



NRCP
RESEARCH JOURNAL

Full Paper

Assessment of Trace Element Concentration in Soil Surrounding Selected Poultry Farms in Leyte Province, Philippines

Lotis M. Balala^{1*}, Janet Alexis A. de los Santos², Shebelle A. Cueva¹, Dixie Grace A. Gelaga¹

¹College of Veterinary Medicine, Visayas State University, Visca, Baybay City, Leyte, Philippines, balalalotis@vsu.edu.ph

²College of Nursing, Visayas State University, Visca, Baybay City, Leyte, Philippines

The escalating global population propels agricultural intensification to increase food production. This entails the use of feed additives such as trace elements allowing their spillover in animal manure. This study assessed the concentrations of trace elements in the soil surrounding selected broiler and layer farms in Leyte. Forty-eight soil samples were collected for four months to analyze the concentration of copper, iron, zinc, cadmium, and lead. A portable soil tester was used to measure soil temperature, pH, and electrical conductivity, and microwave plasma atomic emission spectroscopy to quantify trace elements. Levels of trace elements were within WHO and USEPA standards. Iron had the highest concentration (132.84 mg/kg), and cadmium had the lowest (0.02 mg/kg). Soil surrounding broiler farms contained higher levels of trace elements observed during the harvest season in December. Despite the acceptable levels of trace elements in soil, continuous monitoring is necessitated to prevent buildup of toxic levels.

Keywords; physicochemical properties, poultry, soil, trace elements

Article history

Received : December 19, 2023

Revised : February 1, 2024

Accepted: February 1, 2024

Introduction

The rising human population worldwide shifted conventional food production into intensive techniques employing the use of feed additives to boost growth, occasionally ignoring safe food production. Many current meat production techniques have raised several health and environmental issues, like the high risk of infectious animal diseases, nutrition-related diseases, and environmental degradation leading to subsequent habitat and biodiversity loss (Bhat et al., 2015). Furthermore, the intensification of production necessitates using trace elements as additives to improve feed quality and increase feed conversion ratios (Kumar and Patyal, 2020). Trace elements, or trace metals, refer to minerals the body requires in small quantities (Pajarillo et al., 2021). The US National Research Council Committee on Diet and Health (1989) reports these metals to be toxic if consumed at sufficiently high levels for prolonged duration. Some trace elements are essential because they are needed in the body to promote health. Iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) are essential to health when added to animal feeds (Soumaoro et al., 2021). Other elements like arsenic (As), cadmium (Cd), fluorine (F), lead (Pb), and mercury (Hg) are not essential because they have no significant biological functions but may be present in feedstuffs as contaminants (Hejna et al., 2018).

Over the decade, the continuous supplementation of feed additives has changed the level of trace elements in animal manure (Luo et al., 2009). Profound implications result from the inadequate physiological use of elements, leading to their release in the soil and waterways, consequently affecting the welfare of both the biota and humans (Fatoki et al., 2002). Long-term and repeated exposure to poultry manure results in a substantial buildup of trace elements in the soil (Muhammad et al., 2020). This buildup constitutes a significant health hazard to humans and animals through accidental soil ingestion, soil contamination with edible plants, or the consumption of contaminated products of animal food origin (Alfthan et al., 2015). In addition, the absorption of trace metals in the soil alters the ecological balance.

The poultry sector in Eastern Visayas is rapidly growing, with over a 2.3% increase in the overall volume during the first quarter of 2021 (Perante, 2021). Among provinces in the region, Leyte

comprises the bulk (40.5%) of the chicken population, with at least 1,178.2 thousand chickens as of April 1, 2021. The chicken population is divided into 57.5% native or improved chickens, 21.8% broiler chickens, and 20.6% layers. Furthermore, the topography and climate of Leyte is generally wet throughout the year and is prone to typhoon landfalls (Santos, 2021). This condition favors the leaching of trace elements or runoff of contaminated soil into bodies of water. With continued agricultural expansion, there is a need to conduct surveillance and monitoring of trace element accumulation in soil associated with animal production. In the Philippine literature, there is inadequate information documenting the impact of poultry manure on the level of trace elements in the soil surrounding poultry farms. This study assessed the concentration of some trace elements in the soil contaminated with poultry manure. Spatial and temporal variations were compared to determine which farm type has a higher level of trace elements in their soil and during which period their concentration in soil is high. The information can be valuable in strengthening existing environmental laws, creating government initiatives to increase public awareness of trace element contamination, and redesigning strategies for sustainable agriculture.

Materials and Methods

Study area

The province of Leyte is bound by Carigara Bay on the North, San Juanico Strait and Leyte Gulf in the east, Visayas Sea and Ormoc Sea in the west, and the province of Southern Leyte in the south (Figure 1) (PhilAtlas, 2023). With an estimated land area of 2850 square miles, it is geographically situated 10° 51' 44.8344" North and 124° 52' 52.0284" East (LatLong.info, 2023). The province has a mixed type of climate, Type II on the east part and type IV on the west. There is no specific wet or dry season, but rainfall is pronounced from November to January (Islands Philippines, 2023). Chicken production as of 01 April 2021 totaled to 1,178.2 thousand birds, which took the largest bulk of production in the region. This number is broken down into broilers (143.8 thousand), layers (154.4 thousand), and native or improved chickens (Perante, 2021).

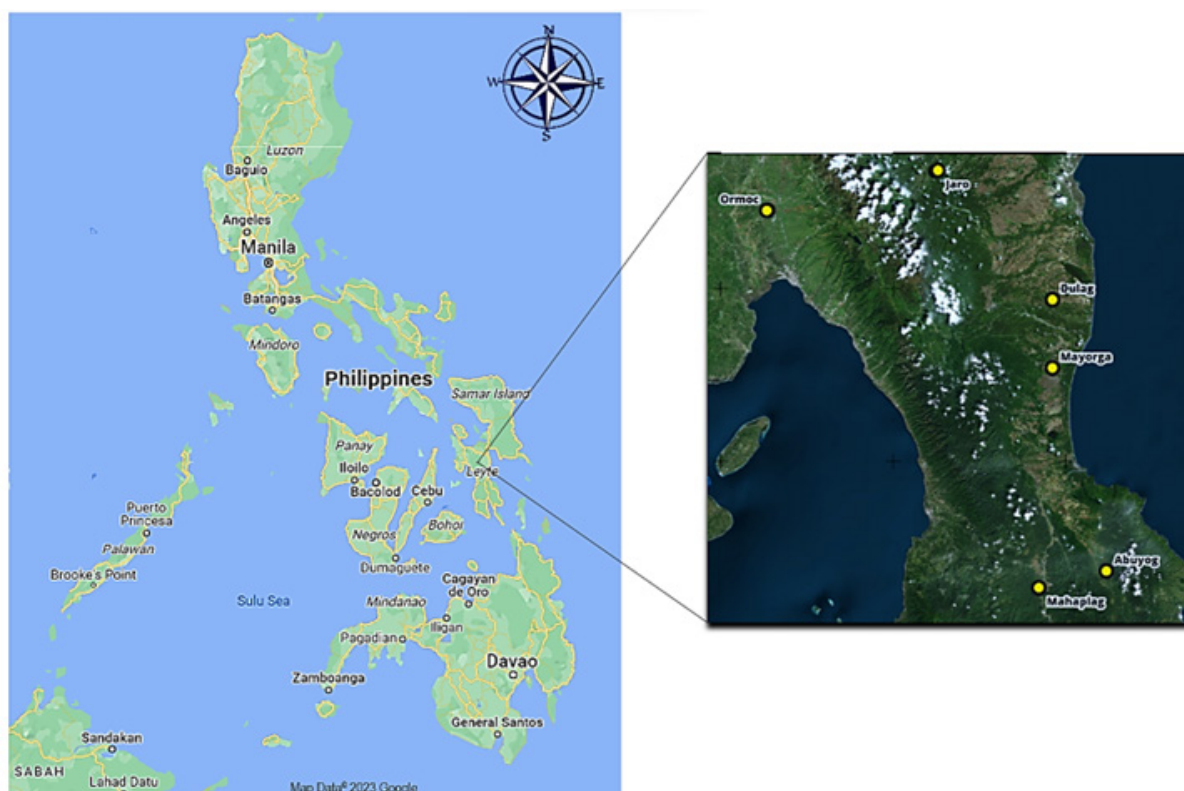


Figure 1. Map of the Philippines and the geographical locations of study farms in Leyte

Selection of Study Farms

A list of farms was obtained from the database of the Department of Agriculture in the locality and from the available data online. Selected farms were those of modest scale production (501 to 5,000) to large scale production (above 10,000) based on the description of FAO (2019) and the Housing and Land Use Regulatory Board Policies (HLURB, 2000). Only the farms proximate to a body of water of at least 50 m from the farm perimeter and whose owners expressed their voluntary participation were included in the study, resulting in the inclusion of three broiler farms located in Mahaplag, Abuyog, and Ormoc City; and three-layer farms located in Mayorga, Dulag, and Jaro, Leyte (Figure 1). Farms were characterized based on the type of production (layer or broiler), volume of production, waste treatment, waste treatment facilities (e.g., septic tank, lagoons, biodigester), type of flooring, and waste collection frequency. Households residing near the farms were asked about how they utilize the nearby water resources.

Sample collection

Soil samples were collected from six poultry farms in Leyte throughout a four-month period (November to February). A total of 48 soil samples (24 directly exposed and 24 indirectly exposed to manure) were collected from soil 15 cm below the ground

surface. Samples were collected following a zig-zag ("W") path across the field (Figure 2). Composite samples were formed by collecting 50 grams of soil from each of the 20 subsample areas. All samples were placed in a properly labeled, clean polythene bag and brought to the Diagnostic Laboratory of the College of Veterinary Medicine, Visayas State University, Baybay City, Leyte. Samples were evenly spread on clean paper and left to dry for a few days. Foreign materials like roots, stones, pebbles, and gravel were removed. After drying, composite samples were reduced by the quartering method described by Gerlach et al. (2022). Briefly, dried soil was thoroughly mixed and arranged into a conical heap. The heap was flattened and divided into four quarters, followed by the removal of two diagonally opposite quarters. The process was repeated with the remaining portions and reduced until 100 g of soil was achieved. The soil was passed through a 10 mm and 40 mm mesh sieve and placed in smaller zip-lock plastic for trace element analysis.

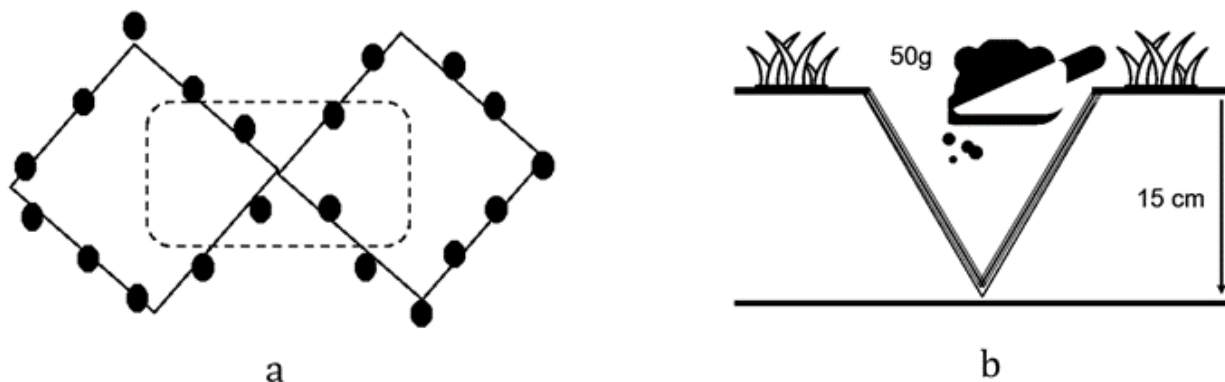


Figure 2. Zigzag path of the subsampling areas (a) and the depth of soil collection from each area (b)

Physicochemical properties

Physicochemical parameters that determine soil health and are affected by the presence of trace elements in the manure are assessed. Soil temperature and pH were measured in situ by inserting a portable soil tester (Sonkir, Ecuador) at least 15 cm below the ground. A soil extract was prepared to assess the electrical conductivity (EC) of the soil. Briefly, 20 g of soil was transferred in a clean beaker containing 40 mL of distilled water and stirred for 5 min. The suspension was left for an hour to allow the settling out of the suspended clay from the suspension. A multiparameter probe (Hanna, USA) was then immersed deep enough into the clear supernatant to read the EC. Readings of the physicochemical parameters were repeated thrice.

Soil extraction and trace element analysis

The standard soil extraction and preparation methods described by Agilent (2021) for microwave plasma atomic emission spectroscopy (Agilent, USA) analysis of soil micronutrients were employed to analyze Cu, Fe, Zn, Cd, and Pb concentrations in the samples. Briefly, soil was extracted by adding 50 mL of 1 M ammonium acetate to 2.5 g of soil. The mixture was mixed thoroughly through a mechanical shaker at $20\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ for 1 hour. The samples were then filtered in Whatman #42 and the clear liquid was analyzed immediately. Multi-element standard solutions were prepared in 1 M ammonium acetate. This was done by pipetting each of the element into 100 mL volumetric flask equal to the desired concentrations. Appropriate amount of the extraction solution was added followed by distilled water up to the appropriate mark. Cesium chloride was used as an ionization buffer. Prior to actual measurements, the calibration curve of commercial standards was performed to establish the samples calibration's correlation

coefficient equaled to or higher than 0.9990. Processed samples were analyzed at the Central Analytical Services Laboratory of the Philippine Root Crop Research and Training Center (PhilRootcrops), Visayas State University, Visca, Baybay City, Leyte.

Disposal of unused samples

Unused soil samples were treated with a water-based soil washing method (Dermont, 2008) before being disposed of into vacant lots. This was followed by washing with water and chemical extraction based on pollutant solubilization using HCl mineral acid.

Data Analysis

Data were initially stored in Microsoft Excel 2019 and analyzed with Jeffreys's Amazing Statistics Program (JASP) statistical software version 0.16.14. Descriptive statistics was generated to express the physicochemical characteristics in mean values \pm standard deviation. A one-way analysis of variance (ANOVA) was used to examine the significant differences in the trace element concentrations from soil directly and indirectly exposed to manure, followed by a post hoc Tukey test. Data were considered significant at $p\text{-value} < 0.05$.

Results

Profile of the study farms

The broiler farms were engaged in large-scale production and owned mainly by contract growers (Table 1). Layer farms were into medium-scale production and owned by either a private entity or a people's cooperative. The largest volume of chicken population was housed in a semi-ventilated building, while the rest were in conventional housing. Only two farms had waste storage facilities, a septic tank and concrete pit. Waste collection was done daily

in most farms while it was periodic or after each cropping in two broiler farms. The manure in the medium-scale farms was distributed to households in the community with gardens, disposed into pits or vacant lots in some, or sold as fertilizer. Bodies of water near the farms were either rivers, creeks, or groundwater and used for various purposes, including drinking, fishing, irrigating, washing, cleaning, swimming, and bathing of animals.

Profile of the study farms

The mean temperature of soil samples was highly variable in soil directly exposed to manure (Figure 3) and ranged from 26.25 °C to 31.08 °C, while it ranged from 27.42 °C to 29.33 °C in indirectly exposed soil across all farms. The highest temperature was 31.08 ± 3.37 °C in Farm 1, which was slightly above the recommended temperature range of 20 °C - 30 °C by the WHO (2002).

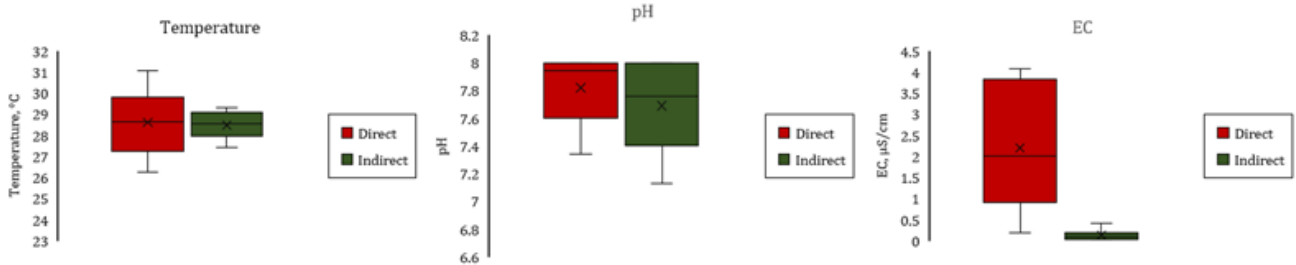


Figure 3. pH, temperature, and EC of soil samples across study farms

The pH of soil samples ranged from 7.34 to 8.00 and 7.13 to 8.00 for soil directly and indirectly exposed to manure, respectively with the highest mean pH (8.00 ± 0.00) observed in Farms 4 and 6. The soil pH across farms was within to slightly above the pH (6-7.5) that allows most plants to thrive according to the Philippine National Standards (PNS/BAFS 183:2020, n.d.).

Table 1. Waste management profile of the selected study farms in Leyte

Farm Code	Location	Type of operation	Population of chickens	Waste management system			How is manure disposed?	Is there a body of water near the farm? What type and how is it used?	Type of housing
				Is there a waste facility in the farm? What type?	What is the frequency of waste collection?	Is waste treated?			
Farm 1	Mahaplag	Broiler	69,000-90,000	Yes, septic tank	Periodic collection	No	Sold as fertilizer	Yes, river	Semi-ventilated
Farm 2	Abuyog	Broiler	22,000-24,000	No	Daily	No	Disposed in vacant lots	Yes, groundwater	Conventional
Farm 3	Ormoc	Broiler	17,000 - 18,000	No	Periodic collection	No	Sold as fertilizer	Yes, river	Conventional
Farm 4	Mayorga	Layer	880	No	Daily	No	Distributed to community	Yes, river	Conventional
Farm 5	Dulag	Layer	830	No	Daily	No	Distributed to community	Yes, river	Conventional
Farm 6	Jaro	Layer	1,024	Yes, concrete pits	Daily	No	isposed in pits	Yes, river	Conventional

Note. Farms 1-3 = broiler; 4-6 = layer

The EC was highly variable between soil samples from directly and indirectly exposed to manure with EC ranging from 0.19 $\mu\text{S}/\text{cm}$ to 4.09 $\mu\text{S}/\text{cm}$ and 0.03 $\mu\text{S}/\text{cm}$ to 0.41 $\mu\text{S}/\text{cm}$, respectively. The highest EC was observed in Farm 1 with a mean value of $4.09 \pm 1.79 \mu\text{S}/\text{cm}$. The EC values in this study were within the acceptable EC range for soil of less than 4000.00 $\mu\text{S}/\text{cm}$ (Abegunrin et al., 2013).

Spatial variation of trace element concentration in soil samples

The mean concentration of trace elements in soil samples ranged from 0.02+2.68 to 132.84+18.91 mg/kg and arranged in this order: $\text{Cd} < \text{Cu} < \text{Zn} < \text{Pb} < \text{Fe}$

(Table 2). None of the trace elements measured exceeded the Philippine National Standards, WHO, and US EPA standards. The mean concentration of Cu in the soil directly exposed to manure ranged from 2.22 mg/kg to 8.70 mg/kg and 2.82 mg/kg to 7.48 mg/kg in indirectly exposed soil. The highest Cu concentration was observed in Farm 3 ($8.70 \pm 1.56 \text{ mg/kg}$) and lowest in Farm 6 (2.22 ± 0.41). Fe concentration in soil directly and indirectly exposed to manure ranged from 66.90 mg/kg to 129.96 mg/kg and 57.07 mg/kg to 132.84 mg/kg, respectively. Fe concentration was highest in Farm 3 ($132.84 \text{ mg/kg} \pm 18.91 \text{ mg/kg}$). Zn concentration in soil directly exposed and indirectly

Table 2. Mean concentration (+SD) of trace elements in soil samples obtained from poultry farms

Soil sources	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	p value
Directly exposed to manure							
Cu	7.10+3.51	4.41+2.77	8.70+1.56	7.29+0.64	4.82+1.25	2.22+0.41	0.00
Fe	113.08+32.58	93.75+17.00	129.96+9.30	113.93+25.40	95.62+20.05	66.90+14.97	0.01
Zn	17.56+9.14	7.74+7.15	13.97+6.90	6.64+5.43	2.84+1.25	3.67+2.20	0.02
Cd	0.05+0.02	0.02+0.01	0.03+0.02	0.05+0.03	0.05+0.03	0.03+0.03	0.30
Pb	14.09+1.77	11.06+3.31	10.53+6.21	15.43+11.28	8.80+3.73	10.34+8.89	0.73
Indirectly exposed to manure							
Cu	5.65+3.53	4.69+0.37	7.39+1.88	7.48+1.61	4.95+0.55	2.82+0.84	0.02
Fe	91.64+12.71	99.16+13.00	132.84+18.91	105.26+5.72	88.36+11.69	57.07+11.75	0.00
Zn	11.68+6.76	10.68+2.23	11.03+5.41	9.07+7.94	8.42+3.88	7.09+4.08	0.83
Cd	0.04+0.04	0.02+0.01	0.03+0.02	0.04+0.02	0.04+0.03	0.03+0.03	0.50
Pb	9.52+5.25	5.10+2.68	12.40+10.49	14.52+11.32	10.87+4.23	10.91+9.40	0.68

Note. Farm 1= Mahaplag; Farm 2= Abuyog; Farm 3= Ormoc; Farm 4 = Mayorga; Farm 5 = Dulag; Farm 6 = Jaro

exposed to manure ranged from 2.84 mg/kg to 17.56 mg/kg and 7.09 mg/kg to 11.68 mg/kg, respectively, and highest in Farm 1 ($17.56 \text{ mg/kg} \pm 9.14 \text{ mg/kg}$). Cd concentration in soil samples ranged from 0.02 mg/kg to 0.05 mg/kg and 0.02 mg/kg to 0.04 mg/kg, respectively, for soil directly and indirectly exposed to manure. Pb concentration ranged from 8.80 mg/kg to 15.43 mg/kg and 5.10 mg/kg to 14.52 mg/kg in soil directly and indirectly exposed to manure, respectively. The highest concentration for Cd (0.05 mg/

kg ± 0.03 mg/kg) and Pb (15.43 ± 11.28 mg/kg) was observed in Farm 4. The variations in Cu, Fe, and Zn concentrations greatly varied ($p < 0.05$); however, the concentration of Cd and Pb did not vary significantly among farms.

The concentration of trace elements in Farms 1 and 4 was higher in soil directly exposed to manure than the indirect exposure. Conversely, trace elements were higher in soil indirectly exposed to manure in Farms 2 and 5. The concentration was similar in directly and indirectly exposed soil in Farms 3 and 6.

Collectively, the concentration of the trace elements did not exceed standard values.

Temporal variations of trace elements concentration in soil samples

Figure 4 shows the temporal variation of trace metal concentration across six farms. The highest level of most metals was observed during December (2022) and February (2023) in the soil directly exposed to manure and in November and December (2023) in the indirectly exposed soil. However, these concentrations did not exceed standard levels.

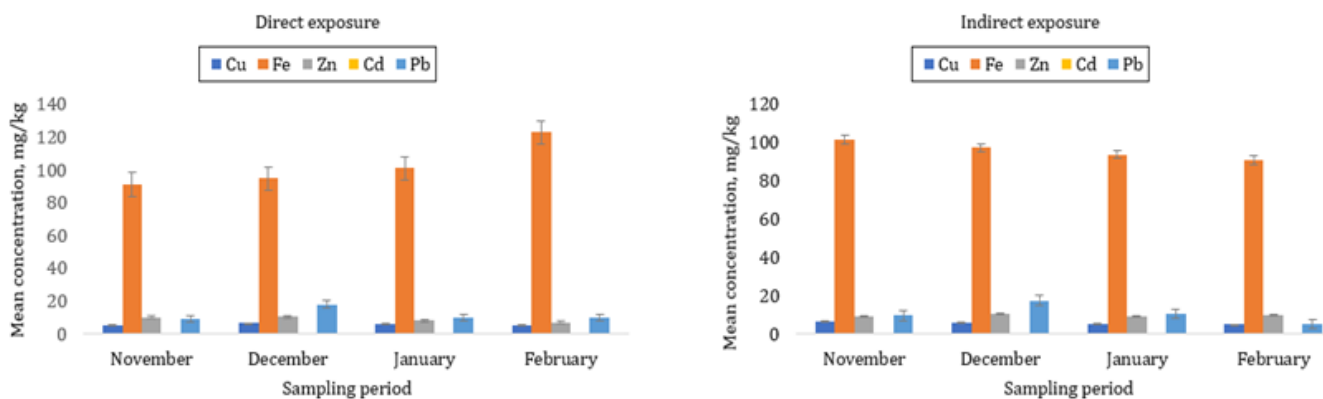


Figure 4. Temporal variation of trace elements in soil directly and indirectly exposed to manure

Cu was highest during December (6.44 mg/kg ± 3.49 mg/kg) and November (6.23 mg/kg ± 2.41 mg/kg) in soil directly and indirectly exposed to manure, respectively. The highest Fe level was observed during February (122.69 ± 35.42 mg/kg) and November (101.42 ± 19.11 mg/kg) in the soil directly and indirectly exposed to manure. Zn level was highest during December for both types of soil samples (10.233 ± 6.75 mg/kg and 10.32 ± 5.61 mg/kg). Differences in the mean concentrations of these metals based on the period of collection were insignificant ($p > 0.05$).

The Cd levels were highest in November (0.06 mg/kg ± 0.02 mg/kg and 0.06 mg/kg ± 0.02 mg/kg) and Pb in December (17.88 ± 9.66 mg/kg and 17.37 ± 11.90 mg/kg) for both types of soil. Differences in the mean concentration of Cd and Pb were significant

at ($p < 0.05$), indicating notable variations in the concentration of these metals at different sampling periods.

Comparison of trace element concentrations in soil by farm type

Table 3 depicts the level of trace elements in soil samples among the selected broiler farms (1-3). Cu, Fe, Zn, Cd, and Pb levels in soil samples were within permissible limits. There were no significant differences ($p > 0.05$) in the mean concentrations of trace elements in soil samples among the farms, suggesting that similar concentration was released regardless of the volume of broiler chickens produced. Only Farm 3 had a significant ($p = 0.01$) level of Fe in the soil, however, this level was below permissible limits.

Table 3. Mean concentrations (+SD) of trace elements in soil directly and indirectly exposed to manure among broiler farms

Trace elements (mg/kg)	Farm	Direct exposure		Indirect exposure		Standard value (mg/kg)
		Mean±SD	P- value	Mean±SD	P- value	
Cu	1- Mahaplag	7.10±3.51		5.65±3.53		36 (WHO, 1996)
	2- Abuyog	4.41±2.77	0.14	4.70±0.37	0.30	
	3- Ormoc	8.70±1.56		7.39±1.88		
Fe	1- Mahaplag	113.08±32.58		91.64±12.71		50,000 (WHO, 1996)
	2- Abuyog	93.75±17.00	0.12	99.16±13.00	0.01	
	3- Ormoc	129.96±9.30		132.84±18.91		
Zn	1- Mahaplag	17.56±9.14		11.68±6.76		50 (WHO, 1996)
	2- Abuyog	7.74±7.15	0.25	10.68±2.23	0.96	
	3- Ormoc	13.70±6.90		11.03±5.41		
Cd	1- Mahaplag	0.05±0.03		0.04±0.04		0.8 (WHO, 1996)
	2- Abuyog	0.02±0.01	0.11	0.02±0.01	0.31	
	3- Ormoc	0.03±0.02		0.03±0.02		
Pb	1- Mahaplag	14.09±1.77		9.52±5.25		85 (WHO, 1996)
	2- Abuyog	11.06±3.31	0.46	5.10±2.68	0.37	
	3- Ormoc	10.53±6.21		12.40±10.49		

Note. Farm 1= Mahaplag; Farm 2= Abuyog; Farm 3= Ormoc.

Furthermore, Farm 3 had high Cu and Fe in all soil samples and high Pb in soil with indirect exposure to manure. Soil samples in Farm 1 were high in Zn and Cd and high Pb in the soil directly exposed.

Levels of Cu and Fe in all soil samples were significantly different ($p < 0.05$) among layer farms (Table 4). However, levels were below permissible limits. The highest concentration of trace elements was found in Farm 4 in all samples, but this was below permissible levels.

Table 4. Mean concentration (+ SD) of trace elements in soil directly and indirectly exposed to manure among layer farms

Trace elements (mg/kg)	Farm	Direct exposure		Indirect exposure		Standard value (mg/kg)
		Mean±SD	P- value	Mean±SD	P- value	
Cu	4- Mayorga	7.29±0.64		7.48±1.61		36 (WHO, 1996)
	5- Dulag	4.82±1.25	0.00	4.95±0.55	0.00	
	6- Jaro	2.22±0.41		2.82±0.84		
Fe	4- Mayorga	113.93±25.40		105.26±5.72		50,000 (WHO, 1996)
	5- Dulag	95.62±20.05	0.03	88.36±11.69	0.00	
	6- Jaro	66.90±14.97		57.07±11.75		
Zn	4- Mayorga	6.64±5.43		9.07±7.94		50 (WHO, 1996)
	5- Dulag	2.84±1.25	0.31	8.42±3.88	0.88	
	6- Jaro	3.67±2.20		7.09±4.08		
Cd	4- Mayorga	0.05±0.03		0.04±0.02		0.8 (WHO, 1996)
	5- Dulag	0.05±0.03	0.59	0.04±0.03	0.60	
	6- Jaro	0.03±0.03		0.03±0.03		
Pb	4- Mayorga	15.43±11.28		14.52±11.32		85 (WHO, 1996)
	5- Dulag	8.80±3.73	0.54	10.87±4.23	0.80	
	6- Jaro	10.34±8.89		10.91±9.40		

Note. Farm 4=Mayorga; Farm 5=Dulag; Farm 6=Jaro.

Comparison of trace element concentration between broiler and layer farms showed significant differences ($p<0.05$) in the levels of Zn (direct exposure) and Fe (indirect exposure), with broiler farms producing higher levels of these elements compared to layer farms.

Discussion

Maintaining acceptable levels of physicochemical properties and trace elements in soil is vital for sustaining life and ecological balance. The temperature, pH, and EC values of soil in the study were within acceptable to slightly above standard limits. Soil temperature impacts the intensity of mineral leaching and weathering (USDA-NCRS, 2022). Increasing soil temperature inside a litter system poultry house alters the rate of organic matter decomposition and the mineralization of various organic materials (Davidson & Janssens, 2006). The pH affects the solubility and availability of trace elements, and there is a proportional change in the mobility of elements as soil pH varies (Gray et al., 1998). The value of EC is positively correlated with manure application because of its abundance of organic matter, nutrients, and ions (Carmo et al., 2016). The EC of soil samples was kept within the acceptable range because of the regular manure collection from poultry houses.

According to WHO (1996), the standard values for Cu, Fe, Zn, Cd, and Fe in agricultural soil are as follows: 36 mg/kg, 50,000 mg/kg, 50 mg/kg, 0.8 mg/kg, and 85 mg/kg, respectively. Based on these values, the levels of trace elements in soil samples were tolerable. This initially implies less environmental concern due to trace element accumulation in the soil of poultry farms in its current situation. The concentration of trace elements in the soil in this study may have been affected by the interference of precipitation during most of the sampling courses. This is because of the unpredictability of climate and the different climatic systems operating in the sampling areas, which happened despite weather monitoring and forecasts provided by PAGASA and AccuWeather. Sampling was resumed a few minutes after the rain completely stopped. Water from precipitation may have penetrated contaminated soil and caused surface runoff and seepage of dissolved elements through the soil to the groundwater and nearby bodies of water. A parallel investigation was done to assess the level of trace elements in water resources. Nonetheless, the study provided robust data that should be validated in future studies.

The concentration of trace elements was more dynamic in broiler operations than layer operations. This was due to the fast turnover of chickens and increased anthropogenic activities in broiler farms, with more than six cropping per year. Higher levels of trace elements were observed in soil indirectly exposed to manure than the directly exposed

soil, which can be explained by the removal of the manure from the soil under slatted buildings or cages and its application in farm vegetation or dumping in vacant lots. The peak concentration of the trace elements was observed in November, December, and February, during which time mature chickens produced more excreta, and anthropogenic activities intensified for two cycles of cropping. The concentration of trace elements in animal manure is mirrored by their portion in the feed, which becomes a high risk to agricultural lands (Wang et al., 2013). The contents of Cu, Zn, Pb, and Cd in chicken manure were reported to range from 1.53–487.43 mg/kg, 15.37–1,063.32 mg/kg, non-detectable–22.10 mg/kg, and non-detectable–37.99 mg/kg, respectively (Zhang et al., 2012).

Data from the study implied negligible accumulation of trace elements in the soil during the period of investigation. However, the absence of complete trace element inventories makes assessing the full extent of local soil pollution difficult. Trace elements are quickly absorbed in the body yet slowly excreted, rendering them untraceable in the waste. The accumulation into food of animal origin greatly depends on the rate of absorption, bioaccumulation, metabolism, and excretion (Cheli et al., 2013). The chemical form, dose, interaction with other compounds, and other factors influence this biological process (Fink-Gremmels, 2012). It should also be noted that despite acceptable levels of trace elements in the manure, its properties should be thoroughly evaluated before utilization. This is suggested by Ravindran (et al., 2017), who observed some level of phytotoxicity in the application of poultry manure containing normal levels of Cu (39.3 – 134.4 mg/kg), Pb (not detected – 107.1 mg/kg) and Zn (330 – 845.1 mg/kg). Where substantial protocols for waste treatment practices are lacking, monitoring of trace element concentration in soil and water is highly essential. Further consideration of the nutritional ecology of trace elements is necessary in formulating a well-balanced ration to supply all dietary needs without the excretion of excess and toxic doses in the environment.

Conclusion and Recommendation

The level of trace elements in soil samples surrounding poultry farms in Leyte was within acceptable values, implying less harm to health and the environment during the assessment period. Future research should aim at a comprehensive study to validate the present findings and assess the input and output of trace elements via the feeds and manure. A One Health structured research

is relevant for an encompassing investigation of human-animal-environment interfaces of trace element contamination.

Ethics Statement

There was minimal involvement of humans and no involvement of animals in this study. The study was reviewed and approved by a technical panel of NRCP-NSTEP Visayas and duly registered under the Office of the Director for Research at the Visayas State University, Visca, Baybay City, Leyte.

Acknowledgement

The authors are grateful to the DOST-NSTEP for funding this research and to the Visayas State University for the laboratory facility.

Declaration of Conflict

The authors have no conflict to declare.

Author Contributions

Lotis M. Balala is the leading proponent and project leader overseeing the implementation of this research.

Janet Alexis A. de los Santos is a project staff who reviews the methodologies.

Shebelle A. Cueva is a project staff who coordinates with the local government units and facilitates the data collection and analysis.

Dixie Grace A. Gelaga is a student researcher who collects, processes, and analyzes the data of the samples.

References

Abegunrin, T.P., Awe, G.O., Idowu, D.O., & Adejumbi, M.A. (2013). Impact of wastewater irrigation on soil physico-chemical properties, growth and water use pattern of two indigenous vegetables in southwest Nigeria. *Catena*, 139, 167-178. <https://doi.org/10.1016/j.catena.2015.12.014>

Alfthan, G., Euroola, M., Ekholm, P., Venäläinen, E.R., Root, T., Korkalainen, K., Hartikainen, H., Salminen, P., Hietaniemi, V., Aspila, P. & Aro, A. (2015). Effects of nationwide addition of selenium to fertilizers on foods, and animal and human health in Finland: from deficiency to optimal selenium status of the population. *Journal of Trace*

Elements in Medicine and Biology, 31, 142–147. doi: 10.1016/j.jtemb.2014.04.009

Bhat, Z.F., Kumar, S., & Fayaz, H. (2015). In vitro meat production: Challenges and benefits over conventional meat production. *Journal of Integrative Agriculture*, 14(2), 241-248. [https://doi.org/10.1016/S2095-3119\(14\)60887-X](https://doi.org/10.1016/S2095-3119(14)60887-X)

Carmo, D.L., Silva, C.A., de Lima, J.M., & Pinheiro, G.L. (2016). Electrical conductivity and chemical composition of soil solution: Comparison of solution samplers in tropical soils. *Revista Brasileira de Ciência do Solo*, 40, 0140795. DOI: 10.1590/18069657rbcS20140795

Cheli, F., Pinotti, L., Rossi, L., & Dell'Orto, V. (2013). Effect of milling procedures on mycotoxin distribution in wheat fractions: A review. *Food Science and Technology*, 54, 307–314. <https://doi.org/10.1016/j.lwt.2013.05.040>

Davidson, E. & Janssens, I. (2006). Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature*, 440, 165–173. <https://doi.org/10.1038/nature04514>

Dermont, G., Bergeron, M., Mercier, G., & Richer-Lafleche, M. (2008). Soil washing for metal removal: A review of physical/chemical technologies and field applications. *Journal of Hazardous Materials*, 1–31. <https://doi.org/10.1016/j.jhazmat.2007.10.043>

FAO. (2019). Poultry Sector Ethiopia. FAO Animal Production and Health Livestock Country Reviews. No. 11. Rome. 15/08/2021/11:42 <http://www.fao.org/3/ca3716en/ca3716en.pdf>

Fatoki, O.S., Lujiza, N., & Ogunfowokan, A.O. (2002). Trace metal pollution in Umtata River. *Water*, 28, 183- 189.

Fink-Gremmels, J. (2012). Animal feed contamination. Effects on livestock and food safety. Woodhead Publishing Series in Food Science, Technology and Nutrition, Cambridge, UK.

Gerlach, R.W., Dobb, D.E., Raab, G.A., & Nocerino, J.M. (2002). Gy sampling theory in environmental studies. 1. Assessing soil splitting protocols. *Journal of Chemometrics*, 16, 321-328. DOI: 10.1002/cem.705

Gray, C.W., McLaren, R.G., Roberts, A.H., & Condron, L.M. (1998). Sorption and desorption of cadmium from some New Zealand soils: Effect of pH and contact time. *Australian Journal of Soil Research*, 36,199-216. DOI: 10.1071/S97085

Hejna, M., Gottardo, D., Baldi, A., Dell'Orto, V., Cheli, F., Zaninelli, M., & Rossi, L. (2018). Review: Nutritional ecology of heavy metals. *Animal*, 12(10), 2156-2170. DOI: 10.1017/

S175173111700355X

- HLURB. (2000). Implementing rules and regulations to govern the processing of application for locational clearance for poultry and piggery as amended. Retrieved from <http://hlurb.gov.ph/wp-content/uploads/laws-and-issuances/policies/R674s2000.pdf>
- IslandsPhilippines. (2023). Climate of Leyte. Retrieved from https://islandsphilippines.com/leyte/leyte_climate.php
- Kumar, A. & Patyal, A. (2020). Impacts of intensive poultry farming on 'one health' in developing countries: challenges and remedies. *Exploratory Animal and Medical Research*, 10(2): 100-111.
- LatLong.info. (2023). Latitude and longitude of Leyte. Retrieved from <https://latlong.info/philippines/leyte>
- Luo, L., Maa, Y., Zhang, S., Wei, D., & Zhu, Y.G. (2009). An inventory of trace element inputs to agricultural soils in China. *The Journal of Environmental Management*, 90, 2524–2530. <https://doi.org/10.1016/j.jenvman.2009.01.011>
- Muhammad, J., Khan, S., Lei, M., Khan, M.A., Nawab, J., Rashid, A., Ullah, S., & Khisro, S.B. (2020). Application of poultry manure in agriculture fields leads to food plant contamination with potentially toxic elements and causes health risk. *Environmental Technology and Innovation*, 19: 100909. <https://doi.org/10.1016/j.eti.2020.100909>
- Pajarillo, E.A.B., Lee, E. & Kang, D.K. (2021). Trace metals and animal health: Interplay of the gut microbiota with iron, manganese, zinc, and copper. *Animal Nutrition*, 7(3):750-761. doi: 10.1016/j.aninu.2021.03.005
- Perante, W. (2021). Chicken Production in Eastern Visayas up by 2.3 Percent in the First Quarter of 2021 (Preliminary). Retrieved from <http://rsso08.psa.gov.ph/article/chicken-production-eastern-visayas-23-percent-first-quarter-2021-preliminary#sthash.5d4MfCEv.dpbs>
- PhilAtlas. (2023). Leyte. Retrieved from <https://www.philatlas.com/visayas/r08/leyte.html>
- PNS/BAFS 183:2020. (n.d.). Philippine National Standard for Organic Soil Amendments. Retrieved from https://bafs.da.gov.ph/bafs_admin/admin_page/pns_file/2021-03-03-PNS%20BAFS%20183-2020%20Organic%20Soil%20Amendments.pdf
- Ravindran, B., Mupambwa, H.A., Silwana, S., & Mnkeni, P.N.S. (2017). Assessment of nutrient quality, heavy metals and phytotoxic properties of chicken manure on selected commercial vegetable crops. *Heliyon*, 3(12), e00493. <https://doi.org/10.1016/j.jenvman.2009.01.011>
- Santos, G.D. (2021). 2020 tropical cyclones in the Philippines: A review. *Tropical Cyclone Research and Review*, 10(3), 191-199. <https://doi.org/10.1016/j.tcr.2021.09.003>
- Soumaoro, I., Pitala, W., Gnandi, K., & Kokou, T. (2021). Health risk assessment of heavy metal accumulation in broiler chickens and heavy metal removal in drinking water using *Moringa oleifera* seeds in Lomé, Togo. *Journal of Health and Pollution*, 11(31), 210911. doi: 10.5696/2156-9614-11.31.210911.
- US EPA. (2002). National Recommended Water Quality Criteria: 2002. Office of Water, EPA-822-R-02-047, U.S. Environmental Protection Agency, Washington DC. <http://www.epa.gov/waterscience/standards/wqcriteria.html>.
- USDA-NCRS. (2022). Soil Conditions: Soil Climate Analysis Network. Retrieved from <https://www.nrcs.usda.gov/wps/portal/wcc/home/snowClimateMonitoring/soilClimateConditions/>
- Wang, H., Dong, Y.H., Yang, Y.Y., Toor, G.S., & Zhang, X.M. (2013). Changes in heavy metal contents in animal feeds and manures in an intensive animal production region of China. *Journal of Environmental Sciences*, 25, 2435–2442. [https://doi.org/10.1016/S1001-0742\(13\)60473-8](https://doi.org/10.1016/S1001-0742(13)60473-8)
- WHO. (1996). Permissible limits of heavy metals in soil and plants (Geneva: World Health Organization), Switzerland.
- Zhang, F., Li, Y., Yang, M., & Li, W. (2012). Content of heavy metals in animal feeds and manures from farms of different scales in northeast China. *International Journal of Environmental Research and Public Health*, 9(8), 2658-2668. <https://doi.org/10.3390/ijerph9082658>