Research Article

Characterization of Metals in Feed, Litter and Air of Intensive Poultry Farming Facilities

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Abstract | Poultry industry is progressing worldwide due to cheap sources of proteins and it is also considered as the center of various organic and inorganic emissions. The current study was designed to see the release of different metals from the poultry farms. Air samples both from indoor and outdoor along with the litter and feed samples of ten poultry houses were collected from the outskirts of Lahore, Punjab, Pakistan. Poultry farms were varied in feed and grouped into three categories: Group A (using Feed A), Group B (using Feed B) and Group C (using Feed C). All collected samples were digested with aqua regia and analyzed by Inductively Coupled Plasma Atomic Mass Spectroscopy (ICP-MS). Fourteen metals were detected and categorized as essential (Calcium (Ca), Potassium (K), Sodium (Na), Phosphorus (P), Magnesium (Mg)), trace (Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn)) and heavy metals (Cadmium (Cd), Chromium (Cr), Mercury (Hg), Nickel (Ni), Lead (Pb)). In general, the concentration of all essential, trace, and heavy metals was found to be highest in feed followed by litter and air samples. However, Cr, Hg and Pb were higher in litter samples of group A as compared to feed and air. All the samples were statistically analyzed using one way ANOVA. A significant difference of feed was present with litter and air samples within groups ($p<0.05$) however, no significant differences were recorded among different groups. Overall it was noticed that the concentration of metals in feed samples were reflecting in litter and air. So, there is a need to ensure intervention and management policies in intensive poultry farming facilities to establish standards for metal in feed to reduce their bioaccumulation in the environment.

Keywords | Feed, Indoor air, Litter, Metals, Outdoor air

Received | August 30, 2023; **Accepted** | September 20, 2023; **Published** | December 01, 2023
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Citation | Yasmeen R, Hafeez F, Ammara U, Younas R, Ahmad S, Ali Z, Nasir ZA (2023). Characterization of metals in feed, litter and air of intensive poultry farming facilities. J. Anim. Health Prod. 11(4): 375-381.
DOI | http://dx.doi.org/10.17582/journal.jahp/2023/11.4.375.381
ISSN | 2308-2801

INTRODUCTION

Poultry is a growing industry across the world to justify the protein demands of people. At the same time, there are high concerns about the emissions (organic dust, gases, and heavy metals) that are coming from such large facilities. The emissions from such facilities goes into different environmental media which results in public health impacts (Bakutis et al., 2004; Lammel et al., 2004; Barrasa et al., 2012; Hu et al., 2017). Among these, metal pollution is a major public health risk and the contribution of intensive poultry farming to heavy metal emissions into the air, soil and water have the potential to negatively affect ecosystems and human populations. Some metals such as Selenium, Copper, Iron and Zinc are purposefully added to the feed to enhance feed efficacy, weight and control diseases in birds (Adekanmi, 2021). However, by different means they entered the environment and may result in surface and groundwater contamination. On the other hand organic waste like poultry manure and litter is in practice to improve the soil and it is rich source of nutrients (Bolan et al., 2010). Different studies were also designed to monitor amount of metals and a higher concentration of Cu and Zn were reported in litter treated soil as compared to the non-treated soil (Han et al., 2000; Jaja et al., 2013). The metals are locked by plants that cultured in poultry waste treated soil and travel via food chain and later it may have adverse effects on the environment and human health (Lopes et al., 2011). Different heavy metals such as arsenic, cadmium, chromium, lead, and mercury are toxic and pose serious threats upon exposure to living organisms (Tchounwou et al., 2012; Jaishankar et al., 2014; Su 2014). Even low amount of these metals effects the reproductive function of males (Wirth and Mijal, 2010). In workplaces where the likelihood of heavy metal detection has increased, the risk has also increased. Risk analysis was carried out by Lopes et al. (2011), with different metals such as Cd, Ni, Cu, Pb, and Zn and findings suggest there is need to regulate amount of Zn in poultry waste. As higher concentration of Zn is posing a threat for environment degradation. However, toxicity also depends on various other factors such as gender, route of exposure, concentration of particular metal and the age of the individual. The adverse human health effects of heavy metals have been reported by international organizations, for example, World Health Organization (WHO) and the International Agency for Research on Cancer (IARC). There could be marked differences in management practices and regulation of intensive poultry farming facilities across the world leading to differences in heavy metals emissions and their pathway into different environmental media (air, soil, water) and resultant exposure. Therefore, the knowledge on metal types and their concentration in feed, litter and air is critical to gain a holistic understanding of the emissions from intensive poultry farming and to devise appropriate intervention measures. There are no standard available regarding levels of metals in feed and no data present till date that describe characterization of metals in the air of poultry farms. In Pakistan, the poultry sector has made enormous progress in the last few decades and significantly contributed in achieving protein demands. Large-scale controlled environment production facilities are prevailing across the country and concerns are being raised for their public health impact with reference to nature and sources of these emission. The present study aimed to characterize types of heavy metals and there concentration in feed, litter and air from controlled environment poultry facilities with differing feed.

MATERIALS AND METHODS

Study sites and collection of samples

It was representative study and ten poultry farms with 26,000-30,000 birds were selected on the basis of differing feed on Raiwind and Kasur Road located near Lahore, Pakistan (Fig 1) . Three major feed brands that were most commonly used in Punjab, Pakistan were selected and categories into three groups: Group A (using Feed A), Group B (using Feed B) and Group C (using Feed C). The samples of feed and litter were collected from each shed in sterilized falcon tubes. While, air samples were collected on glass fiber filter (47 mm diameter, 0.22 um pore size) with portable air sampler (air flow 35l/min).

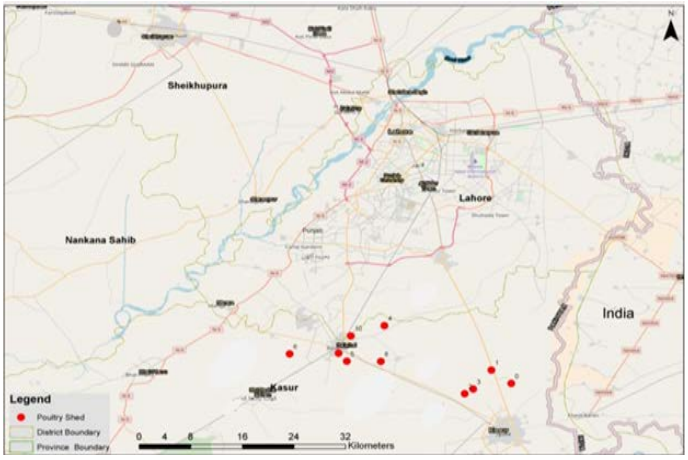

Figure 1: A map showing different visited sites in the vicinity of Lahore

Digestion of samples

Samples of feed and litter were air dried and finely crushed with mortar and pestle and sieved. A stock solution of 3:1 ml nitric acid and perchloric acid. One gram sieved sample of feed and litter were mixed with stock solution. The samples were heated at 150 ℃ and later to 180 ℃ until a clear solution obtained, then 1-2 drops of hydrogen peroxide was added in feed and litter samples. In case of air samples whole filter paper was digested with nitric acid and perchloric acid in 3:1. The samples were heated at 150 ℃ then to 180 ℃ until a clear solution obtained on hot plate. Hydrogen peroxide was not added in air samples. Prior to analysis all the samples were diluted in 15 ml deionized water and stored in borosil glass tubes after filtration (Yasmeen et al., 2019).

Analysis of metals

Fourteen metals were analyzed by Inductively Coupled Plasma Atomic Mass Spectroscopy (ICP-MS) as mentioned by Yasmeen et al. (2019). Selected metals were categorized as essential (Calcium (Ca), Potassium (K), Sodium (Na), Phosphorous (P), Magnesium (Mg)), trace (Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn)) and heavy metals (Cadmium (Cd), Chromium (Cr), Mercury (Hg), Nickel (Ni), lead (Pb)).

Statistical Analysis

The results were statistically analyzed by one way ANOVA using SPSS Version 21.0. Amount of metals in feed and litter samples were presented in mg/kg while for air samples μg/m^3 was used (Yasmeen et al., 2019).

RESULTS AND DISCUSSIONS

The different studied metals were categorized into three groups: essential (Ca, K, Na, P, Mg), trace (Zn, Cu, Fe, Mn) and heavy metals (Cd, Cr, Hg, Ni, Pb) and analyzed in feed, litter, indoor and outdoor air samples. It was noticed that all essential, trace and heavy metals (Ca, K, Na, P, Mg, Zn, Cu, Fe, Mn Cd, Cr, Hg, Ni, Pb) were found higher in all feed samples followed by litter and air samples. A similar study with different heavy metals such as Cd, Cr, Cu, Zn, Pb, Ni, Co, Mn, Ba, Sr, Ti, As, Mo and Hg was carried out in China. It showed that the maximum concentration in feed samples was exceeding National Hygienic Standards and concentrations of metals particularly, Cu, Cr, Cd, Zn and Pb were high in litter samples (Cang et al., 2004). A higher concentration of metals such as Cu and Zn was also noticed in feed and in litter samples and reported by Nicholson et al. (1999). In a study different metals such as N, Na, Mg, Al, Si, P, S, Cl, K and Ca were analyzed in different samples (feed, bedding material and fresh manure) that showed all samples have definite concentration of these metals but in variable concentration (Cambra-Lopez et al., 2010).

In the present study, all essential metals (Ca, K, Na, P, and Mg) were present in higher concentrations in feed samples particularly, Ca, K and P that was also higher in litter and air samples. However, for the outdoor air, Na was noticeably higher in all three groups while Ca was higher in group (B) and Mg in group (A) as compared to indoor air samples (Fig. 2-4). It was noticed that not much published data was reported regarding essential metals that inform about harmful effects of these metals in the air. However, most of the studies discussed harmful effects of N and P in the land and aquatic ecosystem degradation (Mallin 2000; Paik 2000; Mallin and Cahoon 2003; Bolan et al., 2004). An increasing tendency of using animal manures as good resource materials for land amendment practices shows that it has become as a nuisance (surface runoff or ground water infiltration) for the progress of animal industry if strategic improvement plans are not made for the control of environmental hazards from the animal excreta, then it will start degradation of the environment (Mallin and Cahoon, 2003). The enhanced level of nutrients, particularly Nitrogen and Phosphorus, are cause of various

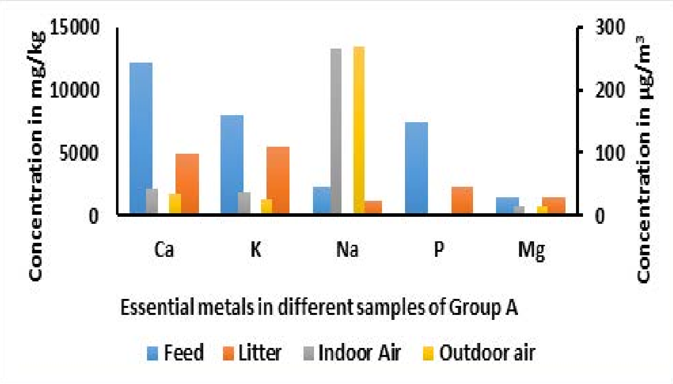

Figure 2: Essential metals in different samples of Group A (Ca: Calcium; K: Potassium; Na: Sodium; P: Phosphorus; Mg: Magnesium)

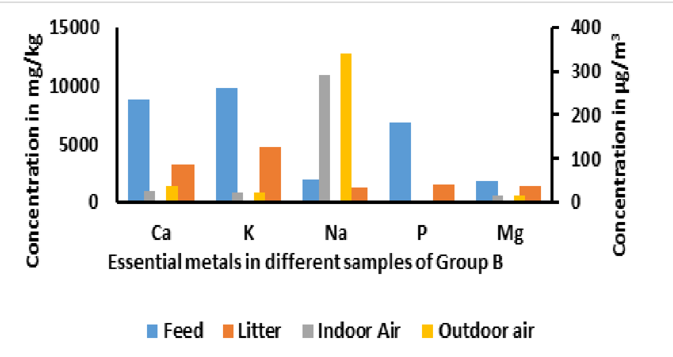

Figure 3: Essential metals in different samples of Group B (Ca: Calcium; K: Potassium; Na: Sodium; P: Phosphorus; Mg: Magnesium)

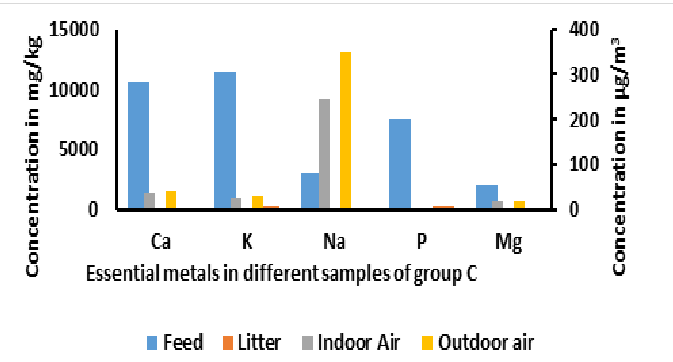

Figure 4: Essential metals in different samples of Group C (Ca: Calcium; K: Potassium; Na: Sodium; P: Phosphorus; Mg: Magnesium)

problems like eutrophication that affects aquatic ecosystem acutely or chronically; whenever; wastes enters directly or indirectly in the water bodies (Mallin. 2000). A study regarding retention of metals such as Ca, K, Na, P, and Mg, explained absorption of metals differed with age of birds (Thomas and Ravindran, 2010). However, in the present study a comparison with differing feed brands showed that even concentration of metals was more or less same in all feed samples but retention of metals was higher for feed of group C as small concentration of metals in litter was noticed as compared to group A and B that showed feed quality and retention of brand C might be good as age of birds in all visited facilities were same.

The intensive agriculture facilities are one of the important source of heavy metals along urbanization, industrialization and transportation and these metals affect the surrounding environment (Falandysz et al., 2007). A significant phytotoxic effect of different air pollutants including heavy metals was seen on different crops such as paddy, pigeon pea, maize, wheat and potato by Sen (2010). According to Suganya et al. (2016), all metals, even essential and trace, becomes toxic for the animal body and environment when present in excessive amount.

The trace metals (Zn, Cu, Fe and Mn) are added as growth enhancers in poultry feed and these metals are of prime importance in biological processes as Fe is important part of hemoglobin and promotes oxygen carrying capacity of red blood cells, Cu prevents anemia while Zn and Mn accelerate various enzymatic and hormonal control processes such as growth, immunity and skeletal integrity (Suleiman et al., 2015). In the present study, trace metals (Zn, Cu, Fe and Mn) were found to be high in feed samples as compared to litter and air samples and it was also noticed that the concentration of trace metals was very low in the outdoor of all selected poultry farms. Moreover, it was seen that a very low concentration of trace metals was present in litter samples of group C as compared to group A and B which showed that birds have good retention ability for minerals of group C (Fig. 5-7).

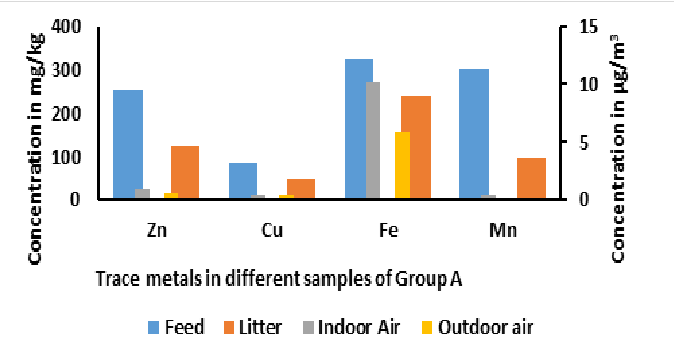

Figure 5: Trace metals in different samples of Group A (Zn: Zinc; Cu: Copper; Fe: Iron; Mn: manganese)

The range of Zn concentration in different feeds of the present study was 142.6-252.6 mg/kg that was lower from Zn concentration in feed (422.30 mg/kg) reported by Islam et al. (2007) and were also as lower as 54.3-482.2 mg/kg compared to study of Mahesar et al. (2010) however, higher than 1.43-11.65 mg/kg according to Suleiman et al. (2015). Similarly, Cu is an essential micro-nutrient that was found to be as high in all feed samples as 23.3- 85.9 mg/kg and the values were very high as compared to 6.52-16.94 mg/kg obtained by Okoye et al. (2011) but lower

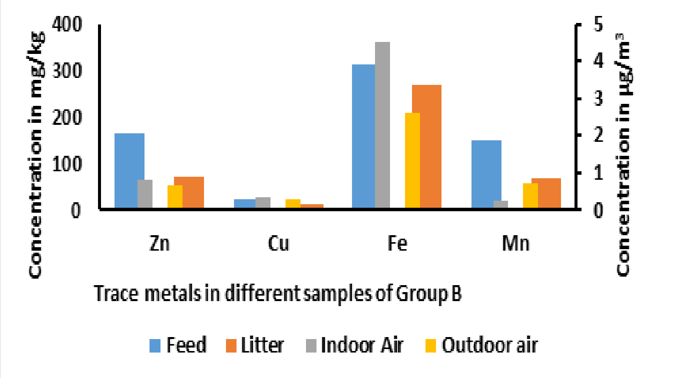

Figure 6: Trace metals in different samples of Group B (Zn: Zinc; Cu: Copper; Fe: Iron; Mn: Manganese)

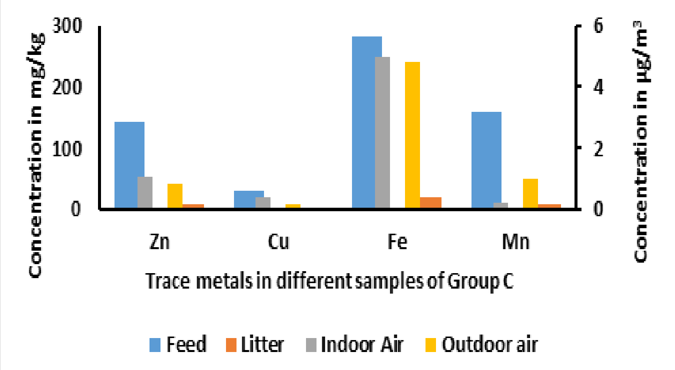

Figure 7: Trace metals in different samples of Group C (Zn: Zinc; Cu: Copper; Fe: Iron; Mn: manganese)

than 2.88–98.08 mg/kg as reported by Zhang et al. (2012). Mn is also an important trace mineral required for normal functioning of various biological processes and was found to be 150.7-304.1 mg/kg in present study and concentration was higher than 26.91-76.74 mg/kg as reported by Okoye et al., (2011) and 0.94-3.12 as noticed by Suleiman et al. (2015). The amount of Cu reported by Okeke et al., (2015) was 69-205 mg/kg in feed and 130-355 mg/kg in chicken litter. One more study conducted in Saudi Arabia showed some metals such as Zn, Cu, Mn and Fe were intentionally added to promote growth of birds in feed of poultry birds (Alkhalaf et al., 2010). However, purposefully added trace metals enhance growth of birds but are also excreted in litter in higher amounts reported by Zhang et al., (2012) and continuous increasing application of litter as manure to improve soil practices is increasing environmental concerns for heavy metals as these, later on, become part of living tissues by bioaccumulation and bio magnification (Abulude et al., 2006; Falandysz et al., 2007). It was noticed there is missing of feed standards for different metals, however, Islam et al., (2007) reported feed standards given by Ministry of Poultry and Livestock Government of the people's Republic of Bangladesh for Zn, Cu and Mn as for starter and grower feed of broilers 50-100 mg/kg, 5-8 mg/kg and 60-120 mg/kg respectively (Islam et al., 2007).

Similarly, the heavy metals (Cd, Cr, Hg, Ni, Pb) were found to be higher in feed samples in comparison to litter and air samples except Group A where Cr, Hg and Pb were highest in the litter that showed some other sources might be responsible for contamination however, indoor air samples represented very small concentrations as compared to feed and litter and all metals were present in negligible concentration in outdoor air samples (Fig. 8-10). The measured concentration of Cd in all three feeds was 0.6-0.26 mg/kg that was higher as compared to reported values 0.038-0.463 mg/kg by Okoye et al. (2011) and for Pb 1.7-4.4 mg/kg in the present study, which was lower than 0.60-20.65 mg/kg according to (Islam et al., 2007). The concentration of Hg in the present study was between 5.3-2.5 mg/kg that was higher as compared to 8.57-16.5 µg/kg however, higher correlation coefficient between feed and manure was reported by (Shah et al., 2010).

It was noticed that a number of studies explained the role of heavy metals in environmental degradation via incorporating in the food chain system by eating meat of birds and agricultural crops obtained from soil amended practices (Li et al., 2013; Wang et al., 2013; Sathyamoorthy et al., 2016). The study is novel in its approach as no relevant published work is seen for heavy metals contamination with reference to indoor and outdoor air of controlled poultry facilities but different studies conducted in different cities as in Iran assessed air quality of Mobarakeh city explained the role of heavy metals in degradation of ambient air (Mobarakeh et al., 2014). Similarly in Kolkata, India a study was conducted to see total suspended particles in residential and industrial sites and different heavy metals such as Cd, Cr, Pb, Fe, Zn, Ni and Mn were evaluated showing industrial air was more contaminated (196.6µm^3) due to industry as compared to rural sites (140.1µm^3) (Karar et al., 2006).So in the present study, use of heavy metals in the feed to improve various biological processes of birds can be a source of contamination in land if litter is used as manure for its improvement and in air via suspended particulate matter. The harmful effects of Cd, Cr and Hg are of great concern particularly the toxicity level for humans and animals that depend on the accumulation ratio of metals in body tissues with variable half-life as reported by Nwude et al. (2010). A continuous increase of 261 % and 196 % in Cd and Cr concentration was observed from 1990-2008 respectively in poultry manures due to excessive use of heavy metals in the feed. Most increase in different metals was recorded from 2002-2008, however, a decrease in Pb, and Hg concentration in manure samples was also seen during this time period. The overall estimation of heavy metals in manure samples from 1990-2008 showed an increased amount of heavy metals in manure that need to be considered as it results in degradation of soil quality (Wang et al., 2013).

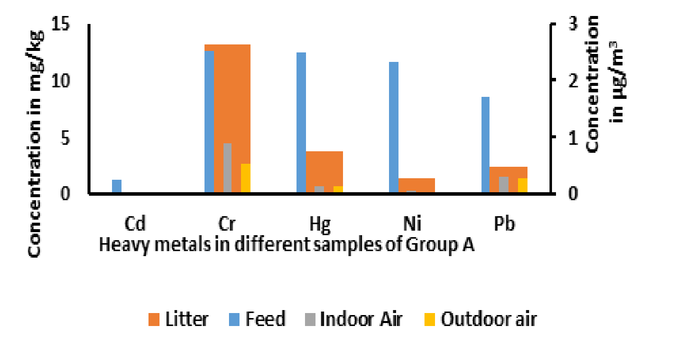

Figure 8: Heavy metals in different samples of Group A (Cd: Cadmium; Cr: Chromium; Hg: Mercury; Ni: Nickle; Pb: Lead)

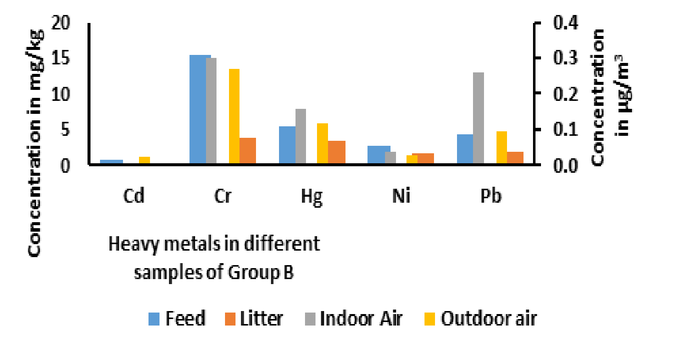

Figure 9: Heavy metals in different samples of Group B (Cd: Cadmium; Cr: Chromium; Hg: Mercury; Ni: Nickle; Pb: Lead)

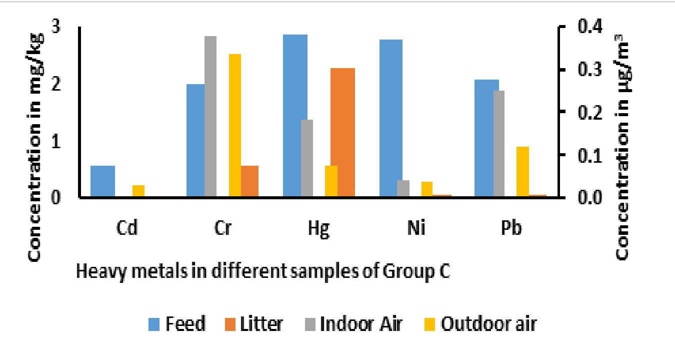

Figure 10: Heavy metals in different samples of Group C (Cd: Cadmium; Cr: Chromium; Hg: Mercury; Ni: Nickle; Pb: Lead)

It was also noticed that the concentration of essential and trace metals, which plays an essential role in the body, was 2-3 times higher as mentioned in the Cobb broiler management guideline for all three brands with the highest concentration in feed brand A. The observed concentration of Cd and Pb in the feed were lower than the maximum acceptable limit for feed specified by European Union (1 mg/kg and 5 mg/kg for Cd and Pb respectively). However, there is a need to focus on management practices used in intensive poultry farming units which may lead to high metal concentration in the poultry litter as high amount of metals (Cr, Hg, Pb) were observed in litter samples in group A. These scenarios may lead to detrimental environmental and public health effects. For example, application of such manure to agricultural lands will offer a pathway of these toxic metals to bioaccumulation in food chain systems.

CONCLUSION

The concerns about the public health impact of emissions from increasing intensive poultry are growing. There is a need to improve the existing state of knowledge on the contribution of these facilities to heavy metal pollution in different environmental media and the resultant risk of exposure to humans. The current study carried out just to estimate the concentration of essential, trace and heavy metals in feed, litter and air samples. Nonetheless, high concentration of metals found in litter samples particularly in group (A) draws attention to the role of management practices which may lead to high metal concentrations in litter. The current practice of unregulated use of poultry litter in Pakistan as fertilizer to agricultural land poses a major risk to public health. The concentration of trace and heavy metals in air samples, both indoor and outdoor was noticed low as compared to litter samples but they may contribute to deposition and build up in soils over time. The trace metals along with other heavy metals are essential for the body, however, there is a need to focus on the feeding lots that the minerals should not exceed the recommended limits. Furthermore, studies on heavy metal analysis of different organs and muscles of birds are needed along with feed and litter samples to better gauge public health risk.

ACKNOWLEDGEMENTS

I am extremely thankful to Environment Protection Agency, Punjab for their support and providing facility for metals analysis using Inductively Coupled Plasma Atomic Mass Spectroscopy (ICP-MS).

CONFLICT OF INTEREST

Authors declare there is no conflict of interest.

NOVELTY STATEMENT

The study is novel in its design as it covers air samples for metals analysis along with feed and litter samples. The study also provide useful information about whole poultry environment.

AUTHORS CONTRIBUTION

All authors have equally contributed.

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