OCCUPATIONAL HEALTH AND TOXICOLOGICAL RISK OF EXPOSURE TO TOXIC ELEMENTS (TEs) IN TOP SOIL FROM RESIDENTIALLY SITUATED AUTOMOBILE WORKSHOPS (AWs)

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INTRODUCTION

In Nigeria, automobile emissions are responsible for around 80% of metal contamination or pollution. These emissions contain Cadmium (Cd), Lead (Pb), Nickel (Ni) and Zinc (Zn), with Pb from petrol and Zn from tires being the most significant sources of contamination (Anapuwa, 2014). AWs provide a variety of maintenance services, from quick and easy oil changes to intricate engine rebuilds. When necessary, they offer welding, spraying, electrical, and auto body repair services. Chemicals, paints, primers, and other hazardous products are frequently used in auto workshops' operational procedures.

Numerous investigations have determined that human exposure to particulate matter may occur by ingestion, skin contact, or respiration (Devi & Yadav, 2018). In addition to polluting the environment, the massive rise in TEs has negative health implications for humans (Iwugube et al., 2019). Exposure to TEs like Zn, Cd, Pb, and Cr has been linked to cancer (Olujimi et al., 2015; Mansour et al., 2019). Additionally, TEs such as Arsenic (As) and Pb have the potential to cause cardiovascular damage and are carcinogenic (Mansour et al., 2019).

In Nigeria, gasoline-powered automobiles emit smoke, which produces dust and metallic oxides, primarily lead oxide (Eludoyin & Ogbe, 2017). While there has been a decrease in the use of leaded petrol in some nations, the decrease in vehicle-based lead (II) ion (Pb(II)) generation has been offset by an increase in the number of automobiles. Automobile waste and...
other variables are responsible for the augmentation of micronutrients in soil (Rakib et al., 2017). In addition, automobile-related activities have been seen in workshops near and around residential areas in Abeokuta, with most of the workers without wearing personal safety equipment. As a result, the goal of this study was to ascertain the topsoil’s TEs (As, Cd, Co, Ni, and Pb) concentration and degree of contamination. Furthermore, since information on these TEs is crucial to assessing both the toxicological risk of exposure and workers’ health on the job, it was assessed in others to meet the Global Goals 3 and 15.

MATERIALS AND METHODS

Study area

The investigation was conducted in Abeokuta (7.1475°N, 3.3619°E), Ogun State, Nigeria in May 2020. Owing to rising urbanization and quick population expansion, Abeokuta’s land area, roughly 2320 km² has continued to rise in all directions (Olayinka et al., 2015). Abeokuta is home to 593,140 people in total. The area’s products are primarily electronics casings, series abattoir effluents, and steel, and mechanical wastes (Umoren et al., 2024). There are also many traditional quarry processors in the area. The city was built on a rocky ledge that towered over the savanna with surrounding woods. It is located in Nigeria’s tropical rain forest zone, which is distinguished by tall trees, a dense canopy of grass, and two separate seasons. Abeokuta has a mean monthly temperature 25.7 – 30.2°C, relative humidity > 50%, and annual rainfall 2,000 mm respectively (Olayinka et al., 2015). The automobile workshops used for the study were selected due to their location within and near residents. All study sites were of the same soil type (sandy loamy) and well-drained. The descriptive map of Abeokuta in Ogun state, Nigeria adopted from Oyedepo et al. (2015) is presented in Figure 1.

Sample collection and processing

Twelve composite soil was sampled the month of May 2020, from twelve strategically selected automobile workshops with are within and in very proximity to residences (homes) in Abeokuta city. Hand auger was used to for the soil sampling which consist of five subsamples. Plant matters and other dirt were hand-picked from samples. Almost 300 g of bulked sample storage was done in labelled, airtight polythene bags. Samples were subjected to repeated reduction (coning and quartering), further air-dried for 72 h, then sieved using a 1 mm mesh size before acid digesting.

Toxic element analysis

All glassware used for the study was pre-treated with 5% trichloroacetic acid (HNO₃) then cleaned with distilled water. Aqua regia was used to digest the prepared sample in a digestion flask, which have oven-dried at 35°C for 15 min. 1 g of the sample was transferred into the flask with 20 cm³ of aqua regia. The mixture was cautiously stirred and then heated in a fume hood for several hours without time reference. The samples were cooled, filtered and diluted with deionized water to mark 50 cm³ in a volumetric flask then analysed for TEs (As, Co, Cd, Pb and Ni) using an AAS (Model: ICE3000 series).

Contamination factor (CF)

The degree of contamination/pollution in a soil can be estimated using by various methods, the present study adopted the contamination factor (CF) for estimating the degree of TE contamination in soil (Famuyiwa et al., 2022a). The degree of TE contamination in the soil was estimated using Equation 1:

\[
CF = \frac{\text{TE Concentration}_{\text{sample}}}{\text{TE Concentration}_{\text{crustal region}}}
\]

where TE ConcentrationSample is the TEs concentration in the soil sample near the automobile workshops; TE ConcentrationCrustal region is the TEs concentration in the reference level.

The classifications used for the degree of contamination is described as: CF < 1 is low, 1 ≤ CF < 3 is moderate, 3 ≤ CF < 6 is considerable, 6 ≤ CF is very high.

Potential risk assessment

An estimation was made of the health risk that results from humans being exposed to TEs from the soil via the skin, oral, and respiratory pathways (Famuyiwa et al., 2022a; Umoren et al., 2024). Exposure pathways calculation for chronic daily intake (CDI) was estimated using equations 2 – 4:

\[
\text{CDI}_{\text{Oral}} = \frac{\text{TE Concentration}_{\text{sample}} \cdot (\text{OralR} \cdot \text{EF} \cdot \text{ED} \cdot \text{MBW})}{\text{AT}},
\]

\[
\text{CDI}_{\text{Respir}} = \frac{\text{TE Concentration}_{\text{sample}} \cdot (\text{RespirR} \cdot \text{EF} \cdot \text{ED} \cdot \text{PEF})}{\text{MBW} \cdot \text{AT}},
\]

\[
\text{CDI}_{\text{Skin}} = \frac{\text{TE Concentration}_{\text{sample}} \cdot (\text{SA} \cdot \text{DAF} \cdot \text{SAF} \cdot \text{EF} \cdot \text{ED})}{\text{MBW} \cdot \text{AT}},
\]

where CDIOral is the chronic daily intake on exposure via oral, mg/(kg·day); CDIRespir is via respiration, mg/(kg·day); CDISkin – via skin contact, mg/(kg·day); OralR (oral rate) is 20 and 200 mg/day for children and adults respectively; RespirR (respiration rate) is 7.63 and 20 m³/day for children and adults respectively (Umoren et al., 2024); EF is the exposure frequency which is 180 and 365 days/year for children and adults respectively; ED is the exposure duration which is 6 and 30 years for children and adults respectively; MBW is the average body weight which is 15 and 60 kg for children and adults respectively; AT is the average exposure time/life expectancy which is 61.33 years (Chen et al., 2014); 10⁻⁵ mg/kg is conversion factor; SA is the exposed skin surface area which is 2100 and 5800 cm² for children and adults; SAF is the skin adherence factor which is 0.2 and 0.07 cm²/cm²/day for children and adults; DAF is the dermal absorption factor used in this study is 0.1 for both children and adult respectively; PEF is the particle emission factor which is 1.36 × 10⁻⁶ m³/kg for both children and adult (Umoren et al., 2024).

Hazard quotient (HQ) and hazard index (HI) according to Famuyiwa et al. (2022b) were employed for estimating the non-cancer risk of TEs in the soil (USEPA, 2011). HQ is an indicator of the health risk of non-cancerous side effects from TE exposure:

\[
\text{HQ}_i = \frac{\text{CDI}_i}{\text{RfD}_i},
\]

where RfD is the reference dose of each TE by the U.S. Environmental Protection Agency (USEPA).

Figure 1. Map of Abeokuta city in Ogun State, South Western, Nigeria
where RfD\textsubscript{i} is the reference dose for a particular TE.

The highest daily TEs dose that can be administered to humans without endangering their health during their lifetime is known as RfD\textsubscript{i}. Reference dose RfD\textsubscript{oral} (mg/kg/day) for ingestion, RfD\textsubscript{skin} (mg/kg/day) for skin contact, and RfD\textsubscript{respire} (mg/m\textsuperscript{3}) for respiration are the three forms of RfD\textsubscript{i} that are used for exposure pathways.

The hazard index measures the cumulative risk of specific chemicals from multiple exposures (HI):

\[ HI = \sum HQ_i, \quad (6) \]

where the index \textit{i} denotes different exposure pathways.

When HI is less than 1, it indicates that there is no appreciable chance of non-cancer side effects. On the other hand, major harmful non-cancer impacts are likely when HI > 1 (USEPA, 2011). The reference dose (RfD\textsubscript{i}) multiplied by the corresponding cancer slope factor (CSF\textsubscript{i}) in mg/kg is used to determine the cancer risks to people. A cancer slope factor, calculated using Equation 7, is the upper bound likelihood that a person will get cancer as a result of respiration, skin contact, and oral exposure to contaminated soil during their lifetime:

\[ TCRs = RfD\textsubscript{i} \times CSF\textsubscript{i}, \quad (7) \]

where TCR is total cancer risk, that is the likelihood that a person will get any kind of cancer from lifetime exposure to cancer-causing factors.

If TCR less than 1 \cdot 10^{-6} specifies negligible cancer risk, while above 1 \cdot 10^{-4} recommends high cancer risk to humans on exposure.

**Statistical analysis**

Data were analysed using SPSS (vs 21) to descriptive statistics while Microsoft Excel (vs 2016) was used for computing the contamination level, risk assessment and data visualizations. The source of the elements in the soil was estimated using the Pearson correlation. p < 0.05.

**RESULTS AND DISCUSSIONS**

**Concentration of toxic elements (TEs)**

The concentration of TE in the soil is represented in Table 1, due to the unavailability of soil guideline values (SGVs) for specific TE in Nigeria, the comparison to the widely used UK environmental agency SGV (EA, 2013) and Canada soil guideline value (CSGV, 2009) was used. The concentration of As, Co, Cd, Pb and Ni from the soil varied from 0.67 – 5.63, 6.21 – 71.2, 8.92 – 134, 32.6 – 211 and 1.89 – 9.20 mg/kg with a mean of 3.16, 46.0, 80.0, 127 and 5.52 mg/kg respectively. The oxidative states and chemical structures of different types of arsenic have a significant impact on their toxicity. As absorbed and passed up through the food chain, the inorganic forms of As found in soil prove to be hazardous, impacting a variety of living species (Shrivastava et al., 2015). The highest As concentration was recorded in sample AW05 (5.63 mg/kg) followed by AW06 (5.56 mg/kg), although As concentration in all samples were below the SGVs by UK (40.0 mg/kg) (EA, 2013) and CSGV (12.040.0 mg/kg) (CSGV, 2009). Constant exposure to As can result in a variety of clinical symptoms, which are the most common of which are epidermal lesions (Shrivastava et al., 2015). Huang et al. (2009) have identified several clinical symptoms linked to arsenic, such as keratosis, melanosis (hyperpigmentation) and leukomelanosis. According to the International Agency for Research on Cancer (IARC, 2012), As is a well-known carcinogen that can lead to malignancies of the skin, bladder, lungs, liver, and kidney. Other conditions include ischemic heart disease, carotid atherosclerosis, and diminished motor and cognitive function (Shrivastava et al., 2015).

Studies on the toxicity of cobalt (Co) to humans and animals have extensively examined the toxic potential of Cobalt and the associated health risks. Prior reviews have frequently concentrated on the effects of Co on a particular physiological system in various Co exposure environments (Catalani et al., 2012; Leyssens et al., 2017) or one particular exposure setting and the associated Co intake routes, toxicity mechanisms, and clinical consequences (Zywiel et al., 2016; Leyssens et al., 2017). The sample with the greatest Co level was observed in AW05 (71.3 mg/kg) followed by sample AW06 (68.9 mg/kg). Excessive cobalt exposure can have gastrointestinal, hematologic, central and peripheral nervous system, metabolic, cardiovascular and endocrine consequences in acute toxicity. Hardmetal illness and occupational asthma are two respiratory disorders brought on by repeated inhalation exposures (Catalani et al., 2012).

According to the ATSDR list, cadmium (Cd) is the sixth hazardous element (Negahdari et al., 2021). Prolonged exposure to Cd causes cellular mutagenesis, lung damage, and testicular harm (Faridi et al., 2015). The highest Cd concentration was recorded in sample AW06 (134 mg/kg) followed by AW05 (122 mg/kg). Burning petroleum fuels, plastics, glass, welding electrodes used by body work specialists and pigments used in paints for vehicle bodywork, are typical sources of Cd (Lawal et al., 2015). The level of Cd in 66.7% of the samples was above the CSGV (22 mg/kg) while 100% were below the UK (150 mg/kg) respectively (CSGV, 2009; EA, 2013).

Lead (Pb) poisoning results from Pb exposure and impacts the human body, potentially leading to problems in the brain, bowels, and stomach (Umoren et al., 2024). The highest Pb level was recorded in sample AW02 (211 mg/kg) followed by AW06 (189 mg/kg). The concentration of Pb in 58.3% of the samples was higher than the CSGV (140 mg/kg) while 100% was lower than the UK (450 mg/kg) respectively (CSGV, 2009; EA, 2013). AWs are frequently surrounded by battery professionals, or "battery chargers", as they are known throughout Nigeria, and they are a significant source of Pb. Additional sources include the gas exhaust from the majority of cars that are being serviced at these AWs (leaded gasoline and additive use are still prevalent) (Lawal et al., 2015).

Nickel (Ni), a trace element, is used by the human body for sustenance (Taiwo et al., 2019). According to Umoren et al. (2024), nickel has several toxicity mechanisms, including sensitizing and allergenic qualities. Additionally, it's a cancer-causing agent that can cause teratogenicity, chronic bronchitis, pulmonary embolism (PE), heart issues, and cancers of the prostate, throat, and nose. The highest Ni concentration was recorded in sample AW06 (9.18 mg/kg) followed by AW06 (8.32 mg/kg). The level of Ni in 100% of the samples was below the UK standard (200 mg/kg) (EA, 2013). The detected indicators are presented in Table 1.

**Contamination factor (CF)**

The contamination factor of TEs in the soil is presented in Table 2, revealing that the soil has low contamination with As (0.24) and Ni (0.08), moderate with Co (2.42) and very high with Cd (265) and Pb (6.34). CF value in the descending order of Cd > Pb > Co > As > Ni.

**Correlation matrix**

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The relationship between TEs can give important suggestions about their emerging origins (Famuyiwa et al. 2022a). The relationship between TEs is presented in Table 3, which reveals that Pb has a positive correlation with Cd ($r = 0.847$), Co ($r = 0.941$), Ni ($r = 0.815$) and As ($r = 0.814$) $p < 0.01$. Cd has a positive association with Co ($r = 0.961$), Ni ($r = 0.739$) and As ($r = 0.874$) $p < 0.01$. Co has a positive association with Ni ($r = 0.856$) and As ($r = 0.937$) $p < 0.01$ while Ni has a positive correlation with As ($r = 0.836$) $p < 0.01$. The TEs that are highly or considerably connected show a similar origin. The substantial correlation between Pb, Cd, Co, Ni and As suggests that these elements have a common anthropogenic (man-made) origin.

Table 1. Toxic element (TE) level in topsoil from automobile workshops

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>As</th>
<th>Co</th>
<th>Cd</th>
<th>Pb</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>AW01</td>
<td>4.18</td>
<td>64.3</td>
<td>113</td>
<td>147</td>
<td>6.92</td>
</tr>
<tr>
<td>AW02</td>
<td>3.15</td>
<td>62.4</td>
<td>107</td>
<td>211</td>
<td>8.32</td>
</tr>
<tr>
<td>AW03</td>
<td>2.96</td>
<td>48.1</td>
<td>100</td>
<td>162</td>
<td>4.68</td>
</tr>
<tr>
<td>AW04</td>
<td>4.02</td>
<td>60.4</td>
<td>111</td>
<td>180</td>
<td>7.02</td>
</tr>
<tr>
<td>AW05</td>
<td>5.63</td>
<td>71.3</td>
<td>122</td>
<td>169</td>
<td>7.81</td>
</tr>
<tr>
<td>AW06</td>
<td>5.46</td>
<td>68.9</td>
<td>134</td>
<td>189</td>
<td>9.18</td>
</tr>
<tr>
<td>AW07</td>
<td>1.48</td>
<td>34.2</td>
<td>82.5</td>
<td>100</td>
<td>2.17</td>
</tr>
<tr>
<td>AW08</td>
<td>5.01</td>
<td>66.5</td>
<td>125</td>
<td>169</td>
<td>5.89</td>
</tr>
<tr>
<td>AW09</td>
<td>1.79</td>
<td>18.3</td>
<td>15.6</td>
<td>49.0</td>
<td>2.45</td>
</tr>
<tr>
<td>AW10</td>
<td>0.67</td>
<td>6.21</td>
<td>8.92</td>
<td>32.6</td>
<td>1.89</td>
</tr>
<tr>
<td>AW11</td>
<td>2.02</td>
<td>28.2</td>
<td>21.7</td>
<td>61.9</td>
<td>5.67</td>
</tr>
<tr>
<td>AW12</td>
<td>1.56</td>
<td>22.8</td>
<td>20.1</td>
<td>50.2</td>
<td>4.24</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td><strong>0.67</strong></td>
<td><strong>6.21</strong></td>
<td><strong>8.92</strong></td>
<td><strong>32.6</strong></td>
<td><strong>1.89</strong></td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td><strong>5.63</strong></td>
<td><strong>71.2</strong></td>
<td><strong>134</strong></td>
<td><strong>211</strong></td>
<td><strong>9.20</strong></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>3.16</strong></td>
<td><strong>46.0</strong></td>
<td><strong>80.0</strong></td>
<td><strong>127</strong></td>
<td><strong>5.52</strong></td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td><strong>1.69</strong></td>
<td><strong>22.8</strong></td>
<td><strong>48.6</strong></td>
<td><strong>63.8</strong></td>
<td><strong>2.47</strong></td>
</tr>
<tr>
<td>EA (2013)</td>
<td>40.0</td>
<td>-</td>
<td>150</td>
<td>450</td>
<td>200</td>
</tr>
<tr>
<td>CSGV (2009)</td>
<td>12.0</td>
<td>-</td>
<td>22.0</td>
<td>140</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. Contamination factor for toxic element (TE) in topsoil

<table>
<thead>
<tr>
<th>TEs</th>
<th>Mean</th>
<th>CF value</th>
<th>Grade</th>
<th>Degree of Contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>3.16</td>
<td>0.24</td>
<td>CF &lt; 1</td>
<td>Low</td>
</tr>
<tr>
<td>Cd</td>
<td>80.0</td>
<td>267</td>
<td>CF &gt; 6</td>
<td>Very High</td>
</tr>
<tr>
<td>Co</td>
<td>46.0</td>
<td>2.42</td>
<td>1 ≤ CF &lt; 3</td>
<td>Moderate</td>
</tr>
<tr>
<td>Ni</td>
<td>5.52</td>
<td>0.08</td>
<td>CF &lt; 1</td>
<td>Low</td>
</tr>
<tr>
<td>Pb</td>
<td>127</td>
<td>6.34</td>
<td>CF &gt; 6</td>
<td>Very High</td>
</tr>
</tbody>
</table>

Table 3. Correlation matrix of toxic elements

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>Cd</th>
<th>Co</th>
<th>Ni</th>
<th>As</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>1</td>
<td>0.947**</td>
<td>1</td>
<td>0.961**</td>
<td>1</td>
</tr>
<tr>
<td>Cd</td>
<td>0.947**</td>
<td>1</td>
<td>0.739**</td>
<td>0.865**</td>
<td>1</td>
</tr>
<tr>
<td>Co</td>
<td>0.961**</td>
<td>0.739**</td>
<td>1</td>
<td>0.836**</td>
<td>1</td>
</tr>
<tr>
<td>Ni</td>
<td>0.815**</td>
<td>0.874**</td>
<td>0.937**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>0.814**</td>
<td>0.961**</td>
<td>0.865**</td>
<td>0.836**</td>
<td>1</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.01 level (2-tailed)

Potential Health Risks

**Chronic daily intake (CDI)**

The chronic daily intake (CDI) of TEs is presented in Table 4, the CDI for TEs in the soil reveals that the TE intake appears in the order $\text{CDI}_{\text{Oral}} > \text{CDI}_{\text{Skin contact}} > \text{CDI}_{\text{Respirate}}$, with Co and Cd being the most dosed for children and adults. This further shows that children are at a more venerability to exposure than adults. The CDI for the TEs is in the order of Co > Cd > Pb > As > Ni for children and adults in the environment.

**Non-cancer and Cancer risk**

Cancer and non-cancer risk associated with TE in soil revealed
that the HI value for toxic elements was < 1, except for Pb for children, what amounted to 27.8 suggesting a significant non-cancer risk for individuals exposed to Pb. The HI values for the toxic elements appear in the order of Pb > Co > Cd > As > Ni (Figure 2). The total cancer risk (TCR) associated with toxic elements exposure in the soil revealed that TCR values for all TEs were within the threshold limit (< 1 · 10^-6), indicating that the exposed humans are free from the likelihood of getting cancer after being exposed to TEs in the soil. The TCR values for the toxic elements appear in the order of As > Pb > Cd > Co > Ni for children and As > Ni > Pb > Co > Cd for adults (Figure 3).

## Table 4. Chronic daily intake, cancer and non-cancer risk

<table>
<thead>
<tr>
<th>TEs</th>
<th>CDIOral</th>
<th>CDIRespire</th>
<th>CDISkin</th>
<th>HQOral</th>
<th>HQRespire</th>
<th>HQSkin</th>
<th>HI</th>
<th>TCR=∑CRi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receptor: Children</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>2.08E-04</td>
<td>7.90E-12</td>
<td>5.82E-07</td>
<td>2.08E-04</td>
<td>7.90E-12</td>
<td>5.82E-07</td>
<td>6.95E-01</td>
<td>2.67E-05</td>
</tr>
<tr>
<td>Cd</td>
<td>5.26E-03</td>
<td>2.00E-10</td>
<td>1.47E-05</td>
<td>5.26E-03</td>
<td>2.00E-10</td>
<td>1.47E-05</td>
<td>5.85E+00</td>
<td>1.08E-10</td>
</tr>
<tr>
<td>Co</td>
<td>3.02E-03</td>
<td>1.15E-10</td>
<td>8.46E-06</td>
<td>3.02E-03</td>
<td>1.15E-10</td>
<td>8.46E-06</td>
<td>1.64E+00</td>
<td>9.65E-11</td>
</tr>
<tr>
<td>Ni</td>
<td>3.63E-04</td>
<td>1.38E-11</td>
<td>1.02E-06</td>
<td>3.63E-04</td>
<td>1.38E-11</td>
<td>1.02E-06</td>
<td>3.53E-02</td>
<td>3.66E-12</td>
</tr>
<tr>
<td>Pb</td>
<td>8.34E-03</td>
<td>3.17E-10</td>
<td>2.33E-05</td>
<td>8.34E-03</td>
<td>3.17E-10</td>
<td>2.33E-05</td>
<td>2.78E+01</td>
<td>6.07E-06</td>
</tr>
<tr>
<td>Receptor: Adults</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>2.23E-05</td>
<td>4.45E-12</td>
<td>5.14E-07</td>
<td>2.23E-05</td>
<td>4.45E-12</td>
<td>5.14E-07</td>
<td>7.59E-02</td>
<td>1.15E-05</td>
</tr>
<tr>
<td>Cd</td>
<td>5.64E-04</td>
<td>1.13E-10</td>
<td>1.30E-05</td>
<td>5.64E-04</td>
<td>1.13E-10</td>
<td>1.30E-05</td>
<td>1.08E+00</td>
<td>2.43E-10</td>
</tr>
<tr>
<td>Co</td>
<td>3.24E-04</td>
<td>6.48E-11</td>
<td>7.48E-06</td>
<td>3.24E-04</td>
<td>6.48E-11</td>
<td>7.48E-06</td>
<td>1.33E+00</td>
<td>2.18E-10</td>
</tr>
<tr>
<td>Ni</td>
<td>3.89E-05</td>
<td>7.78E-12</td>
<td>8.98E-07</td>
<td>3.89E-05</td>
<td>7.78E-12</td>
<td>8.98E-07</td>
<td>5.58E-03</td>
<td>1.36E-06</td>
</tr>
<tr>
<td>Pb</td>
<td>8.93E-04</td>
<td>1.79E-10</td>
<td>2.06E-05</td>
<td>8.93E-04</td>
<td>1.79E-10</td>
<td>2.06E-05</td>
<td>2.98E+00</td>
<td>2.60E-06</td>
</tr>
</tbody>
</table>

Figure 2. Percentage contribution of individual TE to HI

Figure 3. Percentage contribution of individual TE to TCR

**CONCLUSION**

The study has evaluated the amount of TEs present in the top soils of automobile workshop environments within and close to residences in Abeokuta, Ogun state, Nigeria. The investigated soil is polluted with Cd and Pb, and there is a non-cancer-related effect on children with prolonged exposure to Pb. The workers’ attitude to auto maintenance and repairs, as well as their careless and
improper disposal of waste, are the primary causes of the sites' gradual degradation. The activities contribute significantly to pollution in the soil which could be leached to surface and groundwater in the environment leading to negative effects on the environment and ill-health effects. In order to prevent the spread of this hazardous element, automobile workshops should be located distant from residential areas and bioremediation can be utilized to clean up the already contaminated soil.

Author's statements

Contributions

Conceptualization: O.D.U., A.O.F., G.O.A.; Data curation: all authors; Formal and statistical analysis: O.D.U., A.O.F., G.O.A.; Investigation: all authors; Methodology: all authors; Visualization: L.I.A.; Writing – original draft: L.I.A.; Writing – review & editing: all authors.

Declaration of conflicting interest

The authors declare no competing interests.

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Not applicable.

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REFERENCES


