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Effects of welding fumes on haematological parameters of male albino rats (*Rattus norvegicus*)

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ABSTRACT

Welders or metal workers not being an exception are exposed to metals ions or oxides (fumes) at trace concentrations either through direct contact supplementation at occupational sites or indirectly through uptake from contaminated food, water or contaminated soil, dust, or air. The study aims to determine the effects of welding fumes exposure on haematological parameters in blood of experimental animals. The fumes were collected from welding sites during the activity by a skilled welder. 130 male experimental animals were utilized and made into 13 groups. 12 groups were given dosages calculated to correspond to real life workers exposure regimes and 1 group served as control. The dosages were administered intratracheally after been anaesthetized weekly for 12 weeks. The animals were sacrificed and whole blood samples were taken which was then subjected to haematological analysis. The parameters have revealed changes in values whereby RBC, WBC, % lymphocytes, HGB, HCT, MCV, MCH, PLT, PCT and P-LCC have exceeds the control groups values. There was an increase across the treatment groups. However, lymphocytes, MID, granulocytes, % granulocytes, MCHC and MPV have values which were less than the control and no different from one another statistically. This indicates that exposure to welding fumes could cause alterations to most RBC, WBC and PLT indices majorly by effecting an increase. Further studies should be carried out on the response of other markers of toxicity so as to have a broad perception of the effects.

1. Introduction

Welding is an industrial process which is common, and use excessively high temperatures to join metals. Importantly, the process produces metallic fumes and gases that are potentially hazardous [1,2]. There are several reasons why welding is regarded as dangerous occupation: workers suffer excessive heat, burns, radiation, noise, fumes, gases, electrocution, and even the uncomfortable postures involved in the work; the different chemical composition of welding fumes, work piece, method employed, and surrounding environment; and lastly the routes of entry or surface exposed to these harmful agents access the body [3]. Individuals and population are exposed to metals ions or oxides (fumes) at trace concentrations either through direct contact supplementation or indirectly through uptake from contaminated food, water or contaminated soil, dust, or air. Some metals ions, including cadmium, lead, arsenic and mercury, are regarded as non-essential xenobiotics and are injurious to human health [4–7]. Other metals ions, such as chromium, copper, manganese, molybdenum, selenium and zinc, are essential for good health but could be harmful above certain levels [8–12]. Tierney [13] described welding as one of the most

hazardous occupations. Welding processes involves the vaporization of the metals and oxides of an electrode or wire that is consumed during the process to release fumes/dusts. Rapid condensation of the vapours, results in generating particulates composed of different metal oxides that related to the composition of the electrode [14]. Metal works have dotted the urban Kano landscape and been one of the major economic activities in the area. The toxic effects from exposure to metal fumes and particulates are largely overlooked. We are not aware of the extent of the problem in the population of urban. Kano. In addition, health authorities in Kano focus more attention on communicable diseases such as malaria, typhoid, etc caused by vectors or water borne as environmental health problems. The aim of the study was to evaluate toxicity of metal fumes through determination of haematological status of the experimental animal groups.

2. Materials and methods

2.1. Collection of welding fumes

The metal fumes were generated in a cubical open front fume

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chamber (volume = $1\,m^3$) by a skilled welder performing manual metal welding (shielded manual metal arc welding) process using a stainless steel hard surfacing electrode (Hyundai Welding electrode low hydrogen E 7018 3.2 mm) and collected on 0.2-μm nuclepore filters. They were collected in significant amount just before the start of the study. The particle size of the collected fume sample was determined using scanning electron microscopy (SEM) and found to be within the respirable size range [15].

2.2. Experimental design

Male albino rats were chosen for this study. The rats were obtained and housed at the Animal house, Department of Pharmacology, Aminu Kano Teaching Hospital, Kano, Nigeria. Randomized block design was adopted for this study. A total of 130 laboratory rats (*Rattus norvegicus*) were utilized for the study. The animals were maintained in the animal room and were allowed to acclimatize for two weeks before treatment. The animals weigh between 210 and 250 g. The animals were divided into 13 experimental groups with each group composing of 10 rats.

2.3. Housing and feeding conditions

The animal house has restricted access, free from pathogens and other extraneous factors. They were placed in cages with each cage housing 5 animals. The animals were marked on their tails for identification. The temperature in the experimental animal room was maintained at about 22 °C (± 3 °C) and the relative humidity was at least 30%. For lighting, the sequence was 12 h light and 12 h dark. They were given a conventional standard laboratory diet (Corn, Soybean pulp, Sunflower seed meal, Shorts, Bonquality flour, Alfalfa pellets, Molases, Meat and bone meal, Poultry meal, Sepiolite, inorganic DCP, Marble dust, vitamins, minerals) bought from Vital Feed, Kano, Nigeria with water *ad libitum*. Existing protocols for the use of lab animals were adhered to strictly and ethical approval for the study was obtained from College of Health Sciences Research Ethics Committee (CHS-REC), Bayero University, Kano [16].

2.4. Preparation of test substance

The dosing paradigm employed in this study was related to workplace exposures of metal workers. A mathematical calculation was utilized to determine the daily lung burden of a metal worker on a specified number of hours work schedule [17,18]. Below are the factors that were taken into consideration during the calculation:

➢ Fume concentration ($5\,mg/m^3$, threshold limit value for welding fumes)
➢ Human minute ventilation volume (20,000 $mlmin^{-1} \times 10^{-6} m^3 ml^{-1}$)
➢ Exposure duration (no. of hr $day^{-1} \times 60\,min\,h^{-1}$)
➢ Deposition efficiency (15%) [19,20].

With reference to the above factors, metal workers daily burden for various hours per day.

1. Metal worker daily burden (2hrs/day) = Fume concentration ($5\,mg/m^3$) × Human minute ventilation volume (20,000 ml/min × 10-6 m^3/ml) × Exposure duration (2hr/day × 60 min/hr) × Deposition efficiency (15%) = 1.8 mg

Using surface area of alveolar epithelium (rat = $0.4\,m^2$; human = $102\,m^2$) as dose metric [63]. Rat daily burden of exposure was taken as 0.0070 mg.

Then, similar exposure in rats for 3yrs, 5yrs, 10yrs and 20yrs will be 7.66 mg, 12.77 mg, 25.55 mg and 51.10 mg respectively at 365 days per year. Each of these concentrations was then divided into 12 which was administered weekly for the period of the study (12 weeks).

2. Metal worker daily burden (4hrs/day) = Exposure in rats for 3yrs, 5yrs, 10yrs and 20yrs will be 15.44 mg, 25.73 mg, 51.46 mg and 102.93 mg respectively at 365 days per year. Each of these concentrations was then divided into 12 which were administered weekly for the period of the study (12 weeks).

3. Metal worker daily burden (8hrs/day) = Exposure in rat for 3yrs, 5yrs, 10yrs and 20yrs will be 30.88 mg, 51.46 mg, 102.93 mg and 205.86 mg respectively at 365 days per year. Each of these concentrations was then divided into 12 which were administered weekly for the period of the study (12 weeks).

The table below described the working concentrations (dosage) of metal fumes administered to test animals for 12 weeks used for the study. Each concentration was given per animal per week.

Groups		
I	II	III
Group IA (0.64mg/animal/week)	Group IIA (1.29mg/animal/week)	Group IIIA (2.57mg/animal/week)
Group IB (1.06mg/animal/week)	Group IIB (2.14mg/animal/week)	Group IIIB (4.27mg/animal/week)
Group IC (2.13mg/animal/week)	Group IIC (4.29mg/animal/week)	Group IIIC (8.56mg/animal/week)
Group ID (4.26mg/animal/week)	Group IID (8.58mg/animal/week)	Group IIID (17.16mg/animal/week)

The metal fumes sample was prepared in sterile saline and sonicated for 1 min to disperse the particulates. The fumes were prepared weekly prior to administration. Rats were anaesthesized with ketamine (0.1 ml/100 g b.w I.P) and after passing out, immediately followed by intratracheal instillation of the respective dose per animal once a week for 12 weeks. Control animals were given 200 μl of sterile saline via intratracheal route after been anaesthesized.

2.5. Administration and dose of test materials

The study involved chronic toxicity testing of the metal fumes in rats which lasted for 12 weeks and treatment was administered weekly by intratracheal instillation [21].

2.6. Collection of blood samples

The animals were anaesthetized using chloroform and the site of collection cleaned by alcohol. The blood samples were collected 1 week after the last 12 weekly treatments from jugular vein by cutting with a blade into an EDTA container for haematological studies [21,22].

2.7. Determination of haematological parameters

Red blood cells (RBC), white blood cell counts (WBC), lymphocytes (LYM), granulocytes (GRAN), % lymphocytes (%LYMP), % granulocytes (%GRAN), Mid-range absolute count (MID), Platelets (PLT), Mean platelets volume (MPV), platelets large cell counts (P-LCC) and plateletcrits (PCT) were obtained using the Bürker counting chamber method from the whole blood. Hematocrit (HCT) was obtained following blood centrifugation in microcapillaries, while haemoglobin concentrations (Hb) was measured using the Bio-LaTest Sono Hb (Pliva Lachema, Czech Republic). Hematocrit and red blood cell counts, haemoglobin and red blood cell counts, and haemoglobin and hematocrit were employed to determine MCV, MCH, and MCHC, respectively.

Table 1

Mean values of white cells indices of blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	WBC (10*3/μL)	Lymph (10*3/μL)	MID (10*3/μL)	GRAN (10*3/μL)	Lymph (%)	GRAN (%)
IA (3yrs)	3.57 ± 0.49	2.21 ± 0.36	0.5 ± 0.05	1.15 ± 0.01	59.7 ± 5.21	34.75 ± 4.13
IB (5yrs)	3.66 ± 0.78	1.95 ± 0.87	0.45 ± 0.02	0.95 ± 0.012	59.33 ± 6.72	36.93 ± 3.61
IC (10 yrs)	3.7 ± 1.30	1.85 ± 0.35	0.35 ± 0.031	0.87 ± 0.13	62.25 ± 7.28	36.28 ± 2.99
ID (20 yrs)	3.85 ± 0.42[a]	1.88 ± 0.11	0.35 ± 0.022	0.75 ± 0.12	57.38 ± 5.16	35.28 ± 3.04
Control	3.5 ± 0.71[a]	2.7 ± 0.15	0.6 ± 0.07	1.2 ± 0.14	57.7 ± 4.64	38 ± 3.33
P value	< 0.05	> 0.05	> 0.05	> 0.05	> 0.05	> 0.05

p < 0.05: there is significant difference.

p > 0.05: there is no significant difference.

Means ± SD values with same letters as superscript indicate significance.

2.8. Data analysis

Relevant statistical tools were employed to analyze data or results obtained from the study. Means of various parameters were determined and statistical difference of means was tested by one way analysis of variance (ANOVA). Sigmastat v.3.5 was used for the analysis.

3. Results

Tables 1–3 show the blood indices determined in blood of experimental animals in groups I (A, B, C, D), II (A, B, C, D) & III (A, B, C, D). The parameters include WBC, Lymphocytes, MID, granulocytes, % lymphocytes and % granulocytes.

Tables 4–6 show the red cells indices determined in blood of experimental animals in groups I (A, B, C, D), II (A, B, C, D) & III (A, B, C, D). The parameters include RBC, HGB, HCT, MCV, MCH and MCHC.

Tables 7–9 show the platelets indices determined in blood of experimental animals in groups I (A, B, C, D), II (A, B, C, D) & III (A, B, C, D). The parameters include PLT, MPV, PCT and P-LCC.

4. Discussion

The mean values of WBC for groups IA, IB, IC & ID range from 3.57 to $3.85 \times 10^3/\mu L$ as shown in Table 1. The values of WBC for all groups have exceeded the control. The least value of WBC in group ID might be attributed to receiving the highest dosage compared to previous groups. There is significant difference statistically between the group (P < 0.05). The mean values of WBC for group IIA, IIB, IIC, IID ranges from 3.65 to $4.73 \times 10^3/\mu L$ as shown in Table 2. All values of the groups have exceeded the control value of $3.5 \times 10^3/\mu L$. Statistically, there is significant difference exist between the groups (P < 0.05).

The mean values of WBC for groups IIIA, IIIB, IIIC & IIID ranges from 4.53 to $5.66 \times 10^3/\mu L$ as shown in Table 3. The mean WBC values for all groups have exceeded that of the control mean value of $3.5 \times 10^3/\mu L$. Statistically, there is a significant difference between the group (P < 0.05). Thus, indicating that there is slight increase in WBC counts. Similarly, Paula Kauppi et al. [23], revealed that the number of leukocytes and neutrophils increased significantly following mild steel (MS) and stainless steel (SS) welding challenge tests. In addition, Kim

et al. [24], investigated the acute systemic inflammatory response to welding fume exposure and found that compared to non-smokers, smokers had a significantly higher baseline WBC count. In non-smokers, welding fume exposure was associated with a significant increase in WBC and neutrophil counts immediately following exposure. No significant changes in WBC and neutrophil levels were found in smokers. In non-smokers, welding fume exposure was associated with a mean increase in WBC count by 0.86103/ml, a 13% increase from baseline. Likewise, neutrophil counts in non-smokers increased by 1.06103/ml, indicating that the increase in WBC counts following exposure may be mostly attributable to increased neutrophil counts. A significant exposure-response association also was observed between PM2.5 exposure and neutrophil counts in non-smokers (p = 0.04). There was no significant change in WBC and neutrophil counts following welding fume exposure in smokers (p > 0.6). Similarly, smokers had significantly higher neutrophil counts compared to nonsmokers (p,0.001). In previous studies, current smokers have been found to have increased WBC counts compared to former or never-smokers [25,26].

Other studies also have shown that exposure to ambient and occupational particulate matter is associated with increased WBC and neutrophil counts [27,28]. Increased ambient particulate levels have been shown to be associated with increased levels of inflammatory markers, such as white blood cell counts (WBCs) [28]. In the experimental settings, animal studies have shown that concentrated ambient particulate exposures increase the total white blood cell counts (WBCs) and the differential count of circulating neutrophils [29,30]. This is in line with the findings of the current study. In contrast, Ranja and Peyush [61] reported that the total white blood cell counts and the differential white blood cell counts have decreased except for the lymphocytes in which there was a slight increase in common carp *Cyprinus carpio* after exposure to zinc in water. A common laboratory finding in cases of metal fume fever is leukocytosis. The increase in white blood cells is transitory, usually lasting a day or two following the onset of the fever [31]. It is probably related to the release of a histamine-like substance from respiratory epithelial cells that have been damaged by inhaled metal oxide particles ([31]. However, Ross and Hewitt [32], found no significant differences in hemoglobin levels or white blood cell counts between a group of over 350 heavy engineering welders and 100 or more non welders. Schwartz [28] in a study reported a significant

Table 2

Mean values of white blood cells indices in blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	WBC (10*3/μL)	Lymph (10*3/μL)	MID (10*3/μL)	GRAN (10*3/μL)	Lymph (%)	GRAN (%)
IIA	3.65 ± 0.35[ab]	1.81 ± 0.01	0.40 ± 0.03	0.83 ± 0.11	61.33 ± 4.23	35.03 ± 3.01
IIB	3.9 ± 0.51	1.76 ± 0.22	0.43 ± 0.02	0.71 ± 0.13	65.75 ± 4.31[abc]	37.15 ± 2.51
IIC	4.2 ± 0.17[a]	1.84 ± 0.31	0.43 ± 0.01	0.66 ± 0.10	58.5 ± 3.69[c]	36.4 ± 3.41
IID	4.73 ± 0.33[bc]	1.73 ± 0.40	0.32 ± 0.02	0.7 ± 0.09	61.9 ± 3.34	31.475 ± 2.62
Control	3.5 ± 0.71[c]	2.7 ± 0.15	0.6 ± 0.07	1.2 ± 0.14	57.7 ± 4.64[ab]	38 ± 3.33
P value	< 0.05	> 0.05	> 0.05	> 0.05	< 0.05	> 0.05

p < 0.05: there is significant difference.

p > 0.05: there is no significant difference.

Means ± SD values with same letters as superscript indicate significance.

Table 3
Mean values of white blood cells indices in blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	WBC (10*3/μL)	Lymph (10*3/μL)	MID (10*3/μL)	GRAN (10*3/μL)	Lymph (%)	GRAN (%)
IIIA (3yrs)	4.53 ± 0.34	1.72 ± 1.2	0.46 ± 0.04	0.74 ± 0.11	63.15 ± 3.47[a]	31.63 ± 3.21
IIIB (5yrs)	4.88 ± 0.41	1.83 ± 1.04	0.43 ± 0.02	0.64 ± 0.09	58.43 ± 3.61[ab]	35.93 ± 3.10
IIIC (10yrs)	5.33 ± 0.52[ab]	1.90 ± 1.10	0.38 ± 0.01	0 .61 ± 0.08	61.9 ± 4.01	33.48 ± 2.94
IIID (20yrs)	5.66 ± 0.43[b]	1.53 ± 1.21	0.38 ± 0.02	0.52 ± 0.09	64.28 ± 4.06[bc]	32.65 ± 2.87
Control	3.5 ± 0.71[ab]	2.7 ± 1.15	0.6 ± 0.07	1.2 ± 0.14	57.7 ± 4.64[c]	38 ± 3.33
P value	< 0.05	> 0.05	> 0.05	> 0.05	< 0.05	> 0.05

p < 0.05: there is significant difference.
p > 0.05: there is no significant difference.
Means ± SD values with same letters as superscript indicate significance.

positive relationship between WBCs and the differential leukocyte count (DLC) of circulating neutrophils and particulate matter with an aerodynamic mass median diameter ≤ 10 μm (PM10), after controlling for several variables including smoking.

The mean value of Mid-range absolute count (MID) for groups IA, IB, IC & ID ranges from 0.35 to 0.5×10^3/μL as shown in Table 1. Group ID & IC have the least value of 0.35×10^3/μL and IA has the highest value of 0.5×10^3/μL. Groups mean values are less than the control value of 0.6×10^3/μL. There is no significant difference statistically between the groups (P > 0.05).

The mean value of MID in group IIA, IIB, IIC & IID ranges from 0.32 to 0.43×10^3/μL as shown in Table 2. Group IID has the least mean value of 0.32×10^3/μL while group IIB & IIC have the highest value of 0.43×10^3/μL. Groups have mean values less than the control value of 0.6×10^3/μL. There is no significant difference statistically between the groups (P > 0.05).

TThe mean value of MID for groups IIIA, IIIB, IIIC & IIID ranges from 0.38 to 0.46×10^3/μL as shown in Table 3. Group IIIC & IIID have the least mean value of 0.38×10^3/μL while group IIIA has the highest mean value of 0.46×10^3/μL. The mean values for all groups are less than the control value of 0.6×10^3/μL. There is no significant difference statistically between the groups (P > 0.05).

Peripheral blood neutrophilia has also been found to increase following short-term inhalation exposure to other substances, such as ozone [33] and compost dust [34].

The mean values of granulocytes for groups of IA, IB, IC and ID ranges from 0.75 to 1.15×10^3/μL as shown in Table 1. Group ID has the least mean value of 0.75×10^3/μL while group IA has the highest mean value of 1.15×10^3/μL. The mean values of all groups have not exceeded the control value of 1.2×10^3/μL. There is no significant difference statistically between the groups (P > 0.05).

The mean values of granulocytes for groups IIA, IIB, IIC & IID ranges from 0.66 to 0.83×10^3/μL as shown in Table 2. Group IIC has the least mean value of $0.66 \times \times 10^3$/μL while group IIA has the highest mean value of 0.83×10^3/μL. All the mean values of the groups have not exceeded the control value of 1.2×10^3/μL. There is no significant different statistically between the groups (P > 0.05).

The mean values of granulocytes for groups IIIA, IIIB, IIIC and IIID ranges from 0.52 to 0.74×10^3/μL as shown in Table 3. Group IIID has

the least values of 0.52×10^3/μL while group IIIA has the highest value of 0.74×10^3/μL. All groups have mean values that have not exceeded the control value of 1.2×10^3/μL. There is no significant difference statistically between the groups (P > 0.05).

The mean values of lymphocytes for groups IA, IB, IC & ID range from 1.88 to 2.21×10^3/μL as shown in Table 1. All the values recorded are less than the control value of 2.7×10^3/μL. The values decreases progressively from groups IA, IB and IC then increase in group ID. There is no significant difference statistically between the groups (P > 0.05).

The mean values of lymphocytes for group IIA, IIB, IIC & IID ranges from 1.73 to 1.84×10^3/μL as shown in Table 2. Group IID has the least mean value of 1.73×10^3/μL and group IIC has the highest mean value of 1.84×10^3/μL. All mean values of the groups are less than the control mean value of 2.7×10^3/μL. There is no significant difference statistically between the groups (P > 0.05).

The Mean value of lymphocytes for group IIIA, IIIB, IIIC & IIID ranges from 1.53 to 1.90×10^3/μL as shown in Table 3. Group IIID has the least mean value of 1.53×10^3/μL and group IIIC has the highest mean value of 1.90×10^3/μL. All groups have mean values of lymph that is less than the control value of 2.7×10^3/μL. There is no significant difference statistically between the groups (P > 0.05).

The mean values of % lymphocytes for groups IA, IB, IC and ID range from 57.38 to 62.25% as shown in Table 1. Group ID has the least mean of 37.38% while group IC has the highest value of 62.25%. Group IA, IB and IC have mean values that have exceeded the control mean value of 57.7%. Meanwhile, the mean value of group ID is less than the control. There is no significant difference statistically between the groups (P > 0.05).

The mean values of % lymphocytes for groups IIA, IIB, IIC ad IID range from 58.5 to 65.75% as shown in Table 2. Group IIC has the least mean value of 58.5% while group IIB has the highest value. The mean values of all groups have exceeded the control mean value of 57.7%. There is significant difference statistically between the groups (P < 0.05).

The mean value of % lymphocytes for groups IIIA, IIIB, IIIC & IIID range from 58.43 to 64.28% as shown in Table 3. Group IIIB has the least value of 58.43% while group IID has the highest mean value o 64.28%. The mean values of all groups have exceeded the control group

Table 4
Mean values of red cells indices in blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	RBC (10*6/μL)	HGB (g/dl)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dl)
IA	4.48 ± 0.83	12.78 ± 2.11	41.1 ± 4.30	90.6 ± 5.26[a]	34.65 ± 2.37	35.4 ± 2.41
IB	4.58 ± 0.52	12.15 ± 52.02	37.4 ± 3.41	90.1 ± 4.91[b]	30.5 ± 2.15	37.25 ± 2.52
IC	4.35 ± 0.41	13.9 ± 2.22	40 ± 2.25	84.8 ± 4.62[abcd]	31.05 ± 2.61	32.53 ± 2.22
ID	4.7 ± 0.32	11.78 ± 2.1	33 ± 3.11	89.1 ± 3.76[c]	28.18 ± 2.09	31.85 ± 2.05
Control	4 ± 0.14	11.7 ± 1.01	35 ± 3.04	87.7 ± 3.72[d]	22.8 ± 2.70	33.8 ± 2.05
P value	> 0.05	> 0.05	> 0.05	< 0.05	> 0.05	> 0.05

Table 5
Mean values of red cells indices in blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	RBC (10*6/μL)	HGB (g/dl)	HCT	MCV	MCH	MCHC (g/dl)
			(%)	(fL)	(pg)	
IIA	4.48 ± 0.28	10.8 ± 1.30[ab]	30.68 ± 2.58[ab]	92.8 ± 3.8	32.93 ± 2.19	35.18 ± 2.81
IIB	4.85 ± 0.21[a]	14.35 ± 2.03[b]	42.63 ± 3.23[a]	88.18 ± 3.40	32.78 ± 3.17	33.98 ± 2.41
IIC	4.93 ± 0.22[b]	12.77 ± 2.01	37.33 ± 2.84	93.1 ± 4.15	28.53 ± 2.43	33.97 ± 3.02
IID	4.78 ± 0.12[c]	15.63 ± 2.16[ac]	45.03 ± 3.14[b]	89.65 ± 3.22	29.03 ± 2.52	35.63 ± 2.55
Control	4 ± 0.14[abc]	11.7 ± 1.01[c]	35 ± 3.04	87.7 ± 3.72	22.8 ± 2.70	33.8 ± 2.05
P value	< 0.05	< 0.05	< 0.05	> 0.05	> 0.05	> 0.05

p < 0.05: there is significant difference.
p > 0.05: there is no significant difference.
Means ± SD values with same letters as superscript indicate significance.

value of 57.7%. There is significant difference statistically between the groups (P < 0.05). There was a positive significant relationship between Fe in blood and % lymphocytes (p < 0.05). However, there was a negative significant relationship between Al in blood and % lymphocytes (p < 0.05).

The mean value of % granulocytes for groups IA, IB, IC & ID ranges from 34.75 to 36.93% as shown in Table 1. Group ID has the least mean value of 34.75% while group IB has the highest mean value of 36.93%. The mean values of % granulocytes in all groups have not exceeded the control value of 38%. There is no significant difference statistically between the groups (P > 0.05).

The mean value of % granulocytes for groups IIA, IIB, IIC and IID ranges from 31.48 to 37.15% as shown in Table 2. Group IID has the least mean value of 31.48% while group IIB has the highest mean value of 36.4%. All groups have mean values less than the control value of 38%. There is no significant difference statistically between the groups (P > 0.05).

The mean value of % granulocytes for groups IIIA, IIIB, IIIC and IIID range from 31.63 to 35.93% as shown in Table 3, group IIIA has the least mean value of 31.63% while group IIIB has the highest mean value of 35.93%. The mean values of all groups are below the control value of 38%. There is no significant difference statistically between the groups (P > 0.05). However, there was significant relationship between Fe, Al, and Zn in blood and % granulocytes (p < 0.05).

Järvelä et al. [37] investigated cardiorespiratory and inflammatory responses in male workers following exposure to welding fumes and airborne particles in actual workplace conditions. They found out that the total blood leukocytes and neutrophils increased after the work shift. This is in line with the results obtained by Kim et al. [24], who found that welding fume exposure was associated with a significant increase in white blood cell and neutrophil counts, although this finding was only evident in non-smokers. However, this had not been reported in previous studies dealing with acute effects of welding [35,36].

The mean value of Red blood cell (RBC) for groups IA, IB, IC & ID range from 4.35 to 4.7 × 10^6/μL as shown in Table 4. Group IC has the least mean value of 4.35 × 10^6/μL while group ID has the highest mean

Table 7
Mean values of platelets indices in blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	PLT (10*3/μL)	MPV (fL)	PCT (%)	P-LCC (10*9/μL)
IA	243.5 ± 20.1	8.75 ± 1.21	0.12 ± 0.003	51.75 ± 2.97
IB	275 ± 23.5	9.03 ± 1.05	0.18 ± 0.003	57.75 ± 3.30
IC	219.5 ± 21.3	8.45 ± 1.18	0.15 ± 0.002	39.75 ± 2.77
ID	261.8 ± 24.8	9 ± 2.02	0.15 ± 0.001	35.25 ± 2.01
Control	255.8 ± 20.02	9.9 ± 2.0	0.09 ± 0.001	36 ± 2.17
P value	> 0.05	> 0.05	> 0.05	> 0.05

p < 0.05: there is significant difference.
p > 0.05: there is no significant difference.

Table 8
Mean values of platelets indices in blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	PLT (10*3/μL)	MPV (fL)	PCT (%)	P-LCC (10*9/μL)
IIA	285.75 ± 21.5	8.95 ± 1.75	0.15 ± 0.001	49.75 ± 2.71
IIB	225.5 ± 17.3	8.65 ± 1.8	0.16 ± 0.002	43.25 ± 2.4
IIC	261.67 ± 18.2	9.37 ± 2.01	0.16 ± 0.001	39 ± 2.01
IID	273.5 ± 19.4	9.1 ± 2.1	0.15 ± 0.002	57 ± 3.4
Control	255.8 ± 20.02	9.9 ± 2.0	0.09 ± 0.001	36 ± 2.17
P value	> 0.05	> 0.05	> 0.05	> 0.05

p < 0.05: there is significant difference.
p > 0.05: there is no significant difference.

value of 4.7 × 10^6/μL. The mean values of the groups have exceeded the control value of 4.0 × 10^6/μL. There is no significant difference statistically between the groups (p > 0.05).

The mean value of RBC for groups IIA, IIB, IIC & IID range from 4.8 to 4.93 × 10^6/μL as shown in Table 5. Group IIA has the least mean value of 4.48 × 10^6/μL while group IIC has the highest mean value of 4.93 × 10^6/μL. The mean values of all groups have exceeded the control value of 4.05 × 10^6/μL. There is significant difference between the

Table 6
Mean values of red cells indices in blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	RBC (10*6/μL)	HGB (g/dl)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dl)
IIIA	4.45 ± 0.12[a]	13.28 ± 1.12	39.25 ± 2.55	90.98 ± 3.28	30.95 ± 2.44	33.18 ± 1.97
IIIB	5.13 ± 0.13[ab]	12.4 ± 1.07	37 ± 2.2	94.23 ± 3.51	29.25 ± 2.11	34.4 ± 2.02
IIIC	4.78 ± 0.10[c]	15.63 ± 1.83	45.03 ± 2.43	89.65 ± 2.61	29.03 ± 2.20	35.63 ± 2.03
IIID	4.58 ± 0.11[bd]	15.23 ± 1.72	44.5 ± 2.14	88.75 ± 2.41	30.75 ± 2.17	32.85 ± 2.10
Control	4 ± 0.14[cd]	11.7 ± 1.01	35 ± 3.04	87.7 ± 3.72	22.8 ± 2.70	33.8 ± 2.05
P value	< 0.05	> 0.05	> 0.05	> 0.05	> 0.05	> 0.05

p < 0.05: there is significant difference.
p > 0.05: there is no significant difference.
Means ± SD values with same letters as superscript indicate significance.

Table 9
Mean values of platelets indices in blood samples of animals exposed to metal welding fumes for 12 weeks.

Test animal Groups	PLT ($10*3/\mu L$)	MPV (fL)	PCT (%)	P-LCC ($10*9/\mu L$)
IIIA	279.58 ± 21.2	8.73 ± 1.6[ab]	0.18 ± 0.001	52.25 ± 3.1
IIIB	269 ± 23	9.4 ± 1.5[bc]	0.17 ± 0.001	39 ± 2.7
IIIC	273.5 ± 19.4	9.1 ± 1.8	0.15 ± 0.002	57 ± 3.0
IIID	291 ± 19.8	8.83 ± 1.4[cd]	0.15 ± 0.002	52 ± 2.80
Control	255.8 ± 20.02	9.9 ± 2.0[ad]	0.09 ± 0.001	36 ± 2.17
P value	> 0.05	< 0.05	> 0.05	> 0.05

p < 0.05: there is significant difference.
p > 0.05: there is no significant difference.
Means ± SD values with same letters as superscript indicate significance.

groups (p < 0.05).

The mean values of RBC for groups IIIA, IIIB, IIIC and IIID range from 4.45 to $5.13 \times 10^6/\mu L$ as shown in Table 6. Group IIIA has the least mean value of $4.45 \times 10^6/\mu L$ while group IIIB has the highest mean value of $5.13 \times 10^6/\mu L$. The mean values of the groups have exceeded the control value of $4.03 \times 10^6/\mu L$. There is significant difference statistically between the groups (p < 0.05). Thus, implying that the levels of RBCs have increased relatively over the groups as the dosage increase. However, Paula Kauppi et al. [23], reported that hemoglobin levels and number of erythrocytes decreased significantly after both the Mild steel and Stainless Steel welding exposure tests. Taken together, the peripheral blood findings (the increased level of blood leukocytes, neutrophils, and platelets, and the decreased level of hemoglobin and erythrocytes) are in line with the suggestion that a mild systemic inflammatory response takes place during welding exposure [24,36,37]. Similarly, blood cell counts were within normal limits for 20 arc welders exposed to zinc oxide fumes while working on galvanized metals in confined shipyard tasks and having an average of 6.6 years of welding experience, according to Chmielewski et al., [38]. Dreessen et al. [39], sampled blood from arc welders in steel ship construction in 7 United States shipyards. The authors also reported that 7.5% of all female welders and 3.8% of female nonwelders had lower red blood cell counts than expected, although the difference was not statistically significant. Bataille [40], reported a case of hemorrhagic manifestations in a 35-year-old male welder exposed to copper fume (levels not reported). Purpura and stomach hemorrhages, as well as fever, headache, lower back pain, and weakness occurred. Erythrocytosis, leukocytosis, and a reduction in platelet count were revealed. In another study, Ateeq et al. [41], studied the effects of hexavalent chromium on haematological parameters in chrome plating workers and found out that White blood cells (WBCs), red blood cells (RBCs) and haemoglobin (Hb) were significantly (p < 0.001) lower in exposed groups I and II than control. The decrease in RBCs and WBCs levels in chrome plating workers may be due to the chromium induced erythrocyte damage or reduction in red cell glutathione leading to increase free radical which causes cell death [42,43]. It has been reported that reduction in hemoglobin level might be due to the effect of toxic pollutants on hematopoietic system which may cause an anemic condition in human [44]. It has been documented that low WBC count has been associated with severe neutropenia [45].

The mean value of Haemoglobin (HGB) for groups IA, IB, IC & ID range from 11.78 to 13.9 g/dL as shown in Table 4. Group ID has the least mean value of 11.78 g/dL. Meanwhile, group IC has the highest mean value of 13.9 g/dL. The mean values of all groups have exceeded the control value of 11.7 g/dL. The mean value have decreased progressively across the groups from IA, IB & ID. There is no significant difference statistically between the groups (P > 0.05).

The mean values of HGB for groups IIA, IIB, IIC & IID ranges from 10.8 to 15.63 g/dL as shown in Table 5. Group IIA has the least mean value of 10.8 g/dL while group IID has the highest mean value of

15.63 g/dL. The mean values for groups IIB, IIC, & IID have all exceeded the control value of 11.7 g/dL. However, the mean value of IIA is less than the control value. There is significant difference statistically between the groups (P < 0.05).

The mean values of HGB for groups IIIA, IIIB, IIIC & IIID range from 12.4 to 15.63 g/dL as shown in Table 6. Group IIB has the least mean value of 12.4 g/dL while group III has the highest mean value of 15.63 g/dL. The mean values of all groups have exceeded the control value of 12.35 g/dL. There is no significant difference statistically between the groups (P > 0.05). The results of the present study is in line with Schuler et al. [62] who found no anemia or serum hemoglobin levels below 12.5 g/100 ml blood in examinations of 23 arc welders from various industries in Santiago, Chile. This indicates that welding fumes can affect haemoglobin levels because in another study Lead been a component of welding fumes also interferes with hemoglobin synthesis, which may result in anemia [46]. The hemoglobin values in 0.50 and 1.25 mg/m^3 exposure groups were significantly decreased compared with those of the control group [47].

Vinodhini & Narayanan [48] determined the effects of heavy metal pollutants such as cadmium, chromium, nickel and lead in aquatic system on common carp (*Cyprinus carpio* L.) and found out that hemoglobin were in the range of 55.30 ± 1.20 g/L to 74.55 ± 1.33 g/L (p < 0.001) and the packed cell volume was in the range of 26.72 ± 0.26% to 30.68 ± 0.43% (p < 0.01). Concentrations of red blood cells, blood glucose and total cholesterol were significantly elevated. This was in line with the present study. Though, the elevation in the present study was progressive as their levels have exceeded the control values.

However, Mitchell et al. [49], studied effects of tungsten-iron and tungsten-polymer shot on various hematologic parameters and metal residue concentrations in the femur, liver, kidneys, and gonads. They found Lead-dosed mallards had significantly decreased hematocrit, hemoglobin concentration, and whole-blood delta aminolevulinic acid dehydratase activity on day 7, as well as significant changes in a number of plasma chemistry parameters compared to ducks in the control, tungsten-iron, or tungsten-polymer groups. Mallards dosed with tungsten-iron or tungsten-polymer shot had occasional significant differences in hematocrit and plasma chemistry values when compared to control mallards over the 150 day period.

Normal hemograms were reported for 402 arc welders with 5 or more years of experience, according to Marchand et al., [50].

Seaton et al. [51], observed a decrease in circulating red blood cells count (RBCs) and hemoglobin concentration (Hb) have been observed to correlate with particulate exposure in humans which is against the result of the present study. Similarly, Savage et al. [52], mentioning decreased (RBCs) and platelet counts (PLTs) and hemoglobin concentration (Hb) after concentrated ambient particles exposure.

Dreessen et al. [39], sampled blood from arc welders in steel ship construction in 7 United States shipyards and revealed that hemoglobin content was no different for welders and non-welders; non-whites had consistently lower levels than whites, regardless of occupation. Female galvanized metal welders were found to be more anemic than females welding on non-zinc-coated metals; the difference was not evident in males. Inhalation of welding fumes was stated to have caused mild blood dyscrasias in 10 young workers employed in confined arc welding for several years, according to Meneghini and D'Orofrio, [53]. Challen [54], stated that chronic over exposure to fluorides can bring on a syndrome called fluorosis, characterized by anemia, thyroid or digestive tract disorders, or hardening of the bones and ligaments. Lead poisoning, which has been documented in shipyard lead burners and welders exposed to toxic levels of lead fumes, is sometimes detected in blood smears. Basophilic stippling of red blood cells was considered suggestive of lead intoxication but not specific, according to Rieke, [55].

The mean value of Hematocrit (HCT) for groups IA, IB, IC & ID range from 33 to 41.13% as shown in Table 4. Group ID has the least

mean value of 33% while group IA has the highest mean value of 41.13%. The mean value of groups IA, IB & IC have exceeded the control value of 35%.However, the mean value of group IC has exceeded the control value. There is no significant difference statistically between the groups (P > 0.05). The value decreases progressively from groups IA, IB & ID. Similarly, subchronic inhalation toxicity of soluble hexavalent chromium trioxide in rats showed the reduction of the number of red blood cell (RBCs) and hematocrit (HCT) values in the 1.25-mg/m^3 exposure group.

The mean value of HCT for groups IIA, IIB, IIC & IID range from 30.68 to 45.03% as shown in Table 5, Group IIA has the least mean value of 30.68% while group IID has the highest mean value of 45.03%. The mean values increases progressively across the groups from IIA to IIB and IID. Values for groups IIB, IIC and IID have exceeded the control value of 35%. However, the mean values for IIA are below the control value. There is significant difference statistically between groups (P < 0.05).

The mean values of HCT for groups IIIA, IIIB, IIIC, & IIID range from 37 to 45.03% as shown in Table 6. Group IIB has the least mean value of 37% while group IIC has the highest mean value of 45.03%. The mean values of all groups have exceeded the control value of 35%. There is no significant difference statistically between the groups (P > 0.05). Seaton et al. [51], observed a decrease in hematocrit (HCT) and have been correlated with particulate exposure in humans in contrast the result of the present study. Tumor necrosis factor alpha (TNF-α) was a key mediator, playing a large role in the initial response of metal fume fever [56]. Recently, some authors mentioned that tumor necrosis factor alpha (TNF- α) have an inhibitory effect on erythropoiesis [57,58]. Savage et al. [52], mentioning decreased hematocrit (HCT) after concentrated ambient particles exposure. In another study by Ranja and Peyush [61], they evaluated the haematological and biochemical changes resulting from the exposure of a common carp *Cyprinus carpio* to sublethal concentrations (0.05 mg/l) of zinc in water for a period of 10, 20 and 30 days. They found out that the derived haematological indices of sublethal concentrations (0.05 mg/l) of zinc caused a dose dependent decrease in haemoglobin values, coupled with a decrease in HCT values and RBC counts are which indication of anemia of the normal chronic type. Similarly, Firash and Ahmed [59] conduct a study to test whether exposure to welding fume by inhalation of fine and ultra fine particles and different compositions of the electrical welding processes would produce physiological disorders for the blood parameters of exposed rat's animal. They reported that a significant decrease were observed after four weeks of wielding fume inhalation in the hemoglobin (Hb) concentration, RBCs count and packed cell volume (PCV).

The mean value of Mean corpuscular volume (MCV) for groups IA, IB, IC & ID range from 84.75 to 90.6Fl as shown in Table 4. Group IC has the least mean value of 84.75 fL while group IA has the highest mean value of 90.6 fL. The mean values progressively decreases from group IA to IB and IC. Mean values for groups IA, IB & ID have exceeded the control mean value of 87.7 fL. However, group IC has mean value less than the control value. There is significant difference statistically between the groups (P < 0.05).

The mean value of MCV for groups IIA, IIB, IIC & IID range from 88.18 to 93.1 fL as shown in Table 5. Group IIB has least mean value of 88.18 fL while group IIC has the highest mean value of 93.1 fL. Mean values for all groups have exceeded the control value of 87.7 fL. There is no significant difference statistically between the groups (P > 0.05).

The mean value of MCV for groups IIIA, IIIB, IIIC & IIID ranges from 88.75 to 94.23 fL as shown in Table 6. Group IIID has the least mean value of 88.75 fL while group IIIB has the highest mean value of 94.23 fL. The mean values of all groups have exceeded the control value of 87.7 fL. The values decrease progressively from groups IIIA to IIIC & IIID. There is no significant difference statistically between the groups (P > 0.05).

The mean value of Mean corpuscular haemoglobin (MCH) for groups IA, IB, IC & ID range from 28.18 to 34.65 pg as shown in Table 4. Group ID has the least mean value of 28.18 pg, while group IA has the highest mean value of 34.65 pg. The mean values for all groups have exceeded the control mean value of 22.8 pg. There is no significant difference statistically between the groups (P > 0.05).

The Mean value of MCH for groups IIA, IIB, IIC & IID range from 28.53 to 32.93 pg as shown in Table 5. Group IIC has the last mean value of 28.53 pg while IIA has the highest mean value of 32.93 pg. The mean value of all groups have exceeded the control mean value of 22.8 pg. There is no significant difference statistically between the groups (P > 0.05).

The mean value of MCH for groups IIIA, IIIB, IIIC & IIID range from 29.03 to 30.95 pg as shown in Table 6. Group IIC has the least mean value of 29.03 pg while IIA has the highest mean value of 30.95 pg. The mean values of all groups have exceeded the control mean value of 22.8 pg. There is no significant difference statistically between the groups (P > 0.05).

The mean values of Mean corpuscular haemoglobin concentration (MCHC) for groups IA, IB, IC and ID range from 31.85 to 37.25 g/dL as shown in Table 4. Group ID has the least mean value of 31.85 g/dL while group IB has the highest mean value of 37.25 g/dL. The mean value of groups IA & IB have exceeded the control mean value of 33.8 g/dL. However, the mean values of group IC & ID are below the control value. The mean values have decreased from group IA down to IC & ID. There is no significant difference statistically between the groups (P > 0.05).

The mean values of MCHC for groups IIA, IIB, IIC & IID range from 33.97 to 35.63 g/dL as shown in Table 5. Group IIC have the least mean value of 33.97 g/dl while group IIA has the highest mean value of 35.63 g/dl. The mean values of all groups have exceeded the control mean value of 33.8 g/dL. There is no significant difference statistically between the groups (P > 0.05).

The mean values of MCHC for groups IIIA, IIIB, IIIC, & IIID range from 32.85 to 35.63 g/dL as shown in Table 6. Group IIID has the least mean value of 32.85 g/dL while group IIIC has the highest mean value of 35.63 g/dL. The mean values of groups IIIA, IIIB, and IIID have not exceeded the control value of 35.4 g/dL. However, the mean value of group IIIC has exceeded the control value. There is no significant difference statistically between the groups (P > 0.05).

Firash and Ahmed [59] conduct a study to test whether exposure to welding fume by inhalation of fine and ultra fine particles and different compositions of the electrical welding processes would produce physiological disorders for the blood parameters of exposed rat's animal. They reported that a significant decrease were observed after four weeks of wielding fume inhalation in the mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), red distribution width (RDW), mean corpuscular hemoglobin concentration (MCHC).

Ateeq et al., (2016A) studied the effects of hexavalent chromium on haematological parameters in chrome plating workers and found out that mean corpuscular hemoglobin (MCH) and packed cell volume (PCV) were significantly (p < 0.001) lower in exposed groups I and II than control. Microcytic and hypochromic anemia has been observed by a decrease in concentration in MCH, hemoglobin and RBC count (Ateeq et al., 2016C).

The mean value of Platelets (PLT) for groups IA, IB, IC & ID ranges 219.5 to 275 × 10^3/μL as shown in Table 7. Group IC has the least mean value of 279.5 × 10^3/μL, while group IB has the highest mean value of 275 × 10^3/μL.The mean value of group ID has exceeded the control value of 255.8 × 10^3/μL. However, the mean values of other groups are less than the control value. There is no significant difference statistically between the groups (P > 0.05).

The mean value of PLT for groups IIA, IIB, IIC & IID range from 225.5 to 285.75 × 10^3/μL as shown in Table 8. Group IIB has the least mean value of 225.5 × 10^3/μL.while group IIA has the highest mean value of 285.75 × 10^3/μL. The mean values of groups IIA, IIC & IID have exceeded the mean value of 255.8 × 10^3/μL. However, the mean

value of group IIB is less than the control group. There is no significant difference statistically the groups (P > 0.05).

The mean value of PLT for groups IIIA, IIIB, IIIC & IIID range from 269 to $291 \times 10^3/\mu$L as shown in Table 9. Group IIIB has the least mean value of $269 \times 10^3/\mu$L, while group IIID has the highest mean value of $291 \times 10^3/\mu$L. The mean values of all groups have exceeded the control value of $255.8 \times 10^3/\mu$L. There is no significant differences statistically between the groups (P > 0.05). Thus, the values have progressively increased by revealing increase over the control in the higher dose groups. Similarly, Paula Kauppi et al. [23], reported that platelets increased significantly after mild steel and stainless steel welding challenge tests. However, Hartmann et al. [37,60] contradicted this findings. Also, Savage et al. [52], mentioned that there was a decreased platelet count (PLTs) after concentrated ambient particles exposure. This is same to the result of PLTs from least dosage groups (IA, IB, & IC). In addition, Firash and Ahmed [59] reported a significant decrease were observed after four weeks of wielding fume inhalation in the Platelete counts (PLTs) and platelete large cell ratio (PLCR). Bataille, (1946) reported Erythrocytosis, leukocytosis, and a reduction in platelet count were revealed.

The mean values of Mean platelets volume (MPV) for groups IA, IB, IC & ID range from 8.45 to 9.03 fL as shown in Table 7. Group IC has the least mean value of 8.45 fL, while group IB has the highest mean value of 9.03 fL. The mean values of all groups are less than control value of 9.9 fL. There is no significant difference statistically between the groups (P > 0.05).

The mean values of MPV for groups IIA, IIB, IIC & IID range from 8.65 to 9.37 fL as shown in Table 8. Group IIB has the least mean value of 8.65 fL while group IIC has the highest mean value of 9.37 fL. The mean values of all groups have not exceeded the control mean value of 9.9 fL. There is no significant difference statistically between the groups (P > 0.05).

The mean value of MPV for groups IIIA, IIIB, IIIC & IIID range from 8.73 to 9.4 fL as shown in Table 9. Group IIIA has the least mean value of 8.73 fL while group IIIB has highest mean value of 9.4 fL. The mean values of all groups have not exceeded the control value of 9.9 fL. There is significant difference statistically between the groups (P < 0.05).

The mean value of Plateletcrit (PCT) for groups IA, IB, IC & ID range from 0.12 to 0.18% as shown in Table 7. Group IA has the least mean value of 0.12% while group IB has the highest mean value. The mean values of all groups have exceeded the mean value of control which is 0.09%. There is no significant difference statistically between the groups (P > 0.05).

The mean value of PCT for groups IIA, IIB, IIC & IID range from 0.151 to 0.16% as shown in Table 8. Group IIA has the least mean value of 0.151%, while group 110 has the highest mean value of 0.16%. The mean values of all groups have exceeded the mean value of control which is 0.09%. There is no significant difference statistically between the groups (P > 0.05).

The mean value of PCT for groups IIIA, IIIB, IIIC & IIID range from 0.15 to 0.18% as shown in Table 9. Group IID has the least mean value of 0.15%, while group IIIA has the highest mean value of 0.18%. The mean values of all groups have exceeded the mean value of the control which is 0.09%. There is no significant difference statistically between the groups (P > 0.05).

The mean value of Platelet large cell count (P-LCC) for groups IA, IB IC & ID range from 35.245 to $57.75 \times 10^3/\mu$L as shown in Table 7. Group ID has the least mean value of $35.25 \times 10^3/\mu$L. while group IA has the highest mean value of $51.75 \times 10^3/\mu$L. The mean values of groups IA, IB & IC have exceeded the control value of $36 \times 10^3/\mu$L. However, the mean value of group ID is less than the control value. There is no significant difference statistically between the groups (P > 0.05).

The mean value of P-LCC for groups IIA, IIB, IIC & IID range from 39 to $57 \times 10^3/\mu$L as shown in Table 8. Group IIC has the least mean value of $38 \times 10^3/\mu$L, while group IID has the highest mean value of

$57 \times 10^3/\mu$L. The mean values of all groups have exceeded the control mean value of $36 \times 10^3/\mu$L. There is no significant difference statistically between the groups (P > 0.05).

The mean value of P-LCC for groups IIA, IIB, IIIC & IID range from 39 to $57 \times 10^3/\mu$L as shown in Table 9. Group IIC has the least mean value of $39 \times 10^3/\mu$L, while group IIC has the highest mean value of $57 \times 10^3/\mu$L. The mean values of all groups have exceeded the control mean value of $36 \times 10^3/\mu$L. There is no significant difference statistically between the groups (P > 0.05).

5. Conclusion

Haematological parameters have experienced changes in values whereby RBC, WBC, % lymphocytes, HGB, HCT, MCV, MCH, PLT, PCT and P-LCC have exceeds the control groups values with increase that was noticed across the treatment groups. However, lymphocytes, MID, granulocytes, % granulocytes, MCHC and MPV values were less than the control and no different statistically. This indicates that exposure to welding fumes could cause alterations to most RBC, WBC and PLT indices majorly by effecting an increase. Further studies should be carried out to explore the complete toxicological impact of welding fumes and proper actions that needs to be taken by relevant authorities.

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