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Municipal Solid Waste Dumpsite Pollution On Physico-Chemical Properties Of Dumpsite And Surrounding Soils.

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Abstract

The pollution effect of municipal solid waste dumpsite (WDS) on physico-chemical properties of dumpsite and adjoining (CS) soils in heavy rainforest region were investigated. Data were obtained from four points at two depths, and statistical analysis, significant differences, and correlations within the soil and between the sites were made using SPSS version 17 software for windows. The properties registered strong correlation within and significant differences, except K and Ea, between soil sites. The pH indicated alkaline level (7.51±0.27) at WDS and acidic level (5.69±0.67) at CS soil. pH, EC, TOC, base metals, ECEC, SAR and silt were significantly higher in WDS than in CS soils while TN showed the reverse order. The texture was clayey sand with lean clay fraction as a consequence of acidic rainfall leaching in the area. Variability was observed in all physico-chemical properties in WDS and CS except in K in WDS, in root zone depth with concentrations increasing down the profile. However, highly variable properties in profile (CV=55-200%) were EC, K, SAR and silt in WDS and EC, TN, silt and clay in CS, otherwise all others were nearly homogenous. Micro nutrient fertility was rich and SAR was low, suggesting no sodium hazard from comparatively low percentage of exchangeable sodium, which is beneficial to aggregate stability. Irrigation with low salinity irrigation water would not degrade the soil in terms of salinity, alkalinity and sodium dispersion of soil aggregate. Generally, higher values of soil properties at dumpsite than at CS was similarly observed in other countries and suggests that common beneficial management or remediation actions are exchangeable for dumpsite management especially in low economic countries.

Key words: soil pollution, dumpsite, soil properties, pH, sodium hazards, water quality, irrigation, solid waste management.

1. Introduction

Dumping of municipal solid waste in municipality is the main means of waste disposal in the municipality apart from the subdued residential backyard waste disposal arising mainly from low economic status, and cleavage to past tradition of the rural areas which lingers on even to urban residence.

The location of waste dump is not given to predetermined criteria aimed at safeguarding the environmental and public health, rather it is a matter of convenience and cost-savings to discard the waste at marginalized land. In this study the waste dumpsite is on the precipice of a plateau at the urban periphery below which is the dissected ravine with lotic spring. Curious observation has shown that the area of the ravine hither to regarded as marginalized with habitats for men/women of bad character, has now been encroached into in the hope of piece-meal development by unauthorized persons. Therefore, urban waste dump is facing space-competition in the expanding territory of the State Capital.

However, the unsettling problem is that dumping the waste on soil is one means which the soil quality is degraded. The polluted soil affects human health through direct human contact or inhalation of the polluted airborne dust and the consumption of the garden vegetables grown on abandoned dumpsites or around active dumpsites [1] .Coupled to these happenings is the fact that the polluted leachate egress into the underneath land has found its way to sources of water (surface and ground water) through soil percolation or by interflow runoff or actual surface wash off by NPS runoff. The water sources are used by humans and animals for various purposes, and their pollution constitutes quality degradation [2], which easily endangers users if chemical toxicity exists. The other important problem is that the continued in-place decomposition and leachate production on sustained waste dumping, has given rise to percolation of chemical and biological contaminant s to the soil profile with the possibility of spreading to the surrounding area especially on sloppy terrains. Studies have shown evidence of such in-situ and spatial contamination of soil properties at areas of location of such dumpsites and allied location of waste disposal [3],[4],[2],[5]. Some of these contaminants are heavy metals which precipitate on or are adsorbed unto soil; and they do not decay, as such are able to be transferred into vegetables in large quantity, thereby causing various mutagenic and hemorrhage and physical disorders in human beings and animals consuming the affected plants or organisms[6],[7].

Despite these health and environmental problems people around such dumpsites are going about cultivating the surrounding areas of waste dumpsites and abandoned dumpsites oblivious of the danger. Consequently, there is need to take up better information on and management of solid wastes in developing economies who prefer open dumpsite method. However, this is aborted by mis-directed policy, no-policy and lack of government's will to shore up funds for such a project which has a global reckoning.

In the present case, the location is in tropical rainforest region, where the acidic rainfall can act on the soil properties to affect the soil fertility, alkalinity and acidity, and salt and sodium hazards[8],[9],[10],[1],[5],[11],[12] . These cases have been recorded at different locations in different regions of the world and it would be good information data base to establish the status where dumpsites exist and are yet to be so investigated. Even where they have been investigated, the climate, the evapotranspiration and the rainfall are stochastic and vary with season. The soil acid fluctuates[11] so that the base metal adsorption and replacement, hence sodium hazard, can vary with season leaving behind consequences that should be updated periodically for future monitoring and management of dumpsite degrading effect on soil, and the need to plan for better management including bio-agriculture, processing, and recycling. Hence, Uyo municipality was used for the study. Therefore, the study aimed at (1) first time investigation of the soil properties on the active dumpsite and surrounding area in expanding urban area, and (2) establishing any profile of degradation properties and obtaining data base for future monitoring of the deteriorating environment of the dumpsite.

2. Materials and Method

2.1 Study Area

The study was conducted at Old Stadium Road dumpsite along Wellington Bassey Way, Uyo Akwa Ibom State. The area is situated between latitudes $4^0$50` and $5^0$32` North and longitudes $7^0$36` east and $8^0$20` East. The soil is formed from coastal plane parent materials characterized by high sand fraction and low activity clay, with a mangrove vegetation. Uyo municipality had many dumpsites but the one situated along Old Stadium road dumpsite is the main dumpsite now in Uyo with so much dumps (Plate 1). The dumpsite is used by the environmental sanitation authority for solid waste disposal.

Plate 1: Uyo Municipal dumpsite

2.2 Soil Sampling

Random core soil samples were collected at two depths (0 - 10 and 10-20 cm), and sampling at four points: P1, P2, P3, P4. The four points were replicated giving a total of eight (8) representative samples from both the waste dumpsite and the control soils. The samples were collected using the acid clean soil auger pack in a well labeled black polythene bag and taken to the Soil Science laboratory, University of Uyo, Uyo. In the laboratory, the samples were air-dried under room temperature, crushed using mortar-and pistle, and sieved using 2mm mesh wire sieves and then stored for the determination of chemical properties. Apparatus and agent used for physico-chemical properties included the following: Glass-electrode pH meter, beaker, weighing balance, distilled water burette 50ml, Erlenmeyer flask, pipette 10ml capacity and potassium dichromate in $K_2Cr_2O_7$ dissolved.

2.3 Determination of Soil Physical Properties

pH was determined by potentiometer method in 1:25 soil water ratio using a standardized P^H meter model (209 by HANNA) which measured the pH electrometrically by inserting the glass electrode into the soil water suspension[13] (Bates, 1994). Electrical conductivity (EC) used a digital conductivity meter (Dist. 3 by HANNA).

Soil Organic Matter (OM) was determined by the wet acid dichromate digestion method and Walkely and Black Wet Oxidation Method with 1g of soil weighed into Erlenmeyer flask for mixing. The mixture was titrated with ferrous ammonium sulphate to a light blue end point. A blank sample was also run, and OMC was calculated as:

$$OC = (b-t) \times 0.003 \times 0.100 \times 1.33$$

where b is the blank titre value and t is suspension titre value. Total Nitrogen (TN) was determined by the Macro-Kjedahl Method.

Sulphate was determined by turbidimetric method 10ml of the sample aliquot was pipetted into 25ml volumetric flask, and distilled water added to bring the volume to approximately 20ml, 1ml of the gelatin $BaCl_2$ reagent was added which made up the volume with distilled water. The content was mixed thoroughly and allowed to stand for 30 minutes. The standard solution of course contained 1ml of gelatin $BaCl_2$ reagent, 10ml of the blank digest of extracting solution.

Available Phosphorus was extracted using Bray P-1 and Bray P-2 extractants [19] and P in the extract was measured with spectrophotometer (model Spectronic 2DD) using the Molybdenum blue colour method.

2.4 Analysis of Data

Statistical analysis of the collated data included the descriptive statistics and coefficient of variability using SPSS version 17 software for windows.

Quality of waste dump soil was compared with natural background or surrounding soil using t-statistics for test of significant difference; and correlation matrix examined the association among soil properties at the four points at respective sites.

2.5 Soil quality test for irrigation

The following parameters were computed for evaluation of irrigation properties of soil solution: pH and EC. There were as measured above. pH indicated alkalinity (for high pH) and acidity (low pH). pH value between 7.0 and 8.5 is considered as neutral and fit for irrigation[14]. EC indicated salinity or salt status of the soil medium. Salt-affected soil is one with salt-hazard or problems which adversely affect seed germination, plant growth, and crop yield, and the adverse effect are not the same for different soils. Such salt-hazard soils can be classed as saline, saline-alkali, alkali, and sodic soil [11]. EC is an important parameter for describing the salinity problem (status) of water; it assesses drainage also, because drainage leaches salt concentration in soils, reducing it to make the soil environment more conducive for plant growth[15],[16].

ECEC is effective cation exchange capacity which is the sum of the exchangea[ble cations and exchangeable acidity[17],[18], where cation exchange capacity (CEC) is $\sum (Mg^{++} + Ca^{++} + Na^{+} + k^{+})$. Base saturation is (TEB/ECEC) x 100, where TEB is total exchangeable base.

SAR = Sodium adsorption ratio

$$= [Na^{+}] / [[Ca^{++} + Mg^{++}]/2]^{1/2}$$

where Na+, Ca++ and Mg++ are concentrations of cations of base metals (Na, Ca and Mg respectively) in meg/l. This indicates sodium hazard of irrigation water or soil water (i.e. soil solution) because solution is directly linked to soil formation[20]. Acid reaction reduces availability of calcium. Cations of Ca and Mg are weakly adsorbed to the soil clay surface. Rainfall provides excess hydrogen ion (H+) which replaces the weakly adsorbed cations (hence giving the soil acidity), and combines with Carbon dioxide (Co_2) from the atmosphere and water to form a weak solvent Carbonic acid, which then reacts with the cations Ca++ and Mg++ to form Carbonate and as such depletes Calcium and Magnesium cations making room for H+ and as such increases acidity of the soil.

ESP = exchangeable sodium percent, and can be determined by knowing the value of SAR as:

$$ESP = \frac{(-0.0126 + 0.01475\ SAR}{1+ (-0.0126 + 0.01475\ SAR)}$$

3. Result and Discussion

Data collected from the field are presented in table 1 for the physiochemical properties of the waste dumpsite soils (WDS) and control soil (CS) and table 2 for the heavy metal content of the soils. The pollution levels or concentration were tested for significant differences using t-statistics while spatial variability of properties were indicated by the convenience (CV) values.

3.1 Physico-Chemical Properties of Soil of the Waste Dumpsite

3.1.1 Soil pH

Soil pH measures the concentration of hydrogen ion H+ in the soils and is the major cause of soil acidity which affects the performance of crops and activities of micro-organisms. Values of pH in WDS ranged from 7.13 – 7.92, indicating with a mean of 7.51 ±0.27, which was higher than that of CS which ranged from 5.59 ± 2.78 with mean of 5.69 ± 0.67, indicating non-alkaline soil, and conforming to the generally very acidic soil of the region [21](AK-RUSAL, 1989), which is the result of excessive rainfall-runoff saturation of soil resulting in reducing clay content in most cases [11].

The high pH (alkaline in reaction) is attributed to the organic accumulated on the soils. This means that organic solid waste accumulation could significantly reduce soil acidity ($p<0.01$), and confirms observation by [22] that there is increase in salinity in soils under accumulated municipal solid waste. The level of the salinity however, may depend on the composition of the solid waste. Comparatively, soils under this was more alkaline than the one under waste dumpsite at Allahabad India which tended to neutral - alkaline (6.13 – 7.1)[5].

Slight spatial variability in pH was observed (fig. 1) across the sampling points WDS in the order PT2 (7.77) > PT3 PT3 (7.21). The order in CS was PT3> PT4>PT1 (fig.1). The pH value varied only slightly in WDS (CV=3.59) than in CS (CV = 11.77).

3.1.2. Electrical Conductivity (EC)

Values of EC ranged from 0.15 – 0.80 with the mean 0.43 ±0.24 ds/m in WDs while that of CS ranged from 0.03 – 0.06 with the mean of 0.04±0.08ds/m. comparatively, giving significantly higher EC at WDS than in CS (PS<0.01). The high EC is salt-related and may be attributed to the salinity content of the accumulated waste which leachate infiltrated the in-situ soil causing increase in salt content in the WDS [23],[15],[18],[11]. [24] in Enugu State observed that soil under accumulated municipal waste is characterized with high EC value due to increase in salt content. Variability was rather high for WDS but very high in CS indicating very heterogeneous soil property; however, with the value of EC (dS/m) < 0.8, the salinity was low, implying that WDS could retain more cations in it exchange site due to increased negative changes in the exchange complex, it is indicated by high EC content.

Table 1: Physiochemical Properties of polluted waste dumpsite and unpolluted control soils at Old Stadium Road MSW dumpsite

Data	Range	Polluted Soil			control Soil			
	0-10cm – 10-20cm	Mean	Sd	CV	Range	Mean	Sd	CV
PH	7.13 – 7.92	7.51	0.27	3.59	5.59-5.78	5.69	0.67	11.77
EC (Ds/m)	0.18-0.80	0.43	0.24	55.81	0.03-0.06	0.04	0.08	200.00
TOC(%)	2.10-5.76	3.91	1.25	31.97	0.06-1.23	0.09	0.31	34.83
TN (%)	0.05-0.14	3.91	1.25	31.67	2.00-4.00	0.43	0.71	165.20
Ca (coml./kg)	4.08-5.20	4.57	0.45	9.85	2.00-4.00	2.70	0.73	27.04
Mg (cmol/kg)	2.00-2.60	2.19	0.22	10.05	1.20-2.70	1.74	0.48	27.59
Na (coml./kg)	0.06-0.09	0.07	0.01	14.29	0.02-0.02	0.02	0.00	0.00
K(coml./kg)	0.09-0.13	0.11	0.16	145.45	0.09-0.12	0.11	0.01	9.09
EA (coml../kg)	2.00-2.70	2.43	0.26	10.69	1.60-5.20	2.47	1.15	46.59
ECEC (coml../kg)	8.70-10.6	9.38	0.73	7.78	5.89-10.06	7.32	1.56	21.31
SAR (%)	0.02-0.03	0.02	0.03	150.00	0.003-0.013	0.00	0.00	0.00
Sand (%)	7.00-86.00	76.38	6.09	7.97	70.05-92.46	76.4	8.71	11.35
Silt (%)	1.40-9.40	6.63	3.83	57.77	1.16-7.16	3.4	2.71	79.47
Clay (%)	12.6-20.00	16.98	2.50	14.72	4.38-28.58	19.88	8.60	43.26s

EC: Electrical Conductivity, TOC: Total Organic Carbon, TN: Total Nitrogen, Ca: Calcium, Mg: Magnesium, Na: Sodium, K: Potassium, EA: Exchange Acidity, ECEC: Effective Cation Exchange Capacity, SAR: Sodium Adsorption Ratio

3.1.3 Total Organic Carbon (TOC)

Organic carbon reflects organic matter (the decomposed carbon in a material). Values of TOC in WDS ranged from 2.10 – 5 76% with mean of 3.91±1.25%, and in CS, ranged between 0.36 and 1.23 with mean of 0.59±0.31%. Generally, most of the materials in the waste area were organic in nature, therefore so high TOC was expected in WDS than in CS. Variation of TOC in WDS was in the order PT2 > PT1 > PT3> PT4 while the order in CS was PT2 > PT3 > PT1> PT4 fig. 1.

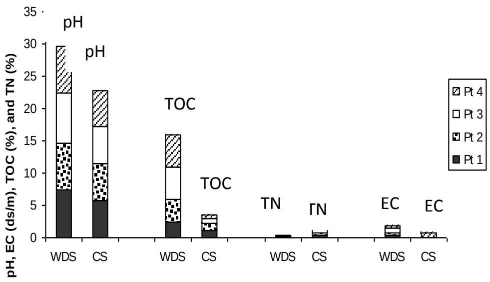

Fig. 1: Variation of soil properties (pH, Total Organic carbon, (TOC), Total Nitrogen (TN) and Electrical conductivity (EC)) in waste disposal soil (WDS) and control soil (CS) at Uyo, Nigeria

Generally, value of total nitrogen in the soil is very low, hence, N is regarded as the most limited nutrient in the soil. In WDS, it ranged from 0.05 – 0.14% with mean of 0.10± 0.13% and between 0.3 and 0.5%, with mean of 0.43± 0.71% in CS. TOC in WDS was lower than the value in CS soil. The high TOC in WDS, the deviation may be attributed to high acid stress in WDS than CS. Under condition of high to strong acidity, most nutrients in the soil are fixed or tied down in soil solution. A strong acidity condition in the soil could also reduce the activities of macro organisms which are involved in mineralization of organic matter to release nitrogen into the soil. Hence CS had higher values of TN than WDS, however their variations were small (CV=31-34%). C/N ratio varied within and between WDS and CS as follows: 33.6, 39.4, 39.1, and 40.5 for PT1, PT2, PT3, and PT4 in WDS respectively, and also 3.2, 2.4, 1.5 and 1.4 at respective points in CS.

3.1.4. Exchangeable Bases

Exchangeable Ca ranged from 4.08-5.20 with mean of 4.57 ± 0.45 Cmol/kg which was higher in WDS than CS, which values ranged from 2.0 – 4.0 with the mean of 2.7 ± 0.73 Cmol/kg. The high value of Ca in WDS reflected the high organic content of soil, however, values varied slightly across WDS (CV=9.85%) and moderately in CS (CV=27.046%). Exchangeable Mg varied from 2.0-2.6 with mean of 2.19±0.22% in WDS and between 1.20 and 2.70 with mean of 1.74±0.48 Cmol/kg in CS; the comparatively high mean of Mg in WDS could also be attributed to high organic matter content in the soil at WDS more than the status at CS. Across WDS sampling site, the distribution was in the order: PT2>PT3>PT1 PT4 while distribution in CS was in the order: PT1 > PT2 > PT3 > PT4. Generally the variability was low (CV = 10.05) and 27.59% in WDS and CS respectively.

Values of exchangeable K ranged from 0.06 – 0.13 with mean of 0.11 ± 0.16 Cmol/kg in WDS, and from 0.09 – 0.12 with mean of 0.11 ± 0.01 Cmol/kg in CS. K had the same mean value (0.11 Cmol/kg) and were very highly homogenous in both sites (CV=1.45 at WDS and 0.09% at CS). The homogeneity of K was similar to the homogeneity of TOC, as such it might have been spatially homogenous in respect to its component at different locations within the dumpsite.

Exchangeable Na values (Table 1) ranged from 0.6 – 0.9 with mean 0.07±0.01 Cmol/kg in WDS while the values were constant (0.02 Cmol/kg) in CS. Comparatively, mean Na content in WDS was greater than in CS; Na varied in WDS (CV=14.9) only. The high Na content in WDS also might be attributed to the high organic matter content of WDS, compared to the control. Generally, it may be inferred that accumulation of municipal solid waste may increase the concentration of the exchangeable bases in the soil.

3.1.5. Exchange Acidity (EA)

This is the concentration of acidic cation (H^+) and Al^{3+} present in soil solution, and ranged from 2.0 – 2.70 with mean of 2.43 ± 0.26 Cmol/kg in WDS and 1.60 – 5.20 with mean of 2.47±1.15 Cmol/kg in CS (table 1). Comparatively, they are used as anion balance for cations. The high effect on the basic cations (Mg^{++}, Ca^{++}, K^+ and Na^+) by high torrential rainfall of the equatorial region, including this dumpsite, affected the Ca. The rain storm washed and the basic cation on a normal soil (control soil) coupled with farming activities; hence, the higher concentration of Ea (Al^{-3} and H^{+}) in control soil than in WDS. Edem[25], concerning coastal plain soil in Akwa Ibom State, observed that soil of South Eastern Nigeria (this dumpsite inclusive) was low in fertility due to leaching of the basic cation in soil so by rain and runoff infiltration, which also resulted in high concentration of acidic ions in the soil solution. Hence, WDS had less concentration of acidic ions than normal soil due to exchangeable base generated from decomposing organic waste to replace the leached cations thereby giving its alkaline properties. That made EA less varied at WDS (CV = 10.69%) than in CS (CV = 46.50%), implying that WDS is more homogenous than CS with respect to the concentration of H^{+} and Al^{3+}. Figure 2 shows the variation of EA across the sampling points; PT2 and PT4 (fig. 2) had significantly more EA than PT1 and PT3 at both WDS and CS.

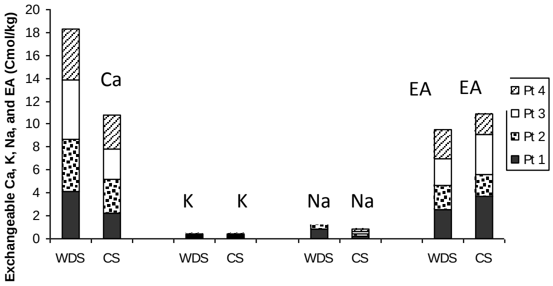

Fig. 2: Variation of soil properties (Exchangeable Ca, K, Na and Exchange Acidity (EA)) in waste disposal soil (WDS) and control soil (CS) at Uyo, Nigeria

3.1.6. Effective Cation Exchange Capacity (ECEC)

Is the sum total of the acidic and basic cation present in the soil solution. The highest mean was obtained in WDS (9.38±0.73 Cmol/kg) and was attributed to its high basic cation content. This implies that the fertility status of WDS may be better than that of CS. CV in CS was 21.31% while that of WDS was 7.78% (table 1). Its variability is shown in fig 2.

3.1.7. Sodium Adsorption Ratio (SAR)

Value of SAR ranged from 0.02 – 0.03 with mean of 0.03 in WDS and 0.01 in CS. WDS had higher SAR than CS. SAR expresses the percentage of Na to other basic cations. The low SAR indicated that Na content of both soils was very low (table 1). Low Na is beneficial to soil aggregate stability.

3.2 Particle Size Distribution

Particle size distribution showed clayey sand texture at both sites with mean sand: silt: clay ratio of 76:7:17 for WDS and 76:3:20 in CS soils (table 1). Sand fraction ranged from 70.00 – 86.00% with mean of 76.38 in WDS, and between 70.46 – 92.46% with mean of 76.71% in CS. Both site soils had almost similar sand content. Silt and clay content were low with silt higher in CS than WDS and clay higher in WDS than in CS (reciprocity effect).

Table 3. Correlation coefficients between soil properties at municipal waste dumpsite.

Prop.	Ec	TOC	TN	Ca	Mg	Na	EA	ECEC	SAR	Sand	Silt	Clay	Nitrate	Nitrite	Sulphate
EC	1														
TOC	0.678	1													
TN	0.587	.955”	1												
Ca	0.703	.820’	.769’	1											
Mg	.720’	0.508	0.521	0.685	1										
Na	0.273	0.046	000’	0.146	0.377	1									
EA	0.282	0.253	0.374	0.112	0.521	0.476	1								
ECEC	.752’	0.752	.763’	.858”	.899”	0.374	0.58	1							
SAR	-0.24	-0.476	-0.523	-520	-0.224	.745’	0.269	-0.285	1						
Sand	872”	0.516	0.472	0.457	.779’	0.432	0.421	0.664	-14	1					
Silt	-921”	-0.589	-0.525	-0.47	-.719’	-0.313	-0.416	-0.656	0.096	-.975”	1				
Clay	-0.7	-0.348	-0.343	-0.38	-.795’	-0.568	-0.4	-610	-0.12	-.938”	.837”	1			
Nitrate	-0.33	-0.205	-0.307	-0.34	-.741’	-0.6	-874”	-737’	-208	-433	0.365	0.507	1		
Nitrite	-0.52	-0.597	-0.537	-0.16	-0.241	-0.369	-0.565	-0.383	-235	-0.602	0.675	0.427	0.25	1	

2. 3. Bulk Density (BD) and Porosity

Formula for bulk density is

$$1 - \frac{BD}{S_d}$$

where BD is bulk density (g/cm^3) and S_d is particle density and was 2.56 s/cm^3. The bulk density and total porosity of the soil under WDS are as follows: for point 1(PT1) to PT4, the bulk densities were 1.20, 1.08, 1.12, and 1.30 g/cm^3 respectively, while the corresponding total porosities were 53.2, 57.80, 56.20 and 50.78% respectively.

3.4 Nitrite, Nitrate, sulphate, phosphate

Nitrite, nitrate, sulphate and phosphorus phosphate had no significant differences between the 0-10cm and 10-20cm soil depths. The mean average values for 0-10cm and 10-20cm were: 513.5 and 521.8mg/kg; 8.95 and 8.80mg/kg; 263.63 and 239.34mg/kg, and 462.88 and 454.13mg/kg, with corresponding percentage mean difference of only 1.6, 1.7, 9.7 and 1.9% respectively. The high values of nitrate and phosphate are indicators of organic characteristics of component of the waste dump.

3.5 Comparing Physico-chemical Properties of WDS with CS

Table 2: t-statistics, significant difference between physio-chemical properties of WDS and CS at Uyo Dumpsite, Nigeria.

Soil Properties	Mean difference	t-value	Remarks
pH	1.81	19.075	**
EC	0.38	4.622	**
TOC	3.02	7.396	**
TN	-0.32	-18.877	**
Ca	1.86	6.460	**
Mg	0.45	2.329	**
Na	0.54	16.595	**
K	0.003	434	ns
Ea	-0.04	-0.102	ns
ECEC	2.06	4.327	**
SAR	0.02	19.137	**
Sand	-0.34	-0.086	ns
Silt	3.22	3.203	**
Clay	-2.91	-0.827	ns

N/B: * Significant at 5%, ** Significant at 1%,
ns: Non Significant at 5%

From table 2, the difference between pH at WDS and CS was significant at P < 01. It was positive in EC (0.38), TOC (3.02), Ca (1.86), Mg (0.45 Cmol/kg), K (0.003 Cmol/kg), ECEC (2.05 Cmol/kg), SAR (0.02%) and Silt (3.21%). For TN, EA, Sand and Clay, their mean differences were negative (-0.32%, 0.07 Cmol/kg, -0335% and -2.905%) respectively. The positive mean difference implies that means of the properties were higher in WDS than CS while negative mean difference means the reverse. Ten (10) out of 14 (i.e. 71%) physico-chemical properties showed significant differences between WDS and CS including pH (t=19.075), EC (t=4.622), TOC (t=7.376), TN (t=18.877), Ca (t=646), Mg (t=2.320), Na (t=16.595), ECEC (t=4.327), SAR (t=19.137) and Silt (t=3.203), while properties with no significant difference (P < 0.95) were K, EA, Sand and Clay. This implies that physico-chemical properties of WDS and CS have significant differences in site properties at the same locality.

3.6 Correlation

Few variables registered high or very high correlations with other elements (table 3). EC had very high correlations with sand, silt (as TDS composition) and sulphate and only high correlation with Mg, ECEC and phosphorus – phosphate (table 3). TOC had very high correlation with TN only and high correlation with Ca and ECEC. The same high correlation was reciprocated by TN to Ca and ECEC. Base metals had selective correlations. Ca and Na correlated very highly with ECEC only (85.8 and 89.9% respectively), and Mg also had high correlation with textural components of sand, silt and clay, while Na was highly correlated with only SAR (74.5%, table 3); K showed no exceptional correlation.

4. Implication for Irrigation

Irrigation is artificial and efficient application of quality water for stress-free germination, growth and high productivity of crops. In optimum application of quality irrigation water, it is expected that the constituent soil properties will not be increased so much that the soil loses its optimum condition for growth; particularly that acidity, salinity and sodicity will not be imposed by such water. Therefore, the quality of water must be safe for soil application and the properties of the root-zone soil must have nutrient and cation- anion balance for optimum root development growth.

4.1 Soil Fertility under Irrigation

Nitrogen fertilizer in the soil varied to a mean of 3.91 $\pm$ 1.25% (CV 32%) but with 0.05% in the 0 – 10cm depth and higher value of 0.14% in the 10-20cm depth (table 1); hence it tended to increase with depth of topsoil, and was 9.1 times higher than the surrounding soil which had a mean of 0.43 $\pm$ 0.71%. Thus, the fertility of the soil under dumpsite was high in terms of NO_3 – N.

Base metals (nutrient) or Ca, Mg, K fertility: The topsoil contained nearly homogenous concentrations of base metals as Ca (CV = 9.9) and Mg (CV = 10.1%, except K with CV = 145.5% which made K to be highly variable. The mean concentrations of base metal, in Cmol/1, were 4.57 $\pm$ 0.45 for Ca, 2.19 $\pm$ 0.22 for Mg and 0.11 $\pm$ 0.12 for K which were respectively 1.69 and 26 times, higher than the control soil for Ca and Mg, and was the same as the surrounding soil in the case of K. However, K decreased with depth in dumpsite but the reverse was the case in adjoining soil. Satisfactorily, Mg and Ca were dominant bases. Fixing the fertility categories as < 2, 2-5 and > 5 Cmol/kg for low, medium and high fertility in terms Ca and <0.3, 0, and > 0.3 Cmol/kg in terms of K [14], the dumpsite topsoil could be rated as medium in Mg – fertility, medium in Ca and high in K fertility especially in the 0 – 10cm. Therefore, application of good quality irrigation water will not encounter macronutrient problems.

4.2 Soil Texture under Irrigation

Acidic rainfall in the humid rainforest results in leaching of the soil and eroding of the surface soil to the valleys so that clay is not always significant in the surface texture [11]. The mean particle sizes of 76.4, 6.6 and 17.0% for Sand, Silt and Clay proportions in WDS soil suggest a clayey sand texture which is the normal texture of the region [21]. WDS and CS had the same texture (table 1), however silt varied considerably on both sites (57.8% at WDS and 79.5% at CS) while clay varied highly only in the CS (CV = 43.3%) but marginally in WDS (CV = 14.7%). In both sites, increase of particle size with increase in depth was observed. Thus, irrigation, especially sprinkler or drip irrigation, would be feasible; however, for surface irrigation, the soil would need to be pulverized very well before any application.

4.3 Soil Quality: Alkalinity, Salinity and Sodicity Status

The pH of the dumpsite soil varied between 7.13 and 7.92 which indicated a highly alkaline pH, which is favourable to the growth of most green vegetables. The EC of the root zone soil ranged between 0.18 and 0.80 dS/m (mean 0.43 dS/m) indicating also an alkali (or salt-free) soil in the 0-10 and 10-20cm depths. FAO[26] classified salt free soil at EC of 0-2 dS/m and 4-6 dS/m as slightly saline soil which may restructure the yield of certain crops, and less than 4 to 8 micro-mhos is class A and B irrigable soil which is good for irrigation[14],[27]. Application of low salinity water (EC: 0.25, TDS < 200[28] may not produce salinity problem in WDS soil [20].

The surrounding soil is acidic (pH 5.69) with a low but salt-free soil (EC 0.03-0.06 dS/m). This is the usually leached soil status of the sloppy terrains of the tropical rainforest area.

4.3.1. SAR

The proportion of Sodium in relation to the two other important bases (Ca and Mg) is Sodium Absorption Ratio (SAR). The SAR of the dumpsite was low value (0.02 – 0.03%), indicating a low or no salinity problem at the WDS soil. Application of low salinity water on irrigation would not harm the soil or alter the structure of the proportion of Sodium concentration to be more than the concentration of the Ca and Mg in the soil solution. When the proportion (SAR) of Sodium in the soil solution is increased, it takes to displace calcium from clay surface. Clay was low in the studied soils and other bases were higher in proportion than sodium. Therefore, salinity of irrigation water could not be increased in the condition of the WDS and adjoining soils.

Also with no salinity hazard (EC < 0.8 dS/m[29]), and the amount of sodium in soil solution in proportion to calcium and magnesium being low (i.e. SAR is low at 0.02% (or 0 – 10 ppm), then addition of low salinity water (good irrigation water quality) would not worsen salinity problem, i.e. it would not result in a breakdown of soil structure nor create water infiltration problems[14],[29]. If irrigation water contains Ca^{++} and Mg^{++} in quantity that is equal to or greater than Sodium ions (Na^{+}) then, although Ca^{++} and Mg^{++} may be depleted under acid rains of the area, a sufficient concentration will still be adsorbed on the clay sites so that a good soil permeability and structure is maintained high [14]. Such water where the sum of Ca^{++} and Mg^{++} > Na^{++} will be very good for irrigation even if the total mineral content is high. It has been observed that, amongst other measures, reducing the SAR of the water supply and addition of organic residues, overcome water infiltration problems (i.e. reduces water shortage available water) in soils [29]. Really the vegetations growing at the WDS site have been observed to be lush even in the dry season suggesting adequate availability of residual water in the root zone [10] than in the surrounding area. Therefore, the low SAR at WDS, with low EC, suggest that the organic residues of the WDS as incorporated into the WDS soil would assist the infiltration rate of the soil just as organic mulch would do[14],[30].

4.3.2. Water pH, Alkalinity and Irrigation Water

Soil water or soil solution with a pH that is too high can result in nutrients deficiencies especially iron micronutrient [20],[29]. This case was not observed in the studied soil because the pH was not too high (not too alkaline; (Table 1)) and the micro nutrients (N,P, K, Ca, Mg,) were not deficient under the dumpsite condition in wet and dry seasons. The pH was also not too low so as to offer micronutrient toxicities to the soil or to change the plant's rooting under irrigation with good quality water. It is rather known that soils of the wetlands and ravine (Valley bottom) below the waste dump do need liming (like addition of CaO fertilizer) to improve its alkalinity [25],[31]. However, the lush water plants suggests that the river ponds and the bed sediment, which have settleable loads from the MSW leachate and suspended load in the NPS runoff from the waste dump site, are rich in micronutrients (O. E. Essien, 2013, Paper in Process).

Although desirable pH range in the root zone that offers comfort to most plants is put at 5.5 – 6.5, which is in agreement with the CS (5.59 – 5.78), the pH of 7.13 – 7.92 is not highly alkaline (being in the pH accepted as standard drinking water quality) to warrant addition of acid to change the water alkalinity, since many local crops which were observed growing there had luxuriant growth.

Less than 45 mg/l $CaCO_3$ is considered to be a low alkalinity soil solution, with low buffering capacity, which if acid is added will quickly affect its pH. However, the Ca of the WDS soil had a mean of 4.57 Cmol/kg which was 91.4 mg/l or 114.11 $CaCO_3$; and Mg was 2.19 Cmol/kg or 26.28 mg/l (91.11 $MgCO_3$) [29]. These quantities are more than the minimum limit of 45 mg/l $CaCO_3$. Hence, the buffering capacity of the soil solution at WDS is high against infiltrating acidic water. In the whole composting these municipal solid wastes for organic amendment of the acidic riparian soils, apart from any possible enrichment of trace or heavy metals, if would augur-well to management of municipal[14],[1]. Solid waste problem at dumpsites prior sorting of metals waste and recycles will reduce metal contamination.

5. Conclusion

Investigation of physico-chemical soil properties at dumpsite and surrounding area was carried out at Uyo MWS dumpsite soil. Samples were taken from four points at two depths (0-10 and 10-20cm) at dumpsite (WDS) and surrounding (CS) soil and tested in the standard procedures for texture and chemical properties including pH, base metals and other macro-nutrients, salinity through (EC) and sodium hazards through (SAR). Definite patterns of higher values of soil properties at dumpsite soil (WDS) than counterparts at surrounding or control soil (CS) were observed and were in line with results from open dumpsite studies in other developing economies (India, China, Iran). The soil pH registered alkali soil (pH 7.51±0.27) at WDS and acidic soil (pH 5-69±0.67) at CS which is the usual pH of the natural soil highly leached by acidic rainfall in the rain forest area. Base saturation showed high values of Ca^{++} and Mg^{++} more than Na+ such that sodium hazard was countered or low at both WDS and CS (SAR 0.02 – 0.03 at WDS and 0.003 – 0.013 at CS). Variability of properties (CV : 55-200%) was limited to EC, K, SAR and silt at WDS and EC, TN, EA, silt and clay at CS, otherwise they were nearly homogenous isentropically. Application of low salinity (or good quality) irrigation water had no degrading effect on WDS soil; however tolerance of medium – to - high salinity irrigation water was negligible. The study has informed us of the properties levels for use in future MSW monitoring and management.

Conflict to interest

The authors declare hereby that there are no known or outstanding impending conflicts on this article for publication or any such matter.

Contribution of the authors

The corresponding author, Dr. O. E. Essien contributed in identifying the research area, mobilizing men and materials for field work, directing field data collection and analysis, writing the paper and exercising overall paper supervision. The co-author assisted in data collection.

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