

## Effect of municipal solid waste leachate on the Geotechnical properties of soil

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**Abstract-**Waste Infiltrate precipitates through the solid waste and leaches the constituents from the decomposed waste while moving down through the dump. This causes the subsurface soil to be contaminated accompanying by deterioration of soil quality. The main objectives present paper to evaluate the impact of municipal solid waste on the properties of soil at Ugwuokwenu waste dump, Nnewi. Soil profile pits were excavated non disposal of solid waste site and solid waste disposal site. Physicochemical and geotechnical properties of soil were estimated. Impact of improper waste management and the effect on the physical and chemical properties of soil were also highlighted. Two soil profile pits from Ugwuokwenu open waste dump area and six other randomly selected sites (uncontaminated soil) but of known distance from the waste dump in Nnewi (representating control site) were excavated and collected. Soil physicochemical properties such as temperature, pH, electrical conductivity, alkalinity, particle size analysis, exchangeable acidity, total nitrogen, specific gravity, coefficient of permeability, shear strength, compressibility, moisture content (MC), organic matter (OM), calcium, magnesium, chloride, nitrate, sulphate, phosphate were studied using various analytical techniques. Results were compared. The study indicates that dumping of solid wastes has altered the physicochemical constituents. Soils at the disposal sites showed low pH, and high EC values in comparison to control sites. The values of natural moisture content, acidity, organic matter, specific gravity, nitrogen, phosphorus, nitrate, chloride, and silt, of the contaminated soil were generally higher compared to those of the uncontaminated soil samples. This indicates that due to disposal of solid waste the quality of the soil is reduced.

**Keywords:** Heavy metals, Leachate, .Soil quality, Ugwuokwenu, Waste disposal sites,

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### I. Introduction

Management and disposal of municipal solid waste (MSW) is one of the major environmental problems in cities. The current practices of the uncontrolled dumping of waste on the outskirts of towns/cities have created a serious environmental and public health problem. The menace of environmental pollution has been haunting the human world since early times and is still growing due to excessive population growth in developing countries. Urban Municipal Solid Wastes (MSW) is usually generated from human settlements, industries and commercial activities [1]. When these wastes are mixed up, they pose a threat for health and may also have long term effect on soil. According to Pattnaik and Reddy, (2009) [2], in majority of countries, most of the smaller units do not have any specific technique of managing these wastes. Improper MSW disposal and management have caused all types of pollution: air, soil, and water. In urban areas, MSW clogs drains, creating stagnant water for insect breeding during rainy seasons. Uncontrolled burning of MSW and improper incineration contributes significantly to urban air pollution. Municipal wastes in the form of garbage and waste from food processing plants have been incinerated or simply dumped [3] Little efforts have been made in order to improve the waste collection and disposal facilities. This has some grave consequences ranging from deterioration of soil quality to reduced plant diversity. The soil has traditionally been an important medium for organic waste disposal [4]. Soil organic matter influences the degree of aggregation and aggregate stability [5], and it can reduce bulk density and increase total porosity and hydraulic conductivity in heavy clay soils [6]. While many researchers have worked on the characterization and management of MSW [7] and their effect on groundwater, little attention has been given to the effect of these wastes on the geotechnical properties of soils [8]. Many researchers have also worked on the management and characterization of municipal solid waste in Nigeria together with their impacts on groundwater quality [9-12]. Owing to rapid development and unprecedented search for land, some urban dwellers have resorted to erecting houses on abandoned municipal solid waste disposal sites. Research is therefore needed to evaluate the

geotechnical properties of municipal solid waste contaminated soil. This study presents the geotechnical characterization of soil on a dumpsite in Nnewi. It aims to create a comprehensive geotechnical database of the soil, which includes its index and engineering properties.

### 1.1 Impact of improper solid waste dump disposal

In Nigeria, open dumpsites are common due to the low budget for waste disposal and non-availability of trained manpower. The contamination of soil by heavy metal can cause adverse effects on human health, animals and soil productivity [13]. Over many years, heavy metals have considerably damaged the soil quality in consequence of increased environmental pollution from industrial, agricultural and municipal sources [14]. Metals cause physiological disorders in soils as absorption through root system consequently retards plant growth and deprives it of vigour [15]. Waste carries different metals which are then transferred to plants by different ways [16]. Depending on the tendency of the contaminants they end up either in water held in the soil or leached to the underground water. Contaminants like Cd, Cu, Ni, Pb and Zn can alter the soil chemistry and have an impact on the organisms and plants depending on the soil [8].

### 1.2 Impact on soil

Precipitation that infiltrates through the municipal solid waste leach the constituents of the decomposed waste, and while moving down causes the subsurface soil to be contaminated by organic and inorganic solutes. And leachate from solid waste contains a considerable percentage of organic matter and elements essential to plants and may play a key role in the physical properties of soil. The addition of waste to soils is expected to trigger numerous physical, chemical, and biological processes that are strongly interrelated and are often synergistic, as occurs in processes that lead to the increased stability of soil aggregates and organic matter stocks [17]. Waste (sewage sludge) changes the soil physical properties, improving soil density, porosity, and water-holding capacity. Changes in the physical properties of soil may limit nutrient adsorption and/or absorption, water infiltration and redistribution, gas exchange, and root system development resulting in decreased agricultural production [17, 18]. Furthermore, the physical and chemical properties of clays, and consequently clay soils may vary depending on environmental changes. Deteriorating soil quality and decrease in vegetation abundance are grave consequences of open waste dumping which have resulted in growing public concern and effect on the geotechnical properties of soil.

## II. Materials And Methodology

### 2.1 Description of the Study Area

This study was performed on soil samples from dumpsites located in Ugwuokwenu, Nnewi in Nnewi North local government of Anambra state, Nigeria located about 22 km south east of Onitsha. (fig 2.1). Nnewi is the administrative headquarters of Nnewi North Local Government Area. It lies on latitude of 6° 1' N of the equator and 6°55' E [19], [20]. Nnewi town, a commercial city, has altitude that ranges from 105m to 300m above sea level [21], [22], [20]. Its commercial nature influences its rapid urbanization [23]. The climate is hot and humid; the year is divided into two major seasons namely: raining season (April to October) and dry season (November to March). The annual rainfall ranges from 165mm in April to 1025mm in September. The mean annual temperature ranges from 13°C in February to 22°C in October [22]. The soil of Nnewi, is derived from the sedimentary rocks of middle cretaceous to lower tertiary age and is of ferralitic type [24]. Although it is rich in free iron, its low mineral reserve and deep porous red colour conveys an illusion of homogeneity of its properties. There are many industries located in Nnewi. Among them are: the Innoson Motor Manufacturing factory, Ibeto battery factory, and Chicason group of industries, Tummy Tummy noddles etc. The town is divided into four quarters of Otolu, Uruagu, Umudim and Nnewichi. The Municipal waste dump is located on Ugwuokwenu, Uruagu, (an open reserved area very close to the auto market) and some randomly sampling points in other three quarters of Nnewi town as shown in fig 2.3. Figure 2.4 is the picture of the waste dump and sampling points, while figure 2.5 is the Google map of the dumping site.

The eight sampling sites were selected as follows: two samples from beneath the waste dump, two sites close to the MSW dumping site, and four randomly selected sites that are few kilometers away from the waste dump. The GPS of each of the six non deposit sampling point is as follows: **S1** (6° 01' 34'' N, 6° 54' 19'' E); **S2** (6° 01' 55'' N, 6° 54' 10'' E); **S3** (6° 01' 3'' N, 6° 53' 20'' E); **S4** (5° 59' 32'' N, 6° 56' 7'' E); **S5** (6° 01' 31'' N, 6° 55' 23''); **S6** (6° 01' 54'', 6° 53' 14'').



Fig. 2.1 Map of Anambra State indicating Nnewi North LGA

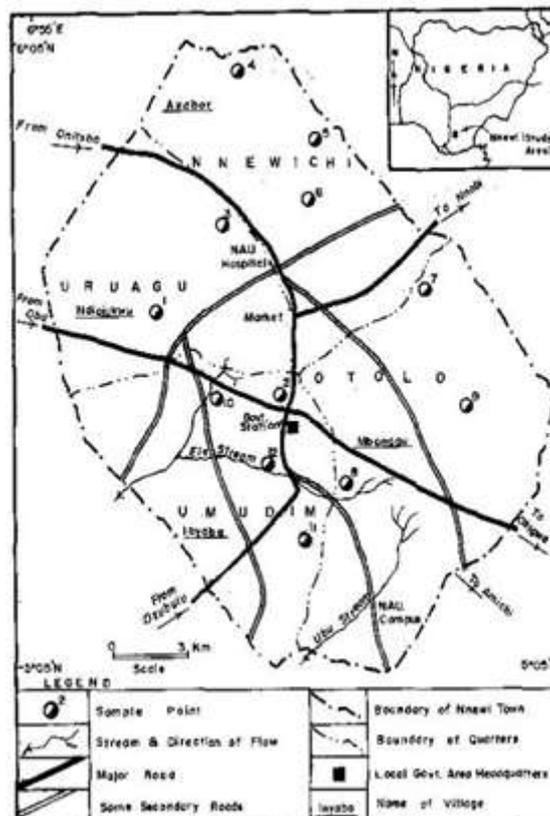


Fig 2.2 Map of Nnewi showing the soil sample across the town [46]

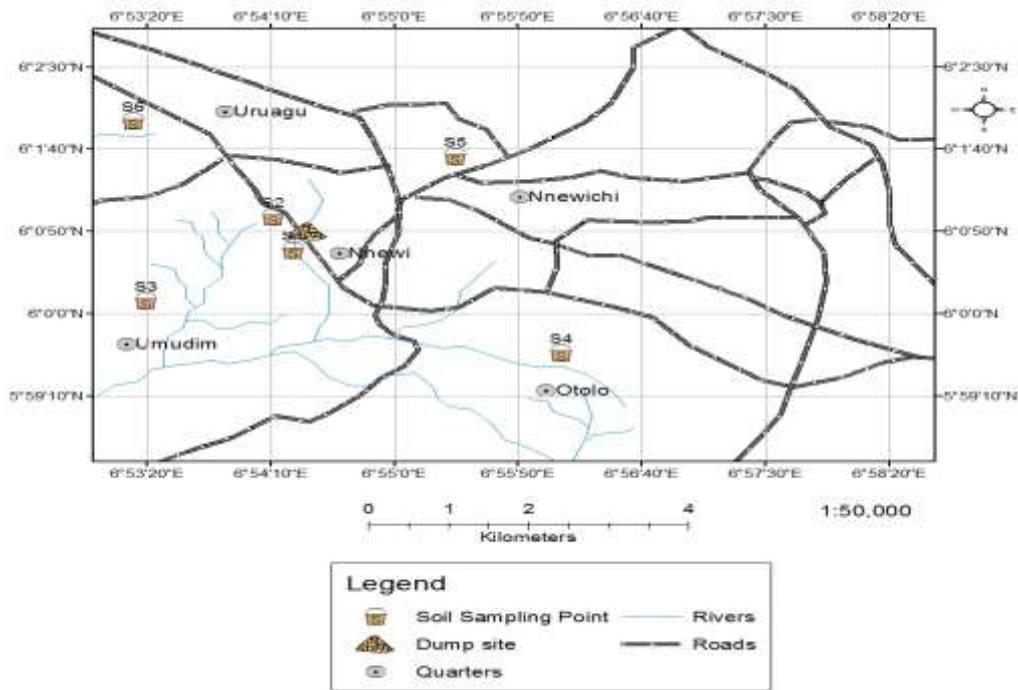


Fig. 2.3 sampling points



Fig. 2.4 Picture of Ugwuokwenu waste dump site



**Fig. 2.5 Google map of Ugwuokwenu waste dump site**

### 2.1 Methods of sample collection

Soil samples from the base of the landfill and six other different locations of the city designated S1 to S6 were excavated at a depth of 200cm below ground surface. The samples were collected using hand auger, put in black cellophane bags to protect them from sunlight so as to minimize any potential reaction (see fig. 2.6). These samples were transported to Springboard laboratory Awka where they were prepared for further analyses. Sample collection, preservation and analysis were done as per the APHA [25] standard methods. The analyses of different parameters were done within the next 48 hours which is recommended for better result in minimizing the quality change.



**Fig 2.6 Soil samples**

## 2.2 Soil Analysis

All the samples were analyzed for selected relevant physicochemical parameters and heavy metals. The parameters examined include, Temperature, pH, electrical conductivity, acidity, alkalinity, chloride, nitrate, phosphate, and heavy metals. The concentrations of cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), Nickel (Ni), and zinc (Zn) were determined using a SpectrAA-20 (Varian) Atomic Absorption Spectrometer (AAS). The geotechnical parameters that affect the soil quality like Natural Moisture Content, Specific gravity, Permeability, Shear strength, Compressibility, Organic matter, and Particle size distribution, were also determined in accordance with the guidelines in [26].

### **Determination of Ph**

pH was measured by the method of McLean (1982), [27].

#### **Procedure:**

A 10% W/V suspension of the sample in distilled water was prepared.

Mix thoroughly in a warring micro – blender, then measure the pH with a good pH meter.

### **Determination of Electrical Conductivity**

Procedure:

A 10 % W/V suspension of the sample in distilled water was prepared.

The conductivity cell was rinsed with at least three portions of the sample.

The temperature of the sample was then adjusted to  $20 \pm 0.1^\circ\text{C}$ .

The conductivity cell containing the electrodes was immersed in sufficient volume of the sample

The Conductivity meter was turned on and the conductivity of the sample recorded.

### **Determination of Acidity**

The exchangeable acidity was determined by the method proposed by Dewis and Fretias (1970) [28]

#### **Procedure:**

The pH of the specimen was measured and recorded with a calibrated pH meter.

A 50ml burette was cleansed and rinsed it with purified water, followed by several rinses with 0.025N NaOH.

The burette was filled with the NaOH solution, making sure there was no air bubbles in the tip and that the meniscus was readable at close to 0.00ml on the burette scale.

100.0ml of the sample to be analysed was measured into a 250ml Erlenmeyer flask with a little splashing or turbulence as possible.

Titrate to a phenolphthalein or metacresol – purple endpoint

At least duplicate (preferably triplicate) titrations on each sample being investigated was carried out

#### **Calculations**

Calculations of acidity are expressed in terms of milligrams of calcium carbonate per litre.

Acidity = (ml NaOH titrant) x (normality of NaOH) x (50,000) / (ml of sample)

### **Alkalinity**

50ml burette was several rinsed with 0.02 N HCL.

Burette was filled with the HCL solution, making sure there were no air bubbles in the tip, and that the meniscus was readable at close to 0.00ml on the burette scale.

100.0ml of the specimen to be analysed was measured into a 250ml Erlenmeyer flask.

This was titrated to a bromcresol green (pH = 4.5) end point.

Double (preferably triplicate) titrations on each sample being investigated was done.

Calculations of alkalinity are expressed in terms of milligrams of calcium carbonate per liter.

Alkalinity = (ml HCL titrant) x (normality of HCL) X (50,000) / (ml of water sample)

### **Determination of Organic Matter**

The mass of an empty, clean, and dry porcelain dish was determined and recorded as  $M_p$

Oven dried test specimen from the moisture content experiment was placed in the porcelain dish,

The mass of the dish and sort soil sample was determined and recorded as  $M_{ps}$ .

The dish was placed in a muffle furnace, and the temperature in the furnace was gradually increased to  $440^\circ\text{C}$

The specimen was left overnight in the furnace.

The porcelain dish was carefully removed using the tongs (the dish was very hot) and allowed to cool to room temperature

The mass of the dish containing the ash (burned soil) was determined and recorded as  $M_{pA}$

### **Calculation**

Determine the mass of the dry soil

$$M_D = M_{pDS} - M_p$$

Determine the mass of the ash in the soil.

$$M_A = M_{pA} - M_p$$

Determine the mass of organic matter

$$M_0 - M_D - M_A$$

Determine the organic matter (content)

$$OM = \frac{M_0}{M_D} \times \frac{100}{1}$$

### **Determination of specific gravity**

Specific gravity was analyzed using the core method and constant head methods, respectively, as proposed by Stolte (1997) [29]. Particle size analysis was by the method described by Gee and Bauder (1986) [30].

### **Determination of % Silt, Clay, Sand (Particle size analysis)**

- 30g of the soil sample into a 250ml beaker
- Fill the beaker with distilled water to 200ml mark.
- Wash the sand four times with distilled water. Prepare 25% sodium hexametaphosphate.
- Add 20ml of the solution and 200ml of distilled water
- Allow to stand for 16hrs (ie over night)
- Transfer into 0.2mm sieve. The sample samples on the sieve is the sand while the sample that pass through is the silt. Dry to a constant weight.

$$\% \text{ sand} = \frac{\text{Residue}}{\text{sample}} \times \frac{100}{1}$$

$$\% \text{ silt} = \frac{\text{Residue}}{\text{sample}} \times \frac{100}{1}$$

$$\% \text{ Clay} = 100 - (\% \text{ Silt} + \% \text{ Sand}).$$

### **Methods for the Heavy Metal Analysis**

Heavy metal analysis was conducted using Varian AA240 Atomic Absorption Spectrophotometer according to the method of APHA 1995 (American Public Health Association)

**Working principle:** Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

### **Dry Digestion**

#### **Digestion**

2g of the sample was weighed into a crucible and put into a muffle furnace for ashing at a temperature of 450<sup>0</sup>c for 2hours. The sample was removed from the furnace and allowed to cool. The dry ash was emptied into a 250ml beaker 20ml of 20% H<sub>2</sub>SO<sub>4</sub> was added, heated in a water bath for 20mins, filtered and made up to 50ml with distilled water and stored in a sample bottle for AAS macro and micro nutrient analysis.

### **Chloride Determination**

**Method:** Chloride analysed according to APHA standard method (APHA; 1998)

#### **Procedure**

A 100ml of the clear 10% sample was pipetted into an Erlenmeyer flask and the pH adjusted to 7-10 with either H<sub>2</sub>SO<sub>4</sub> or NaOH solution. Then 100ml of K<sub>2</sub>CrO<sub>4</sub> indicator solution was added with standard solution of AgNO<sub>3</sub> in a permanent reddish brown colouration. The AgNO<sub>3</sub> titrant was standardized and a reagent blank established. A blank of 0.2-0.3ml is usual for the method

Calculation

$$\text{Chloride conc} = \text{Titre value (x)} \times 10 = 10x\text{mg/l}$$

**Phosphate Determination**

**Methods:** Phosphate was measured using Standard Method 4500-P B.5 and 4500-PE (APHA; 1998)

**Procedure:** Exactly 100ml of the homogenized and filtered sample was pipetted into a conical flask. The same volume of distilled water (serving as control) was also pipette into another conical flask. 1ml of 18M H<sub>2</sub>SO<sub>4</sub> and 0.89g of ammonium persulphate were added to both conical flasks and gently boiled for 1 ½ hrs, keeping the volume of 25-50cm<sup>3</sup> with distilled water.

It was then cooled, one drop of phenolphthalein indicator was added and after neutralized to a faint pink colour with the 2M NaOH solution. The pink colour was discharged by drop wise addition of 2M HCl, and the solution made up to 100ml with distilled water. For the colorimetric analysis, 20ml of the sample was pipette into test tubes, 10ml of the combined reagent added, shaken and left to stand for 10mins before reading the absorbance at 690nm on a spectrophotometer, using 20ml of distilled water plus 1ml of the reagent as reference.

**Methods for Calibration**

Standard phosphate solution: 219.5 mg of dried AR potassium hydrogen phosphate was dissolved in distilled water and made up to 1000ml, where 1ml = 50.0 µg. Of phosphate. 10ml of the stock solution was made up to 1000ml to give 1ml = 0.05 mg. Standards of strength ranging from 0 (blank) to 0.05mg/L at intervals of 0.01mg is prepared by diluting the stock with distilled water.

**Conc of sample = Abs of sample x concentration of standard**

Abs of std

**Nitrate Determination**

**Method:** Nitrate is determined using PD303 UV Spectrophotometer (APHA; 1998).

**Procedure:** A known volume (50ml) of the digested sample was pipetted into a porcelain dish and evaporated to dryness on a hot water bath. 2ml of phenol disulphonic acid was added to dissolve the residue by constant stirring with a glass rod. Concentrated solution of sodium hydroxide and distilled water was added with stirring to make it alkaline.

This was filtered into a Nessler's tube and made up to 50ml with distilled water. The absorbance was read at 410nm using a spectrophotometer after the development of colour. The standard graph was plotted by taking concentration along X-axis and the spectrophotometric readings (absorbance) along Y-axis. The value of nitrate was found by comparing absorbance of sample with the standard curve and expressed in mg/L.

**Conc of sample = Abs of sample x conc of std**

Abs of std

**III. Results And Discussion**

Experimental results obtained on effect of municipal solid waste lechate on the characteristics of soil on both contaminated and uncontaminated soil presented in TABLES 3.1 to 3.5. The present paper mainly focused on identification of selected pollutants in the soil due to lechate generated from municipal solid waste landfill site and uncontaminated soil to serve as control. Finally comparison of both contaminated and uncontaminated soil characteristics was made.

3.1 Results

**Table 3.1 Physicochemical Properties of Waste Dumping Sites and Uncontaminated Sites S1 to S6**

Parameters	Unit	Dumpsite 1	Dumpsite 2	S1	S2	S3	S4	S5	S6
Temperature	°C	28.1	28.1	28	29.1	31.3	31.3	30.2	30.5
pH	-	6.54	6.46	6.93	6.95	7.01	7.05	6.95	7.01
EC	µS/cm	215.1	211	198	178.7	142.5	145	144.8	126.6
Acidity	mg/kg	12.80	11.50	10.9	8.8	3.6	4.7	2.5	2.85
Alkalinity	mg/kg	0.8	0.95	0.8	0.85	2.8	2.5	4.8	4.5
MC	%	22.65	20.17	18.55	17.72	9.95	9.05	10.65	11.30
OM	%	17.69	18	5.71	4.8	1.55	2.87	2.66	1.59
SG	kg/cm <sup>3</sup>	2.61	2.6	1.25	2.3	1.89	1.98	1.95	1.94
Permeability	Cm/s	0.74	0.70	0.79	0.80	0.90	0.95	0.89	1.01
Shear strength	kNm <sup>2</sup>	14.18	15.02	19.6	18.0	18.02	17.3	16.5	17.5
Compressibility	m <sup>2</sup> /kN	1.05	0.85	1.08	1.09	1.13	1.17	1.13	1.18
Clay	%	20.04	29.42	35.5	25.28	31	29.21	29.50	29.05
Silt	%	62.3	60.00	31.93	38.00	23.50	23.79	25.50	23.90
Sand	%	11.66	10.58	32.57	36.72	45.50	47.00	45.00	47.05
Chloride	mg/kg	27	29	26	19.5	14	17.5	16.8	17.2
Phosphate	mg/kg	1.63	1.72	0.87	0.85	0.81	0.81	0.77	0.79
Nitrate	mg/kg	15.64	14.96	15	14.99	2.98	1.98	1.97	1.99
Iron	mg/kg	258.17	255.58	51.98	50.90	50.21	48.50	45.00	39.65

<b>Zinc</b>	mg/kg	21.42	22.66	3.45	4.56	2.43	2.52	2.94	2.48
<b>Copper</b>	mg/kg	2.78	2.8	0.22	0.21	0.20	0.13	0.10	0.11
<b>Lead</b>	mg/kg	4.96	5.85	2.09	1.54	1.40	1.80	1.95	1.85
<b>Cadmium</b>	mg/kg	0.27	0.027	0.009	0.00	0.01	0.00	0.03	0.00
<b>Nikel</b>	mg/kg	5.04	4.99	0.06	0.00	0.00	0.02	0.00	0.00

**Table 3.2. Mean Values of Soil Physicochemical Properties of Control Sites**

Parameters	S1	S2	S3	S4	S5	S6	Mean
Temperature	28	29.1	31.3	31.3	30.2	30.5	30.06667
pH	6.93	6.95	7.01	7.05	6.95	7.01	6.983333
EC	198	178.7	142.5	145	144.8	126.6	155.9333
Acidity	10.9	8.8	3.6	4.7	2.5	2.85	5.558333
Alkalinity	0.8	0.85	2.8	2.5	4.8	4.5	2.708333
MC	18.55	17.72	9.95	9.05	10.65	11.30	12.87
OM	5.71	4.8	1.55	2.87	2.66	1.59	3.196667
SG	1.25	2.3	1.89	1.98	1.95	1.94	1.884
Permeability	0.79	0.80	0.90	0.95	0.89	1.01	0.89
Shear strength	19.6	18.0	18.02	17.3	16.5	17.5	17.5
Compressibility	1.08	1.09	1.13	1.17	1.13	1.18	1.13
Chloride	26	19.5	14	17.5	16.8	17.2	18.5
Phosphate	0.87	0.85	0.81	0.81	0.77	0.79	0.816667
Nitrate	15	14.99	2.98	1.98	1.97	1.99	6.485
Clay	35.5	25.28	31	29.21	29.50	29.05	29.92333
Silt	31.93	38.00	23.50	23.79	25.50	23.90	27.77
Sand	32.57	36.72	45.50	47.00	45.00	47.05	42.30667
Iron	51.98	50.90	50.21	48.50	45.00	39.65	47.70667
Zinc	3.45	4.56	2.43	2.52	2.94	2.48	3.063333
Copper	0.22	0.21	0.20	0.13	0.10	0.11	0.161667
Lead	2.09	1.54	1.40	1.80	1.95	1.85	1.771667
Cadmium	0.009	0.00	0.01	0.00	0.03	0.00	0.008167
Nikel	0.06	0.00	0.00	0.02	0.00	0.00	0.013333

**Table 3.3 Mean Values of Soil Physicochemical Properties of Waste Dumping Sites**

Parameters	Dumpsite 1	Dumpsite 2	Mean
Temperature	28.1	28.1	28.1
pH	6.54	6.46	6.5
EC	215.1	211	213.05
Acidity	12.80	11.50	12.15
Alkalinity	0.8	0.95	0.875
MC	22.65	20.17	21.41
OM	17.69	18	17.845
SG	2.61	2.6	2.605
Permeability	0.74	0.70	0.072
Shear strength	14.18	15.02	14.6
Compressibility	1.05	0.85	0.95
Chloride	27	29	28
Phosphate	1.63	1.72	1.675
Nitrate	15.64	14.96	15.3
Clay	20.04	29.42	24.73
Silt	62.3	60.00	61.15
Sand	11.66	10.58	11.12
Iron	258.17	255.58	256.875
Zinc	21.42	22.66	22.04
Copper	2.78	2.8	2.79
Lead	4.96	5.85	5.405
Cadmium	0.27	0.27	0.27
Nikel	5.04	4.99	5.015

**Tle 3.4 Comparison of Statistical Description of The Contaminated and Uncontaminated Soils**

Parameters	Non Dump Site(Uncontaminated soil)			Dump Site (Contaminated soil)		
	Mean	Variance	Std Deviation	Mean	Variance	Std Deviation
Temperature	30.06667	1.690666667	1.300256	28.1	0	0
pH	6.983333	0.002186667	0.046762	6.5	0.0032	0.056569
EC	155.9333	714.4626667	26.72943	213.05	8.405	2.899138
Acidity	5.558333	12.06041667	3.472811	12.15	0.845	0.919239
Alkalinity	2.708333	2.946416667	1.716513	0.875	0.01125	0.106066
MC	12.87	17.2594	4.154443	21.41	3.0752	1.753625
OM	3.196667	2.915026667	1.707345	17.845	0.04805	0.219203
SG	1.884	0.14793	0.384617	2.605	5E-05	0.007071
Permeability	0.89	0.00724	0.085088	0.072	0.0008	0.55062
Shear strength	17.5	1.0712	1.034988	14.6	0.3528	0.59397
Compressibility	1.13	0.00164	0.040497	0.95	0.02	0.141421
Chloride	18.5	16.616	4.076273	28	2	1.414214
Phosphate	0.816667	0.001386667	0.037238	1.675	0.00405	0.06364
Nitrate	6.485	43.60211	6.603189	15.3	0.2312	0.480833
Clay	29.92333	11.05394667	3.324748	24.73	43.9922	6.632662
Silt	27.77	35.23232	5.935682	61.15	2.645	1.626346
Sand	42.30667	37.59830667	6.131746	11.12	0.5832	0.763675
Iron	47.70667	21.51814667	4.638766	256.875	3.35405	1.831407
Zinc	3.063333	0.688266667	0.829618	22.04	0.7688	0.876812
Copper	0.161667	0.002936667	0.054191	2.79	0.0002	0.014142
Lead	1.771667	0.066376667	0.257637	5.405	0.39605	0.629325
Cadmium	0.008167	0.000136167	0.000587	0.27	0	0
Nikel	0.013333	0.000586667	0.024221	5.015	0.00125	0.035355

### 3.2 Discussion

#### Comparison of quality of contaminated soil and uncontaminated soils

The results of the experiments carried out on the soil samples collected from the municipal solid waste dumping yard at Ugwuokwenu, and the uncontaminated soil, Nnewi is presented and discussed.

#### pH

Basic statistical comparison of the results at both the contaminated and the uncontaminated sites (table 3.4) show that the mean value of the pH was 6.5 at the contaminated soil and 6.98 at the uncontaminated soil. We can conclude that, pH value of uncontaminated soils is higher than the contaminated soils. This shows that the pH of contaminated soil is more acidic. Similar results were reported by Oluyemi et al. [31] who found high organic matter content in Nigerian landfill soil, which was also characterized by a slightly acidic pH

However the current result is not in agreement with the result presented by Woomer et al., (1994) [32], who stated that the dumpsite had higher pH value. According to him, the increase in pH in the dump sites may be because of high organic matter content which tends to buffer the soil by preventing excessive pH changes due to the release of exchangeable cations during mineralization of organic matter.

#### EC

Higher saturated hydraulic conductivities were recorded in the dump site soils with an average of 213.05  $\mu\text{S}/\text{cm}$  relative to non-dump soils of 155.93 $\mu\text{S}/\text{cm}$ . ), indicating their saline character, which is confirmed by their pH values (neutral) [33]

#### Alkalinity

From the table above, the mean alkalinity value of uncontaminated soils (2.71kg/l) is higher than the contaminated soils 0.875kg/l. This could be the reason why the pH value of the contaminated soil is slightly acidic than uncontaminated soil.

#### Natural Moisture Content

The results show that the mean value of the natural moisture content of the uncontaminated soil (12.87) are lower compared to those of the contaminated soil samples (21.41).. Soil natural moisture content refers to the quantity of water contained in a soil sample. It can be given on either gravimetric or volumetric basis. Soil compaction helps to improve the geotechnical properties of the soil. Soil with lower moisture content than the optimum tends to have a lot of void spaces which in turn results in low dry density. Moreover, at moisture content more than the optimum, the dry density is reduced by the additional water which occupies the space which would have been occupied by solid particles [34]. The NMC of the contaminated soil was generally

higher than the uncontaminated soil. This trend is because there was less evaporation of moisture from the contaminated soil caused by the covering of the MSW. Although, NMC is not a major concern to Engineers since it can be managed during construction

### **Specific gravity**

Specific gravity refers to the ratio of the weight of the soil to the unit weight of water. It is an important parameter in the sense that it helps in the computation of other parameters relating to the soil. Contrary to the findings made by Mbagwu (1992) [35], that organic and inorganic materials in the municipal wastes help to increase the soil matrix thereby reducing soil bulk density, this current result proved otherwise. The specific gravity of the contaminated soil samples was relatively high when compared to the control sample as it ranged from 2.6 to 2.61 for the contaminated soil samples (Table 3.3) because of the higher moisture content of the contaminated soil. MSW has high organic content and there is a possibility of MSW containing soluble salts. It also implies that waste constituents have positive impact on the specific gravity of soil.

### **Organic matter**

The organic content values of the soil samples collected from the site gave an average of 17.85%, and that for the control samples collected at various distances gave an average of 2.92%. This infers that the soil below the dump site has high organic content due to the seepage of leachate when compared to the control sample. This also contradicts the one stated by Woome. This is mainly due to release of exchangeable cations during mineralization of organic matter. Soil pH generally has a major contribution in metal bioavailability, toxicity and leaching capability into the surrounding areas [36], [37]. The organic matter content, pH, conductivity, and available heavy metals on open dump sites are greatly affected by the quantity of wastes dumped

### **Chloride content**

The mean chloride concentration in contaminated soil is 28 mg/l where as uncontaminated is 18.5 mg/l. It indicates that it is higher than uncontaminated soil.

### **Particle Size Distribution**

Particle size distribution of a soil is the list of values that define its relative amount by dry mass which is often distributed over certain ranges of particle sizes. From the Table 3.1 the uncontaminated soils are relatively homogeneous. The contaminated soil has more fines than the uncontaminated soil. The higher percentage of fine content recorded for the contaminated soil (61.15% of silt) can be attributed to the fines emanating from the high organic matter in the dumpsite soil. The observed higher percentage of fine content for the contaminated soil could also be as a result of fine particles arising from the decayed municipal solid waste which covers the soil. This conforms to similar work done by Krishna et al.[40]. Similar observation was made by Estabragh et al. [41] while studying the consolidation behaviour of two fine-grained soils contaminated by glycerol and ethanol. Thus, it can be inferred that both physicochemical and mechanical changes in contaminated soils affect their physical properties. Loughery (1973). [42], recommended sandy loam texture as being suitable for waste disposal sites, and that soils with greater than 70% sand are highly unsuitable for waste disposal because they are highly permeable and allow large quantities of leachates to pass through the soil.

Soil is classified based on these four methods such as; US Department of Agriculture (USDA) method, U.S. Bureau of Soil and Public Roads Administration Classification System, American Association of State Highway and Transportation official (AASHTO) Classification and Unified Soil Classification System (USCS) [41-44]. It is worthy of note that the unified soil classification system (USCS) is a type of classification based on test values measured in accordance with the standard set by American Society for testing and materials (ASTM). By and large, the USCS classification of soil is directly linked to the soil properties by which it is defined [45]. According to USCS system, soils are categorized into three classes; coarse-grained (sand or gravel), fine-grained (clay or silt) and highly organic soils

### **Permeability Test of contaminated and uncontaminated soil**

Falling head method was used to determine the coefficient of permeability of the soils. The results shows that, the uncontaminated soil has higher values of coefficient of permeability than then contaminated soils. This result is because of higher percentage of sand in the uncontaminated soil. These results somehow contradict the fact that the contaminated soil particles are loosely arranged which would have ordinarily increased the pore space in the soil. This anomaly may be due to particles flocculation as a result of contamination with MSW. The flocculation process may have altered the behaviours of the fine particles from clay-like to silt-like and consequently, making the soil more permeable.

### **Shear Strength Test Contaminated and Uncontaminated Soil**

The shear strength parameters were determined by undrained triaxial test using undisturbed soil samples. From the results, the shear strength value is higher in case of uncontaminated soil than those recorded for the contaminated soil. However, the relatively high value recorded for contaminated soil samples a result of pseudo-cohesion, brought about by leachate from the decomposing MSW. This may be due to particle flocculation as a result of contamination with MSW

### **Compressibility Test of contaminated and uncontaminated soil**

Consolidation test on the undisturbed samples was used to investigate the effect of the MSW on the compressibility characteristics of the soils. The results show that the contaminated soil has relatively lower values than uncontaminated soil.

### **Heavy Metal**

Regarding heavy metal measurements in the landfill and the uncontaminated soils, the mean contents of the heavy metals under consideration (Fe, Zn, Cu, Pb, Cd, and Ni) are - are 256.88, 22.04, 2.79, 5.41, 0.27, 5.02 mg·kg<sup>-1</sup>; and 47.71, 3.06, 0.16, 1.77, 0.01, 0.01 and, respectively. The higher content of heavy metals in the dump site is not a surprise because of the type of waste (metal scrap, battery etc) being dumped there

## **IV. Conclusions**

Based on the experiment results obtained from the soil sample analysed in both contaminated and uncontaminated soils following major conclusions have been drawn. The natural (uncontaminated) soil within and around the dumpsite is relatively homogeneous, though there are some minor discrepancies. The contaminated soil has higher specific gravity and this shows the presence of heavy organic content in the soil. It equally contains more fine particles, with higher OMC, when compared with the uncontaminated soil. The contaminated soil has higher natural moisture content than that of the uncontaminated soil. Thus, it can be suggested that such soils should be stabilized using additives in order to enhance its engineering properties.

The coefficient of permeability of the uncontaminated soil has higher than the contaminated soils. These results agree with the fact that the contaminated soil has less fine soil particles are loosely arranged. The relatively appreciated value recorded for contaminated soil samples a result of pseudo-cohesion, brought about by leachate from the decomposing MSW. This may be due to particle flocculation as a result of contamination with MSW.

The study concludes that the pH value of contaminated soils is lower than the uncontaminated soils and the alkalinity value of uncontaminated soils is higher than the contaminated soils. This could be the reason that the pH of the contaminated soil is slightly acidic than uncontaminated soil.

The chloride concentration in contaminated soil is 28 mg/l, it indicates that it is higher than uncontaminated soil which is 18.5mg/l. This indicates that due to disposal of solid waste the quality of the soil is reduced and it is clearly indicated by the chloride values of contaminated soils. Study concludes based on the results obtained, the disposal site soil quality is reduced compared to uncontaminated soil. In other words, due to the disposal of solid waste on land the soil quality gets reduced. Thus, it can be suggested that such soils should be stabilized using additives in order to enhance its engineering properties.

The results revealed that the pollution brought by the MSW caused significant changes in some of the physicochemical characteristics of the soil under study. The findings obtained in this study should draw the attention of public officials on the necessity of keeping watch over wastes input, which will probably increase in the future due to growing population, and to start treating and recycling the wastes instead of discharging them into the environment.

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