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RESEARCH ARTICLE

# The Impact of Auto Mechanic Junk on Soil and Groundwater Physicochemical Properties in Selected Sites in Port-Harcourt, Niger Delta, Nigeria

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## Abstract

The proliferation of auto-mechanic sites near houses within cities has made it necessary to study the impact of car assembly and disassembly activities on the adjoining soil and water. Thus, this study hypothesizes that pollutants from auto-mechanic junk (waste) will adversely affect the soil and water. We chose some auto mechanic sites at three locations in Port Harcourt. Three soil and water samples were randomly collected from the three sites (Ikokwu, Elekahia, and Mile 3 auto parts sites) within each location ($n = 18$) using soil augur and water jar, respectively. We sent the samples to the laboratory for the analysis of pH. Cadmium, Lead, Chromium, Iron, and Manganese using the atomic absorption spectrophotometric method (AAS) after digesting 2 g soil samples and immersing in nitric acid ($HNO3$). The ANOVA result reveals no significant difference in heavy metal concentration between the surface and sub-surface soils ($F1, 28, 0.02, P = 0.88$). Nevertheless, the surface soil has a higher concentration of metals than the sub-surface soils. Iron has the highest concentration in surface and sub-surface soils, followed by Chromium, Manganese, Lead, and Cadmium. At the same time, cadmium has the lowest concentration of all metals analyzed. The metallic components in the soil occur in the order Fe>Cr>Mn>Pb>Cd. The result shows that the concentration of Cr and Pb in the soil was above the World Bank Standard (WHO), while the concentration of heavy metals in drinking water was below the WHO standard. Iron has the highest concentration probably because of the ground geology and sedimentary formation of the parent soil. The most polluted site was Elekahiah, followed by Mile 3 and Ikokwu. Although there is a negative correlation between heavy metal concentration between soil and water ($R2 = -0.22$), there was a positive correlation of chemicals between surface and sub-surface soils ($R2 = 0.99$), which shows that migration of chemical components from surface to groundwater may be possible in future. The result implies that auto-mechanic junks can pose public health problems if the soil and groundwater are not constantly monitored.

**Keywords:** Automobile, Mechanic, Contamination, Vehicular Junks, Pollution, Groundwater.

## 1. Introduction

Waste is rejected materials from a manufacturing process that is useful to another process (Seah et al., 2023). Automobile junks are waste products from an auto-mechanic shop (Aisien et al., 2013; Jody et al., 2023). The junk comprises body parts of accident cars as well as the accessories that come from the internal parts of cars (Zhang & Chen, 2018). Examples include metallic parts (e.g., doors, bonnet, roof, boot, base, and sides) and plastic parts (fender, headlamp cover, dashboard, and seats). Other parts include electrical parts and wirings. During salvage operation, accident

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cars are refurbished by changing parts, repairing dented bodies using carbide, spray-painting, and changing engines, batteries, and electrical parts (diode, cables, motor transformers, capacitors, and IC) (Graham et al., 2015).

These activities lead to liquid discharge from the cars and their parts, eventually dropping on the soil and percolating into the groundwater aquifer (Numbere et al., 2023). The discharges from capacitors contain heavy metals and polychlorinated biphenyls (PCBs), which are harmful to the environment when they enter the soil and groundwater (Tansel, 1998; Sun et al., 2023).

The city of Port-Harcourt has many auto mechanic shops close to human habitation. The shops install boreholes and wells to provide water for workers and residents around the area. In the same vein, it is observed that many auto mechanic shops are established close to water bodies, public drainages, and highly populated areas (Fadillah et al., 2023). The proliferation of pre-owned cars has also led to the multiplication of automobile centers around the city. Most of these centers are found in populated areas where many people are car owners. The pre-owned cars always develop mechanical faults, leading to constant visits to the mechanic shop. Thus increasing the amount of automobile waste in and around the premises of the mechanic shop. Over the years, this waste accumulated to form a mountain of old junk that litter the environment. Because of the years of accumulating old and dysfunctional vehicles, the metallic components from the cars enter the soil and water, contaminating the surface and sub-surface soils (Tansel, 1998). Used engine oils from abandoned cars or oil removed during oil changes are poured into the soil to contaminate it. Many mechanic garages in the study area have hard, thick black soils due to years of constant car oil spills. The accumulation of car parts within the mechanic shop can cause public health problems because it is close to living houses with boreholes or dug-out wells that supply drinking water to members of the surrounding community. There is a tendency for heavy metals and petroleum to contaminate surface and sub-surface water (Svensson et al., 2005). Auto-mechanic workshops also trade on vehicle parts that are disassembled from old or accident cars (Tian & Chen, 2016). These parts are sold out to buyers who use them to fix their cars. There are sections of the auto-mechanic shops where metallic parts of old cars are cut into pieces and sold to metal buyers, who then sell them to iron manufacturers. Thousands of cars are either scrapped or recycled annually in the Niger Delta area of Nigeria, which also reduces the burden on the adjoining soil. The most common recyclable materials from cars are plastic and internal parts (floor mats), sold to fix other cars, while the metallic parts are sold as scrap metal (Pietrzak & Ulewicz, 2023). There is also the habit of burning car tires to generate heat for another repair process in the auto-mechanic shops (Kar, 2011).

The automobile junk that is no longer useful is often stacked in isolated sections of the automobile shops. These junks remain at a given point long without being evacuated for a recycling plant. They are, thus, subject to weather conditions such as rainfall and sunlight. The metallic junk corrodes when beaten by rain and drops on the soil, thus increasing the soil's heavy metal concentration—the iron environment of the soil results in this condition. The objectives of the study are (1) To determine the concentration of heavy metals in surface and sub-surface soils, (2) to compare the concentration of heavy metals in soil and water at different auto-mechanic sites, and (3) to determine the relationship between heavy metal concentration in surface and sub-surface soils, and between soil and water.

## 2. Materials and Methods

### 2.1 Study Area

Port Harcourt is a coastal community surrounded by numerous rivers and creeks. It is a metropolitan city with many commercial and industrial activities. The area has high rainfall, which occurs during the wet season (February-October) while the dry season occurs between November-February. These also experience high solar radiation with an atmospheric temperature range of 27-35 °C. The Mile 3 mechanic shop is situated in the heart of Port-Harcourt and is known as Diobu. The shop covers an area of 1,600 m2 and is littered with accidents, spoiled, and abandoned cars. A section of this shop is a dumping group for automobile waste, where all vehicle parts are thrown. The soil is brown to black and saturated with used oil poured on the soil from cars being serviced. The Ikokwu car parts store and mechanic garage are sites for selling different car parts. A part of this area is used for automobile repairs and the dismantling of car parts, which are later sold out in bits to willing buyers. Many micro to macro car parts are discharged into the soil during the recovery processes. The Elekahia site has a much smaller auto mechanic workshop where vehicles are repaired or dismantled. The primary activities at the Elekahia and Mile 3 Diobu study sites are the repair and maintenance of vehicles. In contrast, the Ikokwu site undergoes car dealerships and sales of car parts.

### 2.2 Sample Collection

Soil samples were collected with soil augur in the study sites within a 100 × 100 m quadrant around the automobile dump sites. Composite soil samples consisting of three random samples were collected in each section at 0-15 cm and 15-30 cm depths, referred to as surface and sub-surface samples. They were put in black plastic bags and sent to the laboratory for further analysis. Groundwater samples from all sites were collected with 1 liter of jerricans from a borehole that is junk within the auto mechanic shapes. Labeled containers were sent to the laboratory for further analysis. In each site, three soil and three water samples were collected, making a total of nine samples each for soil and water (n = 18).

### 2.3 Laboratory Analysis

The soil samples were first weighed and digested before analysis using the atomic absorption spectrophotometric (AAS) method. To analyze the soil in the AAS machine, 2g of soil samples were weighed and placed in a beaker. The soil was oven-dried at 45 °C for 30 minutes. Nitric acid (HNO3) was added to the oven-dried soil to expose the organic and inorganic elements. The solution of acid and soil was heated in a fame chamber to expel the organic component and leave behind the inorganic element. The metals were determined by passing 200 ppm of the samples through the AAS for 3-7sec.

For the borehole water samples, two volumes of HNO3 were added to concentrate the ion content. Following these proofs, 1ppm of the metals (i.e., Fe, Cr, Cd, Mn, and Pb) were passed through the AAS machine for four minutes.

### 2.4 Statistical Analysis

An analysis of variance (ANOVA) was conducted since there were multiple samples, i.e., >2 per block (n=18), to test whether there was any significant difference in soil metal concentration between surface and sub-surface soils (Quinn & Keogh, 2002). Logarithmic transformation of the data was performed to meet assumptions of normality and homoscedasticity (Logan, 2010). Furthermore, Pearson's product-moment correlation was done to determine whether a significant difference exists between concentration in surface and sub-surface soils. All analyses were done in R statistical environment 4.2.2 (R Development Core Team).

## 3. Results

### 3.1 The Physico-Chemistry of Surface and Sub-Surface Soils

The ANOVA result reveals no significant difference in heavy metal concentration between the surface and sub-surface soils (F1, 28, 0.02, P = 0.88). Nevertheless, the surface soil has a higher concentration of metals than the sub-surface soils (Table 1). Iron has the highest concentration in surface and sub-surface soils, followed by Chromium, manganese, lead, and cadmium. At the same time, cadmium has the lowest concentration of all metals analyzed. The metallic components in the soil occur in the order Fe>Cr>Mn>Pb>Cd. The result shows that the concentration of Cr and Pb in the soil was above the World Bank Standard (WHO), as shown in Table 1.

**Table 1.** *The mean concentration of metals in surface and sub-surface soils in selected sites in Port Harcourt, Niger Delta, Nigeria (±SE)*

| Soil profile | Metals (mg/kg) | | | | |
|---|---|---|---|---|---|
| | Cd | Cr | Fe | Mn | Pb |
| 0-15 cm | 0.00±0.00 | 521.67±21.67 | 7199.33±92,38 | 497.33±10.48 | 266.67±16.67 |
| 15-30 cm | 0.00±0.00 | 364.44±10.44 | 6844.00±281.17 | 347.77±36.52 | 200.33±0.33 |
| WHO standard | 0.8 | 100 | 20000 | - | 85 |

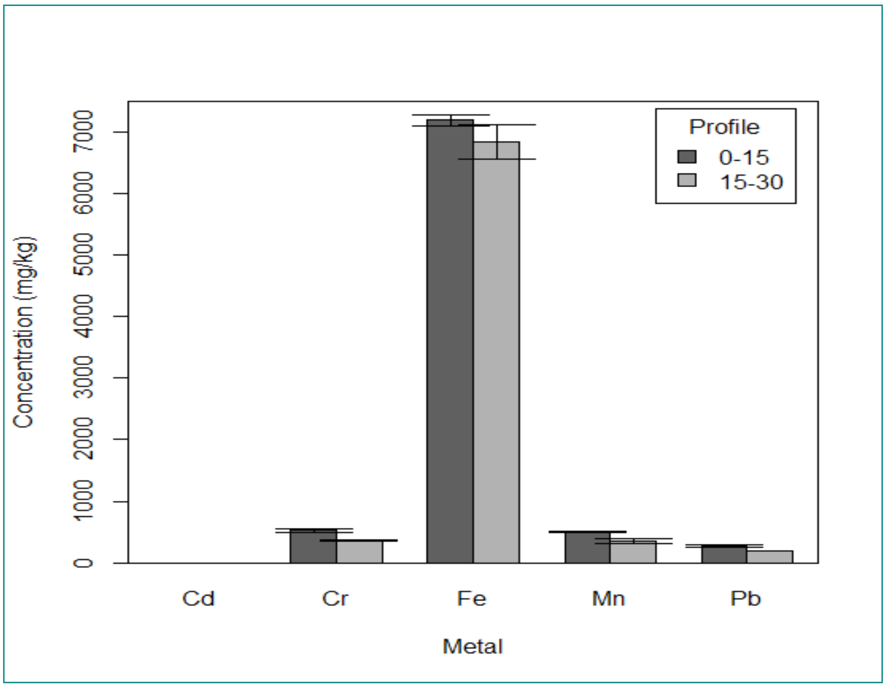


**Figure 2.** *Heavy metal concentration in surface and sub-surface soil at different locations around Port Harcourt, Niger Delta, Nigeria (±SE).*

### 3.2 Soil Physico-Chemistry of Surface and Sub-Surface Soils at Different Locations

The ANOVA result reveals that there is no significant difference in metal concentration between locations ($F2, 27, = 0.006, P = 0.99$). However, Elekahia has the highest concentration of iron, followed by Mile 3 and Ikokwu (Figure 3). The pH of soil at Ikokwu, Mile 3 and Elekahia sites are 6.78, 5.56 and 6.89 respectively. The pH result shows that the soil is slightly acidic.

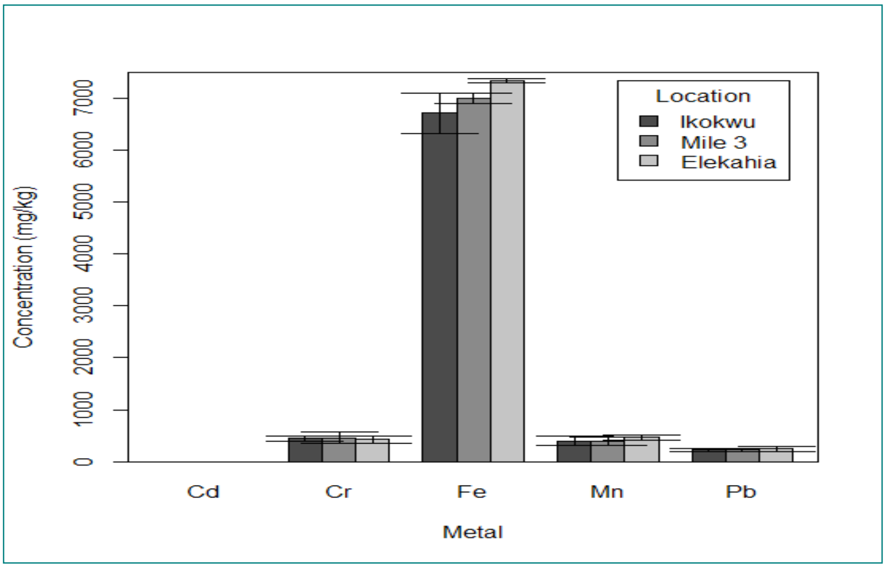


**Figure 3.** *Heavy metal concentration in soil at selected locations around Port Harcourt, Niger Delta Nigeria (±SE).*

### 3.3 The Physico-Chemistry of Borehole Water

The ANOVA result reveals a significant difference in the concentration between metals ($F2, 25, = 6.68, P = 0.0.001$). In contrast, there is no significant difference in metal concentration between locations ($F2, 27, = 0.005, P = 0.0.995$, Figure 4). The pH of water at the Ikokwu, Mile 3, and Elekahia sites is 5.75, 5.78, and 5.69, respectively, which shows that the water is acidic. The concentration of Mn and Cd is insignificant. Meanwhile, iron has the highest concentration in water. In addition, the results reveal that Cd, Fe, Cr, and Pb concentrations are below the WHO limit of <.0 mg/l, 0.05 mg/l, and 0.01 mg/l, respectively, and thus not harmful for drinking.

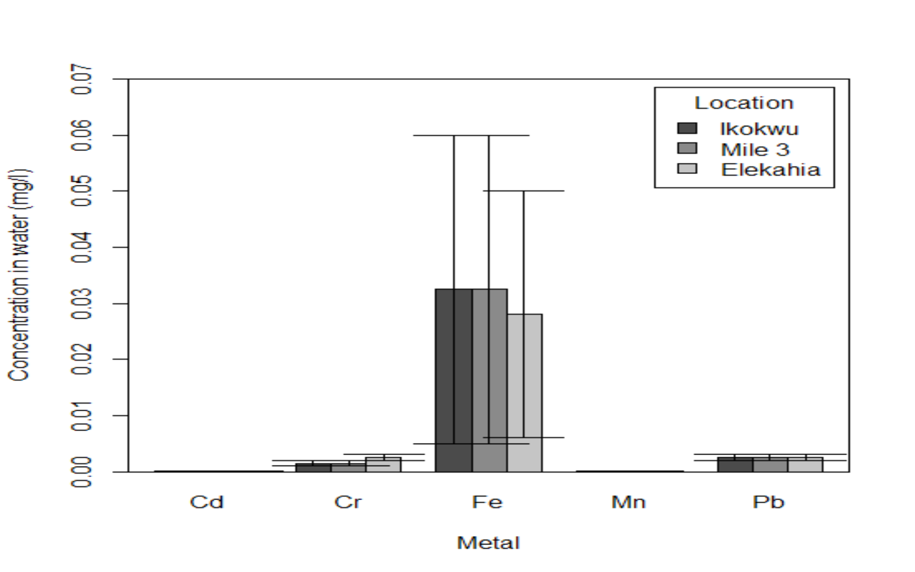


**Figure 4.** *Heavy metal concentration in borehole water collected in different locations around Port Harcourt, Niger Delta Nigeria (±SE).*

## 3.4 Correlation of Concentration Between Surface and Sub-Surface Soil

The Pearson correlation test result reveals that the concentration of heavy metals in the surface and subsurface soils is significantly correlated with a correlation coefficient of 0.99 and a p-value of 0.001 (t = 64.046, df = 13, p-value = 0.001, Cor= 0.9984191, Figure 4). This means that as the surface soil's chemical concentration increases, the subsurface soil's chemical concentration increases positively linearly (Figure 5).

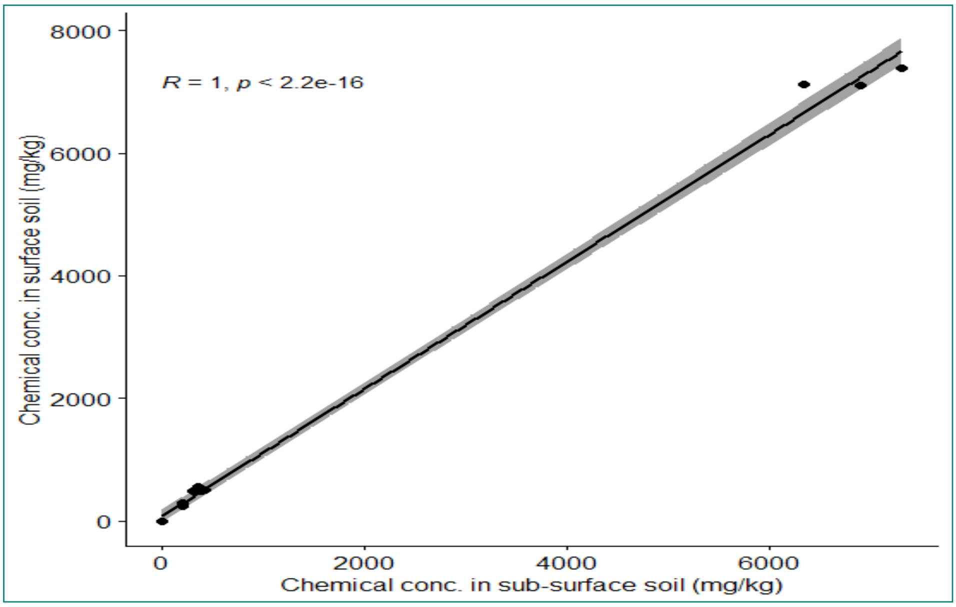


**Figure 5.** *Correlation of chemical concentration in surface soil versus sub-surface soil of auto-mechanic shops in selected sites in Port Harcourt, Rivers State, Nigeria.*

## 3.5 Correlation of concentration between water and soil

The Pearson correlation test results reveal that the concentration of heavy metals in the soil and water are not significantly correlated, with a correlation coefficient of -0.22 and a p-value of 0.23 (t = -1.2207, df = 28, p-value = 0.2324, Figure 6). This means that as the chemical concretion in the soil increases, the chemical concentration in water decreases in a negative linear direction (Figure 6).

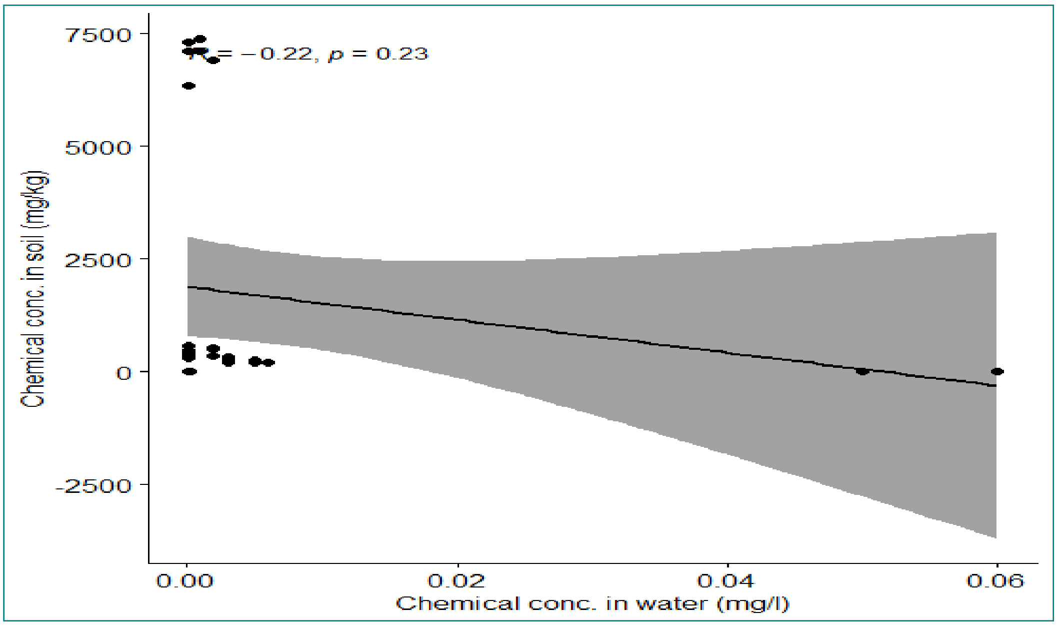


**Figure 6.** *Correlation of chemical concentration in soil and water collected from auto-mechanic shops in selected sites in Port Harcourt, Rivers State, Nigeria.*

## 4. Discussion

Although there is no significant difference in chemical composition in surface and sub-surface soils, the concentration of chemicals in surface soil is higher because it is part of the soil exposed and directly impacted by engine oil from the cars being repaired. The surface soil serves as the platform on which waste from the auto mechanic site is dumped before evacuation by metallic parts dealers. Therefore, there is a reduction in the concentration of metals as the chemicals migrate down the soil profile. Furthermore, iron has the highest concentration in all soil layers because most car parts are metal. Iron concentration is also higher because of the nature of the sedimentary rock formation of the Niger Delta (Numbere, 2017). The parent material of the soil have iron components. The levels of Cr and Pb in the soil were above the international standard (Table 1). High Lead and Chromium concentrations are caused by discharges of used diesel, carbide, and liquid from battery cells containing harmful and toxic chemical components. These chemicals are corrosive and injurious and can contaminate the soil and water in the auto-mechanic sites.

Elekahia has the highest concentration of iron because it contains the largest metallic waste among the three locations. Similarly, salvage and recycling operations are limited compared to other study sites, which results in the heaping of disused automobile parts in the study site. The Ikokwu site has a minor chemical concentration because it is a major outlet for recycling vehicle parts removed from old cars. Here, the metallic components are not allowed to pile up but are sold to scrap metal dealers who buy and evacuate them away from the sites. Another reason for low metal junk at Ikokwu is that it has smaller space and is close to buildings, hence the need to quickly remove automobile waste from the site.

Metallic concentration in the borehole water at the auto-mechanic sites is not above the WHO standard, but causation should be exhibited in drinking water from these sites because of the possibility of future heavy metal migration and contamination of the groundwater since the source of contamination, such as abandoned car, the disposal of used engine oil, burning of condemned car parts, and carbide exposure still occur at the site. In addition, there is a positive correlation in the concentration of heavy metals between the surface and sub-surface soils (Figure 5), creating a high possibility of groundwater contamination soon. There is also no regular monitoring of the soil and water from the site, making it difficult to determine when the concentration will be above the acceptable limit.

The depth of the boreholes is often above 150 feet below the surface and sub-surface, which makes it a long distance for chemicals to migrate into the groundwater. Nevertheless, chemical components' migration into groundwater aquifers depends on rock formation, hydrology, relief, soil texture, land shape, and rainfall in the area. In order to understand the dynamics of sub-surface water movement, more hydro-geological studies are required at different locations. However, physical observations of the study sites are prone to flood during heavy rainfall.

## 5. Conclusion

The findings of this study reveal that auto-mechanic sites are pollution-prone because of the release of toxic fluids (e.g., used diesel oil, engine oil, and liquefied carbide), and metallic components from faulty vehicles on the site which contaminate adjoining soil and water. The result shows that the soil is mainly contaminated with iron while the concentration of Cr and Pb were above the WHO limit, which makes the area a contaminated site that can result in public health problems. The movement of pollutants within soil layers is also a cause for concern during flooding, which transfers water from auto-mechanic sites into areas of human habitation, leading to groundwater contamination. This study, thus, recommends constant soil and groundwater monitoring in areas close to the auto-mechanic sites to prevent future health disasters.

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