AMELIORATION OF LEAD TOXICITY IN AN OCCUPATIONALLY EXPOSED POPULATION WITH ASCORBIC ACID


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Abstract
This study was designed to investigate the ameliorative effects of vitamin C in lead toxicity. Occupationally exposed workforce - artisans from mechanic village, motor park, polyurethane factory as well as students from GTC and university staff (serving as control) in Abeokuta Nigeria participated in the study. The subjects were given 400mg vitamin C supplement daily for a period of 2 weeks. Blood samples were collected from the subjects before and after the 2 weeks of vitamin C treatment. Blood lead and biochemical attendants of lead toxicity were determined. 2-week administration of ascorbic acid resulted in significant reduction in blood lead of the occupationally exposed subjects (p<0.001). A 51% reduction was evident among the polyurethane factory workers, 33% in the mechanic village subjects, 13% in the motor park and 28% in the control group. Observation showed a positive response of the biochemical attendants of lead toxicity to the ascorbic acid supplementation. Concentration of reduced glutathione (GSH) which was lowered as a result of lead toxicity increased on administering ascorbic acid. The ascorbic acid regime also significantly (p<0.001) reduced the elevated level of plasma aminolevulinic acid (ALA) in occupationally exposed subjects. These results indicate the effectiveness of ascorbic acid in treating lead induced toxic manifestations particularly where subjects cannot be removed from the source of lead exposure.

Key Words: Lead, Blood, Biomarkers, Artisans, Ascorbic acid, Nigeria.

Introduction
Environmental pollution by heavy metals is of great public health interest [1 - 2]. These metals are taken into the body in small amounts through food (contaminated plants and animals), air and water, but bioaccumulate over a period of time resulting in various biochemical changes [3]. Some heavy metals have nutritional value when the recommended daily dietary intakes are not exceeded, but become harmful when excessively taken resulting in poisoning or toxicity. However, some heavy metals like Arsenic, Lead, Cadmium and Mercury (As, Pb, Cd, Hg) are not known to have any nutritional value in human beings and consumption of such, even at low doses could be toxic [4]. If such toxicity is not recognized early enough and treated appropriately, it can result in significant illness and reduced quality of life. Lead is one of the most commonly used metals. It is a potent occupational toxin with well documented toxicological manifestations [5]. Lead produces a wide range of hematological, hepatic, renal, neurobehavioural, reproductive, cardiovascular and immunological effects in humans and animals [2, 6-10]. Even though several mechanisms have been proposed to explain the toxic effects of lead, the exact mechanism is yet to be fully understood. Studies have revealed the hematotoxic effects of lead and reports have also shown that lead exposure can promote brain dysfunction which may manifest as behavioural changes in humans and animals [8, 10-11]. Furthermore, lead causes oxidative stress by the generation of reactive oxygen species, reducing the antioxidant defense system of cells via reduction of glutathione, inhibiting sulphhydryl-dependent enzymes, interfering with some essential metals needed for anti oxidant enzyme activities and /or increasing susceptibility of cells to oxidative attack [6, 12-13]. The protective role of antioxidant against toxicity or poisoning has been extensively studied; Vitamin C [2, 11, 13-14], Vitamin E [15] and silymarin supplements [14] have been reported to protect against damages resulting from xenobiotics and metals. In the present study, lead levels in blood of artisans in Abeokuta, South Western Nigeria who are occupationally exposed to lead were determined and related to the levels of ALA, GSH and cholesterol (biochemical parameters). The ability of ascorbic acid (vitamin C), an antioxidant vitamin to ameliorate the effects of lead on the aforementioned biochemical parameters was put to test.

Materials and Methods
Study population included artisans in a mechanic village located at Kobape, Abeokuta, poly urethane factory workers at Abeokuta Commercial Industrial Company, Asero, Abeokuta, commercial drivers from Asero Motor
Park, students of Government Technical College (GTC), Idi-Aba and staff of the Federal University of Agriculture, Abeokuta (control group). Approval to carry out the study was obtained from the authorities of the Federal University of Agriculture, Abeokuta, Nigeria, ethical committee of the Neuro-Psychiatric Hospital, Aro, Abeokuta as well as the heads of the Mechanic village, factory and schools. A total of 272 subjects gave informed consent to take part in the study. These included 111 subjects from the mechanic village, 50 polyurethane factory workers, 20 commercial drivers, 55 students from the GTC and 36 subjects from the University of Agriculture, Abeokuta. Table I shows the study population.

Table 1: Study Population

<table>
<thead>
<tr>
<th>Subject</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNAAB Staff (Control)</td>
<td>36</td>
</tr>
<tr>
<td>Mechanics</td>
<td>111</td>
</tr>
<tr>
<td>Commercial Drivers</td>
<td>20</td>
</tr>
<tr>
<td>Government Technical College Students</td>
<td>55</td>
</tr>
<tr>
<td>Polyurethane workers</td>
<td>50</td>
</tr>
</tbody>
</table>

Blood pressure and pulse
Blood pressure and pulse were measured before blood collection. Measurements were taken twice with a space of 5 minutes apart on the left arm using a digital pressure monitor for each subject in a supine position.

Blood collection
Venous blood samples as well as data were collected from subjects between 8.00am and 10am after an overnight fast each working day. Blood samples were collected before and after 2 weeks of ascorbic acid supplementation. A 10 mL venous blood sample was collected from each subject by a trained Medical Laboratory Technologist into heparinised tubes. These were stored in a cooler box and transferred to the laboratory for analyses.

Biochemical assays and analysis

Determination of lead in blood
Aliquots of blood samples were separated for lead analysis. Lead level was determined by atomic absorption spectrophotometry [6]. The remaining blood samples were centrifuged to separate plasma and red blood cells.

Total cholesterol level
Plasma concentrations of total cholesterol was determined spectrophotometrically by the method of Allain [16] using commercial kits (Randox Laboratories, Crumlin, England).

Plasma Aminolevulinic acid
Aminolevulinic acid (ALA) was determined in the plasma by the method of Labbe and Lamon [17]. Absorbance of sample was read at 553nm using a Jenway 6405 UV/V spectrophotometer (Jenway Ltd., Dunst, Dunmow Essex, U.K).

Glutathione level
Glutathione in plasma was equally quantised by the colorimetric method described by Ellman [18].

Supplementation regime
Vitamin C was administered to all the subjects. A daily dose of 400 mg was administered for two weeks. Subjects were visited regularly during the two-week period of administration to ensure compliance with the supplementation protocol.

Statistical Protocol
Results are expressed as mean ±SD and level of significance was set at P<0.05. Significant differences among means were assessed by one way analysis of variance (ANOVA) followed by Tukey’s test.

Result and Discussion

Demographic and anthropometric characteristics of the subjects
The demographic and anthropometric characteristics of the subjects are shown in Table 2. Their ages ranged between 20 and 51 years. The systolic and diastolic blood pressure of subjects fall in the normotensive range (140 mmHg and 90 mmHg respectively [19].

The observation that the anthropometric indices of the study sample were essentially within normal limits is a confirmation that the subjects selected for the study were physically healthy. Similarly, considering the Body Mass Index (BMI), a measure of body fatness, the mean value of the total sample (22.13 ± 5.52) is within the normal limits of 18.5 – 24.9 kg/m² [20].

BMI in drivers was higher (23.66 ± 3.09) than in other groups. They also presented with highest mean blood pressure. Even though these anthropometric indices are still within normal limits, the fact that motor park workers who had the highest mean blood pressure also had the highest mean values of BMI calls for concern.

Significant positive correlation of anthropometric factors such as BMI with blood pressure has been reported by [21]. A similar positive correlation of BMI with both systolic and diastolic blood pressure was confirmed in the present study (r = 0.219, p < 0.001 and r = 0.234, p < 0.001 respectively).

This is of public health concern since the higher the BMI, the greater the risk of hypertension. In Nigeria, the most likely source of lead exposure is the use of leaded gasoline, therefore the exposure of motor park workers can predispose them to hypertension as low level of lead exposure can contribute to hypertension in both animals and humans [10].
Table 2: Demographic and anthropometric characteristics of the subjects at the various workplaces

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>FUNAAB</th>
<th>Polyurethane Factory</th>
<th>Motor Park</th>
<th>GTC</th>
<th>Mechanic Village</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=36</td>
<td>N=50</td>
<td>N=20</td>
<td>N=55</td>
<td>N=111</td>
<td>N=272</td>
</tr>
<tr>
<td>Mean Age (Yrs)</td>
<td>33 (9)</td>
<td>33 (11)</td>
<td>51 (11)</td>
<td>20 (3)</td>
<td>39 (10)</td>
<td>34 (13)</td>
</tr>
<tr>
<td>Mean Systolic BP (mmHg)</td>
<td>127 (19)</td>
<td>126 (17)</td>
<td>131 (27)</td>
<td>123 (12)</td>
<td>128 (19)</td>
<td>126 (18)</td>
</tr>
<tr>
<td>Mean Diastolic BP (mmHg)</td>
<td>75 (13)</td>
<td>76 (13)</td>
<td>83 (15)</td>
<td>65 (9)</td>
<td>75 (13)</td>
<td>73 (13)</td>
</tr>
<tr>
<td>Mean Pulse (min⁻¹)</td>
<td>70 (8)</td>
<td>74 (10)</td>
<td>75 (11)</td>
<td>74 (10)</td>
<td>73 (11)</td>
<td>73 (10)</td>
</tr>
<tr>
<td>Mean Height (m)</td>
<td>1.71 (0.07)</td>
<td>1.76 (0.15)</td>
<td>1.71 (0.10)</td>
<td>1.70 (0.08)</td>
<td>1.70 (0.08)</td>
<td>1.71 (0.10)</td>
</tr>
<tr>
<td>Mean Body Weight (kg)</td>
<td>63.50 (9.80)</td>
<td>64.54 (12.70)</td>
<td>69.18 (10.84)</td>
<td>59.92 (8.08)</td>
<td>66.56 (9.95)</td>
<td>64.59 (10.51)</td>
</tr>
<tr>
<td>Mean Waist Circumference (cm)</td>
<td>80.03 (8.40)</td>
<td>82.17 (9.45)</td>
<td>86.70 (10.33)</td>
<td>74.45 (5.37)</td>
<td>82.21 (8.64)</td>
<td>80.63 (8.99)</td>
</tr>
<tr>
<td>Mean Hip Circumference (cm)</td>
<td>93.53 (7.93)</td>
<td>93.27 (8.35)</td>
<td>96.62 (7.63)</td>
<td>84.65 (5.86)</td>
<td>95.27 (10.26)</td>
<td>92.56 (9.55)</td>
</tr>
<tr>
<td>Mean BMI* (kg/m²)</td>
<td>20.98 (4.85)</td>
<td>21.26 (6.96)</td>
<td>23.66 (3.09)</td>
<td>20.68 (2.50)</td>
<td>23.38 (6.18)</td>
<td>22.13 (5.52)</td>
</tr>
<tr>
<td>Mean Waist : Hip Ratio</td>
<td>0.86 (0.05)</td>
<td>0.88 (0.05)</td>
<td>0.90 (0.04)</td>
<td>0.88 (0.06)</td>
<td>0.86 (0.06)</td>
<td>0.87 (0.06)</td>
</tr>
</tbody>
</table>

Values are mean. Values in parenthesis are standard deviations.* BMI – Body Mass Index

Some occupational characteristics of the subjects are indicated in Table 3. Workers at the motor park (307.3 ± 132.6 months) and those at the mechanic village (265.0 ± 119.0 months) had spent the longest durations on their present occupations while participants at FUNAAB (58.2 ± 71.4 months) and students at the GTC (23.7 ± 4.4 months) had spent the shortest durations. A similar pattern was revealed in the length of time spent in their present job locations. While workers at the mechanic village (210.5 ± 91.1 months) and those at the motor park (184.0 ± 113.3 months) had spent the longest durations in their present work places, students at the GTC (23.7 ± 4.4 months) and participants from FUNAAB (control population) (47.2 ± 39.2 months) had spent the shortest durations.

Table 3: Some occupational characteristics of respondents

<table>
<thead>
<tr>
<th></th>
<th>FUNAAB N=12</th>
<th>Polyurethane Factory N=26</th>
<th>Motor Park N=18</th>
<th>GTC N=21</th>
<th>Mechanic Village N=92</th>
<th>Total N=169</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Length of Time on Present Occupation: n ± sd months</td>
<td>58.2 ± 71.4</td>
<td>74.5 ± 76.5</td>
<td>307.3 ± 132.6</td>
<td>23.7 ± 4.4</td>
<td>265.0 ± 119.0</td>
<td>195.6 ± 148.2</td>
</tr>
<tr>
<td>Mean Length of Time in Present Job Location: n ± sd months</td>
<td>47.2 ± 39.2</td>
<td>54.5 ± 55.5</td>
<td>184.0 ± 113.3</td>
<td>23.7 ± 4.4</td>
<td>210.5 ± 91.1</td>
<td>148.9 ± 112.5</td>
</tr>
<tr>
<td>Mean No. of Days at Work per Week: n ± sd days</td>
<td>5 ± 1</td>
<td>6 ± 1</td>
<td>6 ± 1</td>
<td>5 ± 0</td>
<td>6 ± 1</td>
<td>6 ± 1</td>
</tr>
<tr>
<td>Mean No. of Hours at Work per Day: n ± sd hours</td>
<td>9.8 ± 2.1</td>
<td>9.5 ± 1.8</td>
<td>11.3 ± 1.7</td>
<td>8.0 ± 0.0</td>
<td>9.4 ± 0.9</td>
<td>9.5 ± 1.5</td>
</tr>
</tbody>
</table>

The mean number of hours spent by participants per day in the work places was 9.5 ± 1.5 with the students spending the lowest number of hours (8.0) and the workers at the motor park, the highest (11.3 ± 1.7). Of the five locations studied, workers at the motor park and those at the mechanic village had spent the longest durations both in their present occupations and in their present job locations. In addition, workers at the motor park spend the highest number of hours at work daily. Since these groups of workers are occupationally exposed to lead, spending a long time at work increases their risk of exposure and health effects. Appropriate legislation may need to be considered to limit the number of hours they spend at work as a way of...
Reducing their risk of exposure to lead. Table 4 depicts the mean blood lead, cholesterol, aminolevulinic acid (ALA) and glutathione (GSH) concentrations at baseline.

**Variation of blood lead levels among subjects**

The mean blood lead level varied from 15.76 ± 2.05µg/dL for workers at FUNAAB to 27.68 ± 11.30µg/dL for those at Asero Motor Park. A significant increase in the blood lead concentrations among the groups (p < 0.001) was evident with workers at Asero Motor Park having a value 1.7 times higher than their FUNAAB and GTC counterparts. Elevated blood lead levels are evident among the occupationally exposed subjects (motor park, polyurethane factory and mechanic village workers), a finding similar to previous observations [2, 6, 22] among petrol attendants and auto technicians in Abeokuta Nigeria. The findings of this study confirm previous observations that environmental factors are a major contributor to the blood lead levels of subjects. The mean blood lead range (15.76 - 27.68 µg/dL) in the present study are above the 10µg/dL generally accepted as the safe limit in many parts of the world [23].

Different cellular, intracellular and molecular mechanisms have been reported for toxicological manifestations caused by lead in the body [5]. Oxidative stress sets in under the influence of lead, producing Reactive Oxygen Species (ROS) like hydroperoxides (HO2•), singlet oxygen and hydrogen peroxide (H2O2) while the antioxidant reserves become reduced [12]. Glutathione (GSH) – an antioxidant present in the cells scavenges free radicals produced. Lead inactivates Glutathione by binding to sulphydryl groups in it which leads to synthesis of GSH from cysteine via γ-glutamyl cycle, which is not effective in replenishing the supply of GSH [13]. Lead also inactivates the enzymes like δ-aminolevulinic acid dehydratase (ALAD), glutathione reductase (GR) and glutathione-S-transferase which further depletes the level of glutathione [24]. The inhibition of ALAD results in elevation of ALA levels which leads to generation of free radicals. Alternatively, ionic mechanism of lead toxicity may be due to the ability to substitute other divalent ions like Ca2+, Fe2+, Mg2+. When this happens, different biological processes of the body which include enzyme regulation, cell adhesion, release of neurotransmitters, etc [25] are affected. The ionic mechanism contributes to neurological deficits when Pb2+ replaces Ca2+ and crosses the blood-brain barrier. All these mechanisms make the cell vulnerable to oxidative stress and may lead to cell death in the subjects with high blood lead levels.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>MEAN BLOOD LEVELS (± SD)</th>
<th>Mech. Village (N=107)</th>
<th>FUNAAB (N=36)</th>
<th>TOTAL Sample (N=255)</th>
<th>ANOVA</th>
<th>P Value</th>
<th>Significant ? (Yes / No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb (µg/dl)</td>
<td>21.33 ± 12.57</td>
<td>18.31 ± 10.19</td>
<td>15.76 ± 12.05</td>
<td>18.80 ± (11.41)</td>
<td>0.000</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cholesterol (mg/dl)</td>
<td>158.25 ± 41.92</td>
<td>119.42 ± 41.18</td>
<td>118.36 ± 34.76</td>
<td>127.93 ± (39.92)</td>
<td>0.000</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ALA (µg/dl)</td>
<td>68.48 ± 46.24</td>
<td>60.60 ± 42.79</td>
<td>51.24 ± 29.11</td>
<td>55.11 ± (39.92)</td>
<td>0.000</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Glutathione (mM)</td>
<td>0.49 ± 0.26</td>
<td>0.36 ± 0.22</td>
<td>0.46 ± 0.41</td>
<td>0.41 ± (0.24)</td>
<td>0.003</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Values are mean ± SD.

The existence of high lead concentration in air and soil in urban areas of which Abeokuta is one has been attributed to the increase in automobiles using leaded gasoline [26]. Environmental lead contamination is increased by uncontrolled refuse burning of wood, paper products, agricultural wastes, and battery casing. While the general populace experiences lead pollution from the environment, the occupationally exposed subjects contend with lead from occupational habits and can suffer from any of the problems associated with it [6]. General work ethics among occupationally exposed subjects (Mechanics and Motor drivers) was observed to be very low. They siphon or suck fuel with their mouth to clean vehicular parts. Lead from welding fumes or chewing wire cables constitute additional intake of lead aside other contributions and all these practices contribute to the lead burden of artisans.

**Plasma levels of cholesterol, aminolevulinic acid and glutathione**

The mean plasma levels of cholesterol, aminolevulinic acid and glutathione each varied significantly from work place to work place. The highest concentration of cholesterol (163.58 ± 54.16mg/dL) was observed in workers at Asero motor park followed by workers at the polyurethane factory, the Mechanic village (119.42 ± 41.18 mg/dL) and FUNAAB (118.36±34.76 mg/dL) respectively. The concentration of ALA ranged from 35.02 ± 28.55 µg/dL for GTC to 68.48 ± 46.24/dL for
workers at Asero Polyurethane factory. Glutathione level varied from 0.36 ± 0.22mM for Mechanic Village workers to 0.49 ± 0.26mM for the Polyurethane factory workers.

Before ascorbic acid supplementation, the occupationally exposed subjects plasma ALA levels was 1.2 - 1.3 times higher than the control while GSH for the Mechanic village and GTC were lower compared to the control group. ALA undergoes auto oxidation at physiological pH giving rise to formation of superoxides, hydrogen peroxide and ALA free radicals [27].

The body cell defends itself against free radicals by reducing the free radicals with glutathione (GSH) [28]. The observation made in the reduction of blood GSH in the groups could be partly due to the reaction of GSH with lead or with the free radicals promoted by lead exposure [6]. The observed reduction could also be due to impairment of GSH synthesis or regenerating enzymes by lead [9]. With the vitamin C supplementation, the mean blood Pb level decreased significantly from 18.80 ± 11.41 µg/dL to 12.52 ± 8.33 µg/dL (t = 6.1514, p < 0.001) for the total sample while there were decreases in the samples from the various work places as shown in Table 5.

### Table 5: Blood Lead levels and biochemical parameters before and after vitamin C administration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Polyurethane Factory</th>
<th>Motor Park</th>
<th>GTC</th>
<th>Mechan. Village</th>
<th>FUNAAB</th>
<th>Total sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Cholesterol (mg/dl)</td>
<td>158.25</td>
<td>113.42</td>
<td>165.58</td>
<td>90.64</td>
<td>111.58</td>
<td>117.82</td>
</tr>
<tr>
<td>±41.92</td>
<td>±55.11(^b)</td>
<td>±54.16</td>
<td>±24.53(^b)</td>
<td>±29.68</td>
<td>±31.70</td>
<td>±41.18</td>
</tr>
<tr>
<td>ALA (ug/dl)</td>
<td>68.46</td>
<td>NA</td>
<td>53.32</td>
<td>21.11</td>
<td>35.02</td>
<td>NA</td>
</tr>
<tr>
<td>±46.24</td>
<td>NA</td>
<td>±29.78</td>
<td>±13.38</td>
<td>±26.55</td>
<td>NA</td>
<td>±42.79</td>
</tr>
<tr>
<td>±0.49</td>
<td>0.71</td>
<td>0.49</td>
<td>0.64</td>
<td>0.37</td>
<td>2.65</td>
<td>0.36</td>
</tr>
<tr>
<td>Glutathione</td>
<td>±0.26</td>
<td>±0.26(^b)</td>
<td>±0.21</td>
<td>±0.19</td>
<td>±0.25</td>
<td>±0.78(^b)</td>
</tr>
<tr>
<td>Pb (ug/dl)</td>
<td>21.33</td>
<td>10.49</td>
<td>27.68</td>
<td>24.19</td>
<td>15.88</td>
<td>13.80</td>
</tr>
<tr>
<td>±12.57</td>
<td>±8.01(^b)</td>
<td>±11.30</td>
<td>±12.70</td>
<td>±10.19</td>
<td>±8.51</td>
<td>±10.91</td>
</tr>
</tbody>
</table>

Values are mean ± SD.

Percentage decrease ranged from 51 among the Polyurethane workers to 13 in the GTC students. The control group recorded a 28% reduction. This reduction in lead level with the supplementation could be explained by the ability of ascorbic acid to quench reactive oxygen species (ROS) along with chelating the metal which makes it a potential detoxifying agent for lead. Chang and others [11] made similar observation in their rat study. Ascorbic acid as an antioxidant donates free electrons to ROS and lipid radicals in the biological systems resulting from oxidative stress due to lead toxicity and converts them to stable molecules. This prevents or delays oxidation process thereby preventing lipid peroxidation that can damage cell membrane [5]. Figure 1[5] shows the chain breaking mechanism of antioxidants.

### Donation of hydrogen to free radicals by antioxidants

\[
\text{A}• + \text{AH} \rightarrow \text{RH} + \text{A}•
\]

\[
\text{RO}• + \text{AH} \rightarrow \text{ROH} + \text{A}•
\]

\[
\text{ROO}• + \text{AH} \rightarrow \text{ROOH} + \text{A}•
\]

\[
\text{A}• + \text{A}• \rightarrow \text{AA}
\]

### Complex formation between free radical and antioxidant radical

\[
\text{R}• + \text{A}• \rightarrow \text{RA}
\]

\[
\text{RO}• + \text{A}• \rightarrow \text{ROA}
\]

\[
\text{ROO}• + \text{A}• \rightarrow \text{ROOA}
\]

\[
\text{A}• + \text{A}• \rightarrow \text{AA}
\]

**Figure 1:** Chain breaking mechanism of antioxidants. R•, RO•, ROO•: Free Radicals, AH: Antioxidant, A•: Antioxidant radical.

With 2-week ascorbate supplementation, the oxidative stress parameters (ALA and GSH), recorded significant decrease (55.11 ± 39.92 µg/dL vs. 29.36 ± 16.10 µg/dL, t = 7.5520, p < 0.001), and increase (0.41 ± 0.24mM vs 1.04 ± 0.94 mM, t = -7.6326, p < 0.001) for the total sample respectively. In this study, ascorbic acid reduced mean plasma ALA by 60%, 50% and 70% in the motor park, Mechanic Village and control groups respectively. The highest rise in blood GSH was evident among the subjects from GTC (616%) while the drivers
Ca(Na₂EDTA) is a commonly used antidote for lead poisoning but has its side effects apart from the fact that it has to be administered by intravenous infusion [29]. The ability of vitamin C to reduce the risk of lead toxicity in animal and human has been reported [11, 14, 15, 26]. Other antioxidants have also provided protection against lead effects [5]. The findings of the study that daily ascorbic acid supplementation resulted in the reduction of blood lead levels in all the work groups suggest the protective effect of ascorbic acid which may probably be due to initiation of intestinal absorption and increased renal clearance of lead [30]. Therefore, ascorbic acid supplementation may provide an inexpensive and convenient method of attenuating the adverse effects of lead.

**Conclusion**
The data obtained from the study, suggests that the levels of blood lead varied from workplace to workplace which also reflects the biochemical effects of lead among the workers. From the findings there is an indication that ascorbic acid may be a convenient and inexpensive prophylactic agent for lead poisoning. With vitamin C removing lead from blood possibly by reducing the intestinal absorption and increasing the renal clearance, it provides an effective reversal in the altered hematopoietic and parameters suggestive of oxidative stress.

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**References**


