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A Microbiological and Physicochemical Assessment of Top Soils from Makeshift Open Waste Dumpsites in the Premises of some Schools in Benin City

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Abstract

A major factor which has contributed to the declining environmental and health conditions of urban communities is the indiscriminate dumping of solid waste in premises of public institutions such as public schools. The microbiological and physicochemical properties of surface soil samples obtained from twelve (12) waste dumpsites located in public schools across Benin City, Edo State were assessed using standard procedures. Sampling was conducted between the months of May and July 2018. The mean heterotrophic bacterial and fungi counts for the soil samples ranged from 2.81 ± 1.01 to 6.38 ± 1.78 (×10^4cfu/g) and 2.00 ± 0.73 to 7.03 ± 0.86 (×10^3cfu/g), respectively. Ten microbial isolates were tentatively identified as follows: Acinetobacter sp., Pseudomonas aeruginosa, Micrococcus sp., Bacillus sp., Klebsiella sp., Enterobacter sp., Aspergillus niger, Penicillium sp., Mucor sp., and Fusarium sp. Pseudomonas sp. was the most dominant (16.00%) amongst the bacterial isolates, whilst Enterobacter sp (4.00%) was the least occurring bacterial isolate. Aspergillus sp. (17.00%) was the highest occurring fungal isolate, while the Fusarium sp. (8.00%) was the least. The mean concentration of the physicochemical results showed values which ranged from 5.82 ± 1.58 to 6.72 ± 1.17, 77.22 ± 6.14± 2.00 to 259.67 ± 64.34 µS/cm, 2.26 ± 0.53 to 5.83 ± 1.18 mg/kg, 29.11 ± 16.11 to 60.06 ± 10.76 mg/kg, 13.99 ± 3.22 to 33.57 ± 26.57 mg/kg, 6.42 ± 0.46 to 13.91 ± 2.43 mg/kg, 1.44 ± 0.72 to 3.83 ± 2.47%, 2.28 ± 0.69 to 6.71 ± 4.05% for pH, electrical conductivity (EC), Sulphate (SO^-_4), Nitrate (NO^-_3), Phosphate (PO_4^{-3}), Ammonium (NH_4^+), Total Organic Carbon (TOC) and Total Organic Matter (TOM), respectively. There was a significant difference between the values of most of the physicochemical parameters of the soil from the dumpsites and control sites. The presence of potential pathogenic microorganisms in the soils collected from the respective dumpsites is a major public health risk.

Keywords: Public schools, dumpsites, physicochemical, microbial and Benin City

1. Introduction

Solid wastes may be regarded as any material resulting from domestic activity and industrial operations for which there is no economic value and thus must be disposed (Sridhar, 1998). Population growth, economic development and urbanization have led to the increase and complexity of waste generated by urban areas dwellers (Verge and Rowe, 2013). Solid waste pollutants are known to serve as an external force which may have an impact on the physicochemical characteristics of soil, and as such can contribute to the poor production of vegetation (Christensen et al., 2014). Improper waste disposal in public schools in Nigeria has become a matter of public health concern for stakeholders such as civil society groups. Most public schools in Nigeria generate solid waste from daily activities such as classwork, sweeping, serving of food, clearing and bush burning. Open dumpsites are common practice in public schools due to insufficient or lack of waste disposal facilities. The common types of solid wastes found in the various schools include paper, grass, nylon (for sachet water, ice cream, sweets), corn cobs, groundnut shells, organic waste, cartons, tree leaves, steel cans, plastic bottles, and chalk (Wahab, 2003). Other forms of solid wastes, which are not directly generated by the students or teachers, but from neighboring residential premises, are also dumped at these sites. The continued increase in the quantity of waste generated in schools may not be unconnected with the increase in the number of students enrolled in schools yearly, improved living standards, urbanization, and technological advancement. Poor waste handling and disposal in schools especially where sanitation facilities are poorly planned and constructed, badly maintained and not properly deployed can lead to environmental pollution. This can further encourage the breeding of insects, animal scavengers and rodents, and result in a range of diseases through different routes of exposure such as fecal-oral and soil transmitted mechanisms. (WHO, 2005). The main aim of this study is to assess the physicochemical and microbiological quality of top soils collected in the vicinity of these makeshift open waste dumpsites located within public schools across Benin City.

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2. Materials and Methods

2.1 Study Area

The study area is Benin City in Nigeria. Benin City is a humid tropical urban metropolis which comprises four Local Governmental Areas, namely Egor, Ikpoba Okha, Oredo, and Ovia North East. It is located within latitudes 6°20′N and 6°58′N, and longitudes 5°35′E and 5°41′E (Okhakhu, 2010). It broadly occupies an area of approximately 112.552 km with an estimated population of 1,086,882 people (NPC 2006). The city has over 500 schools made up of both public and private nursery, primary, and secondary educational facilities.

2.2 Sample Collection

Surface soil samples were collected from twelve open dumpsites within twelve public secondary schools sited across Ikpoba Okha, Egor, Oredo Local Government and Ovia North East area of Edo State. The samples were collected between May and July, 2018. About One-hundred grams of the surface soil samples were collected in triplicates at a depth of 2 cm - 20 cm with the aid of a soil auger. The surface debris of the soils was removed before sampling. The samples were dispensed into sterile containers and appropriately labeled. A control soil was obtained from a farmland in the University of Benin, Ugbowo, Benin City.

2.3 Enumeration and Identification of Heterotrophic Soil Microflora

The mean heterotrophic bacterial and fungal count of the soil samples were examined with the aid of serial dilution and pour plate technique as described by Harley and Prescott (2002) and Aneja (2003).

2.4 Characterization of the Soil Microbiota

The subcultured bacterial isolates were subjected to an array of relevant physiological and biochemical tests which included; catalase production, spore staining, coagulase production, sugar fermentation tests Gram staining, and oxidase test. The results were compiled and the tentative identity of the respective bacterial isolates were ascertained by the comparison of the complied results recorded for the respective isolates with descriptive identification schemes as described by Holt et al. (1989) and Cullimore (2000). The subcultured fungal isolates were identified on the basis of their morphological and microscopic features. The cultural attributes of the subcultured fungal cultures were noted, and the microscopic features of the fungal isolates were observed with the aid of the wet mount procedure as described by Sharma (2009). The mountants were stained with lactophenol cotton blue and distilled water was employed respectively as described earlier by Obayagbona and Enabulele (2013). The microscopic structures observed were recorded and compared to illustrations stated by Barnett and Hunter (1972) and Alexopolulos et al. (1996).

2.5 Physicochemical Analyses of the Soil Samples

The following physiochemical properties of the various soil samples were determined. Parameters which included pH, electrical conductivity (EC), and particle-size distribution were ascertained using the procedures described by Kalra and Maynard (1991). The soil samples were analyzed for their Nitrate (NO^-_3), Ammonium ($NH4^+$), and Phosphate (PO_4^{-3}) contents using the methods described by Onyeonwu (2000). The Total Organic Carbon (TOC) content of the respective samples was obtained according to procedure described by Bremmer and Mulvaney (1982) while TOM was determined according to the method described by Osuyi and Adesiyan (2005).

2.6 Statistical Analysis

The statistics package for social sciences (SPSS version 20) was used to generate analysis of variance (ANOVA), and the Duncan's multiple range tests were used to test significance and mean separation respectively at a 95% level of confidence. Pearson correlation was employed in the correlation analysis to examine and establish the association between and physicochemical characteristics and the microbial parameters of the waste dumpsites' samples.

3. Results and Discussion

The mean concentration of the physicochemical analysis of the soil samples collected from the waste dumpsites across public schools in Benin City is presented in Table 1. The degree of acidity or alkalinity of a soil is a very important property which affects many other physicochemical and biological properties. The mean values of pH across the sampled locations ranged from 5.82 ± 1.58 to 6.72 ± 1.17. The pH of the soils from most of the locations were significantly higher than that of the control soil (4.76 ± 0.68) at $p < 0.0.5$. (Table 1) This could be attributed to liming materials and the activities of some microorganism in the solid wastes (Ayade, 2003, Ideriah et al., 2006). The pH of the soils obtained in this study were slightly acidic, and was similar to the readings recorded by both Abdus-Salam (2009) and Ogbonna et al., (2009) who reported 5.4 to 7.7 and 5.6 to 6.0, respectively but are in contrast with the findings of Oguntimehin and Ipinmoroti, (2008); Parth et al. (2011). The moderate acidic pH values obtained in the sites under study could be attributed to the removal of basic cations or nutrients from the surface of the soils in the dumpsites as a result of the effect of anthropogenic activities such as burning which resulted in the loss of nutrients. The EC values in this study ranged from 77.22 ± 6.14 to 259.67 ± 64.34 µS/cm. These findings were lower than those of Osazee et al. (2013) who reported values from 164.00 to 540.00 µS/cm, respectively. The EC values were significantly higher than those of the control site except at Dumpsite 9 (DS9) with EC of 77.22 ± 6.14 µS/cm.

The high EC values in this study showed that the soil samples have a high concentration of soluble salts which is a good indicator of plant growth. The sulphate ranged from 2.26 ± 0.53 to 5.83 ± 1.18 mg/kg. There were significant differences in the sulphate concentration across the site and the control soil except in DS1.This finding is in agreement with an earlier study by Osazee et al. (2013) who showed a range of 2.38 to 3.44 mg/kg. The nitrate and phosphate values varied from 29.11 ± 16.11 to 60.06 ± 10.76 and 13.99 ± 3.22 to 33.57 ± 26.57 mg/kg, respectively. The Nitrate and Phosphate levels were significantly higher in the soils from the different sampled locations compared to the control sites at $P < 0.5$. This finding is consistent with the report of Akinbile and Yusoff (2012); Akinnusotu and Arawande (2016). The presence of nitrate in the soil may be attributed to the mineralization of nitrogen as a result of organic matter in the soil. Whilst the phosphate concentration could be attributed to the presence of a high amount of organic matter and plant decomposition at the dumpsites (Ideriah et al., 2006). The percentage of TOC and TOM recorded for the respective soils ranged from 1.44 ± 0.72 to 3.83 ± 2.47% and 2.28 ± 0.69 to 6.71 ± 4.05%. These percentages were higher than those of Abdus-Salam et al. (2011) who reported 0.028-0.409 and 0.048-0.707%. The carbon content and organic matter in the various dumpsite soils were significantly higher than those of the control soil samples which were 0.60 ± 0.31 and 1.16 ± 0.97%, respectively. The higher percentage of the concentration of organic matter in the examined soils could be attributed to the presence of organic waste residues which add more organic matter when decomposed. Munoz et al. (1994) also reported that the elevated amount of organic carbon in various soil samples in the vicinity of dumpsites could be suggestive of possible degradation or the presence of degradable and compostable wastes. Biyogue (2016) reported a positive correlation between organic carbon, organic matter, and the available phosphorous across forest soils which means that the high organic matter content increased the availability of soil phosphorous concentrations. This is, however, consistent with the findings of this study. Omar (2015) stated that the soil texture is known to play a critical role in the improvement of the cation exchange capacity (CEC) of the soil and therefore its capacity to hold major and minor nutrients. The percentage proportion of clay, silt, and sand in the soils from waste dumpsite are presented in Table 1. The soil samples from the various sampling points were silty, and this is in agreement with a report by Ogbonna et al. (2009) who observed that top soil samples collected from most waste dumpsites in Port Harcourt, Rivers State, Nigeria were silty in nature. However, this trend is inconsistent with the reports of Eneje and Lemoha (2013), Oyedele et al. (2008) and Ideriah et al., (2010), who observed that the top soils sourced from several municipal dumpsites in Owerri, Eastern Nigeria were sandy. The role of the soil forming materials in determining the textural class of a particular soil could be the reason for the differences in soil texture (Oyedele et al., 2008).

Table 1. Mean concentrations of physicochemical properties of open dumpsites

Locations	pH	EC	SO^-_4	NO^-_3	PO_4^+	NH^+_4	TOC	TOM	Clay	Silt	Sand
		(µS/cm)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(%)	(%)	(%)	(%)	(%)
DS1	6.21 ± 1.04b	116.22 ± 4.49ab	5.83 ± 1.18d	31.68 ± 16.69ab	13.99 ± 3.22ab	6.42 ± 0.46a	2.84 ± 0.68cde	4.53 ± 1.04cd	8.36 ± 0.51a	24.29 ± 0.78bcd	6.62 ±0.81cd
DS2	6.64 ± 1.20b	137.44 ± 11.16b	3.11 ± 0.57bc	41.26 ± 14.20ab	17.24 ± 5.44ab	10.13 ± 3.41ab	3.19 ± 1.25de	4.31 ± 1.37cd	6.96 ± 1.43a	16.11 ± 0.46abc	3.56 ±0.95ab
DS3	5.91 ± 1.84ab	134.89 ± 2.80b	1.93 ± 0.66a	30.86 ± 22.34ab	33.57 ± 26.57b	8.51 ± 6.01ab	2.20 ± 0.47bdc	3.69 ± 0.46bcd	4.66 ± 0.41a	17.89 ± 1.30abc	3.04 ± 0.55a
DS4	5.96 ± 1.43ab	137.33 ± 38.30b	3.50 ± 0.60c	43.44 ± 16.36abc	14.30 ± 1.12ab	10.97 ± 4.46ab	3.09 ± 1.43de	4.36 ± 1.89cd	9.11 ± 0.51a	20.37 ± 3.02abc	8.14 ± 0.59f
DS5	5.82 ± 1.58ab	185.89 ± 4.94c	3.39 ± 1.10c	45.52 ± 5.99bc	32.07 ± 22.81b	12.23 ± 4.77ab	3.22 ± 1.88de	5.52 ± 3.16de	7.20 ± 0.55a	14.80 ± 0.60ab	7.71 ± 1.10ef
DS6	6.28 ± 0.93b	95.22 ± 4.24ab	4.46 ± 0.65c	35.02 ± 19.54ab	33.38 ± 37.02b	8.16 ± 5.45ab	1.76 ± 0.84abc	3.10 ± 1.43bc	8.84 ± 0.62a	22.17 ± 0.50abcd	6.38 ± 0.61c
DS7	6.70 ± 1.31b	259.67 ± 64.34d	4.27 ± 0.67c	60.06 ± 10.76c	33.46 ± 16.27b	13.91 ± 2.43b	3.83 ± 2.47e	6.71 ± 4.05e	10.92 ± 23.66a	30.92 ± 32.85d	7.24 ± 0.39de
DS8	6.11 ± 1.12b	120.00 ± 6.95ab	2.30 ± 0.78a	37.40 ± 17.62ab	32.43 ± 32.63b	10.53 ± 7.82ab	2.59 ± 1.06bcde	3.87 ± 1.16bcd	8.45 ± 0.58a	13.72 ± 1.08a	6.64 ± 0.25cd
DS9	6.47 ± 1.49b	77.22 ± 6.14a	2.26 ± 0.53a	24.39 ± 13.69a	18.80 ± 18.48ab	8.54 ± 6.36ab	1.63 ± 0.85abc	2.28 ± 0.69ab	4.34 ± 0.22a	16.87 ± 1.21abc	4.00 ± 0.48b
DS10	6.72 ± 1.17b	131.89 ± 2.37b	2.61 ± 0.55ab	29.11 ± 16.11ab	28.86 ± 32.59ab	6.90 ± 3.53a	2.16 ± 0.88bcd	3.03 ± 0.49bc	6.58 ± 1.23a	16.21 ± 1.89abc	6.44 ± 0.20c
DS11	6.60 ± 1.44^b	136.00 ± 9.34^b	2.28 ± 0.55^a	31.62 ± 22.40^{ab}	18.98 ± 17.30^{ab}	7.07 ± 4.99^a	1.44 ± 0.72^{ab}	2.66 ± 1.12^{abc}	9.39 ± 1.34^a	20.62 ± 0.96^{abc}	9.07 ± 0.90^g
DS12	6.49 ± 1.26b	90.33 ± 14.32ab	4.28 ± 0.50c	40.39 ± 24.90ab	17.78 ± 13.88ab	9.14 ± 6.10ab	2.01 ± 0.98bcd	3.19 ± 1.61bc	7.68 ± 0.16a	16.93 ± 0.58abc	6.40 ± 0.70c
Control	**4.76 ± 0.68a**	**74.78 ± 147.53a**	**5.56 ± 0.48d**	**23.64 ± 24.26a**	**7.96 ± 6.65a**	**7.92 ± 9.13ab**	**0.60 ± 0.31a**	**1.16 ± 0.97a**	**9.80 ± 0.76a**	**25.17 ± 2.54cd**	**6.92 ± 0.42cd**

Values are Mean ± SD of three replicates. Different superscripts in the same column indicate significant differences at $p < 0.05$ according to Duncan Multiple Range Test (DMRT). EC= electrical conductivity, EC electrical conductivity, SO^-_4 sulphate, NO^-_3: nitrate; PO_4^+ Phosphate, NH^+_4 Ammonium, TOC total organic content, TOM total organic matter, DS= Dumpsites.

The results of the microbial count in waste dump on soils are shown in Table 2.

Table 2. Total Bacterial and Fungal counts of the surface soil samples from the dumpsites

Location	THBC (×10^4cfu/g)	THFC (×10^3cfu/g)
DS1	2.81 ± 1.01a	3.38 ± 0.86abc
DS2	3.22 ± 1.52ab	5.39 ± 1.27de
DS3	6.38 ± 1.78g	4.14 ± 2.88bcd
DS4	5.22 ± 0.63defg	3.07 ± 1.18ab
DS5	3.33 ± 0.99ab	4.03 ± 0.86cd
DS6	3.93 ± 1.87abcd	3.22 ± 1.42abc
DS7	2.67 ± 1.34a	4.61 ± 2.20cd
DS8	5.64 ± 0.65efg	3.02 ± 1.63ab
DS9	5.96 ± 0.72fg	3.39 ± 1.08ab
DS10	4.74 ± 2.41cdef	2.00 ± 0.73a
DS11	4.50 ± 0.69bcde	3.80 ± 0.94bc
DS12	3.86 ± 0.58^{abc}	3.97 ± 0.65bcd
Control	**2.71 ± 0.61a**	**3.03 ± 0.46ab**

Values are Mean ± SD of three replicates. Different superscripts in the same column indicates significant differences at p < 0.05 according to Duncan Multiple Range Test (DMRT). THBC and THFC Total Bacterial and Fungal counts, respectively.

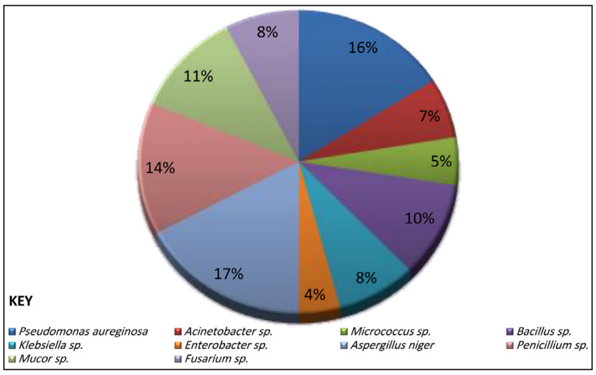

Figure 1. Percentage frequency of occurrence of the microbial isolates

The mean heterotrophic bacterial counts ranged from 2.81 ± 1.01 to 6.38 ± 1.78 (×10^4cfu/g), while the THFC ranged from 2.00 ± 0.73 to 7.03 ± 0.86 (×10^3cfu/g). The bacterial counts in soils from the dumpsites were significantly higher than those of the control soil ($P < 0.05$) except at sites DS1 and DS7. This trend is supported by the higher organic carbon and nitrogen content of the dumpsite soils in comparison to the control soil (Table 2). This phenomenon might be the result of the increased availability of biodegradable organic and inorganic substrates from the variety of municipal wastes being continuously dumped at these sites. There was no significant difference between the total heterotrophic fungal count of the dumpsite soils and the control soil samples.

The isolation of Acinetobacter sp., Pseudomonas sp., Micrococcus sp. Bacillus sp., Klebsiella sp., Enterobacter sp. Aspergillus sp., Penicillium sp., Mucor sp. and Fusarium sp. was similar to a report by Osazee et al. (2013) who isolated similar microorganisms from a municipal waste dumpsite in Benin City. All the microbial isolates identified from the soil samples have been reported to be associated with wastes and waste biodegradation (Obire et al. 2002).

The frequency of the bacterial isolates from the waste dumpsite soils were: Acinetobacter sp. (7.00%) Pseudomonas aeruginosa (16.00%), Micrococcus sp. (5.00%), Bacillus sp. (10.00%) Klebsiella sp. (8.00%) and Enterobacter sp. (4.00%), while those of fungi were Aspergillus niger (17.00%), Penicillium sp. (14.00%), Mucor sp. (11.00%) and Fusarium sp. (8.00%) (Figure 1). The bacterial cultures isolated in this study, with the exception of Arthrobacter, are known to occur more commonly in the air and soil environments, and have been described as opportunistic human pathogens (Cheesebrough, 2006). Pavoni et al. (1975) reported that truly pathogenic forms of fungi may survive in waste. The open dumping of garbage around the schools could also function as a breeding ground for disease vectors such as flies, mosquitoes, cockroaches, rats, and other pests. These dumpsites could pose public health risks to the students, teachers, and populations living around the school premises whose food and water supplies may, perhaps, become contaminated as a result of either waste dumping or leakage from dumpsites during rains. This could lead to an increased risk of the spread of infectious diseases such as food and waterborne diseases (Aboagye-Larbi et al., 2004).

Table 4. Correlation between physicochemical and microbiological parameters of the top soil samples at the dumpsites

	pH	EC (µS/cm)	SO^-_4 (mg/kg)	NO^-_3 (mg/kg)	PO^+_4 (mg/kg)	NH^+_4 (mg/kg)	TOC (%)	TOM (%)	Clay (%)	Silt (%)	Sand (%)
THBC (×10^4cfu/g)	-0.064	-0.354**	-0.466**	-0.241**	0.170	-0.140	-0.059	-0.144	-0.036	-0.126	-0.162
THFC (×10^3cfu/g)	0.234*	0.163	-0.321**	0.265**	0.153	0.307**	0.026	0.005	0.056	-0.081	-0.174

***. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).*

Table 4 revealed that EC, SO^-_4, NO^-_3 correlated negatively but weakly with the total bacterial count (r = -0.354), (r =-0.466) and (r =-0.241), respectively at a $p < 0.01$ significant level. This inverse relationship may be attributed to the high level of EC, sulphate, and nitrates which may become toxic to the bacterial populations. pH correlated positively but weakly with the total fungal count (r = 0.234; at $p < 0.05$). The weak positive association could be attributed to the moderate acidic pH level of the soil due to human activities such as burning. Nitrate and ammonium correlated positively with THFC (r =0.265), (r =0.307) at $p < 0.01$. Tangjang et al., (2009) reported that the higher soil fungal counts were due to the greater availability of nitrate and ammonium nutrients which could be a result of the increased accumulation of biodegradable wastes at the dumpsites.

4. Conclusions

The current study reveals a significant difference in most of the physicochemical parameters of the soils in the vicinity of the waste dumpsites and the control sites. This is an indication of the improvement of the soil quality by the waste, which is being dumped constantly at the sites within the school vicinities. However, this study also shows the presence of a high microbial load which could be linked to the increased nitrate, phosphate, organic carbon, and organic matter levels reported in the examined dumpsite soils. The provision of adequate waste collection facilities and the mainstreaming of hygiene education and sanitation into the schools' systems can improve the collection and management of municipal solid waste (MSW).

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