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# HEMATOLOGICAL CHANGES ASSOCIATED WITH SOLDER PASTE FUME INHALATION IN WISTAR RATS

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## ABSTRACT

Solder paste is widely used by handset repairers who do not use any protective equipment in most developing countries and are exposed daily to the solder paste fumes. The study was conducted to determine the effect of inhalation of solder paste fume on hematological and serum biochemical parameters (Blood Urea Nitrogen and Total Protein) in Wistar rats. A total of forty (40) Wistar rats grouped into experimental and control groups were used. Each rat was exposed to 0.18g of solder paste fume per exposure twice daily (morning and evening) for seven (7) minutes over the period of eight weeks. Blood samples were collected biweekly. The result revealed a statistically significant decrease in Mean Corpuscular Volume (MCV) of the exposed group (63.12 ± 0.56) compared to the control group (65.36 ± 0.53), there was also a significant decrease in total leucocytes count (WBC) (6.01 ± 0.65) in the exposed group compared to the control group (8.56 ± 0.75). However, a significant increase in Mean Corpuscular Hemoglobin (MCH) (22.09 ± 1.4) was observed in the exposed group compared to the control (21.75 ± 0.26). It is concluded that inhalation of solder paste fume have an effect on the hematological profile of Wistar rats.

**Keywords**: Solder paste, Handset repairers, Hematology, Wistar rats

## INTRODUCTION

The widespread ownership and use of mobile phones coupled with the global economic challenges which has more devastating effect on developing countries has created a need for professionals who can repair and service mobile phones. Solder paste is a critical material used in the electronics industry for soldering electronic components onto printed circuit boards (PCB) (Keating et al., 2012). Solder paste is used in the manufacture of printed circuit boards to connect surface mount components to pads on the board (Hirman and Steiner, 2017). Solder paste is primarily used in surface mount technology (SMT) processes, which involve soldering components with small lead spacing onto PCBs. SMT soldering offers several advantages, including higher component density, reduced board size, and improved electrical performance (Tummala et al., 1997). Solder paste is applied to PCBs using stencil printing techniques or dispensing methods, followed by reflow soldering to melt the solder and create the desired connections (Lanin et al., 2024).The solder paste printing process can be divided into three types: printing, dispensing, and jetting, which is the most recently developed process (Becker et al., 2014).

Soldering is a group of joining processes that produce a joining of materials by using a soldering iron or gum and filler metal (solder) with a temperature not exceeding 840°F (450°C) (Li et al., 2008). With the development of surface mount technology (SMT), solder paste becomes the major electronics interconnect materials (Zhang et al., 2019). Solders and soldering processes are used extensively in the electronics industry to physically hold assemblies together (Ismail et al., 2024). Solder paste is one of the important materials used in printed circuit board (PCB) assembly and it is produced by mixing (approximately 90 per cent by weight) a metal alloy powder with a flux approximately 10 per cent by weight (Cheng et al., 2024). Metal powder, usually in the form of solder alloy particles, makes up the remaining portion of solder paste composition (Darveaux, 2000). Common solder alloys used in electronics soldering include eutectic tin-lead (Sn-Pb) and lead-free alternatives such as tin-silver-copper (Sn-Ag-Cu) and tin-silver (Sn-Ag) alloys (Darveaux, 2000).

Toxic fumes generated during soldering process contain various contaminants released at sufficient rates to cause both short- and long-term health problems (Arab *et al*., 2011). Approximately one million workers worldwide perform welding as part of their work duties (Antonio *et al*., 2004). Fumes generated during metal welding have toxic effects on the human body, these fumes cover a wide spectrum from formaldehyde to metal fumes such as lead (Pb) and Stanum (Sn) (Arab et al., 2011). Epidemiological studies have indicated that these gases and fumes can seriously endanger the health of workers (Borska *et al*., 2012). The potential of colophony to cause respiratory diseases has been reported since the 1970s. However, studies among electronics workers involved in soldering have yielded inconsistent results (Lawton et al., 1985). The risk of developing occupational asthma symptoms to be significantly higher in electronics workers exposed to soldering in comparison to those not exposed to (Palmer and Crane, 1997). The International Agency for Research on Cancer (IGRC) has concluded that welding fumes were possibly carcinogenic to humans, despite the fact that the finding was based on limited evidence in humans and inadequate evidence in laboratory animals (Palmer and Crane 1997). However, the toxic effect of solder paste fume has not been thoroughly evaluated in developing countries.

## MATERIALS AND METHODS

A total of forty (40) Wistar rats housed in a 3-step iron made cage purposely designed for practical were used for the study. The rats were grouped into two; the control group which consist of (12 rats) and experimental group consisting of (28 rats), commercial poultry feed (Topfeed®) and borehole water were provided ad libitum throughout the period of the experiment. The experiment group (28 rats) were exposed to 0.178g of solder paste fume per rat per exposure twice daily

(morning by 8:00am and evening by 5:00pm) for seven (7) minutes over a period of eight weeks. The solder paste was heated on a metal plate to produce the fume. A combination of Ketamine (40mg/kg) and Xylazine (5 mg/kg) was used to sedate the rats and blood sample (5ml) was collected through cardiac puncture biweekly by randomly selecting three (3) rats from the control group and seven (7) rats from the experimental group, (3ml) of the blood sample was dispensed in a container containing Ethylenediamine tetra acetic acid (EDTA) while (2ml) was dispensed in plain sample bottles and were used for hematological and serum biochemical analysis respectively.

Hematological parameters including WBC (using hemocytometer), RBC counts, differential leukocyte counts and Wintrobe indices were determined using methods described by Wintrobe (1981), Schalm et al. (1975) and Coles (1974). Blood Urea Nitrogen and total Protein were determined spectrophotometrically using UNICO 1201 spectrophotometer (United Products and Instruments, New Jersey, United state) at 340nm and 280nm respectively.

**Data Analysis**

Data generated was analyzed using Statistical package for the social sciences version 20.0 (SPSS Inc.) comparison between the exposed and control groups was conducted using Independent Samples T- test while comparison between the weeks within the exposed group was conducted using multiple analysis of variance (MANOVA)and (Tukey') Post Hoc Tests. Data are expressed as mean, and standard error. ($P< 0.05$) was considered significant.

## RESULTS AND DISCUSSION

### Results

Hematological parameters and their comparative analysis between the control and the exposed group is presented in Table 1. The result revealed a statistically significant decrease in Mean Corpuscular Volume (MCV) of the exposed group (63.12 ± 0.56) compared to the control group (65.36 ± 0.53), there was also a significant decrease in total leucocytes count (WBC) (6.01 ± 0.65) in the exposed group compared to the control group (8.56 ± 0.75). However, a significant increase in Mean Corpuscular Hemoglobin (MCH) (22.09 ± 1.4) was observed in the exposed group compared to the control (21.75 ± 0.26)

**Table 1: Comparison of Mean and SE of hematological parameters of the control and exposed groups**

| Parameters | Control | Treatment |
|---|---|---|
| PCV (%) | 38.42±0.93 | 40.357±1.07 |
| HB (g/dl) | 12.77±0.25 | 13.275±0.39 |
| RBC (x106cells/mm3) | 5.89±0.19 | 6.4307±0.21 |
| MCV (fl) | 65.35±0.53[a] | 63.128±0.57[a] |
| MCH (pg) | 21.75±0.67[a] | 22.097±1.39[a] |
| MCHC (g/dl) | 33.28±0.25 | 32.922±0.26 |
| WBC (x103/mm3) | 8.56±0.75[a] | 6.0161±0.57[a] |
| NEU (%) | 24.58±2.14 | 23.857±2.07 |
| LYM (%) | 74.42±2.61 | 72.75±2.13 |
| MON (%) | 1.58±0.31 | 2.0714±0.21 |
| EOS (%) | 1.17±0.24 | 1.1429±0.17 |
| BAS (%) | 0±0.0 | 0.0714±0.05 |
| BAND (%) | 0±0.0 | 0.0714±0.05 |

Means with the same superscript along the raw differ significantly ($P< 0.05$).

Biweekly comparison within the exposed group is presented in Table 2. The result revealed an insignificant decrease in PCV in week 4 compared to week 2 and a significant increase in week 6 compared to week 4. However, there was a significant decrease in the PCV level in week 8 compared to week 6. Similarly, a Non-significant difference in RBC in week 4 compared to week 2 and a nonsignificant increase in week 6 compared to week 4 was also recorded. However, a significant decrease between week 8 and 6 was observed. The result showed a significant decrease in MCH in weeks 4, 6 and 8 compared to week 2. A statistically significant decrease in MCHC was also recorded in week 6 compared to 2. The results of the WBC comparison revealed an insignificant increase in week 4 compared to 2 and a significant increase in weeks 6 and 8 compared to 2. However, a significant decrease was recorded in week 8 compared to 6. There was also a nonsignificant rise in monocyte count in weeks 4 and 6 compared to 2. However, a significant decrease in week 8 compared to week 6 was recorded.

**Table 2: Biweekly comparison of hematological parameters within the exposed group**

| Parameters | Week 2 | Week 4 | Week 6 | Week 8 |
|---|---|---|---|---|
| PCV (%) | 41.5 ± 1.7 | 37.9 ± 0.74[a] | 43.4 ± 1.33[ab] | 36.3 ± 1.61[b] |
| HB (g/dl) | 14.01 ± 0.58 | 12.59 ± 0.2 | 14.17 ± 0.45 | 11.7 ± 0.61 |
| RBC (x106cells/mm3) | 6.67 ± 0.38 | 5.80 ± 0.15 | 6.95 ± 0.32[a] | 5.65 ± 0.22[a] |
| MCV (fl) | 62.74 ± 1.09 | 65.47 ± 0.45 | 62.82 ± 1.04 | 64.17 ± 0.8 |
| MCH (pg) | 34.5 ± 7.0[abc] | 25.64 ± 3.73[a] | 20.5 ± 0.32[b] | 20.55 ± 0.52[c] |
| MCHC (g/dl) | 33.8 ± 0.12[a] | 33.6 ± 0.36 | 32.64 ± 0.16[a] | 31.99 ± 0.51 |
| WBC (x103/mm3) | 4.24 ± 0.62[ab] | 6.4 ± 1.04 | 9.32 ± 0.95[ac] | 7.14 ± 0.56[bc] |
| NEU (%) | 23.7 ± 2.83 | 33.4 ± 3.11 | 20.0 ± 2.1 | 20.4 ± 2.8 |
| LYM (%) | 72.6 ± 2.8 | 63.1 ± 3.14 | 77.0 ± 2.17 | 77.9 ± 3.0 |
| MON (%) | 2.0 ± 0.26 | 2.1 ± 0.41 | 2.3 ± 0.37[a] | 1.2 ± 0.4[a] |

| | | | | |
|---|---|---|---|---|
| EOS (%) | 1.7 ± 0.21 | 1.2 ± 0.29 | 0.9 ± 0.23 | 0.8 ± 0.3 |
| BAS (%) | 0.0 ± 0.0 | 0.1 ± 0.1 | 0.1 ± 0.0 | 0.0 ± 0.1 |
| BAND (%) | 0.0 ± 0.0 | 0.1 ± 0.1 | 0.0 ± 0.0 | 0.1 ± 0.1 |

Means with the same superscript along the same row differ significantly (P< 0.05)

The result of the comparison of Total Protein and Blood Urea Nitrogen (BUN) level between the treated and control groups were presented in Table 3. The result revealed a decrease in the total protein and an increase in BUN in the treated group compared to the control. However, these changes were not statistically significant

**Table 3: Total Protein and Blood Urea Nitrogen (BUN) concentration of control and exposed groups**

| Parameter | Control | Treated |
|---|---|---|
| Total protein (g/dL) | 6.72 ± 0.345 | 6.35 ± 0.192 |
| BUN (g/dL) | 54.66 ± 8.9 | 55.75 ± 6.05 |

## Discussion

Throughout the past few decades, there has been a significant increase in the production, use, and maintenance of electronic devices, particularly cell phones. Exposure to the vapors produced during soldering and electrical assembly is one of the main health risks associated with the manufacturing and maintenance operations. Exposure to rosin-core solder flux fumes has been linked to respiratory irritation, which includes coughing, wheezing, and clogged noses, among other symptoms. This has also led to the prevalence of occupational asthma among workers who have been exposed to the fumes (Cullinan et al., 2017). According to La, duo (2006), the fumes produced by the fluxes used in solders are recognized as respiratory sensitizers that have the potential to cause conjunctivitis, rhinitis, and respiratory asthma.

The increase in PCV and decrease in HB in the first weeks of the experiment was due to the fact that inhalation of Solder pastes fume increases the risk of respiratory problems causing dyspnea resulting in low oxygen transport capacity of the red blood cells leading to a significant decrease in Hemoglobin (HB) and an increase in circulating RBC to compensate for oxygen transport. thereby increasing PCV. However, continuous exposure to the fume resulted in variable decrease and increases at different weeks of the experiment. The low values of the parameters could probably be attributed to anemia due to the inflammatory effects of the fume that leads to increased production and release of hepacidin by the Liver, Hepacidin binds to the ferroportin receptor, which reduces the amount of iron released from the liver and macrophages, intestinal absorption, and overall iron availability for erythropoiesis. This conforms with the finding of Kunireddy (2018). The decrease in RBC, MCHC could also be attributed to the effect of inflammatory cytokines that increase RBC destruction and also suppress erythropoiesis by inhibiting the release of erythropoietin. This supports the findings of Camacho et al. (2021).

According to Kender et al. (1966), leukopenia is defined as an absolute decrease in circulating white blood cells below the lower bound of normal values, which includes neutrophils, monocytes, and lymphocytes. This state could be brought on by higher WBC use, destruction, or decreased effective WBC generation. Decreased myeloid proliferation in the marrow or inefficient granulocytopoiesis may be linked to decreased mature neutrophil delivery from the bone marrow (Kender et al., 1966). Accelerated immigration into the tissue in reaction to infection or inflammation is the main cause of an excessive loss of neutrophils from the peripheral circulation (Finch, 1977). The significant increase in WBC could be attributed to the mobilization of polymorphonuclear cells following inhalation of fume which irritates the respiratory system triggering a systemic inflammatory reaction. However, the decrease in WBC at the last phase of the experiment could be associated with the damage to alveolar cells resulting in oxidation of amino acids and lipid peroxidation of cell membrane protein and lipid which lead to emigration of monocytes to increase the number of macrophages and clear the dead tissues. This conforms with the findings of Li and Taneepanichskul (2021).

## CONCLUSION

It is concluded that our studies has shown that inhalation of solder paste fume have an effect on the hematological profile of Wistar rats.

## RECOMMENDATIONS

There is the need to sensitize GSM repairers to the risk associated with solder paste fume inhalation. Manufacturer and repairers of electronic devices should substitute Tin-lead solder pastes with less hazardous lead-free solder pastes to mitigate the undesirable effects. Personal protective equipment is required and should be supplemented with other preventive actions.

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