Changes in Physical and Chemical Properties of Soil in Timber Sawmill Dumpsite in Abakaliki, Abakaliki Southeastern, Nigeria

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ABSTRACT

A study to assess changes in the physical and chemical properties of soil in timber sawmill dumpsite was carried out in Abakaliki between 2007 and 2008. Results showed that soil textural class remained sandy loamy. The lowest soil bulk density of 1.34 and 1.20 g cm⁻³ were obtained in the unburnt dumpsite in 2007 and 2008 resulting in 12% and 20% decline in 2007 and 2008 in the unburnt dumpsite relative to cropped land. The total porosity and gravimetric moisture content was a reverse of the soil bulk density. Higher total porosity and gravimetric moisture content were obtained in the unburnt and burnt dumpsites in that order relative to the fallow and cropped land. Infiltration rate followed the same trends as total porosity of the various sites. The lowest infiltration rate 15.02 and 35.82 mm hr⁻¹ was observed in the cropped land. The soil pH decreased with depth in the dump and non-dumpsite but became strongly acid at 30 – 60 cm and 60 – 90 cm depths. The order of soil organic matter content was unburnt dumpsite > burnt dumpsite > fallow > cropped land. The available P and exchangeable K and Ca were highest in the burnt dumpsite. Heavy metals (Zn, Cu, Fe, and Pb) increased with time in the burnt and unburnt dumpsites but decreased in the cropped land. More concentration of heavy metals was observed in the 0 – 30 cm soil depth. The relative performance of maize
grown on soils of the dump and non-dumpsites showed that there was better growth in the dump sites soils. However, the concentrations of heavy metals on tissue were found to be within normal range. Therefore, long term dumping of sawmill waste can influence soil properties and productivity.

**Keywords:** Burnt dumpsite; cropped land; fallow; heavy metals; timber sawmill and unburnt dumpsite.

1. **INTRODUCTION**

The soil has traditionally been an important medium for organic waste disposal. Within some limits, such wastes enhance soil fertility and can improve or degrade the physical properties of soil. Solid waste handling and disposal is a major environmental problem in many urban centers in Nigeria [1]. When waste management is properly carried out and carefully monitored to supply the crop fertilizer need by urban farmers, it reduces their cost of production. However, lack of effective waste management in over populated cities can have substantial negative effects that include fetid water ways emitting stench from sewage, spreading diseases and harbouring vehicles that spew treadered exhaust into dust filled air [2]. At a time when environmental quality and food production are of major concern, a better understanding of the behaviour of elements in the air-soil-plant system seems to be particularly important. [3] observed that soil differs in their response to organic waste amendments and that it is important to investigate more closely the influence of these organic and inorganic wastes on a range of soil physical and chemical properties.

Waste amended soils have been reported to have high organic matter [4]. Soil organic matter influences soil aggregation status and aggregate stability [5] and it can reduce soil bulk density, increase total porosity and hydraulic conductivity [6]. In addition, organic matter is very important to changes in soil management and strongly influences properties affecting resilience, such as soil structure, nutrient status and microbial population. Soil organic matter content is an early indicator of overall soil quality especially in cultivated soils [7]. However, continuous disposal (dumping) of wastes in soil may bring about increase in heavy metal levels, which may adversely impact soils, crops and human health [8].

In Abakaliki, timber generates a lot of wastes such as wood shavings and dust particles. Both types are used as fuel energy for cooking, in poultry farms as litters and in most cases applied in farmland as organic manure. However, the ever increasing level of the wastes in the timber saw mill site has resulted in the existence of heaps and mountains of these wastes. In some occasion these wastes are set on fire to reduce their presence. It is increasing on the basis of this ever growing wastes from the ever timber industry in Abakaliki that necessitated this study.

The objective of this study was to evaluate the changes in the soil physical and chemical properties of the dumpsite.

2. **MATERIALS AND METHODS**

The study was conducted in the dumpsite of the timber saw mill (burnt and unburnt) in Abakaliki, Ebonyi State, Southeast of Nigeria in the cropping seasons of 2007 and 2008. Abakaliki is situated at Latitude 06°25′N and Longitude 08°65′E, with an elevation of about
400 m above sea level. The sites were located along Abakaliki – Afikpo road and had been in existence for 10 years. The mean annual rainfall is between 1450 – 1800 mm, with a relative humidity between 80–90% and mean annual temperature between 27–31ºC [9].

A reconnaissance survey was carried out in the study area in the March, 2007. Similarly, soil samples were collected in the study area in March 2007 and March 2008. The sites chosen include:

- Dumpsite for burnt timber sawmill waste.
- Dumpsite for unburnt timber sawmill waste.
- Farm land 50 m from dumpsites (inter – cropped with yam, cassava, maize, okro and pumpkin).
- Four – year fallow land 30 m from the dumpsite of the unburnt timber sawmill waste. Dominant grasses and shrubs include *Imperata cylindrica*, *Andropogon spp*, *Bidens pilosa*, *Tridax spp*, *Panicum maximum* etc.

Profile pits measuring 1 m by 1 m by 1 m (in the order of length by width by depth) were dug in each site. Soil samples were taken from each pit at 0 – 30 cm, 30 – 60 cm and 60 – 90 cm depths, bulked separately and excess dust in the soil samples from burnt and unburnt dumpsites profile pits were removed by blowing them with air from an pressure machine as described by [10]. Soil samples from each pits and different depths were analysed for particle size distribution and chemical properties.

Ten undisturbed core samples taken at 0 – 10 cm in each site were analysed for bulk density, while another ten core samples were also taken to measure gravimetric moisture content.

### 2.1 Analytical Methods

Bulk density was determined by the method described by [11], total porosity was calculated from the soil bulk density as the fraction of total volume not occupied by soil assuming a particle density of 2.65 g cm$^{-3}$. Gravimetric moisture content was determined [12]. Water infiltration was measured using the double ring infiltrometer as described by [13]. In this method, double ring infiltrometer cylindrical metals of diameter 30 cm and 40 cm for the inner and outer rings, respectively and a height of 30 cm were driven 10 cm into the soil. Water was ponded at contact depths inside the two rings and the rate at which water moves into the soil measured.

The composite auger soil samples from the different depths of the four sites were analysed for particle size distribution [14]. Soil pH was analysed in soil-water suspension (1:2.5) [15], organic C was determined by Walkley and Black method [16], organic matter was obtained by multiplying organic C by a factor 1.724. Lignin was assessed by the method described by [17], in which cellulose was destroyed using 72% H$_2$SO$_4$, and lignin determined by weight-loss upon ashing. Total N was determined by the modified kjeldahl method [18], available phosphorus was determined using Bray-2 (P) [19], exchangeable K, Ca, and Mg was determined by Tel and Hagarty [20] and Cation exchange capacity (CEC) was determine by the method described by Thomas [21]. Heavy metals (Zn, Cu, Fe and Pb) were analysed [22].
2.2 Maize Growth Experiment

Maize growth experiment established in a complete randomized design was established using soils from each site. Soil samples were collected at a depth of 0 – 20 cm from each site, composited and 4 kg soil were bagged in a 26.41 cm³ polythene bags each perforated both at the sides and bottom to provide drainage. Maize seeds (Oba super 2) were planted at two seeds per bag and thinned to one stand per bag. The plants were allowed to grow without any soil amendments (like fertilizer). The agronomic parameters studied were plant height and shoot dry weight at tasseling. Nutrient content of the maize straw (N, P and K) were analysed using the procedure outlined by [23]. Available heavy metals (Zn, Cu, Fe and Pb) in plant tissue were also analysed. Data obtained from this study were analysed using least significant difference (LSD) as described by [24].

3. RESULTS AND DISCUSSION

The chemical composition of the burnt and unburnt sawmill waste varied (Table 1). The pH of the burnt was alkaline while the unburnt was strongly acid. The organic C, total N and lignin content of the burnt sawmill waste were considerably lower than the values obtained in the unburnt sawmill waste. But the exchangeable K and Ca were relatively higher by 18% of K and 20% Ca over the unburnt. Similarly, CEC of the burnt sawmill waste was higher than the unburnt by 12%. Also, the available P was much higher in the burnt than the unburnt. The high lignin content of the unburnt sawmill waste could present problem during decomposition when applied to the soil. However, heavy metals occurred more in the unburnt than the burnt sawmill wastes. The low values of heavy metals as observed in the burnt sawmill could be advantageous in terms of absorption and accumulation in plants.

Table 1. Chemical components of the burnt and unburnt sawmill waste

| Test Parameter | Burnt Value | Unburnt Value |
|----------------|-------------|---------------|
| pH (H₂O)       | 9.1         | 5.3           |
| C (%)          | 3.04        | 23.9          |
| Total N (gkg⁻¹)| 1.13        | 3.27          |
| P (mgkg⁻¹)     | 55.46       | 47.91         |
| C/N            | 26.9        | 73.08         |
| Ln (mgkg⁻¹)    | 8.74        | 33.96         |
| K (gkg⁻¹)      | 20.04       | 13.84         |
| Ca (gkg⁻¹)     | 68.09       | 46.28         |
| Mg (gkg⁻¹)     | 27.01       | 31.40         |
| CEC (cmolg⁻¹)  | 115.14      | 91.52         |
| Zn (mgkg⁻¹)    | 10.2        | 23.3          |
| Cu (mgkg⁻¹)    | 14.7        | 13.84         |
| Fe (mgkg⁻¹)    | 69.61       | 119.53        |
| Pb (mgkg⁻¹)    | 3.78        | 10.14         |

*Ln = Lignin

3.1 Soil Properties

The profile pits of the study sites were shallow with unconsolidated parent materials within one metre of the soil surface. The bedrock geology of the sites had shale residuum. In the unburnt timber sawmill dumpsite, the soil profile showed evidence of pedo transfers and
argillan features were common. Clay and Silt increased slightly with depth in the unburnt dumpsite (Table 2). This did not change the textural class (sandy loam) because sand separates remained moderately high. The results obtained in this study tended to confirm that soil texture was normally regarded as one of the permanent features of the soil, which hardly changes. The sandy loam texture of the dumpsite was recommended by [25] as being suitable for waste disposal. However, [1] were of the opinion that soil with greater than 70% sand was highly permeable and will allow large quantities of leachates to pass through. This was not so in the results obtained in this study (Table 2).

### Table 2. Particle size distribution at different depths in the dump and non-dump sites

| Sites            | Sand (%) | Silt (%) | Clay (%) | Textural class |
|------------------|----------|----------|----------|----------------|
|                  | 1st      | 2nd      | 1st      | 2nd            | 1st           | 2nd           |
| 0 – 30 cm        |          |          |          |                |               |               |
| Burnt            | 70       | 70       | 18       | 18             | 12            | 12            | SL            | SL             |
| Unburnt          | 70       | 70       | 16       | 16             | 14            | 14            | SL            | SL             |
| Fallow           | 72       | 71       | 14       | 15             | 16            | 16            | SL            | SL             |
| Cropped land     | 75       | 73       | 14       | 16             | 11            | 11            | SL            | SL             |
| 30 – 60 cm       |          |          |          |                |               |               |               |               |
| Burnt            | 70       | 70       | 16       | 16             | 14            | 14            | SL            | SL             |
| Unburnt          | 64       | 64       | 20       | 20             | 16            | 16            | SL            | SL             |
| Fallow           | 70       | 70       | 14       | 14             | 16            | 16            | SL            | SL             |
| Cropped land     | 72       | 71       | 18       | 18             | 10            | 11            | SL            | SL             |
| 60 – 90 cm       |          |          |          |                |               |               |               |               |
| Burnt            | 68       | 68       | 16       | 16             | 16            | 16            | SL            | SL             |
| Unburnt          | 64       | 64       | 20       | 20             | 16            | 16            | SL            | SL             |
| Fallow           | 70       | 70       | 14       | 14             | 16            | 16            | SL            | SL             |
| Cropped land     | 70       | 77       | 18       | 18             | 12            | 12            | SL            | SL             |

*1st* = 2007, *2nd* = 2008, SL = Sandy Loam

### 3.2 Soil Physical Properties

Table 3 shows the results of some selected soil physical properties of the dumpsites and non-dumpsites. There were differences in soil bulk density of the dumpsites and non-dumpsites. The lowest soil bulk density of 1.34 and 1.20 g cm$^{-3}$ occurred in the unburnt dumpsite. Cropped land had the highest soil bulk density of 1.70 and 1.81 g cm$^{-3}$. Soil bulk density declined by 12% in 2007 and 20% in 2008 in the unburnt dumpsite relative to the cropped land. The fallow and cropped lands had soil bulk densities, which were relatively higher than the burnt and unburnt dumpsites. The soil bulk densities of both fallow and cropped lands were significantly different (p = .05) to any of the dumpsites in the two years study. The differences in the soil bulk density between dump and non-dump site soils may be due to differences in organic matter content of the sites (Table 4). This is because higher organic matter helped to reduce the matrix [1]. Similar findings were made by [26]. Total porosity of the different sites was a reverse of the soil bulk density. Higher total porosity was obtained in the two years study in the burnt and unburnt dumpsites relative to non-dumpsites. The unburnt dumpsite was significantly different (p = .05) to the burnt dumpsite and the non-dumpsites. This implied that the sawmill wastes (burnt and unburnt) provided better aeration than the non-dumpsites. Similarly, gravimetric moisture content was highest in the unburnt dumpsite by 28% and 45% relative to the fallow land in 2007 and 2008, respectively and 45% and 46% over the cropped land for the same periods. Studies on water retention and soil physical properties [27], have shown that soil water retention is due
to absorption rather than capillary action and is thus influenced less by the structure and more by the texture and composition of the soil material. It implied therefore that the sawmill waste contributed to the colloidal nature of soil. Infiltration process was a reflection of the porosity of the various sites. The lowest infiltration rate of 15.02 and 35.82 mm hr\(^{-1}\) were obtained in cropped land in 2007 and 2008, respectively. The inability of the cropped land to improve infiltration rate could be attributed to high soil bulk density and destroyed structure resulting from tilling, which decreased porosity. There was significant difference (p=.05) between the unburnt and other treatments.

The ability of organic waste to improve infiltration depends among other things on improved aggregation [28], pore space and organic matter status [26]. The results obtained in this study both in Table 3 and Table 6 confirmed these findings. Therefore, the effect of the sawmill wastes either burnt or unburnt could effectively influence the soil physical properties relative to the fallow and cropped lands without waste and have potentials to sustain the physical conditions of the soil.

Table 3. Soil Physical Properties of the dump and non-dump sites (0 –10 cm)

| Sites          | BD (gcm\(^{-3}\)) | TP (%) | GMC (%) | Infiltration (mm hr\(^{-1}\)) |
|---------------|-------------------|--------|---------|-------------------------------|
|               | 1\(^{st}\)        | 2\(^{nd}\) | 1\(^{st}\) | 2\(^{nd}\) | 1\(^{st}\) | 2\(^{nd}\) | 1\(^{st}\) | 2\(^{nd}\) |
| Burnt         | 1.42              | 1.35   | 46      | 49   | 37   | 48   | 60.36 | 73.36 |
| Unburnt       | 1.34              | 1.20   | 49      | 55   | 49   | 68   | 76.98 | 97.49 |
| Fallow        | 1.63              | 1.51   | 37      | 43   | 28   | 30   | 37.55 | 59.12 |
| Cropped land  | 1.09              | 1.81   | 36      | 32   | 19   | 25   | 15.01 | 35.82 |
| LSD (0.05)    | 0.19              | 0.16   | 2.24    | 2.73 | 2.11 | 2.31 | 4.57  | 6.41  |

*BD = Bulk density, TP = Total porosity, GMC = Gravimetric moisture content, LSD = Least significant difference, 1\(^{st}\) = 2007, 2\(^{nd}\) = 2008

3.3 Soil Chemical Properties

The pH of the various dumpsites ranged from extremely acid to moderately acid (Table 4). At 0 – 30 cm soil depth, the soil pH of the burnt timber sawmill waste dumpsite was moderately acid. But between 30 – 60 cm and 60 – 90 cm soil depths, soil pH became strongly acid. In the unburnt timber sawmill waste dumpsite, the soil pH varied greatly from very strongly acid in 2007 in the three soil depths to extremely acid in 2008 in the 60 – 90 cm soil depth. In the cropped and fallow land the soil pH was extremely acid. The high soil pH values obtained in the burnt dumpsite could be as a result of the ash property. [29] reported that ash increased soil pH, due to the abundance of alkaline earth materials. The high pH of the burnt timber sawmill waste (Table 1) could be responsible for the increased values obtained in the dumpsite. Soil organic matter content of 11% and 14% were obtained in the 0 – 30 cm soil depth of the unburnt dumpsite. Among the different dumpsite, soil organic matter content was in the order of unburnt dumpsite > burnt dumpsite > fallow land > cropped land. Therefore, cropped land had the lowest soil organic matter in the three soil depths studied. The decline in soil organic matter could be due to continuous cultivation. [27] in their study found that intensive tillage increases the loss of organic matter by speeding decomposition, while tillage primarily burns younger organic matter. The high soil organic matter content of the unburnt dumpsite could be related to the level of organic C in the unburnt timber sawmill waste (Table 1). Also, it could be attributed to continuous reception of fresh timber waste and improved decomposition. The improved soil organic matter obtained in the dumpsites relative to the fallow and cropped land could be taken as a crude measure of the fertility status of the soils of the dumpsites.
Total soil N was also highest in the unburnt dumpsite in the three soil depths (Table 4). The value of the soil total N decreased with depth. Between 0 – 30 cm and 60 – 90 cm, the percent decrease in soil N was 30% and 50% in the burnt dumpsites and 26% and 28% in the unburnt dumpsites for 2007 and 2008, respectively. Also, soil N increased at 0 – 30 cm soil depth and this soil depth had soil total N relative to cropped land by 68% and 88% for burnt and 80% and 90% for the unburnt. The total soil of N of the unburnt dumpsite was significantly different (p = .05) relative to soil N in all the other sites in the three soil depths.

[30] working on sawdust ash and wood ash observed an increased soil N as a result of ash application, but this was not so in this study as more soil N was observed in unburnt dumpsites. But in comparison to the fallow and cropped land the burnt dumpsite showed significant different (p = .05) to the two sites in 2007 and 2008. The C/N ratio was consistently higher in the burnt dumpsite relative to the unburnt in the 30 – 60 cm and 60 – 90 cm soil depths. The decline in C/N ratio of unburnt dumpsite of these soil depths irrespective of organic C content was dependent on the total soil N values. Soil depths with lower soil N values had higher C/N ratios (Table 4). In the second year of the study, the C/N ratio of the fallow land was significantly different (p = .05) relative to the other sites. This could be attributed to decline in the N level in the two lower depths. Available P increased significantly in the burnt dumpsite than was observed in both the fallow and cropped land. The relative level of available P in the burnt dumpsite could be linked with the values obtained in the chemical composition of burnt sawmill waste (Table 1). The available P decreased in all sites with increasing depth of the profile with the lowest available P decreased in all sites with the lowest available P of 2.61 mgKg\(^{-1}\) and 3.08 mgKg\(^{-1}\) obtained in the cropped land. The available P in the burnt dumpsite was significantly different (p = .05) relative other to the sites in the three profile depths. The changes in the soil pH brought about by ash content of the burnt sawmill waste might have influenced the level of availability of P at the different soil depths, since the availability of P and its solubility is pH dependent. The exchangeable soil K and Ca tended to be highest in the burnt dumpsite but the exchangeable Mg was observed to be the highest in the unburnt dumpsite (Table 5). The result obtained in this study over the level of Mg on the unburnt dumpsite differed from that of [31] and [32] who observed increased soil exchangeable K, Ca and Mg in Nigeria with ashing from sawdust. The level of exchangeable bases in this study might probably be responsible to the improved pH values of the dumpsites relative to the non-dumpsites. Higher exchangeable K, Ca and Mg in the dumpsites relative to non-dumpsite soils implied that dumpsite soils have more exchangeable cations, which is a positive productivity indicator. The increase in soil nutrient contents in the dumpsites of the sawmill waste whether burnt or unburnt might also be attributed to enhanced microbial activities [33]. The decline in the soil nutrient content with depth confirms [25] assertion that sandy loam soils were most suitable as dumpsites. But it did not agree with [1] who reported that leaching could lead to loss of nutrients to lower depths in sandy loam soils, since nutrient decline were more noticeable in the lower soil depths.
Table 4. Soil chemical properties of the dump and non-dump sites at different depths

| Sites            | pH (H$_2$O) | Org C (%) | OM (%) | Total N (gkg$^{-1}$) | C/N | Avl.P (mgkg$^{-1}$) |
|------------------|-------------|-----------|--------|----------------------|-----|---------------------|
|                  | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| Burnt            |     |     |     |     |     |     |     |     |     |     |     |     |
| 0 – 30 cm        | 5.9 | 6.0 | 3.25 | 4.11 | 6.07 | 7.08 | 0.42 | 0.67 | 8.38 | 61.3 | 36.28 | 46.80 |
| Unburnt          | 5.3 | 5.7 | 6.59 | 7.84 | 11.36 | 13.52 | 0.71 | 0.92 | 9.28 | 82.5 | 27.32 | 32.11 |
| Fallow           | 5.0 | 4.9 | 1.88 | 2.04 | 3.24 | 3.52 | 0.39 | 0.51 | 4.82 | 40.0 | 12.67 | 19.45 |
| Cropped land     | 4.8 | 4.6 | 0.16 | 0.28 | 2.21 | 1.86 | 0.08 | 0.05 | 3.52 | 32.0 | 7.20 | 8.17 |
| LSD (0.05)       | NS  | NS  | 0.36 | 0.41 | 1.08 | 1.26 | 0.04 | 0.06 | 1.11 | 0.95 | 1.74 | 2.32 |
| 30 – 60 cm       |     |     |     |     |     |     |     |     |     |     |     |     |
| Burnt            | 5.6 | 5.7 | 1.63 | 1.98 | 2.80 | 3.41 | 0.21 | 0.39 | 7.76 | 50.8 | 27.37 | 32.60 |
| Unburnt          | 5.2 | 5.0 | 2.49 | 3.21 | 4.29 | 5.53 | 0.55 | 0.63 | 4.53 | 51.0 | 20.64 | 29.04 |
| Fallow           | 4.8 | 4.9 | 0.64 | 0.97 | 1.10 | 1.67 | 0.12 | 0.15 | 5.33 | 64.7 | 10.68 | 17.22 |
| Cropped land     | 4.5 | 4.4 | 0.09 | 0.12 | 0.16 | 0.21 | 0.06 | 0.08 | 1.50 | 15.0 | 3.21 | 5.07 |
| LSD (0.05)       | NS  | NS  | 0.08 | 0.11 | 0.14 | 0.17 | 0.02 | 0.01 | 1.02 | 0.96 | 2.16 | 2.05 |
| 60 – 90 cm       |     |     |     |     |     |     |     |     |     |     |     |     |
| Burnt            | 5.4 | 5.5 | 1.42 | 1.30 | 2.45 | 2.24 | 0.19 | 0.22 | 7.47 | 59.1 | 16.48 | 19.66 |
| Unburnt          | 5.0 | 4.8 | 2.12 | 2.75 | 3.66 | 4.74 | 0.41 | 0.52 | 5.17 | 52.9 | 11.21 | 15.35 |
| Fallow           | 4.6 | 4.4 | 0.49 | 0.63 | 0.84 | 1.09 | 0.07 | 0.09 | 7.00 | 70.0 | 9.45 | 10.20 |
| Cropped land     | 4.3 | 4.2 | 0.08 | 0.09 | 0.14 | 0.16 | 0.02 | 0.04 | 4.00 | 45.0 | 2.61 | 3.08 |
| LSD (0.05)       | NS  | NS  | 0.04 | 0.06 | 0.03 | 0.02 | 0.003 | 0.005 | 1.35 | 1.12 | 1.48 | 1.36 |

*OrgC = Organic Carbon, OM = Organic Matter, C/N = Carbon: Nitrogen ratio, Avl.P = Available Phosphorus, 1$^{st}$ = 2007, 2$^{nd}$ = 2008
The results of the study also showed that the cation exchange capacity (CEC) was highest in the dumpsites relative to the soils of the fallow and cropped lands (Table 5). CEC of 7.29 and 6.68 cmolkg\(^{-1}\) in 2007 and 10.15 and 9.05 cmolkg\(^{-1}\) in 2008 were obtained in the upper layer (0 – 30 cm) of the soils of the burnt and unburnt dumpsites, respectively. In the same soil layer (0 – 30 cm) fallow land and cropped land had CEC values of 3.56 and 2.84 cmolkg\(^{-1}\) in 2007 and 4.65 and 3.74 cmolkg\(^{-1}\) in 2008, respectively. Although there was decrease in the CEC values with increase in depth, the dumpsites had higher CEC values relative to the fallow and cropped lands (even at 60 – 90 cm depth). The high soil organic matter content in the dumpsites probably contributed to the high exchangeable bases and in turn high CEC values. [34] in their studies found that organic matter tended to buffer soils and cause the release of exchangeable cations during mineralization of organic matter.

Table 5. Exchangeable K, Ca, Mg and CEC at different depths of the dump and non-dump sites ( cmolkg\(^{-1}\))

| Sites          | K  | Ca  | Mg  | CEC |
|----------------|----|-----|-----|-----|
|                | 1st| 2nd | 1st | 2nd |
| 0 – 30 cm      |    |     |     |     |
| Burnt          | 0.84| 1.02| 5.29| 7.77|
| Unburnt        | 0.57| 0.82| 4.34| 6.81|
| Fallow         | 0.43| 0.59| 2.87| 3.19|
| Cropped land   | 0.35| 0.44| 2.09| 2.65|
| LSD (0.05)     | 0.11| 0.16| 1.07| 1.31|
| 30 – 60 cm     |    |     |     |     |
| Burnt          | 0.66| 0.88| 4.24| 5.92|
| Unburnt        | 0.46| 0.64| 3.68| 5.11|
| Fallow         | 0.21| 0.29| 1.72| 2.45|
| Cropped land   | 0.16| 0.20| 1.31| 1.66|
| LSD (0.05)     | 0.05| 0.09| 0.93| 1.06|
| 60 – 90 cm     |    |     |     |     |
| Burnt          | 0.40| 0.58| 3.66| 4.98|
| Unburnt        | 0.30| 0.52| 3.19| 4.37|
| Fallow         | 0.14| 0.19| 1.01| 1.31|
| Cropped land   | 0.08| 0.12| 0.46| 0.92|
| LSD (0.05)     | 0.01| 0.04| 0.51| 0.88|

*CEC = Cation exchange capacity, 1st = 2007, 2nd = 2008

The results of the heavy metal content of the soils of the dumpsites and non-dumpsites are shown in Table 6. Heavy metals studied were found to increase with time in the burnt and unburnt sites and the fallow land but decreased in the cropped land in the second year of study. The relative increase in Zn, Cu, Fe and Pb in dumpsites over the non-dumpsites may be attributed to the sawmill waste. However, the heavy metals were more concentrated in the upper layers (0–30 cm) of both the dumpsites and non-dumpsites. [35] showed that surface soils are better indicators for metallic burdens. The Zn content of the dumpsites were 45.10 and 54.4 mgKg\(^{-1}\) in burnt dumpsites for the two years, respectively; 72.64 and 88.14 mgKg\(^{-1}\), in the unburnt dumpsites in the same period (2007 and 2008), respectively. These values were below the normal range (10–3000 mgkg\(^{-1}\)) obtained in the soil [36]. Among the heavy metals the least accumulated metal in the soil was Cu. The values obtained in both dumpsites and non-dumpsites were found to be within normal range in soil (2 – 250 mgKg\(^{-1}\) as presented by Kabata-Pendias, 1984). The Cu content of the unburnt dumpsites was found to be significantly different (p = .05) relative to the rest of the sites in the two years.
studied. The Fe content of the sites for two years respectively were 116.49 and 121.35 mgKg\(^{-1}\) in the burnt dumpsites, 267.91 and 299.04 mgKg\(^{-1}\) in the unburnt dumpsites, 96.88 and 104.12 mgKg\(^{-1}\) in the fallow land and 70.43 and 61.08 mgKg\(^{-1}\) in the cropped land. The unburnt dumpsite Fe level was 47% and 49% relative to the fallow land in 2007 and 2008 respectively, and 59% and 63% over the cropped land for the same period. However, Fe is a nutrient required in abundance by both plants and animals and its toxicity is not common. Pb in the soils of the dumpsite and non-dumpsite ranged from 27.51 mgKg\(^{-1}\) in the cropped land to 66.41 mgKg\(^{-1}\) in the unburnt dumpsite in 2007, 21.63 mgKg\(^{-1}\) in the cropped land to 75.29 mgKg\(^{-1}\) in the unburnt dumpsite in 2008. The values obtained in any of the site were found within the normal range (2 to 300 mgKg\(^{-1}\)) according to Kabata-Pendias and Pendias (1984).

Table 6. Heavy metals content of the dump and non-dump sites (mgkg\(^{-1}\))

| Sites           | Zn 1st | Zn 2nd | Cu 1st | Cu 2nd | Fe 1st | Fe 2nd | Pb 1st | Pb 2nd |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Burnt           | 45.10 | 54.40 | 18.22 | 19.45 | 116.49| 121.35| 51.28 | 69.17 |
| Unburnt         | 72.64 | 88.14 | 32.07 | 36.28 | 267.91| 299.04| 66.41 | 75.29 |
| Fallow          | 29.31 | 31.17 | 11.34 | 12.07 | 96.88 | 104.12| 38.77 | 46.04 |
| Cropped land    | 22.04 | 18.68 | 9.24  | 6.24  | 70.43 | 61.08 | 27.51 | 21.63 |
| LSD (0.05)      | 2.14  | 2.47  | 1.66  | 1.42  | 8.04  | 9.84  | 3.12  | 3.66  |

*St = 2007, 2nd = 2008*

### 3.4 Growth Performance of Maize

Table 7 shows data on growth and performance of maize. Soils from both burnt and unburnt sawmill waste dumpsites increased significantly (p=.05) plant height and shoot dry weight relative to that of fallow and cropped lands. The highest plant height of 80 cm was obtained from maize plants grown in soils of the unburnt dumpsite in 2008. Shoot dry weight tended to follow the same pattern as plant height, implying that plants with high vegetative growth also had high shoot dry weight. The results obtained in this study suggested that availability of nutrient (Table 4) contributed to the performance of maize. Growth of maize in the soils of the burnt dumpsite increased in P and K content of the plant tissues. These were significantly different (p = .05) to all the other treatments. More N and Mg occurred in the tissues of maize grown in the unburnt dumpsite soil. The value of N content of maize tissue from the unburnt dumpsite was significantly different (p=.05) relative to the other treatments.

Table 7. Crop performance with soils of the dump and non-dump sites

| Sites        | P/t (cm) 1st | SDW (gplant\(^{-1}\)) 1st | N (gkg\(^{-1}\)) 1st | P (mgkg\(^{-1}\)) 1st | K (mgkg\(^{-1}\)) 1st |
|--------------|-------------|--------------------------|----------------------|-----------------------|-----------------------|
|              | 2nd |     | 2nd |     | 2nd |     | 2nd |     | 2nd |     | 2nd |     | 2nd |     |
| Burnt        | 71   | 76  | 51  | 58  | 8.7 | 8.9 | 4.8 | 5.2 | 1.34| 1.49|
| Unburnt      | 74   | 80  | 52  | 61  | 11.8| 13.2| 3.6 | 4.1 | 1.06| 1.02|
| Fallow       | 61   | 66  | 40  | 46  | 6.3 | 6.7 | 2.3 | 2.7 | 0.92| 0.99|
| Cropped land | 43   | 52  | 31  | 39  | 1.4 | 1.11| 1.8 | 1.9 | 0.50| 0.41|
| LSD (0.05)   | 4.07 | 4.24| 2.37| 2.50| 0.81| 1.02| 0.45| 0.72| 0.09| 0.12|

*P/t = Plant height, SDW = Shoot dry weight, 1st = 2007, 2nd = 2008*
Table 8 shows that there is a significant difference \( p = .05 \) in heavy metals content of plant tissues in the various sites studied. The concentration of Zn in the plant tissue was very low ranging between 6.1 and 8.8 mg Kg\(^{-1}\) in the cropped land and unburnt dumpsite in 2007 and 4.5 and 21.4 mg Kg\(^{-1}\) in the same site in 2008, respectively. Cu content in the plant tissue was the lowest among the heavy metals, with the highest concentration of 5.6 mg Kg\(^{-1}\) occurring in 2007. [37] noted that Zn and Cu will be toxic to plants before they accumulate in sufficient tissue concentrations to affect animals or humans. As a result over application tends to kill and stunt plants. Therefore, the use of sawmill waste either as burnt or unburnt may not accumulate Cu to a poisonous concentration for animals and humans consuming maize. [38] postulated that an adult man requires 80 mg of Cu. Results from this study show that Cu uptake by maize does not constitute potential danger since observed values were within normal human range. The concentration of Fe in the plant tissue was relatively higher than any other heavy metals in this study. The lowest observed values of 34.8 and 29.9 mg Kg\(^{-1}\) in 2007 and 2008 were obtained from the cropped land and the highest of 72.76 and 95.68 mg Kg\(^{-1}\) in the same studied period were obtained in the unburnt dumpsite soil. This is in contrast with the findings of [39]; [40] and [41] who showed that addition of wastes did not promote significant changes in Fe content of plants. The high concentration Fe in the plant tissue does not pose any problem because Fe is not known to be injurious. Pb uptake by maize in this study was considerably low when compared with result of [42] who studied plant uptake of heavy metals in a garbage dumpsite at the university of Ife, Nigeria. He found that lead content of waterleaf leaves (Talinum triangulare) was 83.92 mg Kg\(^{-1}\) in dumpsite soil. The values of Pb content of maize plant tissue obtained in this study was similar to that of [41] and within the critical concentration of 30 – 300 mg Kg\(^{-1}\). However, the result obtained from this work differed from the opinion of [37], who postulated that Pb is not taken up by plants to any degree and that plants are not a major risk pathway for ingesting Pb.

### Table 8. Heavy metals content of the plant tissue (mgkg\(^{-1}\))

| Sites          | Zn 1st | Zn 2nd | Cu 1st | Cu 2nd | Fe 1st | Fe 2nd | Pb 1st | Pb 2nd |
|---------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Burnt         | 12.4   | 19.4   | 3.2    | 3.8    | 63.1   | 80.0   | 15.6   | 20.8   |
| Unburnt       | 18.8   | 21.4   | 5.6    | 5.3    | 72.6   | 95.68  | 19.9   | 23.1   |
| Fallow        | 9.5    | 11.6   | 1.87   | 2.7    | 43.9   | 52.8   | 10.7   | 12.4   |
| Cropped land  | 6.1    | 4.5    | 0.92   | 0.61   | 34.8   | 29.9   | 4.5    | 2.3    |
| LSD (0.05)    | 1.08   | 1.14   | 0.64   | 0.41   | 5.36   | 5.98   | 1.08   | 1.54   |

*\(^{1}\)1st = 2007, 2nd = 2008

### 4. CONCLUSION

Results obtained from this study have shown that continuous dumping sawmill waste significantly affected the physical and chemical properties. Significant improvement in soil bulk density, total porosity and moisture content were observed. Also, the infiltration rate improved positively. The chemical properties of the soil were on the increase. The soil organic matter, total and exchangeable Mg increased in the unburnt dumpsites while the pH changed from strongly acid to moderately acid in the burnt dumpsites. Burnt dumpsites soil had higher available P and exchangeable K and Ca were similarly increased. Although heavy metals were observed but there concentration was beyond the normal range. Therefore, the dumpsites did not pose much danger to animal health and could be harnessed to improve soil fertility and productivity.
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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