

Elevated blood mercury and haematological response in free ranging chicken (*Gallus Gallus domesticus*) from gold mining areas in Zamfara State Nigeria

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ABSTRACT

Gold mining and other anthropometric activities in mining areas result in pollution. Mercury toxicosis is thus a common occurrence in chickens from gold mining areas (GMAs). The study was designed to evaluate and compare haematological response in chickens (*Gallus Gallus domesticus*) from Anka GMAs and Gusau Non-gold mining areas (NGMAs) of Zamfara State, Nigeria. A total of sixty adult chickens were randomly selected in six locations (thirty each in GMAs and NGMAs). Blood mercury concentration was measured with atomic absorption spectrophotometer (AAS) with thermal decomposition. Haematological parameters which include packed cell volume (PCV), Red blood cell count (RBC), haemoglobin, heterophils, lymphocytes, total white blood cell count (TWBC), monocytes and heterophil/lymphocyte (H/L) ratio were measured using standard procedure. Both multivariate and univariate analysis were used to measure differences while correlation and regression were also used to analyse relationship between mercury and haematological parameters. Mean PCV 23.26%, RBC $2.661 \times 10^6/L$, Haemoglobin 13.70 g/dL, TWBC $5.07 \times 10^9/L$, Heterophils $2.00 \times 10^9/L$ and Lymphocytes $2.65 \times 10^9/L$ were significantly lower ($p < 0.05$) in chickens from GMAs when compared with 33.39%, $3.77 \times 10^6/L$, 19.79 g/dL, $10.13 \times 10^9/L$, $2.82 \times 10^9/L$ and $4.91 \times 10^9/L$ respectively from NGMAs. However, monocytes $0.44 \times 10^9/L$ and H/L Ratio 0.788 were significantly higher in chicken from GMAs when compared with $0.24 \times 10^9/L$ and 0.54 from NGMAs. Haematological parameters are direct correlates of mercury concentration. A unit increase in monocytes significantly ($p < 0.05$) correspond to an increase in blood Hg level by 0.262 µg/mL. In conclusion, this research suggested that mining activities in GMAs exerts deleterious impacts on chicken haematological parameters. Result of this study will be of diagnostic significance in local chicken mercury toxicosis.

1. Introduction

In recent times, food consumption constitute a major route of transfer of toxic elements to man and animals, exposure is through ingestion, inhalation and dermal contact [1–9]. Many of the diseases have been shown to be a direct correlates of increased concentrations of heavy metals in various organs of the body [5,6,10–15]. Chicken meat is one of the integral parts of human diet as they are important sources of many crucial nutrients, including protein (essential amino

acids), minerals (iron, zinc and selenium), vitamins (Vitamin E) and fats (Omega 3 fatty acids) [16,17]. Although the meat contents are essential and vital for normal body development, growth and tissue repair, their contamination with potential toxic metals have serious detrimental consequences for public health, as they can be easily transferred to varying body parts thus compromising the proper functioning of the affected part and the whole organism at large [15,18]. Metals can be transferred from parents to offspring and can be sequestered from hens to eggs along the food chain through environmental

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contamination due to fossil fuel burning, industrial waste disposals, agricultural and mining activities [19,20].

As chicken meat is among the major protein sources in Nigeria, including Zamfara state, heavy metals contamination in these components may contribute to the total metal intake. Among heavy metals, mercury is considered as one of the most toxic non-radioactive elements in the universe. It is ubiquitous, indestructible and exists in inorganic, metallic and organic forms in nature.

Zamfara State is blessed with abundant mineral resources most especially gold deposits which were found in Maru, Anka and Bukkuyum Local Government Areas of the State [21]. The gold deposits have been in existence for many years and are being mined by Artisanal Gold Miners (AGMs). Artisanal and small scale gold mining (ASGM) is a vital source of income, but it is also very dangerous because miners use toxic mercury to separate the gold from the ore, they are thus in constant exposure to mercury [9,14,22–24].

Haematology is an important element of the clinical care of avian patients since it is a reflection of the animal's overall health [25]. Consequently, changes in haematological parameters are indicative of early pathological changes due to heavy metal exposure [26–30]. The study was designed to evaluate haematological response in chickens from gold mining locations of Zamfara State, Nigeria. This study results will be of diagnostic significance in local chicken mercury toxicosis.

2. Materials and methods

2.1. Ethical approval

Animal Use and Care Committee of Ahmadu Bello University, Zaria gave approval number of No: ABUCAUC/2021/059 to this study after critical evaluation and review. All protocol in this study followed the National Institutes of Health's guidelines for the use and care of laboratory animals and relevant methods were followed to ensure that animals were not subjected to excessive stress and discomfort in the course of this experiment.

2.2. Study area and sample collection

Target animals for this study were apparently healthy free-ranging adult chickens (*Gallus Gallus domesticus*). These animals were selected randomly from three polluted (evidence of recent artisan gold mining activities as Nigeria government has banned gold minning activities in Zamfara state) areas which include Dareta, Sunke and Abare with GPS coordinates 5°57' 17.49"E: 12° 1'49.80"N, 5°54'44.14"E: 11°53'45.56"N and 5°57'24.95"E: 12° 4'37.79"N respectively. The GPS coordinates of unpolluted areas (evidence of non-gold mining activities in the last twenty years) include 6°44' 27.24"E:12°9'7.55"N, 6°40'7.38"E:12° 9'28.63"N and 6°39'47.02"E: 12°11'8.47"N for Tudun Wada, Tasha Magami and Ungwar Yarima respectively. All unpolluted areas are in Gusau LG. Other details about the study area have been reported in our earlier publication [31]. This cross sectional study procured ten adult chickens which were randomly selected out of available fifty adult with bird trap in each study location (not >1000 m radius from the GPS coordinates provided above). Previous studies had opined that mercury amalgam is usually employed for gold mining activities by ASGM in Zamfara state Nigeria [32–34]. Thus mercury was the target for this study as it is usually abundant in ASGM areas. Consequently, ASGM activities have contributed immensely to the elevated mercury concentration in Zamfara state gold mining areas. These have also been reported in earlier in pee-reviewed articles in other gold mining areas throughout the world [9,14,22,24].

2.3. Mercury analysis

One millilitre of blood was dissolved in 5 mL HNO₃ (nitric acid). This was then followed by digestion in a 1600 W microwave at 200 °C for 15 min before being kept in the oven for another 15 min. The mixture was then added to 2 mL of H₂O₂ (hydrogen peroxide) solution. The mixtures

were maintained in the tubes for sixty minutes. The mixture was made up to 10 mL with distilled water in polypropylene flasks and maintained at 4° Celsius. Cold vapour atomic absorption spectrometry (CVAAS) was used to determine Hg amounts in whole blood [35,36]. Limit of detection (LOD) of Hg was computed using standard formular as $LOD = 3.3 \frac{s}{m}$.

Key:

m: slope of the calibration curve under ideal experimental circumstances.

s: standard deviation of 10 measurements of reagent blanks.

The resulted LOD was 2.679 µg/L.

2.3.1. Haematological parameter

Whole blood sample was collected from the jugular veins for haematological analysis. To evaluate packed cell volume (PCV), non-heparinized capillary tube was filled up to about ¾ of its length from one end and the second end was heat-sealed using Bunsen burner. The blood in the sealed capillary tube was then centrifuged for 5 min at 4400 xg using the SH120 Tabletop laboratory medical haematocrit machine. Then the proportion of cells in the total volume of blood was measured and recorded as a percentage using the Micro-haematocrit Reader.

Blood haemoglobin concentration (Hb) was estimated using colorimetric method as described earlier [37–42].

2.3.2. Haemoglobin concentration

$$\text{Haemoglobin (g/dL)} = \frac{A_{\text{Sample}}}{A_{\text{Standard}}} \times \text{Concentration of standard}$$

Red blood cells (RBC) and total WBC (or TWBC) counts were determined with the Natt-Herrick solution (1:200 dilution) and the Improved Neubauer haemocytometer as both counts can be prepared directly from the same sample placed in the haemocytometer [41,42].

For TWBC count, the WBC in the four outer large squares of the haemocytometer were counted and calculated using the formula below:

$$WBC \times 10^9/L = \frac{N}{20}$$

Where N = Number of WBC counted in the four outer large squares (or in 64 small squares).

For RBC count, the cells contained in the four corner and central squares in the mid-section of the haemocytometer were counted. Following the "L" rule: cells that touch the centre triple lines of the ruling on the left and the bottom sides were counted but cells that touch the centre triple lines of the ruling on the right and the top sides were not counted. The RBC count was calculated using the formula below:

$$RBC \times 10^{12}/L = \frac{N}{100}$$

Where N = Number of RBC counted in the 5 squares in the mid-section of the haemocytometer (or in 160 squares).

The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC) were calculated using the following standard formulae as described by earlier researchers [41,42].

$$MCV (fL) = \frac{PCV}{RBC} \times 10$$

femto litres (fL)

$$MCH (pg) = \frac{Hb}{RBC} \times 10$$

picogram (pg)

$$\text{MCHC (g/L)} = \frac{\text{Hb}}{\text{PCV}} \times 100$$

gram per litre (g/L)

The differential leucocyte count was evaluated on blood films stained with Giemsa stain granulocyte counts (heterophils, eosinophils, and basophils).

Using the same procedure as the indirect measurement of total WBC, an estimated thrombocyte count was obtained from the stained blood film. Absolute number of thrombocytes was calculated using the formula below [41]:

$$\text{Absolute Thrombocyte} \times 10^9/\text{L} = \frac{\text{Number of thrombocyte counted}}{100} \times \text{TWBC}$$

All haematological analysis were done as described earlier [39–42].

Multivariate analysis was used to differentiate and visualize difference in haematological parameter from free ranging chickens in both gold mining and non-mining sites. One-way analysis of variance (ANOVA) was used to determine difference in study group followed by post hoc Tukey tests. Relationship between mercury level and haematological parameters were analysed using correlation analysis. Robust logistic regression was used to evaluate the associations between body weight, study location, haematological parameters and blood mercury levels. In all tests, a significance level of $p < 0.05$ was used. Statistical analyses was performed with SPSS 24.0 (SPSS, Chicago, IL, USA).

3. Results

Chicken from Gusau metropolis (Tasha Magami, Unguwar Yarima and Tudunwada) and those from gold mining areas (Abare, Dareta and Sunke) serve as control and those with potential exposure to mercury respectively. The Shapiro-Wilk test shows that data generated for this study was normally distributed ($p > 0.05$).

Body weight of chicken used in the study ranges from 1028 ± 171.9 g to 891 ± 198.7 g been recorded in animals sampled from Abare and Sunke respectively. However, there is no significant difference in the body weight of animals from different locations used in the study.

The mercury level in animals from gold mining areas are statistically similar and ranged from 0.227 ± 0.08 to 0.229 ± 0.09 $\mu\text{g/mL}$ while it was not detected in animals from Gusau L.G.

Principal component analysis (PCA), an unsupervised multivariate analysis technique, was used to examine whether it was possible to distinguish between control animals (Tasha Magami, Unguwar Yarima, and Tudunwada) and animals sampled from gold mining areas (Abare, Dareta, and Sunke) based on their haematological parameters. The PCA score plot indicated that the control group could be distinguished from animals in gold mining areas (Fig. 1A). Hierarchical clustering Heatmaps, which provide an intelligible representation of the data, were used to support the ANOVA results. Each colored cell on the map indicates the concentration value of a certain haematological parameter, with samples in rows and characteristics in columns (Fig. 1B).

As shown in Tables 1 and 2, there is no significant difference in the haematological parameters (PCV, RBC, Haemoglobin, WBC, Lymphocytes, Heterophils, heterophil/lymphocyte (H/L) ratio and Monocytes in animals from Tasha Magami, Unguwar Yarima, Tudunwada. Similar result was obtained from animals in gold mining areas (Abare, Dareta and Sunke). However, activities of these haematological parameters were significantly ($p < 0.01$) different in the blood of mercury-exposed chicken from mining areas when compared with those assessed in the control group (Tables 1 and 2). But MCV, MCH, MCHC, Basophils and Thrombocytes are statistically similar.

Furthermore, these haematological parameters are significant correlate ($p < 0.05$) of Hg levels from the study group (Table 3). As shown in Table 4, both body weight and gender did not have significant role in variation of blood Hg level while location significantly affect Hg levels in the study

group as seen in β unstandardized coefficient (0.012), 95% confidence interval (0.002; 0.017) and significant p value (< 0.05). Multiple regression analysis to check if haematological parameters can act as a Predictive factor for blood mercury level in local chicken show that a unit increase in Monocytes significantly ($p < 0.05$) correspond to an increase in blood Hg level by $0.262 \mu\text{g/mL}$ (Table 4). But other haematological parameters were not significant predictor of blood Hg.

4. Discussion

Mercury and its different forms in the environment have been linked to a variety of pathological changes in birds. Mercury may be classified as haematotoxins with immunomodulatory effects on animals [43–45]. Avian haematology provides important clinical parameters of the local chicken since it reflects the chicken's overall health. Hence, have the potential to be useful bioindicator of ecosystem quality. [25].

This study's finding of significantly higher blood mercury levels in chickens from gold-mining regions is consistent with earlier research that found high mercury levels in the organs and blood of chicken (0.33 – $2.46 \mu\text{g/L}$), farmed duck (1.37 – $4.56 \mu\text{g/L}$) and free-grazing duck (2.30 – $4.57 \mu\text{g/L}$) in Northern Thailand's largest gold-mining region [46]. Similarly, Binkowski, Fort, Brault-Favrou, Gallien, Le Guillou, Chastel and Bustamante [47] reported total mercury in blood ranging from 0.32 to $3.10 \mu\text{g/g}$ in chick gulls from the English Channel. Finally, a similar report was obtained in poultry in the Wanshan Mercury Mine, China, where blood total mercury ranged between 12.3 and 338.0 ng/g and MeHg ranged from 1.4 to 17.6 ng/g [48]. These similar reports are due to human-made practices of mercury-dependent ASGM, which typically employ Hg to purify gold [9,23]. As a result, ASGM releases tons of mercury into the environment and food chain.

The findings of this study shows that free-ranging chickens from gold mining areas were exposed to mercury as evidenced by elevated mercury levels in their blood, which may have resulted in significant changes of some blood parameters like red blood cell count, packed cell volume, haemoglobin content, white blood cell count, and lymphocyte. These findings are consistent with prior findings [26–30].

Decreased in red blood cell count reported among chicken in gold mining areas is similar to a study that showed that mercury exposure caused a progressive increase in Total Iron Binding Capacity (TIBC) and reduction in the erythrocyte count [49,50]. This can be attributed to the decrease iron within erythrocytes or its haemoglobin content and this causes decrease oxygen carrying capacity of the blood.

Reduced WBC reported in chickens from gold mining areas is different from a report on the haematological findings on fish (*Hoplias malabaricus*) exposed to sub-chronic and dietary doses of methylmercury, where they reported increased leukocytes due to methylmercury exposure [51]. Both results show that mercury exposure have detrimental effect on the immune system.

Most vertebrates, including chicken species, exposed to various environmental contaminants recorded the destruction of mature RBCs and the inhibition of erythrocyte production due to a reduction in haemosynthesis, which causes acute haemolytic crisis, resulting in severe anaemia [52]. According to Khadre [52], destruction of erythrocytes or decreased production causes moderate anaemia in chicken from gold mining regions, in contrast to more severe anaemia produced by disease processes that impact the peripheral blood or bone marrow [25].

Some studies attributed a decrease in the number of blood cells to the changes caused by mercury in the bone marrow of those cells. Mercury influences erythropoiesis directly or indirectly [39], therefore they have immunomodulatory effects on free-ranging hens [43]. Instead of calcium, mercury accumulate in the bone, creating a defect in the structure and decreasing the bone's capacity to synthesise blood cells [53]. Anaemia can occur as a result of mercury's impact on red blood cells as it might culminate into rupturing and disintegration of the erythrocyte membrane leading to erytholysis [30]. Most of the changes in blood that occur

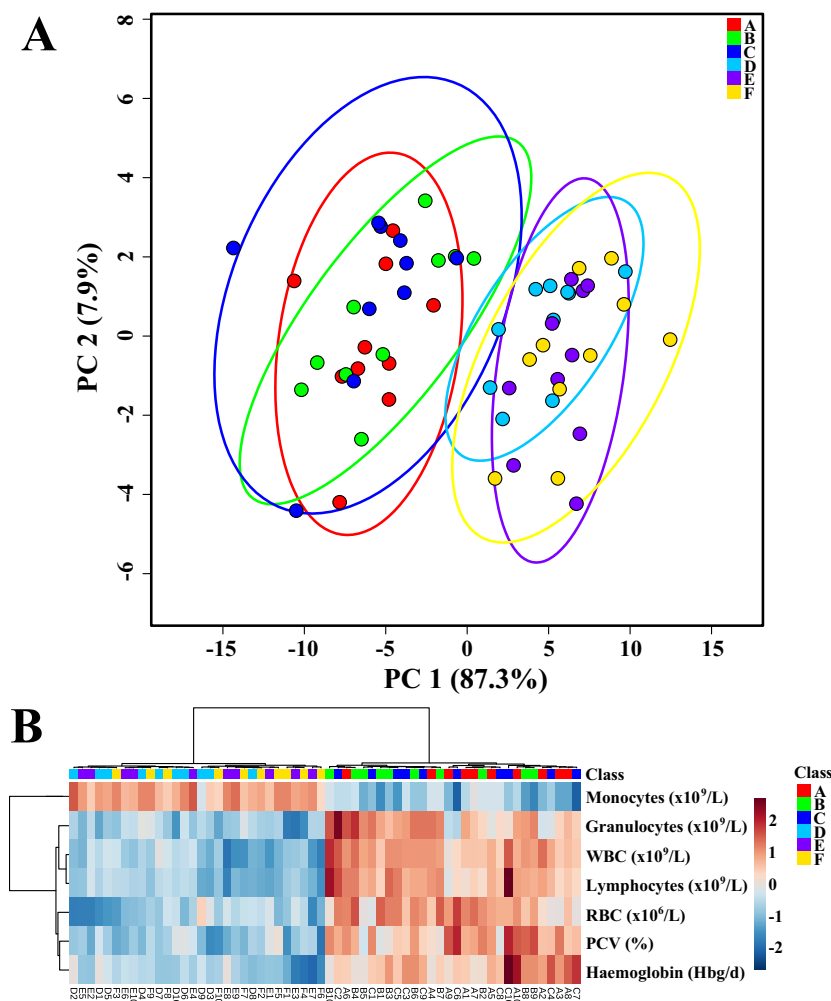


Fig. 1. Principal component analysis (PCA) developed from haematological parameters (A) of free ranging chickens from control and Anka LG gold mining areas. Unsupervised hierarchical clustering shown as heatmap of haematological parameters (B) of free ranging chickens from control and Anka LG gold mining areas. Red and blue indicate increased and decreased levels, respectively. Control (A; Tasha Magami, B; Unguwar Yarima and C; Tudunwada) and animals from gold mining areas (D; Abare, E; Dareta and F; Sunke).

when exposed to Hg are caused by a decrease in the life span of red blood cells or an increase in their disintegration.

The drop in the total number of white blood cells (leucocytes) implies that rather than an increase in leucocyte synthesis, the number of cells in circulation has reduced. Increased granulo-leucocytic involvement is suggested by a decrease in lymphocytes and an increase in heterophils [39].

Significant increase of H/L in chickens from gold mining areas is in line with earlier reports that short exposure to an environmental stressor might result in an increased H/L ratio [54,55].

Individuals involved in the gold mining operations, their families, and those in the gold mining communities are consistently exposed to high levels of elemental Mercury vapour, as evidenced by high levels of mercury concentrations in their body. This is evidenced by elevated mercury concentrations in animals, plants and humans near mines [18,46,56]. Thus, animal and population in the gold mining communities and downstream of the gold mining communities consume food that may be heavily contaminated with mercury or its compounds as demonstrated by high concentration of mercury in their systems that lead to compromised

Table 1

Variation in Haematological parameters due to Hg exposure.

Parameter	TashaMagami	UnguwarYarima	Tudunwada	Abare	Dareta	Sunke
PCV (%)	33.920 ± 2.542 ^a	32.613 ± 3.972 ^a	33.330 ± 3.917 ^a	24.585 ± 2.629 ^b	24.311 ± 2.038 ^b	23.261 ± 3.341 ^b
RBC (x10 ⁶ /L)	3.670 ± 0.273 ^a	3.774 ± 0.352 ^a	3.631 ± 0.381 ^a	2.711 ± 0.415 ^b	2.661 ± 0.378 ^b	2.750 ± 0.210 ^b
Haemoglobin (g/dL)	18.915 ± 2.030 ^a	18.283 ± 1.421 ^a	19.787 ± 2.287 ^a	15.205 ± 1.0607 ^b	14.126 ± 1.848 ^b	13.702 ± 1.332 ^b
MCV (fL)	92.795 ± 8.958 ^a	87.233 ± 14.310 ^a	92.487 ± 12.779 ^a	93.035 ± 19.087 ^a	92.888 ± 13.991 ^a	84.790 ± 12.523 ^a
MCH (pg/cell)	5.189 ± 0.739 ^{bc}	4.877 ± 0.521 ^{abc}	5.5258 ± 0.999 ^c	4.731 ± 1.160 ^{abc}	4.223 ± 1.101 ^{ab}	3.866 ± 0.832 ^a
MCHC (g/dL)	5.594 ± 0.624 ^{ab}	5.679 ± 0.717 ^{ab}	5.984 ± 0.752 ^b	5.187 ± 1.305 ^{ab}	4.547 ± 0.906 ^a	4.699 ± 1.435 ^{ab}
TWBC (x10 ⁹ /L)	9.403 ± 0.899 ^a	10.130 ± 1.011 ^a	9.888 ± 1.097 ^a	6.031 ± 0.919 ^b	5.075 ± 1.309 ^b	5.38 ± 1.136 ^b

Packed cell volume (PCV), Red blood cell count (RBC), Mean corpuscular volume (MCV), Mean cell haemoglobin (MCH), Mean corpuscular haemoglobin concentration (MCHC) and Total white blood cell count (TWBC).

Data are presented as mean ± standard deviation, Different superscript in a row are significantly different at $p < 0.05$.

Table 2

Variation in differential leucocyte count, heterophil/lymphocyte ratio and estimated absolute thrombocyte count due to Hg exposure.

Parameter	TashaMagami	UnguwarYarima	Tudunwada	Abare	Dareta	Sunke
Heterophils (x10 ⁹ /L)	2.630 ± 0.312 ^a	2.818 ± 0.292 ^a	2.598 ± 0.395 ^a	2.068 ± 0.313 ^b	2.056 ± 0.2431 ^b	2.005 ± 0.334 ^b
Basophils (x10 ⁹ /L)	0.345 ± 0.101 ^a	0.368 ± 0.095 ^a	0.352 ± 0.071 ^a	0.272 ± 0.066 ^{ab}	0.238 ± 0.066 ^b	0.271 ± 0.079 ^{ab}
Eosinophils (x10 ⁹ /L)	0.903 ± 0.285 ^{ab}	1.041 ± 0.244 ^a	1.026 ± 0.222 ^a	0.762 ± 0.148 ^{ab}	0.724 ± 0.217 ^b	0.712 ± 0.125 ^b
Monocytes (x10 ⁹ /L)	0.277 ± 0.045 ^a	0.258 ± 0.057 ^a	0.242 ± 0.068 ^a	0.424 ± 0.047 ^b	0.438 ± 0.033 ^b	0.425 ± 0.036 ^b
Lymphocytes (x10 ⁹ /L)	4.465 ± 0.501 ^a	4.896 ± 0.687 ^a	4.914 ± 0.869 ^a	2.858 ± 0.389 ^b	2.749 ± 0.510 ^b	2.653 ± 0.390 ^b
H/L Ratio	0.591 ± 0.061 ^a	0.583 ± 0.084 ^a	0.535 ± 0.078 ^a	0.734 ± 0.134 ^b	0.788 ± 0.259 ^b	0.780 ± 0.215 ^b
Thrombocytes (x10 ⁹ /L)	0.496 ± 0.055 ^a	0.519 ± 0.044 ^a	0.483 ± 0.045 ^a	0.511 ± 0.052 ^a	0.475 ± 0.055 ^a	0.505 ± 0.020 ^a

heterophil/lymphocyte (H/L).

Data are presented as mean ± standard deviation, Different superscript in a row are significantly different at $p < 0.05$.**Table 3**

Correlations between blood mercury level in local chicken with blood parameter.

Parameter	Pearson's (r)*
PCV (%)	− 0.836
RBC (x10 ⁶ /L)	− 0.835
Haemoglobin (Hgb/dL)	− 0.798
MCV (fL)	− 0.017
MCH (pg/cell)	− 0.433
MCHC (g/dL)	− 0.420
WBC (x 10 ⁹ /L)	− 0.893
Lymphocytes (x10 ⁹ /L)	− 0.865
Monocytes (x10 ⁹ /L)	0.871
Heterophils (x10 ⁹ /L)	− 0.718
Basophils (x10 ⁹ /L)	− 0.513
Eosinophils (x10 ⁹ /L)	− 0.528
H/L Ratio	0.542
Thrombocytes (x10 ⁹ /L)	− 0.028
PCV (%)	− 0.836

Note: All correlations reported are two-tailed.

Packed cell volume (PCV), Red blood cell count (RBC), Mean corpuscular volume (MCV), Mean cell haemoglobin (MCH), Mean corpuscular haemoglobin concentration (MCHC) and White blood cell count (WBC).

* Significant at $p < 0.05$.**Table 4**

Regression Analysis of haematological parameters as Predictive Factor for blood mercury level in local chicken.

Description	β	95% CI*	p
Body weight (g)	0.0000	0.000	0.564
Location	0.012	0.002; 0.022	0.017
Gender	− 0.001	− 0.027; 0.026	0.971
PCV (%)	− 0.002	− 0.013; 0.008	0.659
RBC (x10 ⁶ /L)	− 0.038	− 0.140; 0.065	0.462
Haemoglobin (Hgb/dL)	0.000	− 0.006; 0.006	0.972
MCV (fL)	0.001	− 0.003; 0.005	0.687
MCH (pg/cell)	− 0.020	− 0.083; 0.043	0.519
MCHC (g/dL)	0.012	− 0.044; 0.067	0.676
WBC (x 10 ⁹ /L)	− 0.014	− 0.031; 0.004	0.136
Lymphocytes (x10 ⁹ /L)	− 0.005	− 0.036; 0.025	0.730
Monocytes (x10 ⁹ /L)	0.262	0.098; 0.425	0.002
Heterophils (x10 ⁹ /L)	− 0.001	− 0.055; 0.054	0.981
Basophils (x10 ⁹ /L)	− 0.063	− 0.169; 0.043	0.239
Eosinophils (x10 ⁹ /L)	− 0.019	− 0.062; 0.024	0.373
H/L Ratio	− 0.051	− 0.196; 0.093	0.479
Thrombocytes (x10 ⁹ /L)	0.022	− 0.163; 0.207	0.810

β : Unstandardized coefficient represents the amount of change in a predictive variable due to a unit change of Hg level. Confidence interval (CI). Packed cell volume (PCV), Red blood cell count (RBC), Mean corpuscular volume (MCV), Mean cell haemoglobin (MCH), Mean corpuscular haemoglobin concentration (MCHC) and White blood cell count (WBC).

* Significant at $p < 0.05$.

health especially toxicosis in chicken [9,31,57]. This study results might be of diagnostic significance in local chicken mercury toxicosis.

5. Conclusion

The results obtained from this research study suggest that free ranging chicken from gold mining areas are exposed to mercury and this might have led to the disturbance and change in dynamics of haematological parameters. The result of this study is useful as relevant stakeholders will be aware of the danger of uncoordinated artisan gold mining activities.

CRediT authorship contribution statement

Zainab Abdulmalik: Data curation, Writing – original draft, Writing – review & editing. **Muftau Shittu:** Conceptualization, Methodology, Software, Visualization, Investigation, Supervision, Validation, Writing – review & editing. **Sani Adamu:** Conceptualization, Methodology, Software, Visualization, Investigation, Supervision, Validation, Writing – review & editing. **Suleiman Folorunsho Ambali:** Conceptualization, Methodology, Software, Validation, Writing – review & editing. **Bolaji Fatai Oyeyemi:** Data curation, Writing – original draft, Writing – review & editing.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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