar et al. 2021). Contrary to commercial broiler chickens raised under controlled feed and water, backyard poultry could consume non-feed ingestible substances such as metals, plastic, stone, and wood. (Huang et al. 2019; Rajkumar et al. 2021). The ingested objects could relate to a higher level of the

Editorial responsibility: Nabin Aryal.

✉ A. I. M. Ali
asep_ali@fp.unsri.ac.id

[1] Department of Animal Science, Faculty of Agriculture, Universitas Sriwijaya, South Sumatra, Kota Palembang, Indonesia

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contaminants in their body (Anderson et al. 2000; Taggart et al. 2006; Kar et al. 2018; Mikołajczyk et al. 2021).

The urban population growth in Palembang increases the demand for waste management services, where more than 25% of waste was not collected and directed to the local landfill (Papargyropoulou et al. 2015). Uncontrolled rubbish disposal around backyard could potentially increase contaminant exposure to the household environment and food chain (Cheng et al. 2018; Kar et al. 2018; Riani et al. 2018; Mikołajczyk et al. 2021). The current study aimed to determine the levels of Pb and Cd contamination in the tissues of backyard chickens and ducks (*Anas platyrhynchos* f. domestica), as well as the health risks of the local community associated with poultry meat consumption.

Materials and methods

Sample collection

Between March and July 2023, 24 backyard chickens and 24 backyard ducks (> 1 year old) were randomly selected from different locations in a Palembang suburbs, South Sumatra, Indonesia. For comparison,, 24 broiler chickens (28 days old) were collected from three farms of major broiler producers (Fig. 1). We interviewed farmers to collect information about the age of the birds, source of feed and drinking water, and scavenging areas. Water samples (500 ml) were collected from twelve different locations of rivers and residential sewage streams, while the sample of drinking water was taken from municipal water supply and wells. The sewage stream sample was collected where the location was accessible by the backyard poultry, whereas the sample location of the river is downstream of the sewage. Samples of corn, rice bran, and broiler concentrate (100 g) were collected from six poultry shops based on the information provided by the farmers. Broiler feed samples were taken from the broiler farms.

Heavy metal analysis

The pectoral meat and liver samples were cleaned with distilled water, chopped with a stainless steel knife, and kept at − 20 °C in a freezer. The primary feather samples were washed with tap water and cleaned from adherent external contamination before being washed with distilled water. The feather samples were cut (1–2 cm) by scissors before rinsing with acetone for 5 min. Afterward, all the samples were dried at 60 °C for three days until no more weight loss occurred. Distilled water and ethyl alcohol were used for cleaning the knife and scissors.

The organ and feed samples were accurately weighed (0.01 g) and then ashed at 450 °C under a gradual increase (≤ 50 °C). Afterward, 6 M HCl was added, and the solution was evaporated to dryness. The residue was dissolved in 0.1 M HNO_3 and filtered (Whatman filter paper) (AOAC 2012; method 999.11). About 250 ml of water sample was transferred to beakers, and 5 ml of HNO3 was added. The sample was heated (85 °C) to a final volume of about 15–20 ml, transferred to a 25-ml flask, and then filtered (APHA 2012). The metal concentrations were measured with a Thermo Scientific ICE 3500 atomic absorption spectrophotometer. A blank digestion solution was made for comparison. A multi-element standard solution (Merck) with different concentrations of Pb (0.1, 0.2, 0.4, 0.6, 0.8, 1.2, and 1.6 mg/L) and Cd (0.02, 0.04, 0.08, 0.1, 0.2, and 0.4 mg/L) was made to check the accuracy of the method. The detection limits for each metal were 0.03 and 0.01 mg/kg for Pb and Cd, respectively, whereas the mean recovery percentages of Pb and Cd were 99 and 99.6%, respectively. The apparatus, chemicals, and standards from well-known companies were used to assure the quality of the chemical analysis.

Data analysis

Data analysis was carried out with Statistical Analysis Systems (SAS Institute). Data less than the detection limit was entered as half of the detection limit. The normality of the data was assessed using the Kolmogorov–Smirnov test. The data was analyzed using the Kruskal–Wallis test with the Dwass-Steel-Critchlow-Fligner test for the comparison between animal groups for each metal concentration. A P value of < 0.05 was considered statistically significant. The daily intake value (mg/kg body weight, bw) was calculated using the concentration of the heavy metals, average poultry meat consumption, and body weight.

Results and discussion

Feed samples had detectable concentrations of Pb, while Cd was not detectable in all feed and water samples (Table 1). According to the European Commission (2013), the Pb concentrations in the feed samples were lower than the maximum permissible level in complete feed (5 mg/kg). The Pb concentration in the commercial broiler feed was within the range in complete feed samples (0.08–0.36 mg/kg) reported in Germany. The Pb levels in corn and rice bran samples were higher than levels in cereals and legumes (0.03–0.20 mg/kg), whereas for Cd levels, the present values were lower than the range in the compound feed (0.02–0.05 mg/kg), cereals, and legumes (0.01–0.5 mg/kg) (Wolf and Cappai 2021).

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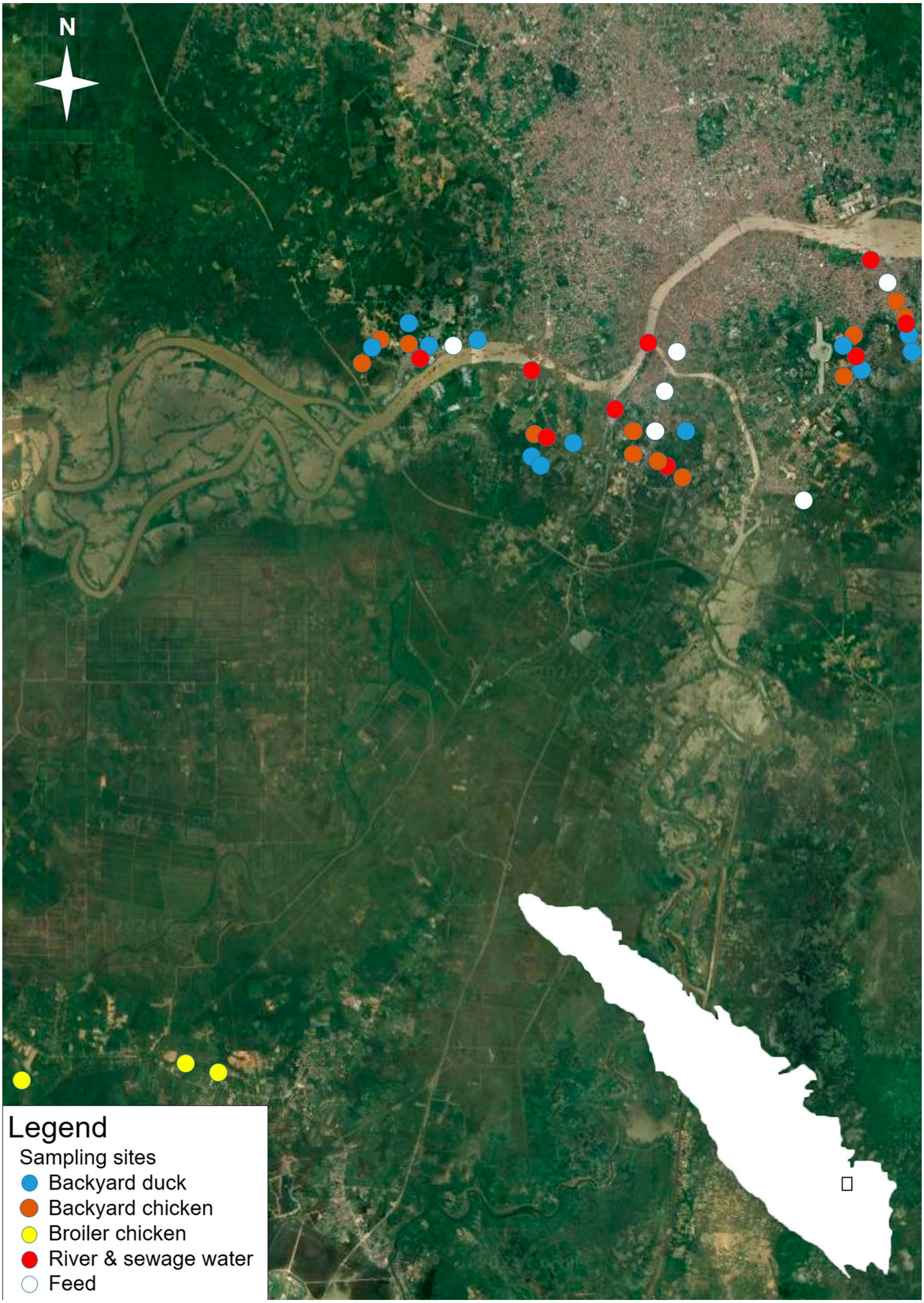

Fig. 1 Location of the study area and sampling sites around Palembang, South Sumatra, Indonesia (Google Maps, 2024)

Table 1 Lead and cadmium levels (mean ± standard error) in feed (mg/kg) and water (mg/L) offered to broiler chickens, backyard chickens, and ducks

	Lead			Cadmium
Commercial broiler feed	0.09	±	0.02	ND
Corn	1.14	±	0.19	ND
Rice bran	1.30	±	0.06	ND
Drinking water*	ND			ND
Municipal waste streams	ND			ND
River	ND			ND

*well and municipal water supply, ND: non detected

In the pectoral muscle, Pb and Cd levels did not differ between the poultry species, whereas the Pb and Cd concentrations in the liver were higher ($P < 0.01$) in the backyard chickens and ducks than in broiler chickens. In the feather, Cd levels were similar between the animal groups, while the lowest Pb level was found in broiler chickens ($P < 0.05$) (Table 2).

The maximum tolerable levels of Pb in poultry products are 0.10 and 0.50 mg/kg fresh weight in the meat and liver, respectively, and for Cd, the levels are 0.05 and 0.50 mg/kg fresh weight in the meat and liver, respectively (EC 2014). The values in the present study were lower than the recommended levels in all meat and liver samples. Only one duck had a higher Pb concentration in the liver (0.52 mg/kg fresh weight) than the recommended level. The present values were also lower than the maximum levels of Pb and Cd allowed in poultry meat and offal regulated by international and Indonesian institutions (FAO/WHO 2002; SNI 2009; FAO/WHO 2023).

Table 2 Comparison of lead and cadmium levels (mg/kg dry weight) in poultry meat, liver, and feather from sub-urban Palembang city, South Sumatra

Organ		Lead				Cadmium			
Meat									
Broiler chickens	Mean	ND				ND			
	Median	ND				ND			
	CIs	ND				ND			
Backyard chickens	Mean	ND				0.01			
	Median	ND				ND			
	CIs	ND				ND	–	0.02	
Backyard ducks	Mean	0.02				0.01			
	Median	0.01				ND			
	CIs	ND	–	0.05		ND	–	0.02	
P value		0.370				0.240			
Liver									
Broiler chickens	Mean	0.10				0.05			
	Median	0.01			a	0.01			a
	CIs	0.06	–	0.15		0.03	–	0.08	
Backyard chickens	Mean	0.29				0.36			
	Median	0.22			b	0.36			b
	CIs	0.16	–	0.42		0.31	–	0.40	
Backyard ducks	Mean	0.42				0.39			
	Median	0.37			b	0.44			b
	CIs	0.27	–	0.57		0.35	–	0.43	
P value		0.001				< .0001			
Feather									
Broiler chickens	Mean	0.39				ND			
	Median	0.34			a	ND			
	CIs	0.30	–	0.47		ND			
Backyard chickens	Mean	0.36				ND			
	Median	0.38			ab	ND			
	CIs	0.26	–	0.46		ND			
Backyard ducks	Mean	0.52				0.01			
	Median	0.57			b	0.01			
	CIs	0.41	–	0.62		ND	–	0.01	
P value		0.033				0.368			

CIs 95% confidence intervals, ND non detected, different superscript show a significant difference between animal groups

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Adults in Indonesia consumed an average of 23 g of chicken meat per day (BPS 2024), with an average body weight of 60 kg (SNI 2009). The maximum daily intake values for Pb and Cd were determined to be 2.0 and 0.9×10^{-4} mg/kg bw, respectively. The maximum intakes for Pb and Cd were set at 2.0 and 1.0×10^{-3} mg/kg, respectively (EFSA 2010; Sprong et al. 2023). The weekly maximum intake of Pb and Cd in the present study (1.4 and 0.6×10^{-3} mg/kg, respectively) was also lower than the provisional tolerable weekly intake proposed by FAO/WHO 2002 and SNI 2009 (2.5 and 0.7×10^{-2} mg/kg, for Pb and Cd, respectively) and FAO/WHO 2023 (2.5×10^{-2} mg/kg for Cd).

The health risk of the toxic contaminants from chicken and duck meat consumption might be low because of the low level of poultry meat consumption. However, the children might be more susceptible to the high risk of the contaminants since they consume more food per unit of bw. Moreover, poultry meat only accounted for a part of the human diet. Other foods such as eggs, fish, vegetables, and rice might contain higher levels of the metals, which could increase the risk of toxic metals ingestion. Egg production from backyard poultry might account for a significant portion since chicken egg consumption was fourteen times higher than poultry meat consumption, whereas duck egg consumption was similar to the poultry meat consumption (BPS 2024).

Urban expansion poses more pressure on communal waste management to provide an effective and efficient system of waste management (Guerrero et al. 2013). For instance, about 15.3% of municipal waste was discarded on streets, rivers, and park areas (Meidiana and Gamse 2010), while 91% of respondents disposed hazardous material (electronic waste, metals, and plastic) together with other household waste (Aprilia et al. 2013). This uncontrolled waste disposal might relate to the increase in heavy metal exposure in rivers, coast sediment (Sindern et al. 2016), and water biota (Riani et al. 2018). Furthermore, Cheng et al. (2018) observed substantial sources of heavy metals exposure in the household, such as painting, smoking, and wall covers. In the current investigation, uncontrolled rubbish disposal was also observed in the study area (Papargyropoulou et al. 2015). Before being disposed of at a community garbage facility, home waste was dumped in the kitchen or backyard area, while other households disposed of or burned the waste in the backyard area to minimize household expenses.

The higher Pb and Cd levels in the livers of backyard chickens and ducks than in broiler chickens might explain the household heavy metal exposure due to the low level of the metals in the water and offered feed (Table 1). Kar et al. (2018) reported a high level of heavy metals in the chicken organs in an industrial area. The Pb and Cd levels were higher in the liver in the industrial area than in the reference site (2.04 vs. 0.07 and 1.86 vs. 0.22 mg/kg fresh weight for Pb and Cd, respectively). The elevated levels of heavy metals in duck and chickens organs were also reported around a mining area (Aendo et al. 2022; Elkribi-Boukhris et al. 2022). To our knowledge, this is the first study to indicate a potential heavy metal accumulation in free-range poultry in household area.

The backyard poultry are left free for scavenging. They consume natural feed such as insects, greens, grain, and kitchen waste (Prakash et al. 2020; Rajkumar et al. 2021) and non-feed substances such as metals, plastic, stone, and wood (Huang et al. 2019). Similarly, the backyard ducks consumed the naturally available feed and household waste (Barua and Yoshimura 1997; Zhang et al. 2009; Li et al. 2019). The high content of Pb and Cd in the consumed plants can also result in the high levels of the toxic metals in the organs of the free-range poultry (Ebrahimpour and Mushrifah 2008; Ali et al. 2021; Elkribi-Boukhris et al. 2022). Moreover, other studies (Anderson et al. 2000; Taggart et al. 2006) reported that the ducks also consumed pellet shot as grit in the gizzard to enhance digestibility. In the present study, we found nail, plastic, and bottle cap fractions in the crop of the ducks. The digestive tract eroded the metal substances and absorbed the soluble Pb and Cd.

In conclusion, the potential health risk posed by Pb and Cd contamination was minimal. The higher level of the heavy metals in the organs of the backyard poultry reflects an accumulation of ingested toxic materials around contaminated backyard areas. Therefore, there is an urgent need for an extensive study to evaluate the potential contamination of other foods, such as eggs, fish, and crops originating from the suburban area. Regarding backyard poultry as a source of nutrients for family consumption and household income, household waste management is essential for minimizing heavy metal contamination. It is critical to raise free-range poultry in an uncontaminated environment and to provide natural grit to the animals.

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Declarations

Conflict of interest The authors declare that there is no conflict of interest.

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