Indian Journal of Biochemistry & Biophysics
Vol. 62, May 2025, pp. 469-479
DOI: 10.56042/ijbb.v62i5.10815

Impact of lead acetate oral administration on wistar rat lung health: Histological evaluation

Oyedayo Phillips Akano[1]*, Opeyemi Adebola Adetunji[2], Oluwafeyisola Soneye[2], Bayo Olufunso Adeoye[3], Iyanuoluwa Oluwadunsin Adebayo[1], Ayodeji David Adeoye[1], Sanmi Tunde Ogunsanya[2], Nnena Linda Nwobi[4], Olubukola Akinnawo[2], Chigbogu Joseph Nwobi[3], Corniluis Bangsi Achor[3], Samson Adeyemi[5], Barakat Temitope Adebayo[6] & Moyosoluwa Dada[2]

[1]Department of Physiology; [2]Department of Anatomy; [3]Department of Biochemistry, School of Basic Medical Sciences; & [4]Department of Chemical Pathology, Faculty of Basic Clinical Sciences, Benjamin S. Carson (Snr.) College of Health and Medical Sciences, Babcock University, Ilishan Remo, Ogun State, Nigeria

[5]Department of Chemistry, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

[6]Department of Biochemistry, Ladoke Akintola University of Technology (LAUTECH) Ogbomoso, Oyo State, Nigeria

Received 30 April 2024; *revised 31 January 2025*

Lead, a pervasive heavy metal, poses significant health risks to various bodily functions, including respiratory health. In this study, we aimed to investigate the impact of lead acetate exposure on lung histoarchitecture and glycogen levels in male Wistar Albino rats. The primary objective of this study was to assess the effects of lead acetate on lung histoarchitecture and glycogen levels in male Wistar Albino rats. Specifically, we aimed to determine the dose-dependent changes in lung morphology and glycogen content following oral administration of lead acetate solutions. Forty mature male albino rats were divided into four groups: a control group receiving clean water and pelletized feed, and three experimental groups receiving lead acetate solutions orally at doses of 50 mg/kg, 100 mg/kg, and 150 mg/kg body weight for 35 days. At the end of the experimental period, lung tissues were harvested, fixed in normal saline, and subjected to histological examination using routine hematoxylin and eosin staining to assess lung histoarchitecture. Additionally, Periodic Acid-Schiff (PAS) reaction was employed to demonstrate glycogen levels in the lung tissues. Histological analysis revealed significant alterations in lung histoarchitecture in the experimental groups compared to the control group, including inflammation, fibrosis, and cellular damage. Furthermore, lead acetate exposure led to a dose-dependent decrease in glycogen levels within lung tissues. Our findings demonstrate the detrimental impact of lead acetate on lung histoarchitecture and glycogen levels in male Wistar Albino rats. These results underscore the importance of mitigating environmental exposure to lead to preserve respiratory health. Further research is needed to elucidate the underlying mechanisms of lead-induced lung toxicity and explore potential therapeutic interventions.

Keywords: Environmental exposure, Glycogen levels, Lead acetate, Lung histoarchitecture, Respiratory health, Wistar albino rats

Lead acetate is a highly toxic heavy metal that poses significant environmental and health risks worldwide. Its widespread use has led to contamination of various environmental compartments, including air, water, and soil, resulting in numerous adverse effects on human health and ecosystems. Lead acetate, a bright silvery metal that tarnishes upon exposure to air, is commonly found in industrial operations, food, water, and residential sources[1].

Historically, lead acetate was extensively used in gasoline, house paint, plumbing pipes, and various consumer products. Although regulations have reduced its use in certain applications, lead acetate remains a persistent pollutant due to its long environmental half-life[2]. Human exposure to lead acetate occurs primarily through ingestion of contaminated food and water, as well as inhalation of lead-containing dust and fumes[3].

Lead acetate exerts toxic effects on multiple organ systems in the human body, with no known biological function. Its ability to interfere with various physiological processes leads to a wide range of health disorders, including neurological, respiratory, urinary, and cardiovascular diseases[4,5]. Furthermore, lead acetate exposure is associated with oxidative stress and inflammation, disrupting the oxidant-antioxidant balance and triggering inflammatory reactions in affected organs[6].

*Correspondence
Phone: +2347035645623
E-mail: akanooyedayo@gmail.com; akanooy@babcock.edu.ng

Among its many adverse health effects, lead acetate poisoning can result in anemia by inhibiting enzymes involved in heme production, such as ferrochelatase and δ-aminolevulinic acid dehydratase (ALAD)[7]. Additionally, lead acetate exposure leads to oxidative stress by altering antioxidant molecules and enzymes, causing cellular damage and lipid peroxidation[8].

Immunological disturbances are also observed in individuals exposed to lead acetate, with effects on lymphocyte proliferation, interferon production, and natural killer cell cytotoxicity[9]. Occupational exposure to lead acetate among battery manufacturing workers has been associated with respiratory symptoms and decreased pulmonary function, highlighting its detrimental effects on lung health[10].

Furthermore, epidemiological studies have linked lead acetate exposure to increased risk of respiratory conditions, such as asthma, particularly in children[11]. The toxic effects of lead acetate are not limited to humans; they also extend to plants, where lead contamination disrupts growth and impairs photosynthetic processes[12,13].

The study utilized male albino Wistar rats to ensure consistency and standardization in physiological responses, as this model is well-documented in toxicological research. Male rats were chosen to avoid the confounding effects of hormonal variability associated with the estrous cycle in females, which could influence metabolic and immune responses. Additionally, male rats are often more susceptible to certain toxic effects of heavy metals, making them a relevant model for studying lead-induced toxicity. The availability of extensive historical data on male Wistar rats further supports their use in this study.

Despite extensive research on the toxic effects of lead acetate, there remains a need for further investigation into its mechanisms of toxicity, particularly regarding its impact on specific organ systems. In this context, the present study aims to evaluate the effects of oral administration of lead acetate on the lungs of Wistar rats. By examining histological changes and functional alterations in lung tissues, this study seeks to contribute to a better understanding of lead acetate-induced lung toxicity and its potential implications for human health.

Materials and Methods

Materials

The materials used in the experiment included analytical grade lead acetate, distilled water, animal cages, drinkers, animal feed, syringe, intubation tubes, electronic weighing balance, triple beam balance, Bouin's fluid, specimen bottles, EDTA sterile test tubes, beakers, pipette, glass slides, cover-slips, hemocytometer and reagent, centrifuge, microscope, absolute alcohol, xylene, paraffin wax, hematoxylin and eosin stains, mutant, glycerol, and microtome.

Experimental animals

Mature male albino Wistar rats weighing between 150 to 220 grams were obtained from the Department of Anatomy, Babcock University, Nigeria laboratory animal reserves. A total of forty rats were used in the study, divided into four groups based on their weight. The animals were acclimatized for 14 days before the start of the experiment and housed in well-ventilated cages with access to water and pelletized feed.

Procurement of reagent

Lead acetate was procured from Yomi-Esthory company in Ilorin, Kwara State, Nigeria.

Animal grouping

The forty rats were divided into four groups: Control Group (Group I) Group II, Group III, and Group IV, based on their body weight. Group I served as the control and received only water and pelletized feed, while the other groups received lead acetate solution orally at different doses.

Experimental design

Each group received a specific treatment regimen over a period of 35 days. Group II received 2.5% lead acetate solution, Group III received 3.0%, and Group IV received 3.5%. The lead acetate solution was administered daily via orogastric intubation.

The volume of lead acetate solution administered to each rat was calculated based on body weight to ensure accurate dosing. For example, a rat weighing 200 g (0.2 kg) receiving a 2.5% (25 mg/mL) solution at 50 mg/kg was administered 0.4 mL daily. Similarly, a 3.0% (30 mg/mL) solution at 100 mg/kg required 0.67 mL, and a 3.5% (35 mg/mL) solution at 150 mg/kg required 0.86 mL. The body weight of each rat was measured every 2 days to adjust the volume as needed, ensuring consistent and accurate delivery of the lead acetate solution.

The 35-day experimental period was selected to model chronic lead acetate exposure and assess its dose-dependent effects on lung histoarchitecture and biochemical parameters. This duration is consistent with established protocols for chronic toxicity studies in rodents, allowing sufficient time for the development

of measurable pathological changes. Previous studies have demonstrated significant lead-induced toxicity within 4–6 weeks of exposure, supporting the appropriateness of this timeframe. Additionally, ethical considerations and practical feasibility were taken into account to minimize animal suffering while ensuring robust and reproducible results.

Preparation of solution

Lead acetate was dissolved in distilled water to prepare the stock solution. The appropriate dosage of lead acetate solution was administered to each animal based on its body weight.

Administration of solution to experimental animals

The lead acetate solution was administered daily to the experimental animals for the duration of the experiment. The animals were monitored for any changes in body weight throughout the experiment.

Measurement of body weight

The body weight of the animals was measured every 2 days using a weighing balance and bowl to assess any changes in weight.

The initial body weight of the rats was recorded before the start of lead acetate exposure, during the 14-day acclimatization period. This baseline measurement ensured uniformity in the distribution of rats across experimental groups and provided a reference for evaluating changes in body weight over the course of the experiment. The initial body weight is independent of lead acetate concentration, as it was recorded prior to any exposure. Final body weights were recorded at the end of the 35-day experimental period to assess the impact of lead acetate administration.

Animal sacrifice and organ harvest

After 35 days of treatment, the animals were sacrificed, and their organs, particularly the lungs, were harvested for further analysis. The sacrifice was performed by cervical dislocation, and proper disposal of the carcasses was ensured to avoid environmental pollution.

Histological analysis

The lung tissues were fixed in 10% formal saline solution and processed using routine histological tissue analysis procedures. Hematoxylin and eosin (H&E) stains were used to demonstrate the general morphology and histology of the lung tissue, while Periodic Acid Schiff (PAS) stain was used to detect the presence of glycogen and inflammatory syndromes.

Biochemical assay

Blood samples were collected from the experimental animals for biochemical analysis, including a full blood count test (hemoglobin, White Blood Cell, neutrophil and lymphocytes) and calcium test. These tests were conducted to assess any changes in blood parameters and calcium levels due to lead acetate exposure.

Creatinine kinase

Creatinine kinase (CK) levels in the blood were measured using a Jaffé rate reaction method to assess muscle and kidney function. The test was performed to evaluate any potential impact of lead acetate on muscle and kidney health.

Results

Body weight

The comparison of initial and final body weights among the experimental groups is depicted in (Fig 1) . Initially, the control group (Group I) had an average body weight of 134.20 ± 10.84 grams. Group B, exposed to 2.5% lead acetate, had a slightly lower initial body weight than the control group, with an average of 117.70 ± 16.74 grams. Group C, exposed to 3.0% lead acetate, also had a lower initial body weight compared to the control group, with an average of 119.40 ± 11.28 grams. In contrast, Group D, exposed to 3.5% lead acetate, showed a higher initial body weight than the control group, with an average of 135.90 ± 9.46 grams. However, statistical analysis revealed no significant difference in initial body weights across the groups, as indicated in (Fig. 1) .

Upon evaluating the final body weights, it was observed that the control group had an average final body weight of 148.10 ± 7.01 grams. Group B,

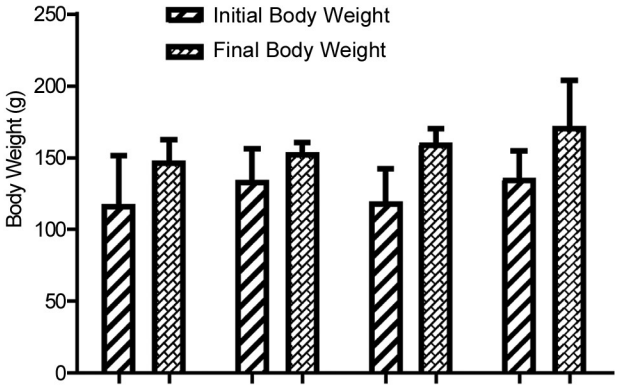

Fig. 1 — Bar chart of initial and final body weight of animals in the experimental rats. Values are mean ± SEM of data required; significant difference was observed ($p<0.05$) was obtained

exposed to 2.5% lead acetate, exhibited a higher final body weight compared to the control group, with an average of 153.60 ± 3.51 grams. Similarly, Group C, exposed to 3.0% lead acetate, also showed a higher final body weight compared to the control group, with an average of 160.50 ± 4.90 grams. Group D, exposed to 3.5% lead acetate, displayed the highest final body weight among all groups, with an average of 172.20 ± 15.83 grams. Despite these observations, statistical analysis did not reveal a significant difference in final body weights across the groups. However, it is noteworthy that there appeared to be a trend of increased body weight following the administration of lead acetate, particularly in Group D, based on observational data.

Body weight was monitored every 2 days throughout the 35-day experimental period to assess the relationship between lead acetate exposure and changes in body weight. While no statistically significant differences were observed across groups, a trend of reduced weight gain was noted in the lead-exposed groups, particularly in those receiving higher doses (3.0% and 3.5% lead acetate) . The maximum reduction in body weight gain was observed around day 28–35 of exposure, suggesting a time- and dose-dependent effect of lead acetate on metabolic processes. The control group and the group receiving the lowest dose (2.5%) maintained relatively stable weight gain throughout the study.

Hematological parameters

Statistical analysis revealed no significant differences in hematological parameters, including Packed Cell Volume (PCV) Platelet count, Hemoglobin (Hb) Neutrophil count, White Blood Cell (WBC) count, and Lymphocyte count, across the experimental groups. Although subtle trends were observed, such as a slight decrease in hemoglobin levels and an increase in lymphocyte count in lead-exposed groups, these changes were not statistically significant ($P > 0.05$)

Pack cell volume

As shown in the Figure 2, the PCV of the control group was (46.25±2.010) . The PVC of Group B (2.5% lead acetate) was lower than that of control group at (42.60±2.169) . The PVC of Group C (3.0% lead acetate) was lower than that of control group at (42.63±1.758) . The PVC of Group D (3.5% lead acetate) was higher than that of control group at (46.97±1.337) . There was no scientific significant difference across the groups

Platelet

As shown in the Figure 3, the platelet of the control group was (614.50±94.56) . The platelet of Group B (2.5% lead acetate) was lower than that of control group at (587.00±71.84) . The platelet of Group C (3.0% lead acetate) was significantly higher than that of control group at (713.80±102.20) . The platelet of Group D (3.5% lead acetate) was higher than that of control group at (674.30±86.47) . There was no scientific significant difference across the groups

Hemoglobin

As shown in the Figure 4, the hemoglobin of the control group was (14.55±0.58) . The Hb of Group B (2.5% lead acetate) was lower than that of control group at (13.65±0.74) . The Hb of Group C (3.0% lead acetate) was lower than that of control group at (13.77±0.63) . The Hb of Group D (3.5% lead acetate) was higher than that of control group at (15.75±0.48) . There was no scientific significant difference across the groups

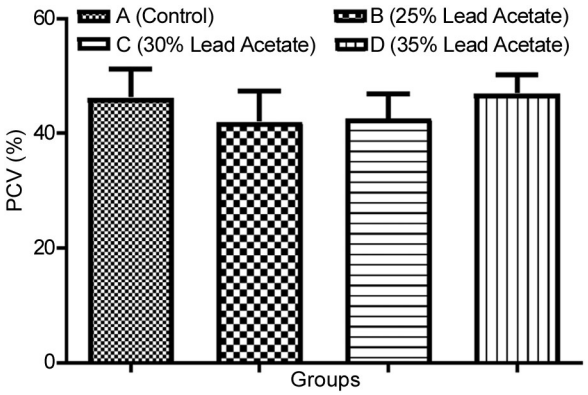

Fig. 2 — Bar chart of PCV. Values are mean ± SEM of data required; significant difference was observed ($p<0.05$) was obtained

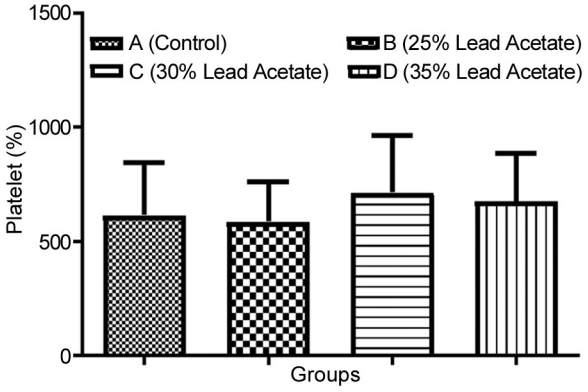

Fig. 3 — Bar chart of platelets. Values are mean ± SEM of data required; significant difference was observed ($p<0.05$) was obtained

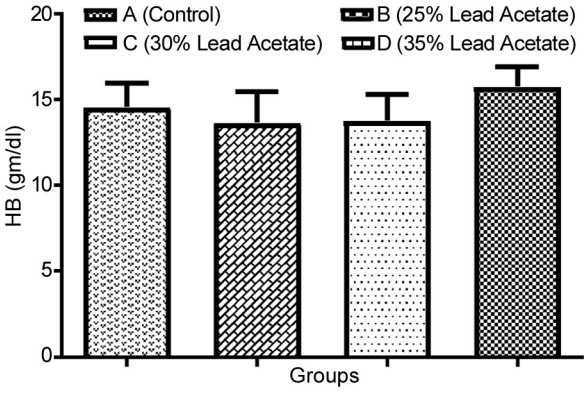

Fig. 4 — Bar chart of hemoglobin. Values are mean ± SEM of data required; significant difference was observed ($p<0.05$) was obtained

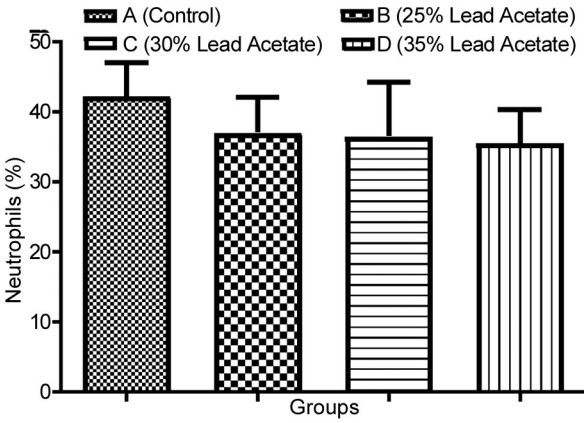

Fig. 5 — Bar chart of neutrophils. Values are mean ± SEM of data required; significant difference was observed ($p<0.05$) was obtained

Neutrophil

As shown in the Figure 5, the neutrophil of the control group was (42.17±1.96) . The neutrophil of Group B (2.5% lead acetate) was lower than that of control group at (37.00±2.08) . The neutrophil of Group C (3.0% lead acetate) was lower than that of control group at (36.50±3.17) . The neutrophil of Group D (3.5% lead acetate) was significantly lower than that of control group at (35.50±1.95) . There was no scientific significant difference across the groups

White blood cell

As shown in the Figure 6, the WBC of the control group was (11383.00±2035.00) . The WBC of Group B (2.5% lead acetate) was lower than that of control group at (11017.00±2630.00) . The WBC of Group C (3.0% lead acetate) was significantly higher than that of control group at (14333.00±1804.00) . The WBC of Group D (3.5% lead acetate) was higher than that

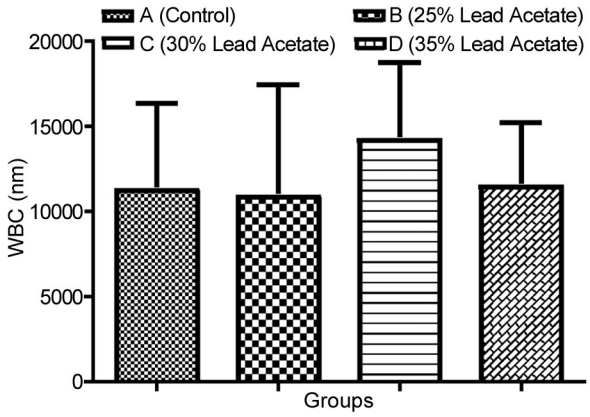

Fig. 6 — Bar chart of WBC. Values are mean ± SEM of data required; significant difference was observed ($p<0.05$) was obtained

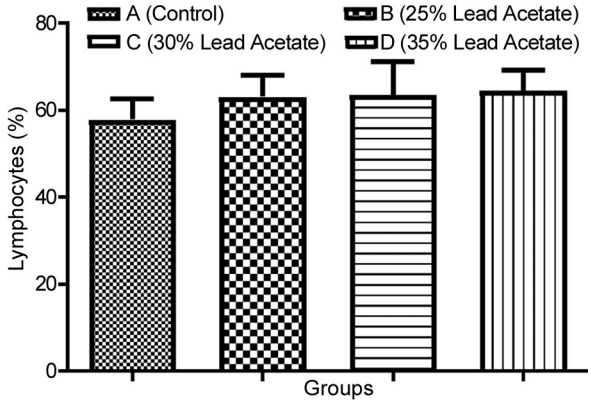

Fig. 7 — Bar chart of lymphocytes. Values are mean ± SEM of data required; significant difference was observed ($p<0.05$) was obtained

of control group at (11617.00±1464.00) . There was no scientific significant difference across the groups

Lymphocyte

As shown in the Figure 7, the lymphocytes of the control group were (57.83±1.96) . The lymphocytes of Group B (2.5% lead acetate) were higher than that of control group at (63.00±2.082) . The lymphocytes of Group C (3.0% lead acetate) were higher than that of control group at (63.50±3.17) . The lymphocytes of Group D (3.5% lead acetate) were significantly higher than that of control group at (64.50±1.95) . There was no scientific significant difference across the groups.

Calcium

As shown in the Figure 8, The calcium levels of the control group were 4.65 ± 0.06 mg/dL. The calcium levels of Group B (2.5% lead acetate) were higher than that of the control group at 6.10 ± 0.41 mg/dL. The calcium levels of Group C (3.0% lead acetate)

were higher than that of the control group at 6.43 ± 0.21 mg/dL. The calcium levels of Group D (3.5% lead acetate) were significantly higher than that of the control group at 6.18 ± 0.30 mg/dL. A statistically significant difference was observed across the groups ($P< 0.05$)

Creatinine kinase

As shown in the Figure 9, The CK levels of the control group were 1.520 ± 0.04340 U/L. The CK levels of Group B (2.5% lead acetate) were higher than that of the control group at 1.648 ± 0.06343 U/L. The CK levels of Group C (3.0% lead acetate) were higher than that of the control group at 1.608 ± 0.01315 U/L. The CK levels of Group D (3.5% lead acetate) were significantly higher than that of the control group at 1.428 ± 0.2395 U/L. No statistically significant difference was observed across the groups ($P> 0.05$).

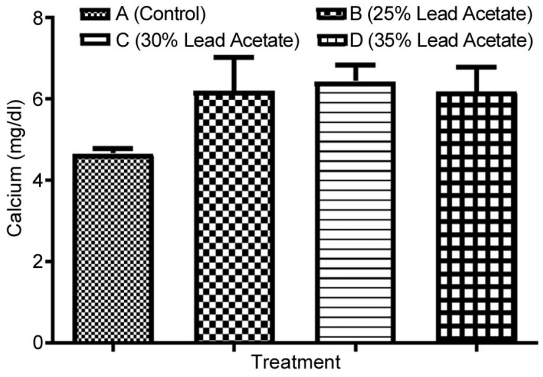

Fig. 8 — Bar chart of calcium. Values are mean ± SEM of data required; significant difference was observed ($P< 0.05$) was obtained

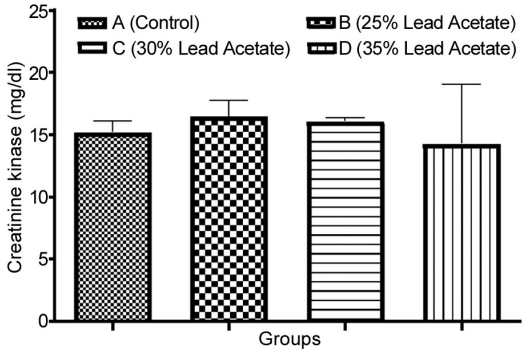

Fig. 9 — Bar chart of Creatinine kinase. Values are mean ± SEM of data required; significant difference was observed ($P< 0.05$) was obtained

Histological stains

Hematoxylin and eosin stain

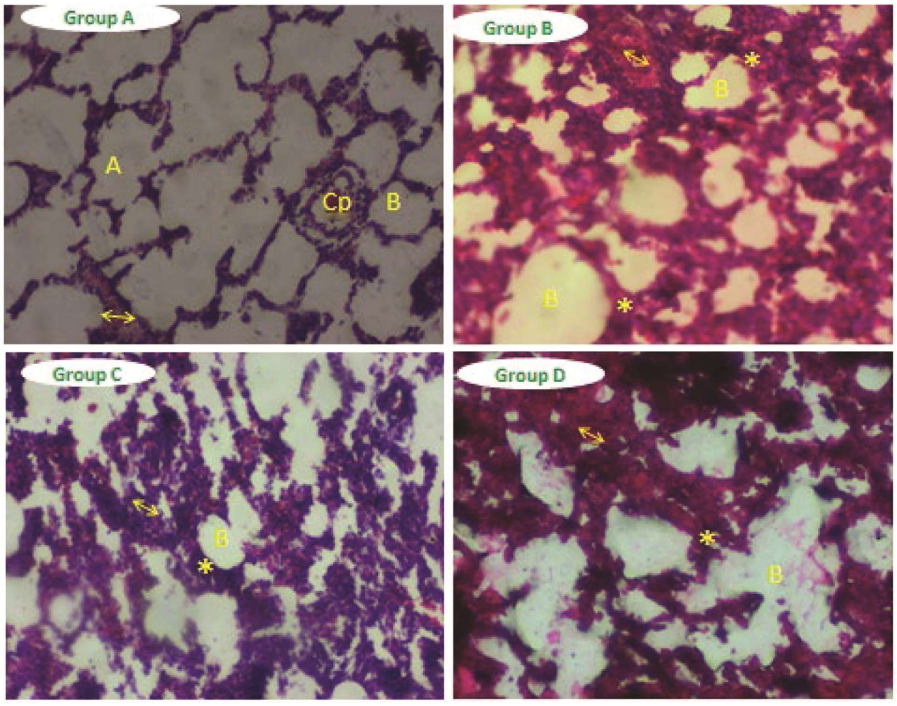

Plate 1 — Photomicrograph of the lungs of rat exposed to graded doses of lead acetate (PB) : H&E-stained lung sections, Control Group A showing normal Capillary (Cp) Alveolus (A) bronchiolar (B) and with normal peribronchiolar lymphoid aggregation (double head arrow) . Group B, C and D showing distorted lung morphologies: collapsed alveolar space with inflammatory exudates, wider and thickened interalveolar septa, mild bronchiolitis and peri bronchiolitis note the intense inflammatory cells involving the bronchiolar lumen and wall (*) that merge with lymphoid aggregation (double head arrow)

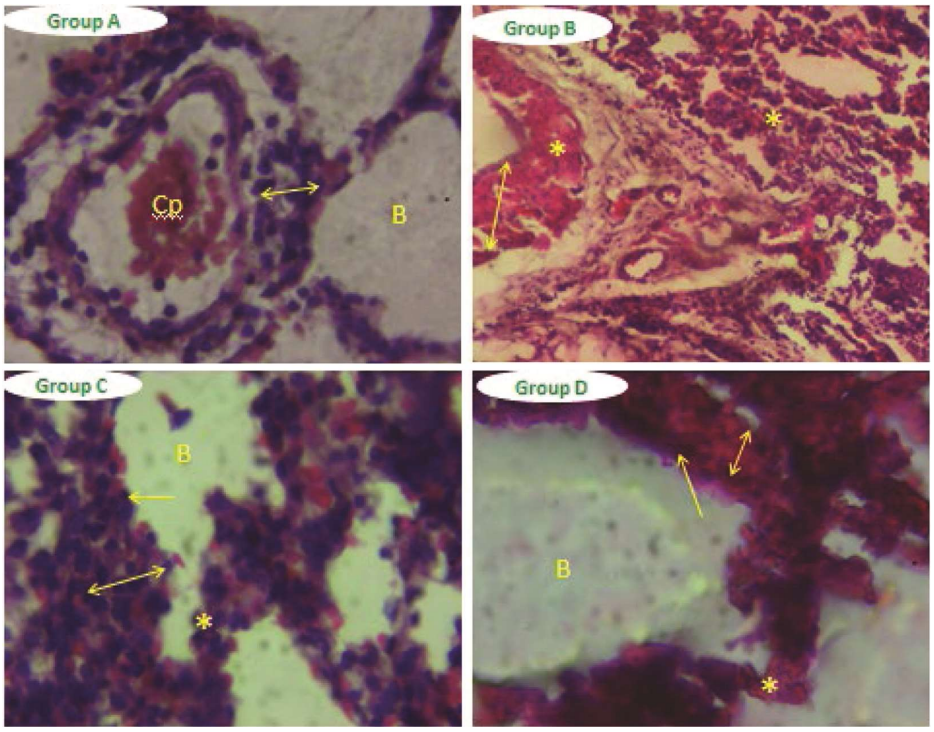

Plate 2 — Photomicrograph of the lungs of rat exposed to graded doses of lead acetate (PU) Control Group A showing normal Capillary (Cp) Bronchiolar (B) with normal peribronchiolar lymphoid aggregation (double head arrow) . Group B, C and D showing Focal hyperplasia of bronchial epithelium (arrow) with the endothelial swelling and inflammatory cells aggregation in vascular lumen. Thou Group D showing hyperplasia of bronchiolar epithelium with less inflammatory reaction involving the peribranchial (*) with slight hyperplasia of the lymphoid aggregation (double head arrow)

Periodic acid Schiff

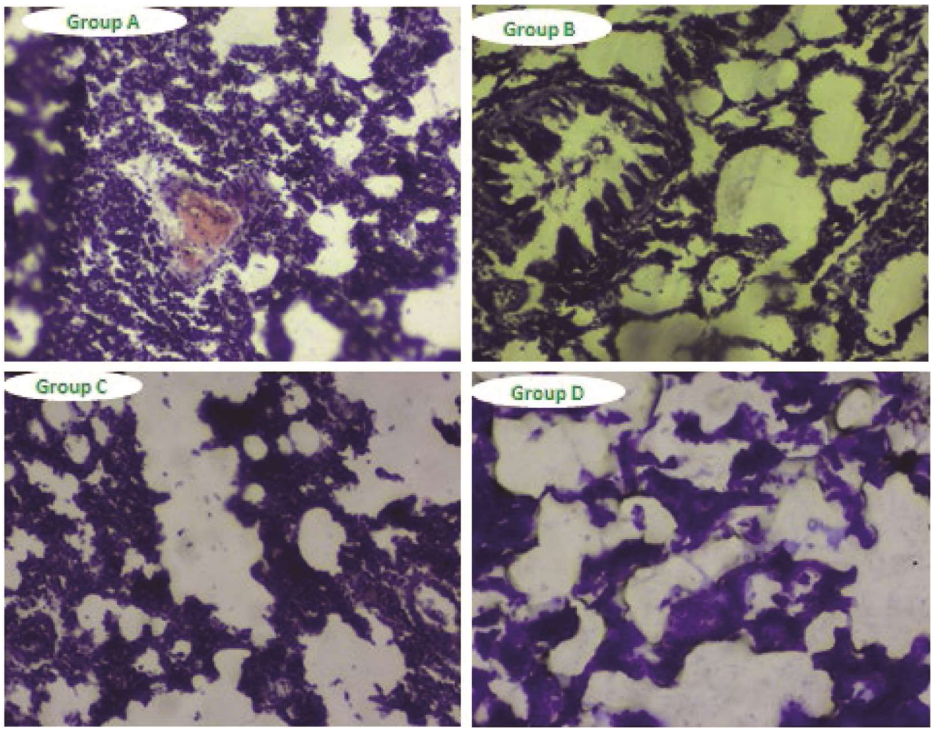

Plate 3 — Periodic acid-Schiff (PAS) stain of lung tissue demonstrates the presence of alveolar macrophages

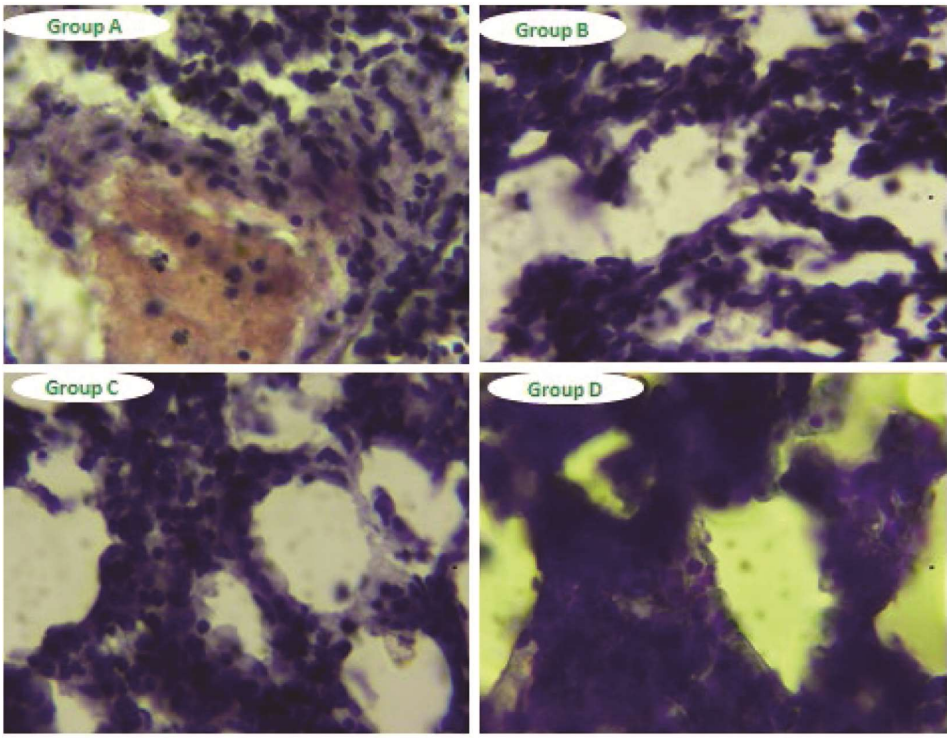

Plate 4 — Photomicrograph of the fongs of rat exposed to praded dmes of lead acetune (P) and stained with periodic acid Schiff stain for the demonstration of glycogen: periodic acid-Schiff (PAS) stain of lung tissue demonstrates the presence of alveolar macrophages

Masson trichrome

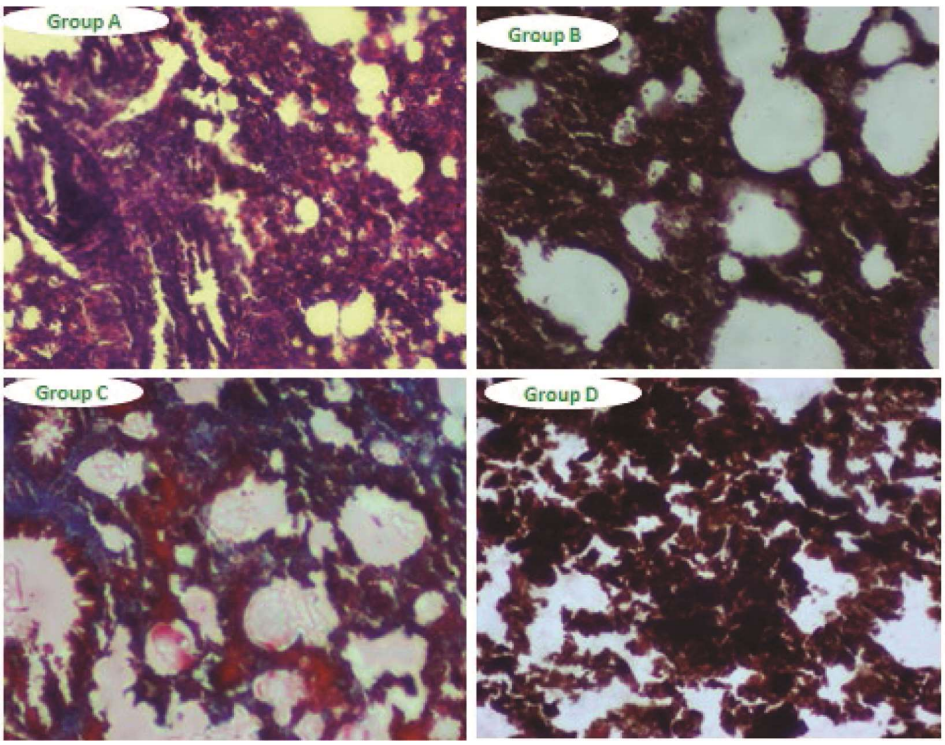

Plate 5 — Masson staining of lung tissue in Control Group A, normal lung morphology: almost no deposition of collagen in lung parenchyma. Group B, C, and D showed distorted lung morphologies: alveolar thickening, collagen fiber agglomerates (blue) initial formation of silicon nodules and dense accumulation of collagen. and reduced amounts of collagen

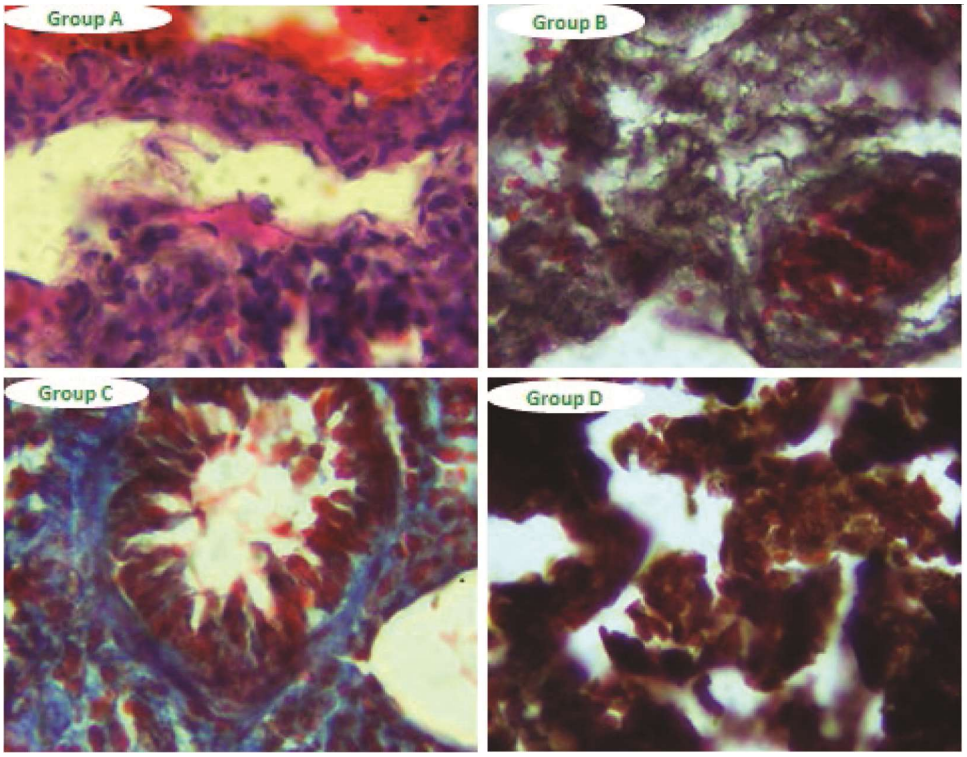

Plate 6 — Masson staining of lung tissue in Control Group A, normal lung morphology: almost no deposition of collagen in lung parenchyma. Group B, C, and D showed distorted lung morphologies: alveolar thickening, collagen fiber agglomerates (blue) initial formation of silicon nodules and dense accumulation of collagen. and reduced amounts of collagen

Discussion

The discussion section provides a comprehensive analysis of the effects of chronic administration of lead acetate on various physiological parameters in adult male Wistar rats. This study aimed to elucidate the impact of lead toxicity on lung structure and morphology, as well as hematological indices, shedding light on the potential health hazards associated with exposure to lead acetate.

Lead contamination remains a significant public health concern worldwide, originating from diverse sources such as industrial activities, including mining, smelting, and manufacturing[14]. Additionally, the historical use of leaded products like paint, batteries, and pipes has contributed to widespread environmental contamination[15]. Despite regulatory efforts to minimize lead exposure, its persistence in the environment poses risks to human health and ecosystems, particularly in urban areas with a legacy of industrial activity[16].

Evaluation of body weight serves as a fundamental indicator of overall health status and metabolic function. In this study, chronic exposure to lead acetate resulted in subtle changes in body weight across experimental groups, although not statistically significant. This finding is consistent with previous research indicating that toxic metal exposure may influence metabolism, leading to alterations in body weight regulation[17]. Furthermore, the displacement of essential metals by lead disrupts metabolic pathways, potentially contributing to weight fluctuations observed in response to lead acetate administration[18].

The results of this study did not reveal statistically significant differences in hematological parameters, including Packed Cell Volume (PCV) Platelet count, Hemoglobin (Hb) Neutrophil count, White Blood Cell (WBC) count, and Lymphocyte count, across the experimental groups. However, subtle trends were observed, such as a slight decrease in hemoglobin levels and an increase in lymphocyte count in lead-exposed groups, which may warrant further investigation. While these trends did not reach statistical significance, they could suggest potential biological effects of lead acetate that may become more pronounced under longer exposure periods or higher doses. Future studies with larger sample sizes or extended durations are needed to explore these trends further and determine their biological relevance. This is in slight deviation from previous studies[19-21].

Lymphocytes play a crucial role in immune function, and alterations in their count can signify underlying inflammatory processes. The observed increase in lymphocyte count following lead acetate exposure suggests immune system activation in response to toxic insult[22]. This finding underscores the immunomodulatory effects of lead and its potential to compromise host defense mechanisms against pathogens[23]. Furthermore, chronic exposure to lead acetate may predispose individuals to immune-related disorders and infectious diseases due to immune system dysregulation[24].

Platelets play a vital role in hemostasis and blood clotting, and their dysfunction can lead to bleeding disorders or thrombotic events[25]. Although no significant difference in platelet count was observed among the experimental groups, subtle changes in platelet function may occur due to lead exposure[26]. Further investigation is warranted to elucidate the impact of lead on platelet structure and function, particularly in the context of coagulation disorders associated with lead toxicity[27].

Lead competes with calcium for binding sites in the body, primarily accumulating in bone tissue. The observed decrease in calcium levels in response to lead acetate exposure underscores the displacement of calcium by lead, leading to bone demineralization and impaired bone health[28]. This phenomenon contributes to the pathogenesis of lead-induced skeletal abnormalities, including osteoporosis and skeletal deformities[29]. Moreover, chronic exposure to lead acetate during periods of bone growth and development may have long-term implications for bone health and fracture risk later in life[30].

Elevations in creatinine kinase levels indicate muscle damage and membrane integrity disruption. Although no statistically significant difference in creatinine kinase levels was observed among the experimental groups, a slight increase in creatinine kinase activity was noted[22]. This suggests potential subclinical muscle damage secondary to lead toxicity, highlighting the need for further investigation into its effects on musculoskeletal health[31]. Chronic exposure to lead acetate may compromise muscle function and integrity, contributing to fatigue, weakness, and impaired physical performance[32].

Conclusion

In conclusion, chronic exposure to lead acetate exerts multifaceted effects on physiological parameters, including body weight regulation, hematological indices, immune function, bone health, and muscle integrity. These findings underscore the pervasive nature of lead toxicity and its detrimental impact on overall health and well-being. Future research endeavors should focus on elucidating the mechanisms underlying lead-induced toxicity, developing precise biomarkers for heavy metal monitoring, and implementing public health interventions to mitigate environmental lead exposure. Additionally, education and awareness campaigns aimed at promoting lead-safe practices and reducing human exposure to lead-containing products are essential for safeguarding public health and preventing lead-related health hazards in vulnerable populations.

Conflict of interests

All authors declare no conflict of interests.

References

1 Adnan M, Xiao B, Ali MU, Xiao P, Zhao P, Wang H & Zhang Y, Heavy metals pollution from smelting activities: A threat to soil and groundwater. *Ecotoxicol Environ Saf*, 274 (2024) 116189.

2 LeBrón AMW, Torres IR, Valencia E, Dominguez ML, Garcia-Sanchez DG & Logue MD, The State of Public Health Lead Policies: Implications for Urban Health Inequities and Recommendations for Health Equity. *Int J Environ Res Public Health*, 16 (2019) 1064.

3 Sani, AH & Amanabo, M, Lead: A concise review of its toxicity, mechanism and health effect. *GSC Biological and Pharmaceutical Sciences*, 15 (1) (2021) 055.

4 Ferreira G, Santander A, Chavarría L, Cardozo R, Savio F & Sobrevia L, Functional consequences of lead and mercury exposomes in the heart. *Mol Aspects Med*, 87 (2022) 101048.

5 Boskabady M, Marefati N, Farkhondeh T, Shakeri F, Farshbaf A & Boskabady MH, The effect of environmental lead exposure on human health and the contribution of inflammatory mechanisms, a review. *Environ Int*, 120 (2018) 404.

6 Zafar MS, Quarta A, Marradi M & Ragusa A, Recent Developments in the Reduction of Oxidative Stress through Antioxidant Polymeric Formulations. *Pharmaceutics*, 11 (2019) 505.

7 Geraldine M & Venkatesh T, Ameliorative effects of nutritional minerals on lead-induced hematological alterations in male Wistar albino rats. *Drug Chem Toxicol*, 45 (2021) 1.

8 Kelainy EG, Ibrahim Laila IM & Ibrahim SR, The effect of ferulic acid against lead-induced oxidative stress and DNA damage in kidney and testes of rats. *Environ Sci Pollut Res*, 26 (2019) 31675.

9 Harshitha P, Bose K & Dsouza HS, Influence of lead-induced toxicity on the inflammatory cytokines. *Toxicology*, 503 (2024) 153771.

10 Kargar-Shouroki F, Mehri H & Sepahi-Zoeram F, Biochemical and hematological effects of lead exposure in Iranian battery workers. *Int J Occup Saf Ergon*, 29 (2023) 661.

11 Mattila T, Santonen T, Andersen HR, Katsonouri A, Szigeti T, Uhl M & Kolossa-Gehring M, Scoping Review—The

Association between Asthma and Environmental Chemicals. *Int J Environ Res Public Health*, 18 (2021) 1323.

12 Zulfiqar U, Farooq M, Hussain S, Maqsood M, Hussain M, Ishfaq M & Nawaz A, Lead toxicity in plants: Impacts and remediation. *J Environ Manage*, 250 (2019) 109557.

13 Rani M, Vikas Kumar R, Lathwal M & Kamboj A, Effect and Responses of Lead Toxicity in Plants. In: Kumar N & Jha AK. (Eds.) Lead Toxicity Mitigation: Sustainable Nexus Approaches, *Springer Nature Switzerland*, (2024), 211.

14 O'Connor D, Hou D, Ye J, Zhang Y, Ok YS, Song Y & Li X, Lead-based paint remains a major public health concern: A critical review of global production, trade, use, exposure, health risk, and implications. *Environ Int*, 121 (2018) 85.

15 Dignam T, Kaufmann RB, Le Stourgeon L & Brown MJ, Control of Lead Sources in the United States, 1970-2017: Public Health Progress and Current Challenges to Eliminating Lead Exposure. *J Public Health Manag Pract*, 25 (2019) S13.

16 Dietrich M & Filippelli GM, Positive outcomes from U.S. lead regulations, continued challenges, and lessons learned for regulating emerging contaminants. *Environ Sci Pollut Res*, 30 (2023) 57178.

17 Planchart A, Green A, Hoyo C & Mattingly CJ, Heavy Metal Exposure and Metabolic Syndrome: Evidence from Human and Model System Studies. *Curr Envir Health Rpt*, 5 (2018) 110.

18 Wani AL, Hammad Ahmad Shadab GG & Afzal M, Lead and zinc interactions – An influence of zinc over lead related toxic manifestations. *J Trace Elem Med Biol*, 64 (2021) 126702.

19 Cai SZ, Zhou Y, Liu J, Li CP, Jia DY, Zhang MS & Li Y, Alleviation of ginsenoside Rg1 on hematopoietic homeostasis defects caused by lead-acetate. *Biomed Pharmacother*, 97 (2018) 1204.

20 Rahimpoor R, Rostami M, Assari MJ, Mirzaei A & Zare MR, Evaluation of Blood Lead Levels and Their Effects on Hematological Parameters and Renal Function in Iranian Lead Mine Workers. *Health Scope*, 9 (2020) e95917.

21 Rawat PS, Singh S, Zahid M & Mehrotra S, An integrated assessment of lead exposure in children: Correlation with biochemical and haematological indices. *J Trace Elem Med Biol*, 68 (2021) 126835.

22 López-Vanegas NC, Hernández G, Maldonado-Vega M & Calderón-Salinas JV, Leukocyte apoptosis, TNF-α concentration and oxidative damage in lead-exposed workers. *Toxicol Appl Pharmacol*, 391 (2020) 114901.

23 Mookherjee N, Anderson MA, Haagsman HP & Davidson DJ, Antimicrobial host defence peptides: functions and clinical potential. *Nat Rev Drug Discov*, 19 (2020) 311.

24 Rasouli-Saravani A, Jahankhani K, Moradi S, Gorgani M, Shafaghat Z, Mirsanei Z & Mohammadi M, Role of microbiota short-chain fatty acids in the pathogenesis of autoimmune diseases. *Biomed Pharmacother*, 162 (2023) 114620.

25 Sang, Y, Roest M, de Laat B, de Groot PG & Huskens D, Interplay between platelets and coagulation. *Blood Rev*, 46 (2021) 100733.

26 Chwalba A, Maksym B, Dobrakowski M, Kasperczyk S, Pawlas N & Birkner E, The effect of occupational chronic lead exposure on the complete blood count and the levels of selected hematopoietic cytokines. *Toxicol Appl Pharmacol*, 355 (2018) 174.

27 Nielsen VG, Goff T, Hunsaker BD & Neves CD, The Gilded Clot: Review of metal-modulated platelet activation, coagulation, and fibrinolysis. *Int J Mol Sci*, 24 (2023) 3302.

28 Virgolini MB & Aschner M, Molecular mechanisms of lead neurotoxicity. In: Aschner M & Costa LG. (Eds.) Advances in Neurotoxicology, *Academic Press*, 5 (2021) 159.

29 Li X, Li B, Shi Y, Wang C & Ye L, Targeting reactive oxygen species in stem cells for bone therapy. *Drug Discov Today*, 26 (2021) 1226.

30 Yan R, Ding J, Yang Q, Zhang X, Han J, Jin T & Li Y, Lead acetate induces cartilage defects and bone loss in zebrafish embryos by disrupting the GH/IGF-1 axis. *Ecotoxicol Environ Saf*, 253 (2023) 114666.

31 Satarug S, Gobe GC, Vesey DA & Phelps KR, Cadmium and Lead Exposure, Nephrotoxicity, and Mortality. *Toxics*, 8 (2020) 86.

32 Hughes RL & Holscher HD, Fueling Gut Microbes: A Review of the Interaction between Diet, Exercise, and the Gut Microbiota in Athletes. *Adv Nutr*, 12 (2021) 2190.