Influence of abattoir wastes on soil microbial and physicochemical properties

ABSTRACT

Aim: To assessed the Influence of abattoir wastes on soil microbial and physicochemical properties with regards to its agronomical potential

Design: Soils impacted with abattoir wastes were collected from two each of Ikot Ekpene (IK1, IK2) and Eket (EK1, EK2) Local Government Areas in Akwa Ibom State, Southern Nigeria. Soils far from the abattoir wastes area were also obtained from the two area and used as control.

Methodology: Physicochemical, essential and trace metal levels, microbial studies of both abattoir and control soils were carried out using standard analytical and microbiological methods.

Results: Studied abattoirs and the control soils were in the sandy-clay-loamy soil category with varied quantities of sand, silt and clay. Physicochemical properties of studied abattoir soils were higher than in control. Essential elements (K, Na, Ca, and Mg) and trace metals (Fe, Zn, Cd, Cu, Pb, Cr and Ni) levels were also higher in abattoir soils than in control though were within permissible limit in soil except for Fe. Pollution status calculations using empirical models indicated slight to moderate pollution of abattoir soils by most of the trace metals studied. Microbial studies revealed total heterotrophic bacteria ranged from 6.41±0.43 to 7.91±0.58 log_{10}CFU/g while fungal count ranged from 4.94±0.26 to 5.79±0.34 log_{10}CFU/g. Among the four (4) locations, IK2 had the highest heterotrophic bacterial densities of 7.91±0.58 log_{10}CFU/g while IK1 had the highest fungal count of 5.79±0.34 log_{10}CFU/g. A total of six (6) bacteria (*Klebsiella, Micrococcus, Pseudomonas, Bacillus, Escherichia* and *Enterobacter)* and two (2) fungi (*Aspergillus* and *Penicillium*) species were isolated.

Conclusion: Soil impacted with abattoir wastes is richer in plant nutrients and can be exploited for growing of crops. But it is advised that routine checks be conducted to forestall trace metals accumulation above safe levels in these soils.

Keywords: Microbial, physicochemical properties, abattoir waste, pathogens

INTRODUCTION

Studies have shown that environmental pollution and its attendant problems on land, air and water qualities are severe now than before. There are several evidences to this fact ranging from soil fertility loss, depletion of biodiversity, several health problems (those leading to metabolic disorder), ecological effect and others [1-3].

The major cause of these pollutions is the indiscriminate discharge of wastes into these natural habitats thereby tampering with the natural workings of the environment. Solid and liquid wastes are usually disposed off on open landfills, waterways, rivers and stream indiscriminately by most industries (small and large), and the entire populace. These practices are very common in Nigeria till date since there are no well define management protocols on solid waste disposal.

Abattoir waste is another emerging solid waste whose rate of generation is becoming alarming. Meat processing is usually carried out in a specialized environment known as abattoir or slaughter house. According to [4]; it is a place or building where animals are killed and processed for their meat. Several activities are involved in the operation including receiving and holding of livestock, slaughter carcass, dressing of animals, chilling of carcass products, carcass boning and packaging, drying of animal skins [5]. However, in Nigeria, meat processing activities are mostly carried out in unsuitable places or building by butchers who have little or no idea of sanitary principles. These activities are usually accompanied by the generation of large amount of wastes like blood, fat, organic and inorganic solids, salts which are hitterto discharged into soils and water bodies around the abattoir premises [6 – 7].

Abattoir wastes have complex composition and can be very detrimental to any environment where they are discharged. Various organs of cattle like muscles, blood, liver and kidney have been reported to contain trace metals, faeces of livestock consist of mucus, bacteria, cellulose fibre, paunch manure which is very acidic in nature and others [8 – 11]. Additional reports have been made on the effect of abattoir wastes on soil including increase concentration of trace metals, increase population of decomposers, loss of aesthetic value, excessive soil nutrient enrichment and increase toxin accumulation, as well as large accumulation of sulphides, mercaptans, amines and organic acids [3, 11, 12 -15].

In Akwa Ibom State, most abattoirs have farmlands surrounding them and these farmlands are usually cultivated by local farmers living in the vicinity of these abattoirs. These soils are used to plant crops mostly vegetables and legumes which are consumed by humans due to good crop yields from these abattoir soils without any assessment of its sanitary nature. Therefore this study seeks to investigate the influence of abattoir wastes on the physicochemical properties, trace metal levels and diversity of microorganisms in such soils.

Materials and Method

Sample collection, treatment and analysis

Top soil samples were obtained from four different abattoir soils, two each from Ikot Ekpene (IK1, IK2), and Eket Local Government Area (EK1, EK2) respectively in Akwa Ibom State, Southern Nigeria. At each Local Government Area, top soil not close to a slaughter house or abattoir waste was also collected as Control samples (IKC, EKC). The abattoir soils were collected after clearing off waste materials from the soil within the vicinity of these abattoirs and were done in January 2018. Soil samples were collected by using Soil Auger to obtain soil from the depth of 0 – 20 cm. A total of six (6) soil samples were collected for this study. Soil samples for microbial studies were placed in sterile polythene bags and transported to the laboratory for immediate analysis. For chemical analysis, samples and Control were air dried for three days to drive off any liquids, ground and sieved using a 2mm mesh. One gram of the sieved samples and Control was mixed with Aqua Regia (HCl/HNO_3 3:1) and digested on a hot plate. The filtrate obtained was used for the determination of total Fe, Zn, Cd, Cu, Pb, Cr, Mg, and Ni levels using Agilent 710 Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). Na, K and Ca were determined using flame emission spectrophotometer (Model 381&391) at different wavelengths

Determination of textural class and physicochemical properties

Particle size distribution through the physical analytical test was carried out using the hydrometer methods as describe by [16]. Textures class of the abattoir soils and Control were determined using United States Department of Agriculture (USDA) textural triangle, while Bulk density was determined by gravimetric method as described by [17]. The pH of studied abattoir soils and Control was determined in a 1: 2.5 (v/v) soil/water suspension as described by [18]. Electrical conductivity was measured using portable meters after calibration with standard solutions. Salinity was determined following the method of [19]. Moisture content was determined gravimetrically after drying the soils in an oven (Gallenkamp OV-330) at 105 °C until a constant weight was obtained. Total organic matter content was measured by wet oxidation methods of Walkley and Black reported by [20]. Total organic carbon and cation exchange capacity were determined using the methods of [21] and [22] respectively. Total petroleum hydrocarbon content, nitrogen and phosphorus were done by methods describe by [23 – 25] respectively in their previous works.

Microbiological Analysis of the Abattoir soil Samples

The microbiological analysis of the soil samples were carried out according to the methods described by [26]. Bacterial and Fungal Counts were enumerated using pour plate method as described by [27]. The bacteria culture plates were incubated at 37°C for 48 hours, the fungal plates were incubated at room temperature (28 ± 2^{o}C) for 4 days. The emerging colonies were enumerated using the Quebec colony counter and recorded as colony forming unit per gramme of sample (CFU/g).The emerging colonies after the incubation period were discretely isolated and sub-cultured repeatedly on freshly prepared Nutrient agar for bacteria and Sabouraud Dextrose agar for fungi to obtain pure isolates. The pure isolates were maintained on agar slants and stored at 4°C for further use. The bacterial isolates were characterized based on their cultural and morphological attributes as well as their responses to standard biochemical test as described by [28] and identified as described in Bergey's manual of determinative bacteriology [29]. Fungal isolates were characterized on the basis of their cultural attributes, and identified by consulting various taxonomic books and monographs available on various groups of fungi [30].

Determination of Pollution status of trace metals in studied abattoir soils.

Metal pollution index (MPI)

Metal pollution index (MPI) usually indicates the relationship between metal in studied soil and in reference soil (Control). MPI was calculated in this work using equation (1) given below

$$MPI = \frac{\textit{Concentration of metal in studied soil}}{\textit{Reference soil (control)}} \quad \text{---} \ (1)$$

The classifications of MPI according to [31] are given in Table 1 below

Table 1: Classification of metal pollution index in soil and their implications

MPI	Significance	Remarks
< 0.1	Very slight contamination	No negative effect on soil, plant and environment
0.10 -0.25	Slight contamination	No negative effect on soil, plant and environment
0.26 – 0.50	Moderate contamination	No negative effect on soil, plant and environment
0.51 – 0.75	Severe contamination	No negative effect on soil, plant and environment
0.76 – 1.00	Very severe contamination	No negative effect on soil, plant and environment
1.10 – 2.00	Slight pollution	Will pose negative effect on soil, plant and environment
2.10 – 4.00	Moderate pollution	Will pose negative effect on soil, plant and environment
4.10 – 8.00	Severe pollution	Will pose negative effect on soil, plant and environment
8.10 – 16.00	Very severe pollution	Will pose negative effect on soil, plant and environment
> 16.00	Excessive pollution	Will pose negative effect on soil, plant and environment

Degree of contamination (Cdeg)

Degree of contamination of each location within the studied abattoir soils and Control was calculated using equation (2)

$$Cdeg = \sum MPI \quad ------------------------(2)$$

where MPI denotes the sum of metal pollution index for all the elements at a particular location. The different classifications of Cdeg according to [32] are as follows: Cdeg < 8 = low degree of contamination, 8 < Cdeg < 16 = moderate degree of contamination, 16 < Cdeg < 32 = considerable degree of contamination and 32 < Cdeg = very high degree of contamination.

Enrichment factor (EF)

Enrichment factor and percent enrichment of each metal were determined using equations (3) and (4) below

$$EF = \left(\frac{M}{Fe}\right) D \Big/ \left(\frac{M}{Fe}\right) C \quad ------------------------ \ (3)$$

where D = Abattoir soils studied; C = Control; M = metal studied; Fe in the equation is used for normalization [33]. EF values close to one indicate natural origin; values less than 1.0 suggest a possible mobilization or depletion of metals, while EF > 1.0 indicates that the element is of anthropogenic source [34].

Geoaccumulation index (Igeo)

Geo-accumulation index (Igeo) of trace metals in studied soil was determined using equation (5) below

$$Igeo = Log\,2(Cn/1.5Bn) \quad ------------------------- (5)$$

where Cn is the measured concentration of metal in studied abattoir soils, Bn is the concentration of metal in Control site while 1.5 is a constant to allow for fluctuations of a given metal in the environment as well as small anthropogenic influences [35]. The different classes of geo-accumulation index as proposed by [36] are as follows: Igeo < 0 = unpolluted, 0 – 1 = unpolluted to moderately polluted, 1 – 2 = moderately polluted, 2 – 3 = moderately to strongly polluted, 3 – 4 = strongly polluted, 4 – 5 strongly to extremely and Igeo > 5 = extremely.

Pollution load index (PLI)

Pollution load index (PLI) of metals in a particular location was obtained using equation (6).

$$PLI = (MPIFe \times MPIPb \times MPICd \times MPIZn \times MPICu \times MPICr \times MPINi)^{\frac{1}{7}} \quad ------(6)$$

Where MPI represents metal pollution index for the metals at each location. The different categories of PLI as proposed by [37] are as follows: No pollution (PLI <1), moderate pollution (1< PLI < 2), heavy pollution (2 < PLI < 3) and extremely heavy pollution (3 < PLI)

Results and Discussion

Results for bulk density (gcm^{-3}), pH, and textural characteristics (quantity of sand, silt and clay) of abattoir and Control soils are presented in Table 2

Table 2: Quantity (g/kg) of sand, silt and clay, textural class, bulk density and pH of abattoir soils and Control from Akwa Ibom State, Southern Nigeria

	Sampling points					
	IK1	IK2	IKC	EK1	EK2	EKC
Parameters						
Sand (%)	58	55	48	56	52	50
Silt (%)	12	8	15	10	14	17
Clay (%)	23	22	18	25	20	24
Texture	SCL	SCL	SCL	SCL	SCL	SCL
Bulk density (gcm^{-3})	1.42	1.28	1.14	1.38	1.36	1.17
Soil pH*	5.30	5.18	4.60	4.95	4.78	4.74

pH* (1:2.5 soil: water ratio); SCL – Sandy-clay-loamy soil; IK1-Ikot Ekpene abattoir soil 1; IK2-Ikot Ekpene abattoir soil 2; IKC-Ikot Ekpene control soil; EK1-Eket abattoir soil 1; EK2 - Eket abattoir soil 2; EKC - Eket control soil

The results indicated varied textural characteristics, bulk density and soil pH among the studied abattoir soils and Controls. For the two abattoir soils, the percentage of sand, silt and clay in the soil samples were within the range of 50 – 58% (sand), 8 -15% (silt) and 20 -25% (clay); while their Controls were 48 – 50% (sand), 15 - 17% (silt) and 18 - 24% (clay). The percentages of sand, silt and clay obtained for abattoir soils in this work agrees with 52 – 59% (sand), 10 -16% (silt) and 25 -30% (clay) reported by [19] for abattoir soils from Port Harcourt, River State, Southern Nigeria but disagrees with 76 – 83% (sand), 1.5 – 2.0 % (silt) and 13 -23% (clay) reported by [38] for abattoir soils from Calabar, Cross River State. All the abattoir soils studied and their Controls fell in the sandy – clay – loam (SCL) class of soil, with higher percentage of sand, followed by clay and then silt. Soil texture parameter was measure so as to reveal the physical properties of the soil such as water retention capacities, permeability, easy or toughness of tillage of the soil studied among other things. From these findings, the abattoir soils under investigation were seen to have potential of holding more water within the particle because of the high percentage of clay [39].

Results for bulk density (gcm^{-3}) and pH of abattoir soils and their Controls are presented in Table 2. The results indicate that both parameters varied differently among the abattoir soils and the Control with bulk densities having ranges of 1.28 – 1.42 for the two abattoir soils and 1.14 -1.17 for the Control. The result also reveals that the bulk densities of the abattoir soils were higher than those of the Control. The variations maybe as a result of differences in soil texture and organic matter content of abattoir soils and the Control. Also, Abattoir soil recorded greater percentages of sand than the Control soil and soils with higher percentage of sand is usually more prone to high bulk density [17]. The range of bulk density obtained in this work is in agreement with 1.16 – 1.81 gcm^{-3} reported by [40] for abattoir soils from Abeokuta, South western Nigeria, but in contrast with 1.50 -1.65 gcm^{-3} reported by [41] for abattoir soils from Makurdi, Benue State, Nigeria. However, the values for bulk densities obtained in this work are considered suitable for crop production and also within the critical range [42 -43]

The pH values for the two abattoir soils and their Controls recorded in this work were 4.78 – 5.30 and 4.60 - 4.74 respectively as indicated in Table 2. This parameter was determined because pH (acidity or alkalinity) plays a great role in determining the availability of nutrients in soil to plant and the type of organism found in the soil [44]. The results indicated that all the soils (abattoir and Control) studied were acidic in nature, with their Control soils showing higher acidities than the abattoir soils. However, the obtained ranges reported in this work are lower than 6.22 – 7.44 reported by [45] but are consistent with 4.99 – 6.73 obtained by [5] in abattoir soils though with slight differences. Also, the observation of higher pH obtained for abattoir soils than in the Control soil obtained in this work is in line with the findings of [46]. This could be attributed to biodegradable waste materials in studied abattoir soils which may lead to reduced anaerobic activities in these soils [47]. Consequently, pH of soils impacted by abattoir wastes could be affected considerably. Although there is no acceptable standard for pH for an ideal soil for planting as it depends upon the type of crops, researches have shown that most minerals and nutrients are best available to plants in soil with a pH of between 6.5 -6.8 [48 – 49].

Table 3: Physicochemical parameters of selected abattoir and Control soils

	Sampling points					
	IK1	IK2	IKC	EK1	EK2	EKC
Parameters						
Temperature (^oC)	30.45	32.10	27.33	31.67	30.98	28.49
EC (µS/cm)	40.60	38.62	19.56	42.18	44.05	20.86
Salinity ($mgkg^{-1}$)	18.00	22.00	10.50	15.00	26.06	13.15
Moisture content (%)	10.35	12.86	3.78	11.70	10.06	4.05
TOM (%)	8.65	7.94	4.37	7.27	8.42	4.64
TOC (%)	13.76	12.92	5.67	14.31	15.05	6.82
CEC (Cmol/kg)	28.63	26.80	20.84	25.11	26.95	21.67
TPH ($mgkg^{-1}$)	8.06	7.15	2.61	11.72	13.63	4.52
Nitrogen (%)	0.04	0.06	0.01	0.09	0.10	0.02
Phosphorus ($mgkg^{-1}$)	2.21	3.18	0.38	2.19	1.84	1.09

*EC – Electrical conductivity; TOM – Total organic matter, TOC –Total organic carbon, CEC – Cation exchange capacity, TPH – Total petroleum hydrocarbons; IK1-Ikot Ekpene abattoir soil 1; IK2-Ikot Ekpene abattoir soil 2; IKC-Ikot Ekpene control soil; EK1-Eket abattoir soil 1; EK2 - Eket abattoir soil 2; EKC - Eket control soil

Results for the physicochemical properties of selected abattoir soils and their Controls are presented in Table 3. Temperature (^oC) ranges for the two abattoir soils studied and their Controls were 30.45 – 32.10 and 27.33 – 28.49 respectively. The results also indicate that abattoir soils recorded varied temperatures and were higher than those of their respective Controls. The reasons for the differences in the temperatures among the abattoir soils may be attributed to factors such as variation in water content of the abattoir soils, soil relief and cover [19]. Temperature range for the abattoir soils obtained in this work is lower than (33.60 – 35.30) ^oC reported by [19] for abattoir soils from Port Harcourt, Rivers State, but higher than (18.80 – 21.43) ^oC reported by [50] for abattoir soils from Delta State, Nigeria. Temperature range for the Control soils recorded in this work is in agreement with 27.33 – 29.00^oC reported by [26] for soils from different part of Southern Nigeria.

Levels of electrical conductivities (EC) in µS/Cm varied from 38.62 to 40.60 for abattoir soils obtained from IK, 42.18 to 44.05 for abattoir soils from EK and 19.56 -20.86 for the Control soils (Table 3). Ranges obtained for EC in studied abattoir soils are higher than 2.03 – 2.54 µS/Cm reported by [51] but lower than 60.00 – 110.00 µS/Cm obtained by [45] in abattoir soils. Electrical Conductivity levels in studied abattoir soils were higher than values obtained at the Control soils, which is indicative of negative impact of abattoir wastes on studied soils. The findings of higher EC in abattoir soils than in Control are consistence with the report of

[52]. This could be attributed to the low cation exchange capacity (CEC) of Control soil and variations in rates at which metallic salts and organic matter complexes are formed [53 - 54]. Hence, EC of abattoir waste-impacted soils could be significantly affected by the wastes. However, EC values recorded in abattoir soils in this study is within the permissible limit (below 100µS/Cm) stipulated by [55].

Ranges for salt content (mgkg^{-1}) of abattoir and Control soils as presented in Table 2 were 15.00 - 26.06 and 10.50 – 13.15 respectively. This result indicates that soil content of abattoir soils were higher than those of the Control soils. Although, salt content in soil are caused by natural factors such as weathering, continuous irrigation or pouring of wastewater (after washing of animal parts) on soil can also increase salt content of soil. This is so because almost all water contains some dissolve salts. Range for salinity of abattoir soils obtained in this study is lower than 29.00 – 59.00 mgkg^{-1} reported by [19] and (475.05 – 667.88 mgkg^{-1}) by [45] for abattoir soils from Port Harcourt, River State, Southern Nigeria. However, the abattoir soils recorded salinity values that are within permissible limit (200 mgkg^{-1}) established for soil. The Low values of salinity recorded in abattoir soil is advantageous, since high salinity in soil usually leads to poor plant growth and lower soil microbial activity caused by osmotic stress and toxic ions [15].

Moisture content in % varied from 10.35 to 12.86 for abattoir soils obtained from IK, 10.06 to 11.70 for abattoir soils from EK and 3.78 to 4.05 for the Control soils (Table 3). The variations in these values especially between the abattoir soils and the Control may be as a result of the effect of the abattoir effluent on soil. Ranges obtained for moisture content in studied abattoir soils are higher than 7.03 – 9.54% reported by [56] but lower than 19.01 – 21.07% obtained by [19] and 17.91 – 19.50% obtained by [40] in abattoir soils. The findings of higher moisture content in abattoir soils than in Control are consistence with the report of [52]. This observation can be explained by the fact that in ruminants, the first stomach or paunch contains undigested materials or paunch manure. The paunch manure which is disposed on the soil could have a moisture content of about 88% [10].

Results in Table 3 indicate ranges for total organic matter (TOM) for IK, EK abattoir soil and Control soil as 7.94 – 8.65%, 7.27 – 8.42% and 4.37 – 4.64 respectively. These ranges are higher than 0.69 – 7.42% reported by [3] for abattoir soils, and is inconsistent with values obtained by [57] but lower than 5.57 – 24.13% obtained by [5]. Values of OM obtained in studied abattoir soils were also higher than values at Control which is consistent with report by [58 – 59]. This disparity may be attributed to the absence of biodegradable wastes at Control site thereby indicating that; waste materials from abattoir may increase the OM of soil significantly. Also, the faeces of livestock have been observed to consist of undigested food which hitterto will increase the OM content of abattoir soil [10]. However, soil organic matter usually act as a ‘‘storehouse or reservoir’’ for most metals hence it can influence their availability in soil either positively or negatively [46].

Total organic carbon (TOC) results indicated ranges of 12.92 – 15.05% for the abattoir soils and 5.67 - 6.82% for the Control soils. The Control soils recorded lower TOC than the abattoir soils. This may be due to high organic matter content of the abattoir soil. This observation corroborates with the reports of [3] and [60] in their respective studies. Ranges obtained for abattoir soils in this study are lower than 6.1 – 7.6% reported by [38] for abattoir soil from Calabar Metropolis, Cross River State Nigeria, but higher than 12.68 – 30.02% reported by [19]. The differences in the reported values of total organic carbon and those earlier reported for abattoir soils may be due to the rate of decomposition and composting of animal wastes such as dung, body part, blood, bones etc [3]. Organic carbon content in soil plays a vital role in soil development, fertility, and moisture availability in soil.

Cation exchange capacity (CEC) of studied abattoir soils varied from 26.80 to 28.63 Cmolkg^{-1} for IK abattoir soils, 25.11to 26.95 Cmolkg^{-1} for EK abattoir soils, and 20.84 to 21.67 Cmolkg^{-1}for the Control soils (Table 3). The result also shows that the respective abattoir soils recorded higher CEC than the Control soils. This is may be due to higher total organic matter content of the abattoir soils than in the Control soils including the clay content of the soil [61]. Higher content of CEC in abattoir soils than in the Control soils obtained in this study is in agreement with the report of [62]. Also, the obtained ranges of CEC in abattoir soils are higher than

12.54 - 16.84 $Cmolkg^{-1}$ reported by [57] in abattoir soils. CEC is a measure of the soil's ability to hold positively charged ions. It is very important to plant as it influences soil structure stability, nutrient availability, soil hydrogen concentrations (pH), and the soil's reaction to fertilizers and other ameliorants [63]. Although most crops do well in soil with low CEC, but vegetables and other productive food crops like vegetables are perform best in soil with moderate to high CEC [64]. This study thus reveals the impact of abattoir wastes on the CEC of soils impacted by wastes generated from abattoir activities.

Results presented in Table 3 reveals that total petroleum hydrocarbons (TPH) content of the abattoir soils ranged from 7.15 - 8.06 $mgkg^{-1}$ for abattoir soil samples from IK, 11.72 – 13.63 $mgkg^{-1}$ for abattoir soils from EK and 2.61 – 4.52 $mgkg^{-1}$ for the Control soils. For the abattoir soils, ranges obtained in this study is within the range (11.37 -27.68 $mgkg^{-1}$) reported by [19] for abattoir soils from Port Harcourt, River State, Nigeria. EK abattoir soils recorded higher TPH content than IK abattoir soils as shown in the Table 3. This is because EK hosts some oil companies like Exxon Mobil PLC, while there is no such in IK. For the Control soils, the range obtained in this study is lower than 3400 – 6800 $mgkg^{-1}$ reported by [65], for soils from Owaze in Abia State, and 581.02 $mgkg^{-1}$ reported by [61]. The large variation in the reported values of TPH content for the Control soils in this study and those earlier reported is as a result of lesser frequency of crude oil spill in the Control site used for this study. Areas of frequent crude oil spillage are expected to have higher TPH values than those of sparsely crude oil spillage. However, the lower concentrations of TPH in both abattoir and Control soils in this study is still a source of concern as TPH have been reported as a contaminant in any environment due to its toxicity to humans and other environmental receptors [66].

Total nitrogen content (%) (both as NH_4^+ - N and NO_3^- - N) and phosphorus ($mgkg^{-1}$) of the abattoir soils and Control soils are presented in Table 3. For Nitrogen, ranges are 0.04 – 0.06; 0.09 – 0.10 and 0.01 – 0.02 for IK, EK and Control soils respectively, while 2.21 – 3.18, 1.84 – 2.19 and 0.38 - 1.09 for IK, EK and the Control soils respectively. The variations between nitrogen and phosphorus contents among the abattoir and Control soils obtained in this study may be as a result of varied amounts of nitrogenous compounds in the abattoir impacted soils and the Control. The results also show that the abattoir soils recorded higher content of Nitrogen than the Control soils. This finding agrees the report of [38] who also reported higher nitrogen content for abattoir soils from Calabar, Cross River State than in the Control. Nitrogen content in abattoir soil obtained in this study is lower than 0.48 – 3.01% reported by [19] and 0.18 - 0.65% reported by [38] for abattoir soils, but higher than (0.008 -0.009%) reported by [67] for abattoir soils from Yola metropolis, Adamawa State, North Eastern Nigeria. For the Control soil, the obtained range is lower than 0.08 – 0.09% reported by [38]. For phosphorus, both abattoir soils recorded higher phosphorus content than the Control soils. This result also agrees with the report of [38]. This could be explained by the higher pH (less acidity) values and higher organic matter of the abattoir soils as indicated in Table 2. Range of phosphorus recorded in this study is in agreement with 2.46 – 3.61 $mgkg^{-1}$ reported by [67], though lower than 0.005 – 0.007 $mgkg^{-1}$ reported by [26] for abattoir soils obtained from Sokoto State, Nigeria. Both nitrogen and phosphorus contents of abattoir soils obtained in this study all fell within the permissible limits (nitrogen $<$ 40% and phosphorus $<$ 40 $mgkg^{-1}$) stipulated by [55] for soils. Although, nitrogen and phosphorus are needed in soil by plants since the first is a building block of protein, nucleic acid and other cellular constituents which are essential to all forms of life, the later is a component of the complex nucleic acid structure of plants, which regulates protein synthesis in plants [68]. However, excess nitrogen and phosphorus in soil usually causes plants to mature too rapidly in addition to reducing Zn, Cu and Fe availability in soil. Consequently, the moderate levels of nitrogen and phosphorus in the abattoir soils under investigation is plausible in lieu of its usage for planting of crops [45].

Results for essential elements and trace metal levels of abattoir soils and Control soils are presented in Table 4. The results indicated significant variations in the levels of all essential and trace metals investigated for the abattoir and Control soils. Results for potassium (K) indicated the following ranges: 0.81 -0.93 Cmol/kg for abattoir soils from IK, 0.68 – 0.74 Cmol/kg for EK and 0.17 – 0.26 Cmol/kg for the Control. The reason for this variation may be as a result of the high moisture content of the abattoir soils as indicated in Table 3. Levels of potassium in the Control soils were lower than those of the abattoir soils and this finding corroborates with the report of [57] who also reported similar findings. Ranges of potassium obtained in this study for the abattoir soils are consistent with the reports of [69] and [57] in their respective studies. Potassium has many different roles in the soil relative to plants. It is involve in photosynthesis as it regulate the opening and closing of stomata, regulate carbon(IV)oxide, triggers activation of enzymes and its essential for production of adenosine triphosphate (ATP) [64]. For other exchangeable bases (Sodium, calcium and magnesium), abattoir waste had significant influences on their levels in the studied abattoir soils.

From the results presented in Table 4, the abattoir soils recorded highest value of Na, Ca and Mg than in Control soils. In the case of Na, ranges were 0.42 – 0.51 mol/kg for samples from IK, and 0.53 -0.67 mol/kg for samples from EK. Ca and Mg recorded ranges of 1.83 – 2.04 mol/kg and 2.08 – 3.92 mol/kg for IK, while EK were 1.65 – 1.83 and 2.19 – 2.67 mol/kg. Ranges of Na obtained in this study for abattoir soils is higher than 0.1 – 0.12 mol/kg reported by[38], but lower than 2.24 – 2.47 mol/kg reported by [67] for abattoir soils obtained from Yola Metropolis, Adamawa State, Nigeria. Ca and Mg ranges obtained for abattoir soils in this study are higher than 0.48 – 0.50 mol/kg Ca and 0.51 – 0.77 ml/kg Mg reported by [67] but lower than 12.6 – 15.6 mol/kg Ca and 4.06 – 9.80 mol/kg reported by [38]. The Control soil samples recorded lower levels of Na, Ca and Mg than the studied abattoir soils. These results agree with the reports of [57] and [38] although at variance with the report of [67], who reported lower Ca level in abattoir soils than in the Control soils. Several factors affect the levels of exchangeable bases in soil and this includes soil texture, organic matter content, CEC and moisture content of the soil [64]. Exchangeable bases such as Na, Ca and Mg are important in soil because they are involve in translocation of carbohydrates and nutrient within plants, cell growth, are component of chlorophyll for photosynthesis, protein synthesis and energy transfer within plants. Although, there are no limits to the amount of these bases in soil, higher levels of Na usually causes dispersion of fine particle of soils into pores thereby reducing water penetration and blocking plant root access. Higher levels of Ca in soil reduces uptake of other cation nutrients [57].

Table 4: Essential elements and trace metals levels of selected abattoir and Control soils

	Sampling Points					
	IK1	IK2	IKC	EK1	EK2	EKC
Essential elements						
K (mol/kg)	0.93	0.81	0.26	0.74	0.68	0.17
Na (mol/kg)	0.42	0.51	0.16	0.67	0.53	0.32
Ca (mol/kg)	1.83	2.04	1.23	1.65	1.83	0.98
Mg (mol/kg)	2.08	3.92	0.83	2.67	2.19	1.03
Trace metals						
Fe (mg/kg)	643.45	604.76	548.10	611.04	665.10	562.82
Zn (mg/kg)	19.23	21.05	15.09	24.13	18.56	12.15
Cd (mg/kg)	0.35	0.47	0.17	0.46	0.52	0.23
Cu (mg/kg)	16.82	14.94	4.94	20.92	16.30	3.56
Pb (mg/kg)	0.73	0.66	0.32	1.01	0.89	0.37
Cr (mg/kg)	0.32	0.26	0.05	0.18	0.22	0.08
Ni(mg/kg)	9.73	11.47	6.19	10.21	8.84	4.23

*IK1-Ikot Ekpene abattoir soil 1; IK2-Ikot Ekpene abattoir soil 2; IKC-Ikot Ekpene control soil; EK1-Eket abattoir soil 1; EK2 - Eket abattoir soil 2; EKC - Eket control soil

Results in Tables 4 indicate that, Fe varied between (604.76 – 643.45mgkg^{-1}) for IK abattoir soils, (611.04 – 665.10mgkg^{-1}) for EK abattoir soils, and (548.10 – 562.82mgkg^{-1}) for the Control soils. Levels of Fe obtained for both abattoir soils in this study is lower than 2569.00 – 4130.00mg/kg reported by Yahaya *et al* [3], but higher 59.36 – 81.70mgkg^{-1} obtained by [70]. Also, from the results, abattoir soils recorded higher levels of Fe than the Control soils and this finding is consistent with the reports of [57]. This is indicative of additional source of Fe in studied abattoir wastes-impacted soils. The highest level of Fe was obtained at EK2 abattoir soil, while the lowest level was recorded in sample obtained from IK2. Results obtained in this study revealed direct relationship between activities at abattoir and Fe accumulation in studied abattoir soils. However; levels of Fe in both studied abattoir soils and Control are higher than 400.00mgkg^{-1} recommended by [71] for Nigerian soils. This confirms that Nigerian soils have elevated levels of Fe as clearly shown by their reddish nature. Nevertheless; the availability of Fe in soil for plant uptake may not be guaranteed as Fe oxides (the major form of Fe in soil) are highly insoluble in soil [72].

Results obtained showed that concentrations of Zn in studied abattoir soils varied between (19.23 – 21.05mgkg^{-1}) for IK abattoir soils, (18.56 – 24.13mgkg^{-1}) for EK abattoir soils, and (12.15 – 15.09 mgkg^{-1}) for the Control soils. Ranges of Zn obtained in this study are lower than 1.302 – 5.2362 mgkg^{-1} reported by [5] in abattoir soils, but lower than 50.91 – 92.50 mgkg^{-1} obtained by [3] and 171.93 mgkg^{-1} obtained by [40]. Levels of Zn reported in studied abattoir soils were relatively higher than values obtained at the Control site. This is in agreement with the report of [57] who also reported a higher level of Zn in abattoir soils than in Control soils. However; the obtained ranges are lower than 140.0 mgkg^{-1} limit by [73] for Nigerian soils. Nevertheless, since toxicity of metal may not be identified by total metal concentration alone its availability may not be established. Also, lower levels of Zn obtained in this study for Zn when compared to the permissible limit in soil is plausible because Zn though very essential in soil, it is needed by plant in trace amount.

For Cd, results indicated the following ranges: (0.35 – 0.47mgkg^{-1}) for IK abattoir soils, (0.46 - 0.52mgkg^{-1}) for EK abattoir soils, and (0.17 – 0.23mgkg^{-1}) for Control soils. For the abattoir soils, Cd showed highest abundance in abattoir soil from EK2 and least in abattoir soil from IK1, while Control soils recorded lower levels of Cd than the abattoir soils studied. Ranges for Cd obtained in this study agrees with 0.43 – 0.71 mgkg-1 obtained by [45] for abattoir soils from Obiaakpor Area, River State, Nigeria, but higher than 0.25 mgkg^{-1} reported by [40]. However, levels of Cd obtained in this study were below the permissible limit (2.0 -3.0 mgkg^{-1} stipulated for soil by[73]. This shows that studied abattoir soils were not overloaded with Cd even though other parameters may need to be evaluated to really ascertain the status of the abattoir soils as it relates to Cd.

Results in Tables 4 indicate ranges for Cu as 14.94 – 16.82 mgkg^{-1}, 16.30 – 20.92 mgkg^{-1} and 3.56 – 4.94 mgkg^{-1} for IK, EK abattoir soils and Control soils respectively. Ranges of Cu obtained for abattoir soils are higher than 0.05 - 1.7 mgkg^{-1} reported by [74] in abattoir soils within Umuahia, Nigeria but lower than 36.46 – 40.60 mgkg^{-1} obtained by [58] in Abeokuta, Nigeria. The highest concentration of Cu was recorded in samples from EK1 abattoir soil, while the lowest Cu level was also obtained in abattoir soil from IK1. Concentrations of Cu in studied abattoir soils were higher than values obtained at the Control Soils. This indicated availability of Cu-containing waste materials in studied abattoir waste-impacted soils. This is in agreement with the findings by [45] in abattoir soils. The obtained Cu values are also lower than 36.0mgkg^{-1} stipulated by [73] for Nigerian soils. Nonetheless, bioavailability and toxicity of Cu could not be confirmed based on total concentration alone.

Results obtained for total Pb in studied abattoir soils indicated a range of 0.66 – 0.73 mgkg^{-1} and 0.89 – 1.01 mgkg^{-1} for IK and EK abattoir soils (Tables 4). Levels of Pb obtained in studied abattoir soils are lower than 7.17 – 12.50 mgkg^{-1} reported by [45] in abattoir soils within Obio Akpor, Port Harcourt, River State Nigeria but higher than 0.18 – 0.83 mgkg^{-1} obtained by [5] except for IK abattoir soils. Highest level of Pb was reported in samples from EK1 while lowest Pb concentration was obtained in IK2 abattoir soil. Concentrations of Pb in studied soils were higher than values obtained in the Control site revealing negative impact of abattoir wastes on Pb levels in studied soils. However; levels of Pb obtained were below 85.00mgkg^{-1} recommended by [73] for soil in Nigeria.

Levels of Cr and Ni in studied abattoir soils (IK and EK) ranged from 0.26 – 0.32 mgkg^{-1} and 0.18 - 0.22 mgkg^{-1} for Cr and 9.73 – 11.47 mgkg^{-1} and 8.84 – 10.21 mgkg^{-1} for Ni (Tables 4). The ranges for Cr are lower than 4.25 – 5.86 mgkg^{-1} reported by [45] but higher than 0.0717 – 0.1358mgkg^{-1} obtained by [5] in abattoir soils. For Ni, Levels of Ni obtained are higher than 2.160 – 4.690 mgkg^{-1} reported by [70] but lower than 33.50 – 107.13mgkg^{-1} recorded for Ni in abattoir soils by [3]. The highest Cr level was obtained in abattoir soil from IK1, while the lowest concentration was in EK1 abattoir soil. For Ni, highest Ni level was obtained in abattoir soil from IK2, while the lowest level was obtained in EK2 abattoir soil. Levels of Cr and Ni in abattoir soils were higher than levels obtained in soil from the Control site and are in agreement with findings reported by[45] in abattoir soils. However, values of Cr and Ni obtained in studied abattoir soils are much lower than 100.0 mgkg^{-1} Cr and 35.0 mgkg^{-1} Ni limits in soil by [73]. Nevertheless, pollution status of these metals may not be ascertained using information from total concentration, but lower levels of Cr and Ni obtained in this study are significant especially since abattoir soils studied are already used by farmers in planting crops.

Pollution status of trace metals in studied abattoir soils

To ascertain the pollution status of the studied abattoir soils, metal pollution index (MPI), degree of contamination (Cdeg), trace metals enrichment factor (EF), geo-accumulation index (Igeo) and metal pollution load (MPL) were evaluated. Metal pollution index (MPI) was used to differentiate between contamination and pollution levels in studied abattoir soils. It denotes the ratio between metal level in studied abattoir soils and reference value obtained in Control [75]. The different categories of MPI as indicated in Table 4 shows that Fe recorded MPI values ranging from 1.09 – 1.53 for all abattoir soils under investigation indicating slight pollution of the studied abattoir soils by Fe. Consequently, negative impact on soil, plants and the environment are predicted in and around studied abattoir soils. However, Fe is an essential element with very low bioavailability factor in studied soils hence; the effect may not be alarming. Results in Tables 4 also indicates that MPI values for Zn was in slight pollution (1- 2) category (Table 1), while Cd, Cu, Pb, Cr, and Ni were in moderate pollution (2.1 – 4.0) category except for abattoir soils from EK1 and EK2 that were in severe pollution (4.1 -8.0) category for Cu and IK1 and IK2 for Cr. This means that Zn, Cd, Cu, Pb, Cr and Ni have slightly polluted the studied abattoir soils and is expected to affect the soil, plants and the studied environment negatively.

Enrichment factors (EF) of metals were calculated for the abattoir soils using the continental crust average where Fe was used as reference element for normalization (Table 5). Fe exhibited an EF value of 1.00 in all the abattoir soils studied indicating that a greater proportion of Fe may have emanated from natural soil forming processes [34]. EF for Zn, Cd, Cu, Pb, Cr and Ni for all the abattoir soils studied were greater than 1.0 indicating that these trace metals are from anthropogenic source [34]. Results for the geo-accumulation index (Igeo) of trace metals in studied abattoir soils are presented in Tables 4. Results obtained showed the following ranges: 0.26 – 0.39, 0.40 – 0.55, 0.61 – 1.18, 0.41 – 0.56, 0.45 – 1.28 and 0.31 – 0.48 for Zn, Cd, Cu, Pb, Cr and Ni respectively for all the abattoir soils studied. From these results, the metals were in the 0 – 1 class (unpolluted – moderately polluted) following the classifications for geo-accumulation index by [36]. Cu In abattoir soil from EK1 and Cr in abattoir soil from IK1 were in the 1 – 2 class (moderately polluted)

Degree of contamination (Cdeg) was determined to assess the extent of contamination of the four (4) studied abattoir soils and the results are presented in Figure 1. From the results, Cdeg values were 18.10, 17.38, 18.33 and 17.15 for IK1, IK2, EK1, and EK2 respectively. The varied Cdeg reported in this study by the abattoir soils may be attributed to the volume of abattoir wastes and abattoir activities in each of these sites. From the Cdeg results, it can therefore be deduced that the abattoir soils were considerably contaminated (16 < Cdeg < 32) based on the model predicted by [32].

Results obtained for pollution load index (PLI) for the four abattoir soils examined are indicated in Figure 1. PLI values were found to range from 2.17 for abattoir soil from IK1 to 2.33 for abattoir soil from EK1. Thus, PLI values of all the studied abattoir soils were within the heavy pollution (2 < PLI < 3) category according to [37]. These PLI values obtained in this study further confirm findings by degree of contamination of studied abattoir soils. This work has therefore revealed the negative impact of abattoir wastes on underlying soils with regards to metal accumulation.

Table 5: Metal pollution index (MPI), enrichment factor (EF) and geo –accumulation index (Igeo) of trace metals in studied abattoir soils

	Fe	Zn	Cd	Cu	Pb	Cr	Ni
MPI							
IK1	1.17	1.20	2.08	3.40	2.28	6.40	1.57
IK2	1.10	1.39	2.76	3.02	2.06	5.20	1.85
EK1	1.09	1.98	2.00	5.87	2.73	2.25	2.41
EK2	1.53	1.53	2.26	4.58	2.41	2.75	2.09
EF							
IK1	-	1.09	1.75	2.90	1.94	5.45	1.33
IK2	-	1.26	2.51	2.74	1.87	4.71	1.68
EK1	-	1.83	1.84	5.41	2.51	2.07	2.33
EK2	-	1.29	1.01	3.87	2.04	2.33	1.77

Igeo							
IK1	-	0.26	0.41	0.68	0.46	1.28	0.31
IK2	-	0.28	0.55	0.61	0.41	1.04	0.37
EK1	-	0.39	0.40	1.18	0.56	0.45	0.48
EK2	-	0.31	0.45	0.92	0.48	0.55	0.41

*MPI – Metal pollution index; EF – Enrichment factor; Igeo – Geo-accumulation index; IK1-Ikot Ekpene abattoir soil 1; IK2-Ikot Ekpene abattoir soil 2; IKC-Ikot Ekpene control soil; EK1-Eket abattoir soil 1; EK2 - Eket abattoir soil 2; EKC - Eket control soil

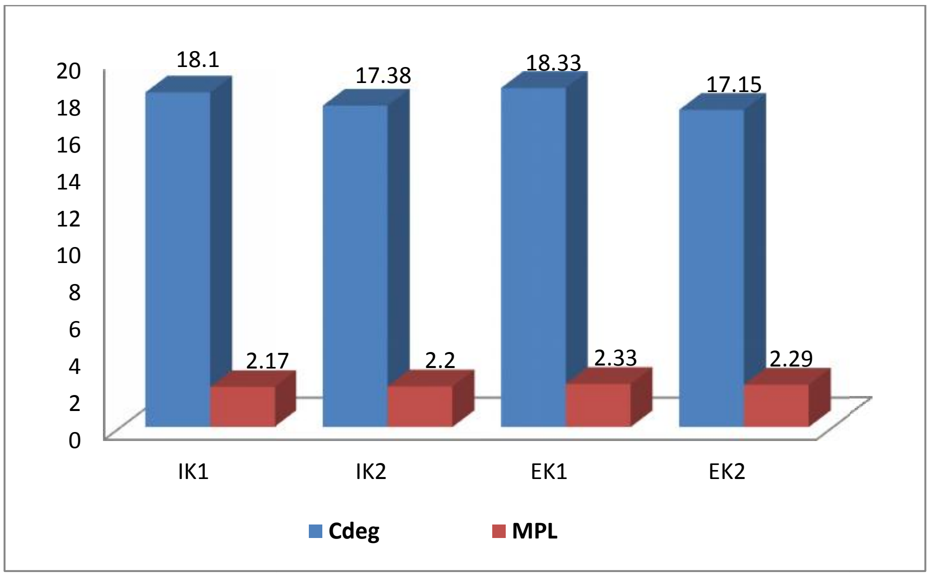

Figure 1: Degree of contamination (Cdeg) and pollution load index (MPL) of trace metals in studied abattoir soils

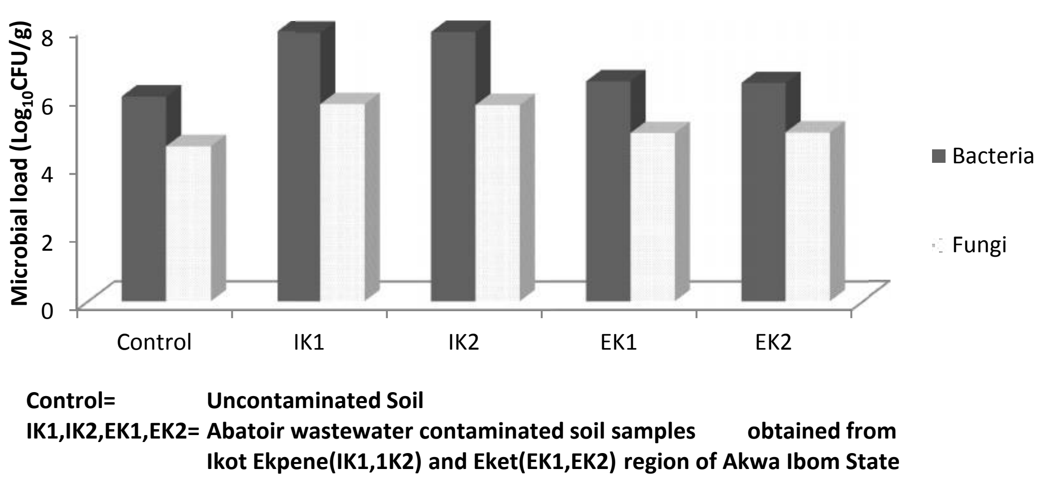

Figure 2: Microbial Load (CFU/g) of abattoir soils obtained from Ikot Ekpene and Eket region of Akwa Ibom State.

Microbial loads of abattoir soils

Figure 2 shows the microbial load (log_{10}CFU/g) of soil samples. The result shows the density of the culturable bacterial community present in 1g of samples obtained from the four (4) abattoir locations ranges from 6.41 ±0.43 to 7.91 ±0.58 log_{10}CFU/g for total heterotrophic bacterial count and 4.94 ± 0.26 to 5.79 ± 0.3 log_{10}CFU/g for fungal count. Among the four (4) abattoir soils, IK2 had the highest heterotrophic bacterial densities of 7.91 ± 0.58 log_{10}CFU/g while IK1 had the highest fungal count of 5.79 ±0.34 log_{10}CFU/g.

Cultural and Biochemical Characteristics of microbial Isolates

The cultrural and biochemical characteristics of the microbial isolates are presented in Table 6 and 7. Six (6) species of bacteria were obtained from the soil samples using the aerobic culture techniques. These were *Klebsiella, Micrococcus, Pseudomonas, Bacillus, Escherichia* and *Enterobacter* species. While the two (2) fungal species isolated were *Aspergillus* and *Penicillium* species

Table 6: Morphological and Biochemical characteristics Bacterial of Isolates

Isolates	G.R	Shape	Motility	Catalase	Starch hydrolysis	Oxidase	Indole	Citrate	MR	VP	Glucose	Lactose	Mannitol	Probable Organism
1	-	R	-	+	-	-	+	+	-	+	AG	AG	-	*Klebsiella*pneumoniae
2	+	S	-	+	-	-	-	-			-	-	-	*Micrococcus luteus*
3	-	R	+	+	-	-	-	+	-	+	AG	AG	-	*Enterobacter*cloacae
4	+	R	-	+	+	-	+	+	-	-	-	-	-	*Bacillus polymyxa*
1.	+	R	-	+	+	-	-	-	-	-	-	-	-	*Bacillus subtilis*
2.	-	R	+	+	-	+	-	+	-	-	A	-	A	*Pseudomonas aeruginosa*
3.	-	R	+	+	-	-	+	-	+	-	AG	AG	-	*Echerichia coli*

Key: G.R = Gram Staining; + = Positive; - = Negative; R = Rod; S = Spherical; A = Acid only; AG = Acid and Gas produced

Table 7: Colonial and morphological characteristics of fungal (mould) isolates

Isolates	Colonial Morphology	Somatic cell type	Type of Hyphae	Asexual spores	Special Reproductive Structure	Conidia Head	Vesicle shape	Probable Fungi
1	Compact white with dark basal colour	Filamentous	Septate mycelium	Globose conidia	Conidiospore	Globose	Subglobose	*Aspergillusniger*
2	Whitish, yellowish to grey mycelium	Filamentous	Septate mycelium	Globose conidia	Conidiospore	Sub-globose to ellipsoidal	-	*Penicilliumfrequentans*

Occurrence and Distribution of microbial isolates within the samples and location

The distribution of microbial isolates within the soil samples is shown in Table 8 and 9. *Micrococcus luteus, Pseudomonas aeruginosa and Bacillus subtilis* 5(100%) had the highest frequency of occurrence, while *Enterobacter*cloacae and *Klebsiellapneumoniae* had the least 2(40%). For the fungal isolates, *Aspergillusniger* 5(100%) had the highest frequency of occurrence, while *Penicillium frequentans* had the least 3(40%) frequency of occurrence. Also, samples taken from Ikot Ekpene region were more contaminated than those taken from Eket abattoir soils

Table 8: Occurrence and distribution of bacterial isolates in abattoir and Control soil samples

Isolates	**Sample Points**					**% Occurrence**
	Control	**IK1**	**IK2**	**EK1**	**EK2**	
Klebsiella puemoniae	-	+	+	-	-	2(40%)
Micrococcus luteus	+	+	+	+	+	5(100%)
Enterobacter cloacae	-	+	+	-	-	2(40%)
Pseudomonas aeruginosa	+	+	+	+	+	5(100%)
Escherichia coli	-	+	+	+	+	4(80%)
Bacillus polymyxa	+	+	+	-	-	3(60%)
Bacillus subtilis	+	+	+	+	+	5(100%)

*Key: + = Present; - = Absent

Table 9: Occurrence and distribution of fungal isolates in abattoir and Control soil samples

Isolates	**Sample Points**					**% Occurrence**
	Control	**IK1**	**IK2**	**EK1**	**EK2**	
Aspergillusniger	+	+	+	+	+	5(100%)
Penicillumfrequentans	+	+	+	-	-	3(60%)

*Key: + = Present; - = Absent

The significant (p=0.05) increase in microbial loads encountered in the contaminated soil against that of the control soil is not surprising and it could be directly linked to the impacted abattoir wastes disposed on the studied land. This is because abattoir waste may contain many growth factors that could serve as an easily utilizable source of nutrient and encourage rapid multiplication by microorganisms. This result is in agreement with the report of [56] and [26] who independently reported similar increase in microbial load of soil samples contaminated with abattoir effluents. Eket (EK1 and EK2) abattoir soils were found to harbor less number and species of microorganisms. This could be because the region is well known for oil exploration activities and is expected to harbor more of microorganisms that could survive in soil contaminated with hydrocarbon. The presence and abundance of species of *Bacillus* and *Micrococcus*, *Aspergillus* and *Penicillum* observed in both the abattoir and Control soils is not surprising as these organisms are indigenous to soil environment and are known to persist and thrive especially during carbon and nitrogen sources influx in the soil [76]. However, presence of *Pseudomonas aeruginosa, E. coli, Enterobacter cloacae* and *Klebsiella pnuemoniae* in the abattoir soil may be attributable to the high load of animal excreta in the abattoir wastes since these microorganisms are well known flora of fresh beef. Their presence in the abattoir soil samples is indicative of recent faecal pollution as they are mostly indicator organisms. Similar findings were reported by [76]. Most of the fungal isolates were also soil-inhabiting microorganisms as well as common spoilage organisms associated with beef industry [76-77]. The presence of these organisms is a pointer to possible pollution and may have an effect on the soil ecological balance.

Conclusion

The results of this study have shown the physicochemical characteristics, total essential and trace metal levels, total heterotrophic bacterial and fungal loads of abattoir and Control soils from Ikot Ekpene and Eket Local Government Areas of Akwa Ibom State, Nigeria. Metal pollution index (MPI), enrichment factor (EF), geo-accumulation index (Igeo), degree of contamination (Cdeg) and pollution load index (PLI) of trace metals have also been calculated using empirical pollution models. Essential elements and trace metal levels were higher in abattoir soils than in Control though were within permissible limit in soil except for Fe. Also, microbial results revealed a significant increase in the number and varieties of microorganisms most of which may be pathogenic, but are more often than not indicators of recent faecal pollution in the soil impacted with abattoir wastes. This study, therefore, concludes that soil impacted with abattoir wastes is richer in plant nutrients and can be exploited for growing of crops. But it is advised that routine checks be conducted to forestall trace metals accumulation above safe levels in these soils.

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