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Effects of Anthropogenic Activities on Some Engineering Properties of Two Selected Soils

Akinyele, Oluwaseun Akinsola[1]*, Ewemoje, Oluseyi Elizabeth[2] and Bamgboye, Adeleke Isaac[2]

[1]Department of Agricultural and Bio-Environmental Engineering, Federal College of Agriculture, Ibadan, Nigeria
[2]Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria
**Corresponding Author: seunakinyele.oa@gmail.com*

ABSTRACT

There is need to examine the possible pollution effects of human activities on soil and immediate environment. Various engineering properties of the soil around auto-mechanic workshops and cassava processing mills were analyzed using standard test methods. Hydrometer method was used to determine the particle size (sand, silt, and clay) while the soil pH was determined using glass electrode digital pH meter. One-way Analysis of Variance was used to statistically analyze all the experimental data obtained while Duncan Multiple Range Test was used to separate the means in order to check their significance and variations among the parameters of the soil. The coefficient of static friction ranged from 0.40 to 0.51, angle of repose: 31.09° and 40.63°, bulk density: 1.42 and 1.66 g/cm^3, particle density: 2.60 to 2.65 g/cm^3, porosity: 36.41 to 46.34%, moisture content: 2.60 and 17.38%, and cation exchange capacity: 2.62 and 7.05 cmol./kg. The soil pH showed that the soil is moderately acidic while the particle size revealed that the soil is very sandy leading to high rapid water infiltration and very low nutrient storage capacity. For all of the soil parameters except for pH and particle density, the results also showed significant differences at $P \leq 0.05$. The wastes resulting from these anthropogenic activities have had negative impacts on the soil properties and that the elevated level of heavy metals in the soil also poses health risk on the human and the immediate environment.

Key words: Anthropogenic, Auto-mechanic, Cassava processing, Properties, Soil

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1. INTRODUCTION

Anthropogenic activities are human actions such as deforestation, mining activities, mechanization, urbanization, and agricultural activities which have greatly affected the soil and render it unproductive for planting of crops. Soils are known to be natural bodies that have been built over time through the relationship between climate, parent material and living organisms [1]. The human influence on soil is traceable to such activities as ploughing, manuring, liming and fertilizer application. Human interventions in an indirect manner are capable of changing the natural soil formation which includes vegetation, change through deforestation, change by levelling and terracing, soil moisture regime change through irrigation or drainage, modification of parent material through waste dumping, and erosion.

Human activities have significantly altered soil quality and reduce the ability of the soil to perform its essential functions. It could be extremely difficult, and sometimes impossible for the soil to be restored once it is contaminated or damaged. Human influence on soil formation happens through all forms of natural soils as a part of the genetic soil type and not as a deviance. In order to avoid a propagation of classes it is necessary that anthropogenic soils be incorporated in a unified soil classification system. Soil degradation has been described as an effect of human activities that are depleted and their relationship with the natural environment. It was noted that the processes are the mechanisms responsible for the deterioration of soil quality [2]. Soils themselves can become sources of pollutants in certain cases, and these pollutants could affect the water quality by finding their ways into watercourses. Thus, good soil management is essential to maintain and improve the soil properties and quality. This research therefore aims at studying the possible impacts of common anthropogenic (human) activities on the engineering properties of soil and the immediate environment.

2. METHODOLOGY

Soil Collection and Preparation

The soil samples used for the experiment were collected from two different sites (Auto-Mechanic Workshop and Cassava Processing Mill) at different locations within Ibadan, Nigeria. The samples were replicated three times and taken at two selected sites for each activity however the samples used as control were taken at 50 m away from the selected sites for each activity. The samples of auto-mechanic activity were taken at Odo-Ona and Ologuneru while that of cassava processing activity were collected at Odo-Ona and Eleyele. All the soil samples were taken with a soil auger at a root depth of 30 cm except that for bulk density and moisture content which were taken separately using a core sampler of 4.80 cm high and 2.55 cm radius. The soil samples were kept in polyethylene bags and labelled appropriately before transported to the laboratory, where they were air-dried for seven days. The soil samples were pulverized and sieved with a 2 mm mesh-sized sieve.

Soil Analysis

The sieved soil samples were thereafter analysed using ASTM and ASAE standard test methods in order to determine the engineering properties. For bulk density and moisture content, the samples were weighed and oven-dried on same day they were collected in order to prevent the moisture loss.

(a) Particle Size

The particle size (sand, silt and clay) was determined using hydrometer method [3-4].

(b) Coefficient of Static Friction

The soil frictional coefficient (μ) was determined using mild steel surface. The soil samples were placed on inclined plane apparatus and an incorporated screw jack was gently tilted to the table until the frictional force between the sample and the surface was overcame by gravity and just start to move down the slope. The angle of inclination was read from the graduated scale on the tilting table and this was replicated thrice each for the two anthropogenic soils. Thus, the coefficient of friction was calculated as the tangent of this angle which is given by the following equation:

$$\mu = \tan\theta$$

Where: μ s the coefficient of static friction and $\theta$is the angle of inclination (measured in degrees).

(c) Angle of Repose

The soil angle of repose was evaluated using a specially constructed topless and bottomless box with a removable front panel. The box was filled with soils and placed on the floor, the front panel was quickly removed allowing the soils to slide down and assume natural slope. The angle of repose of the soils was calculated from tangent inverse of ratio of the height to the base of the pile, which is given by the following equation [5].

$$\theta = \tan^{-1}\left(\frac{h}{l}\right)$$

Where: θ is the angle of repose (measured in degrees), h is the height of the free surface of the soils (measured in metres), and l is the length (measured in metres) of the heap formed outside the box.

(d) Bulk Density

The soil sample for bulk density was collected using a metal ring called core sampler, which is pressed into the soil and the volume of the soil was measured. The soil sample was oven-dried and weighed. The core sampler was of 4.80 cm high and 2.55 cm radius. The average bulk density of the soil was then calculated using following equation [6].

$$\text{Bulk Density} = \frac{\text{Mass of oven dried sample}}{\text{Volume of soil sample}}$$

(e) Particle Density

The soil particle density was determined by volumetric flask method, which is given by the following equation [7].

$$\text{Particle Density} = \frac{\text{Mass of oven dried sample}}{\text{Volume of soil solids only}}$$

(f) Porosity

The porosity of the soil was calculated by the following equation [8-9].

$$\text{Porosity} = \left(1 - \frac{\text{Bulk Density}}{\text{Particle Density}}\right) \times 100\%$$

(g) Moisture Content

The soil moisture content was determined in accordance with ASABE standard method as given by equation below. Two (2) grams each of the soil samples was put in moisture can and oven dried at 105°C (24 hours) until constant weight was attained after a period of cooling in a desiccator.

$$\text{Moisture Content} = \frac{\text{Weight of wet sample} - \text{Weight of dry sample}}{\text{Weight of wet sample}} \times 100\%$$

(h) Cation Exchange Capacity (CEC)

The cation exchange capacity of the soil was determined by addition of exchangeable cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) found in each sample [10].

(i) Soil pH

The soil pH was determined using a glass electrode digital pH meter i.e. by potentiometric method [11].

Data Analysis

The experimental data was statistically analysed by One-way Analysis of Variance and the means were separated using Duncan Multiple Range Test (DMRT) to check their significance and variations among the parameters of the soil. The experimental layout adopted was Completely Randomized Design (CRD) replicated thrice.

3. RESULTS AND DISCUSSION

(a) Particle Size Distribution

Table -1 Particle Size Distribution of the Two Selected Soils

Parameter	Auto-Mechanic Site 1	Auto-Mechanic Site 2	Auto-Mechanic Control	Cassava Processing Site 1	Cassava Processing Site 2	Cassava Processing Control	Nature of Significance at $P \leq 0.05$
Sand (%)	85.47 ± 0.83^{b}	81.47 ± 0.83^{c}	85.53 ± 0.95^{b}	88.57 ± 0.65^{a}	85.47 ± 0.83^{b}	84.20 ± 1.00^{b}	Significant
Silt (%)	9.20 ± 0.10^{a}	9.13 ± 0.12^{a}	7.20 ± 0.10^{b}	5.20 ± 0.20^{c}	7.43 ± 0.15^{b}	9.33 ± 0.23^{a}	Significant
Clay (%)	5.50 ± 0.10^{d}	9.37 ± 0.25^{a}	7.37 ± 0.21^{b}	5.27 ± 0.31^{d}	6.23 ± 0.21^{c}	7.37 ± 0.25^{b}	Significant

*(a, b, c, d) represents ranges of Means respectively [*Means having similar superscript in a row are insignificantly different at $P \leq 0.05$ by Duncan Multiple Range Test (DMRT)]

The particle size distribution (Table 1, Figures 1, 2, 3) at the first site of auto-mechanic was 85.47% Sand, 9.20% Silt, and 5.50% Clay, and at the second site, the particle size was 81.47% Sand, 9.13% Silt, and 9.37% Clay at the depths of 0 - 30cm respectively. At cassava processing, it was obtained to be 88.57% Sand, 5.20%Silt, and 5.27% Clay at site 1, and 85.47% Sand, 7.43% Silt, and 6.23% Clay at site 2. It was observed that the soils of both sites have very high sand content leading to high infiltration of water, and low water holding and nutrient storage capacities. Both soils have almost stable values of silt and clay with high sand content. The distribution of particle size places the soils in sandy – silty - clayey textural classification. The concentrations of heavy metals such as Pb, Cd, Zn, Cu, and Ni may increase with depth possibly due to surface leaching. The study has shown that the anthropogenic activities have significant effect on the soil particle density.

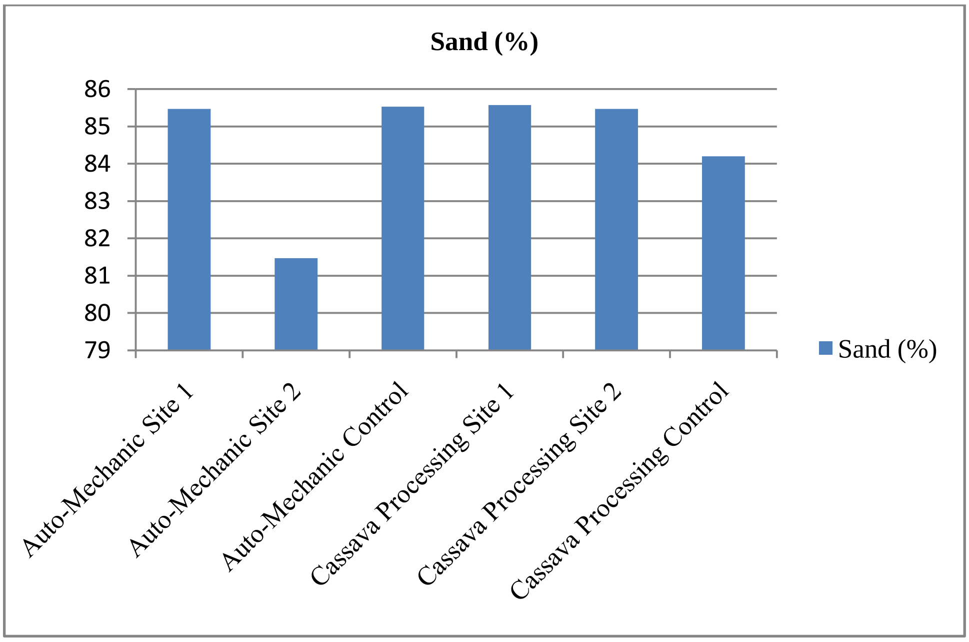

Fig. 1 Effects of the Anthropogenic Activities on Particle Size (Sand)

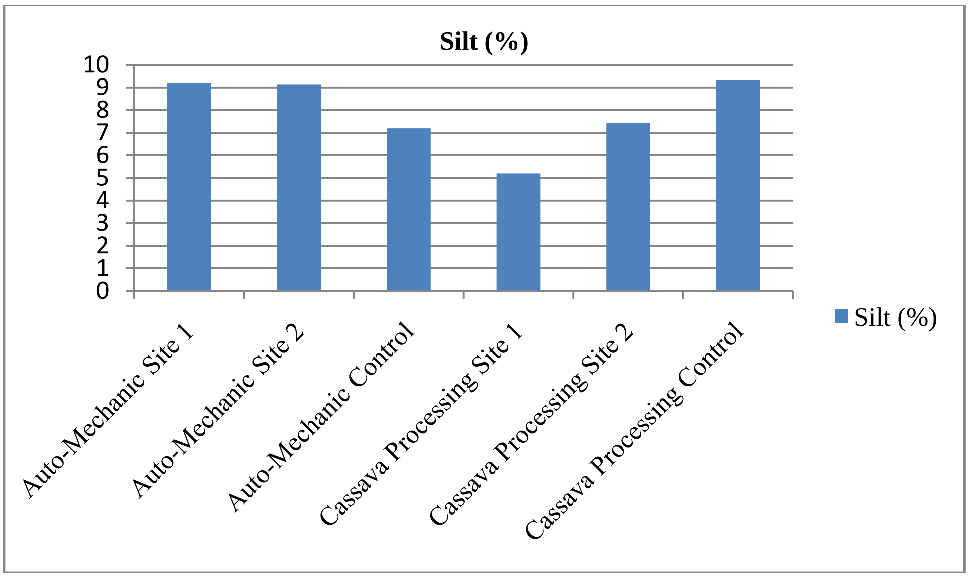

Fig. 2 Effects of the Anthropogenic Activities on Particle Size (Silt)

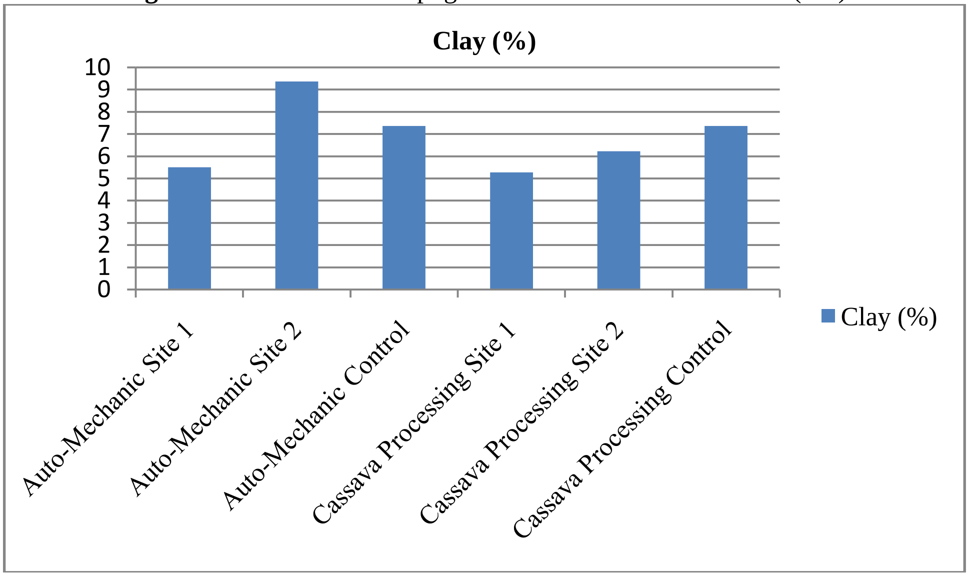

Fig. 3 Effects of the Anthropogenic Activities on Particle Size (Clay)

(b) Engineering Properties

Table -2 Engineering Properties of the Two Selected Soils

Parameter	**Auto-Mechanic Site 1**	**Auto-Mechanic Site 2**	**Auto-Mechanic Control**	**Cassava Processing Site 1**	**Cassava Processing Site 2**	**Cassava Processing Control**	**Nature of Significance at $P \leq 0.05$**
Coefficient of Static Friction	0.47 ± 0.02^{c}	0.51 ± 0.02^{a}	0.49 ± 0.02^{abc}	0.47 ± 0.02^{bc}	0.40 ± 0.01^{d}	0.50 ± 0.02^{ab}	Significant
Angle of Repose (°)	36.08 ± 1.57^{b}	32.48 ± 1.05^{cd}	32.42 ± 0.91^{cd}	40.63 ± 0.69^{a}	31.09 ± 1.04^{d}	33.42 ± 0.76^{c}	Significant
Bulk Density (g/cm^3)	1.42 ± 0.02^{f}	1.52 ± 0.02^{d}	1.46 ± 0.02^{e}	1.62 ± 0.02^{b}	1.66 ± 0.02^{a}	1.57 ± 0.02^{c}	Significant
Particle Density (g/cm^3)	2.65 ± 0.04	2.62 ± 0.03	2.60 ± 0.02	2.63 ± 0.03	2.62 ± 0.05	2.63 ± 0.05	Not Significant
Porosity (%)	46.34 ± 1.31^{a}	41.91 ± 0.74^{bc}	42.98 ± 0.87^{b}	38.40 ± 0.74^{de}	36.41 ± 1.63^{e}	40.37 ± 1.10^{cd}	Significant
Moisture Content (%)	17.38 ± 0.74^{a}	16.35 ± 1.38^{a}	8.18 ± 0.45^{c}	2.60 ± 2.15^{d}	10.63 ± 0.40^{b}	3.53 ± 0.31^{d}	Significant
Cation Exchange Capacity (CEC) (cmol./kg)	4.58 ± 0.29^{c}	4.81 ± 0.12^{c}	3.41 ± 0.02^{d}	2.62 ± 0.12^{e}	5.25 ± 0.23^{b}	7.05 ± 0.10^{a}	Significant
pH	6.35 ± 0.18	6.10 ± 0.22	6.09 ± 0.59	6.31 ± 0.54	6.19 ± 0.73	6.02 ± 0.45	Not Significant

*(a, b, c, d, e, f) represents ranges of Means respectively [*Means with same superscript in a row are not significantly different at $P \leq 0.05$ by Duncan Multiple Range Test (DMRT)]

(c) Coefficient of Static Friction

The coefficient of friction of the soil ranged between 0.47and 0.51 for auto-mechanic sites and 0.40 and 0.50 for cassava processing sites as shown in Table 2 and Figure 4. The soils from both sites were observed to be mostly sandy which resulted in low degree of compaction when compared to a clayey soil. In order to consider this kind of soil for construction or building purposes in terms of their load bearing capacity, it must be mixed with additives such as cement so as to improve the strength. Therefore, the anthropogenic activities could have been responsible for these low frictional coefficients of the both soils, which indicated little significant difference at $P \leq 0.05$ as obtained in the analysis. The frictional coefficient is required in design of equipment used for construction projects such as in building of roads and airfields using variety of soil types. The physical characteristics and load bearing capacity determines the fitness of the soil for construction purposes.

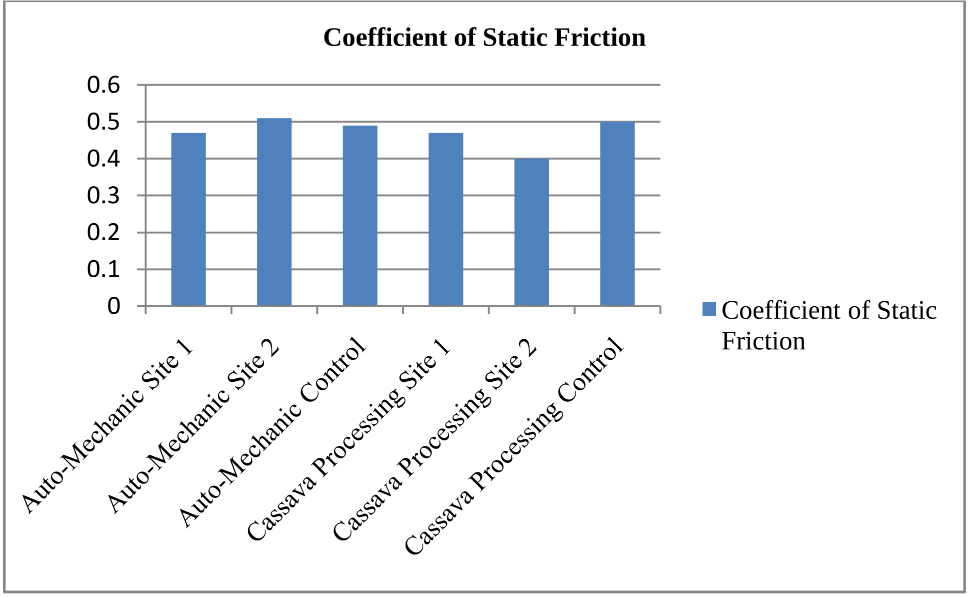

Fig. 4 Effects of the Anthropogenic Activities on the Soil Coefficient of Static Friction

(d) Angle of Repose

The least repose angle was obtained as 31.09° while the highest value was 40.63°at cassava processing site while the least and highest repose angles at auto-mechanic site were obtained as 32.42°and 36.08°(Table 2 and Figure 5). This was in accordance with ASTM standard value for angle of repose of dry soil which ranges between 35° and 36° except at cassava processing site 1 which was 40.63°. It was observed that the anthropogenic activities have significant effects ($P \leq 0.05$) on the soil which might also be responsible for the high repose angle, or may be a firm soil must have been used instead of loose soil. It was then observed that a firm soil has a steeper slope than loose soil. The soil repose angle is useful in the design of hoppers for agricultural machines, conveyors (such as belt conveyor), and moving equipment such as excavator. This also depends on the soil gradation and physical characteristics.

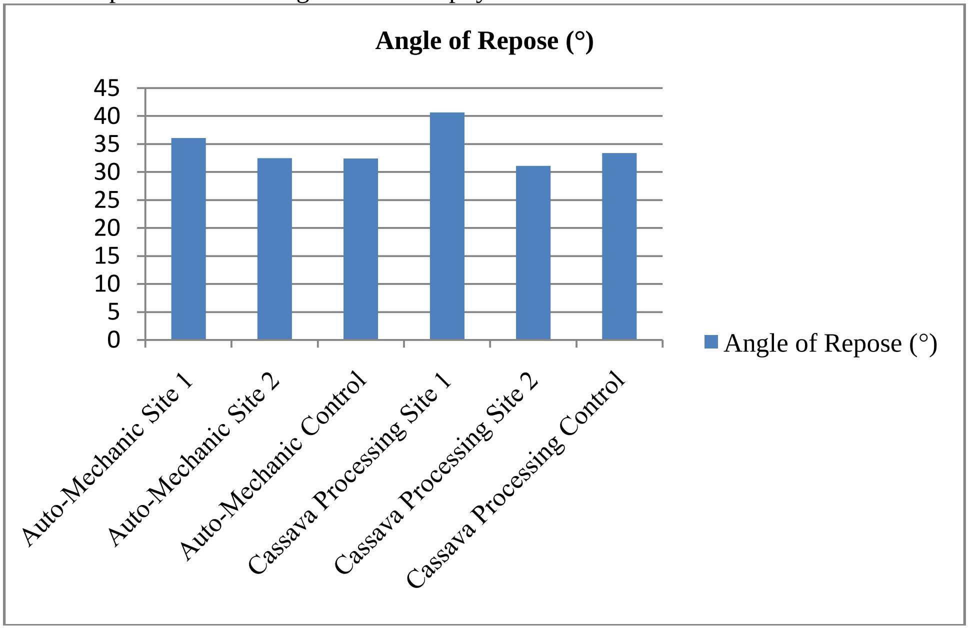

Fig. 5 Effects of the Anthropogenic Activities on the Soil Angle of Repose

(e) Bulk Density

The bulk density for auto-mechanic and cassava processing sites ranged from 1.42 g/cm^3 to 1.52 g/cm^3 and 1.57 g/cm^3 to 1.66 g/cm^3 respectively (Table 2 and Figure 6). It was observed to be relatively low, indicating low degree of compaction which could have been responsible by the nature of the soil in that area and may not really favour plant growth and other agricultural practices due to the spillage of engine oil from auto-mechanic workshops and presence of waste effluents from cassava processing. It can then be inferred from the analysis that anthropogenic activities have significant effect on the soil bulk density of the areas. The level of soil compaction is however measured by bulk density. Generally, when the bulk density is high there would be less pore space for movement of water, root growth and seedling germination. Bulk densities above thresholds indicate impaired function. Therefore, high bulk density can decrease the length of plant root and of course, the root penetration in dump soil could be limited [12].

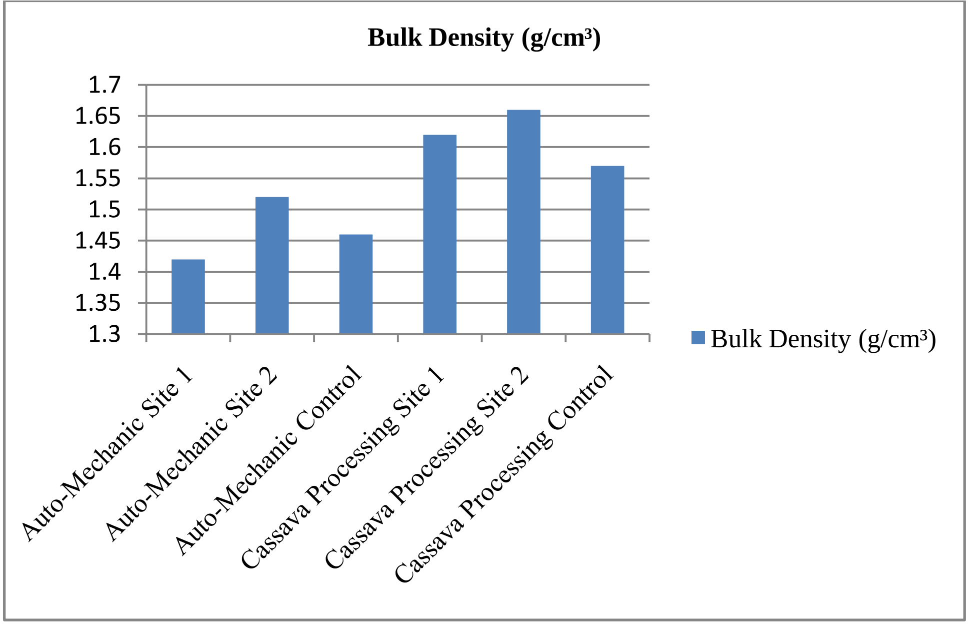

Fig. 6 Effects of the Anthropogenic Activities on the Soil Bulk Density

(f) Particle Density

The particle densities for auto-mechanic and cassava processing ranged from 2.60 g/cm^3 to 2.65 g/cm^3 and 2.62 g/cm^3 to 2.63 g/cm^3 respectively as shown in Table 2 and Figure 7, indicating that there was no significant difference at $P \leq 0.05$ among the particle density of both sites. This suggests that the anthropogenic activities do not really impact on the soil particle density of the area. From experiment, the soil particle density measures the mass of soil samples in a given volume and focuses on the soil particles and not the total volume that the particles and pore spaces occupy in the soil.

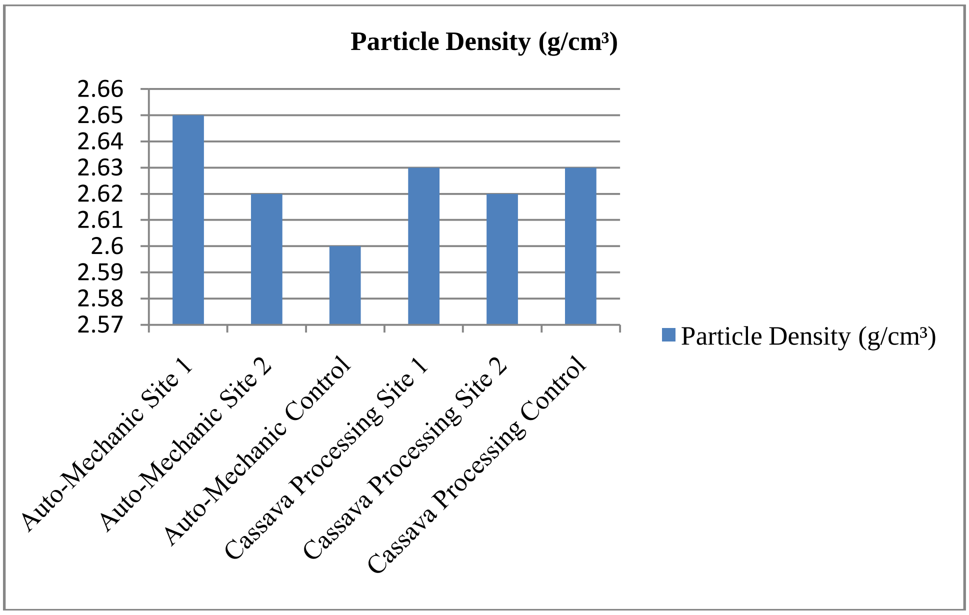

Fig. 7 Effects of the Anthropogenic Activities on Soil Particle Density

(g) Porosity

The porosity for auto-mechanic and cassava processing decreased from 46.34% to 43.64% and 40.37% to 36.41% respectively as shown in Table 2 and Figure 8. A reduction in porosity is likely to prevent water infiltration which eventually results in increased run-off. The sandy soil is responsible for the high porosity [13]. Increased total porosity associated with reduction in soil bulk density was found in this study, which also resulted in increased water infiltration and water holding capacity leading to decrease in soil temperature. It was observed from the analysis that there was significant difference at $P \leq 0.05$ in the porosity values obtained and the implication is that the anthropogenic activities have impacted on the soil porosity in both sites.

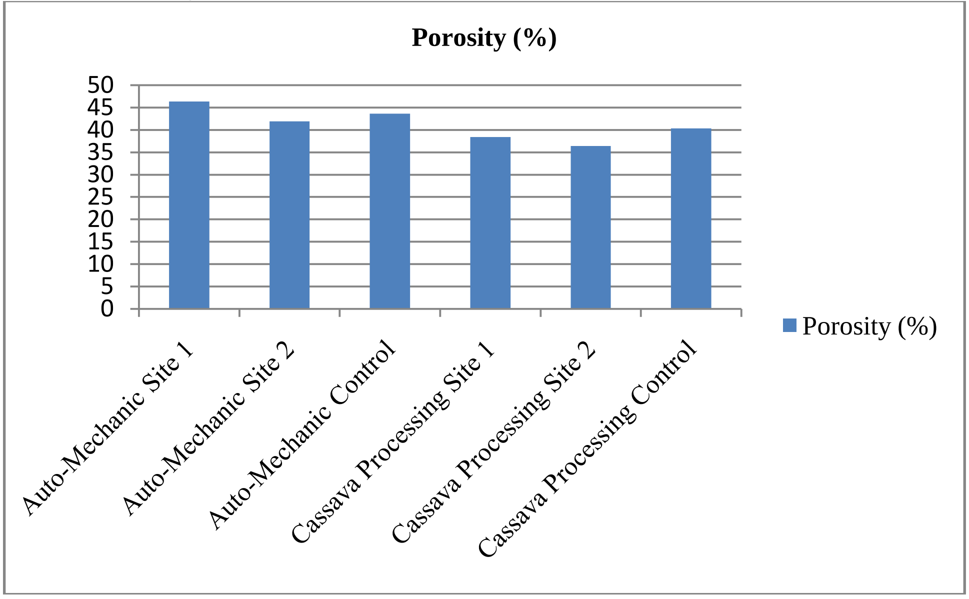

Fig. 8 Effects of the Anthropogenic Activities on Soil Porosity

(h) Moisture Content

The moisture contents of the soil of auto-mechanic workshops were 17.38% and 16.35% as compared to the values obtained from cassava processing, 2.60% and 10.63% as shown in Table 2 and Figure 9. The control for auto-mechanic was 8.18% while cassava processing was 3.53%. It was observed that the oil-affected soils at auto-mechanic workshops retained more water compared to the soil in cassava processing sites. The high moisture content of 17.38% and 16.35% at auto-mechanic sites could be attributed to poor aeration of the soil that might have escalated from the air displacement in the oil-affected soils; this probably reduce evaporation rate. It was noticed that the soil moisture contents were significant different at $P \leq 0.05$ while the anthropogenic activities especially the auto-mechanics have great (negative) impact on the soil.

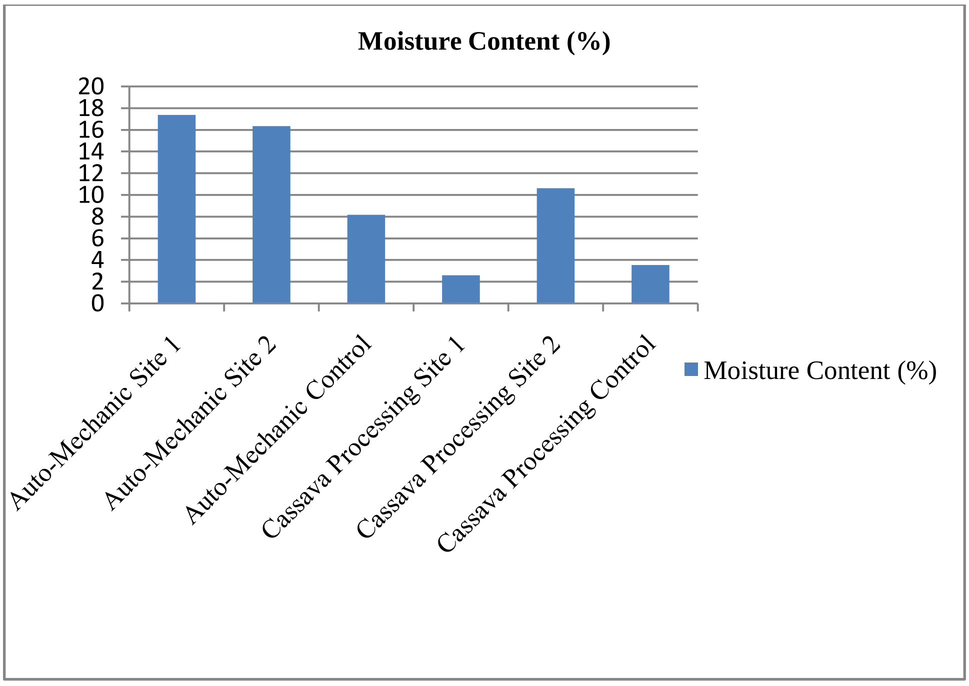

Fig. 9 Effects of the Anthropogenic Activities on Soil Moisture Content

(i) Cation Exchange Capacity (CEC)

The soil cation exchange capacity for auto-mechanic and cassava processing sites ranged from 3.41 cmol./kg to 4.58 cmol./kg and 2.62cmol./kg to 7.05 cmol./kg respectively as shown in Table 2 and Figure 10. It was reported that the cation exchange capacity (CEC) regulates the movement of metals in the soils and that sandy soils have lower cation exchange capacity compared to loamy soils [14]. Since cation exchange capacity is a good indicator of soil quality and productivity, it was observed that high cation exchange capacity in clay soils are less vulnerable to leaching and the water holding capacity is also high when compared to low cation exchange capacity in sandy soils that can possibly develop deficiencies of potassium, magnesium and other cations. The anthropogenic activities from auto-mechanic workshops and cassava processing sites impacted significantly (at P ≤ 0.05) on the soils from both areas.

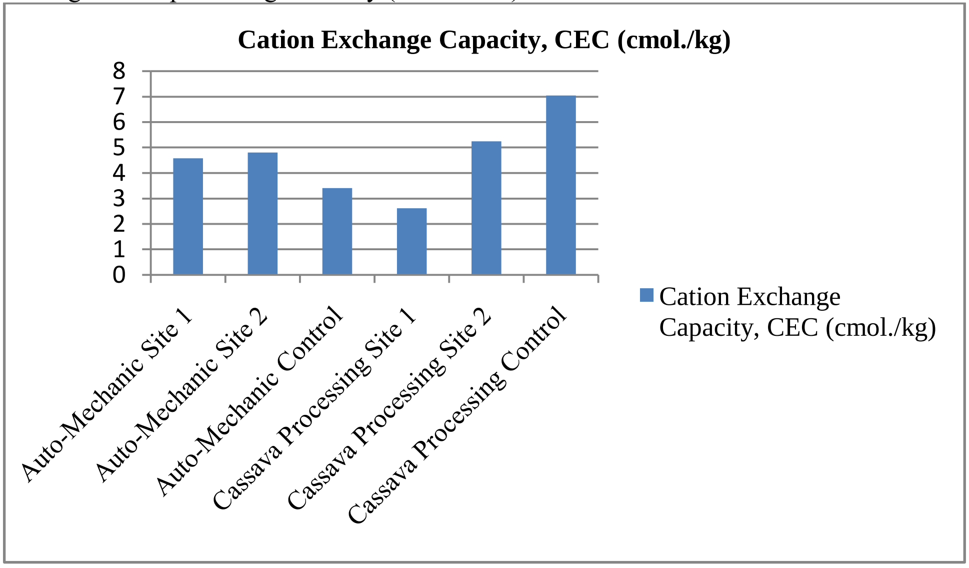

Fig. 10 Effects of the Anthropogenic Activities on the Soil Cation Exchange Capacity

(j) Soil pH

The soil pH for auto-mechanic workshops ranged from 6.09 to 6.35 while that of cassava processing area 6.02 to 6.31 as shown in Table 2 and Figure 11, which indicated that the soils of these areas are acidic. This suggests that the effluent (which contains cyanide) from cassava processing and engine oil from auto-mechanic activities are toxic and impacted acidic properties to the soil. From experiments, acidic soils often show calcium, phosphorus and magnesium deficiencies while alkaline soils exhibit deficiencies in phosphorus and various micronutrients. The presence of aluminium and manganese could also show some toxic levels in acidic soils and damage the growth of plant. Acidic soils often cause stunting and yellowing of leaves which can affect crop growth and yield as the pH decreases. It was observed that the values of pH obtained in this research are similar to those reported by [15-16]. However, they are higher than those reported by [17-18]. The pH values obtained indicated a high tendency for heavy metals availability in plant uptake. The soil pH acts indirectly on plant growth and affects the nutrients availability, the presence of toxins and the growth of soil microorganisms [19]. It is therefore observed that the anthropogenic activities from both sites might have impacted greatly and significantly on the soils though the pH values were significantly indifferent at P ≤ 0.05.

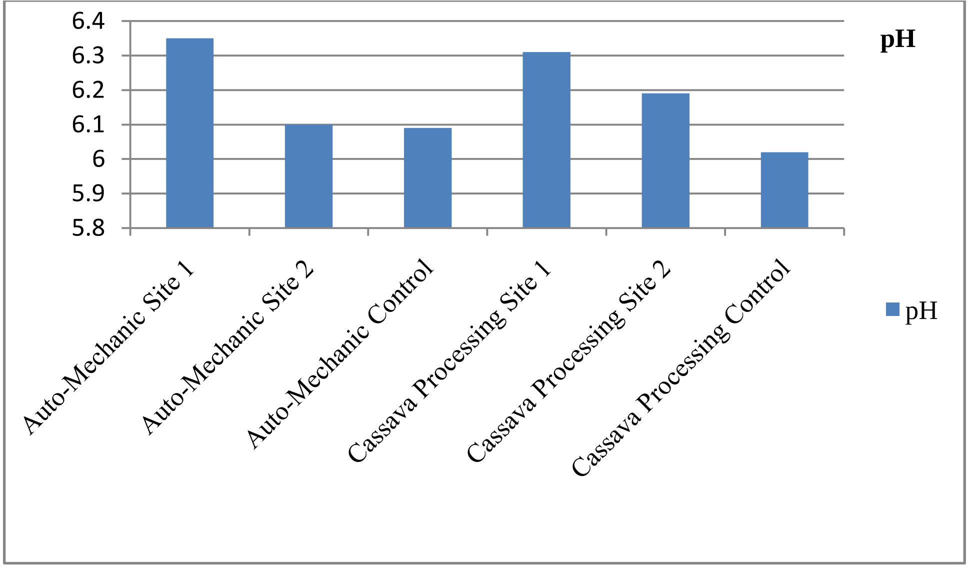

Fig. 11 Effects of the Anthropogenic Activities on Soil pH

4. CONCLUSIONS

The research examined the impacts of anthropogenic activities (auto-mechanic and cassava processing) on some soil engineering properties (such as coefficient of friction, angle of repose, bulk density, particle density, porosity, moisture content, cation exchange capacity, pH), as it affects the human lives and the immediate environment. The following conclusions were made based on the results obtained from this research:

1. The wastes from these activities reduced the coefficient of static friction, bulk density, particle density, cation exchange capacity, pH while it leads to high levels of repose angle, porosity and moisture content of the soils.
2. The high level of heavy metals poses health risks to inhabitants of those areas that engage in backyard farming and also contaminate the nearby water sources.
3. These anthropogenic activities also have negative impacts on the environment and therefore call for strict regulation on the areas and how waste coming from these vicinities can be disposed of properly.

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