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Effects of Effluents on Soil Chemical Properties in Forest-Derived Savanna Transition

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Abstract: *Experiment was conducted at the Teaching and Research Farm of Ambrose Alli University, Ekpoma in Nigeria to evaluate the effects of some effluents on soil chemical properties in maize cultivated soil. Treatments consisted of poultry, abattoir, cassava mill, oil palm mill and fish pond effluents with control. Effluents were uniformly applied to the soil surface at the rate of 5 t/ha a month before planting to allow for equilibration. Results showed that effluents increased pH from 5.47 to 5.62, organic carbon 10.10 g/kg to 12.20 g/kg; total N 0.50g/kg to 1.00 g/kg; available P 2.90mg/kg to 6.76 mg/kg; exchangeable Ca 2.28cmol/kg to 4.25 cmol/kg; Mg 0.15cmol/kg to 2.09 cmol/kg; K 0.13cmol/kg to 0.15 cmol/kg and ECEC 2.94 cmol/kg to 6.34 cmol/kg. Organic carbon had positive correlation with Ca, Mg, P and ECEC but was significant with Ca. Soil N correlated positively with soil P and K but was negatively correlated with available P. Effluents have fertilizer value; poultry and abattoir effluents are preferred to the use of fish pond, palm oil mill and cassava mill effluents due to higher enhancement of soil chemical properties.*
Keywords: *effluents, soil chemical properties, treated, untreated*

I. Introduction

Municipal wastewater or sewage contains a significant amount of N and P along with organic and inorganic substances (Bashan *et al*., 2004). Industrial wastewaters are also an important source of phosphorus. Insufficient and improper treatment facilities of these effluents cause serious soil and water pollution, including eutrophication in the surrounding areas. Studies have shown that the application of organic wastes (such as effluents, compost and sewage sludge) to soils increases plant growth; and that organic wastes contain considerable amounts of plant nutrients including micronutrients that benefits plant growth (Osemwota, 2010; Kaldivo and Nelson, 1979).

Soil application of cassava effluent has shown that there are always some physical-chemical changes in the soil properties. Its application increased potassium, sodium, phosphorous, and organic carbon but decreased calcium, nitrogen and magnesium (Ebhoaye *et al*., 2004). Ehiagbonare *et al.* (2009) investigated the effect of cassava mill grating effluents on texture, chemical and biological properties of soils in Okada, they found that cassava mill effluents increase soil pH and organic carbon significantly while available P also increased in both effluent and non-effluent treated soils A lot of palm oil mill effluent is generated in Edo state with little or no utilization agriculturally to ascertain its potentials. The controlled application of the POME has been reported to increase soil pH, K, Ca, Mg and organic matter (Onyia *et al.*, 2001). Application of POME lead to the increase in soil organic matter and reduced nitrate runoff (Drinkwater *et al*., 1998). Ogboi *et al*. (2010) reported that soil contaminated with POME had superior growth and yield performance of maize than non POME contaminated soil. Nwoko and Ogunyemi (2010) reported that fermented POME enhanced maize crop production.

Pond effluents are also known to contain high amount of nitrogen and phosphorus (Ola *et al.*, 1994). Fish pond effluents also contains relatively high organic matter (Ziemam *et al.,* 2007).The presence of high plant nutrient made pond effluents receive wide application to crop as irrigation water (Al Jaloud *et al.*, 1993). Osaigbovo *et al*. (2011) found that fish pond effluents increased the pH of the soil from 5.11 to 5.81 and 5.95 after first and second cropping respectively with 100% effluents application. The increase was attributed to high suspended solids, dissolved solids, and slightly acidic nature of the fish pond effluent. Fish pond effluent application raised soil contents of K, Mg, Ca and Na significantly from 0.01 to 1.65, 0.01 to 0.65, 0.05 to 1.68 and 0.01 to 0.28 cmol/kg respectively at 75% effluents application in the first cropping season, but decreased the parameters in the second cropping season (Osaigbovo *et al.*, 2011).

Osemwota (2010) reported that abattoir effluent increased soil pH, available P and Zn, Mn and Fe significantly, but observed that exchangeable cations were reduced significantly compared to the control. Poultry manure (solid/liquid waste) has high residual capacity, therefore has high tendency to supply nutrients even after its year of application. Thus reduces high dependence on regular application, which is a regular practice with inorganic fertilizers (Isitekhale and Osemwota 2010). The inorganic forms of nutrients in effluents will be immediately available to plants and the organic form takes time to be available. This gives most effluents its residual characteristics that make them beneficial as manure. The high content of organic matter can play a major role in soil aggregate formation, thus improving soil physical and chemical conditions and facilitate crop production (Isitekhale, 2010). The objective of the experiment therefore was to evaluate the effect of different effluents on soil chemical properties.

II. Materials And Methods

I. Laboratory Studies

Composite soil sample collected from the location before field experiment was air-dried at room temperature, crushed and sieved through 2 mm sieve to remove debris and other materials and kept in plastic containers with cover for routine analysis. Soil samples after field experiment, were also collected from individual plots that received different treatment combinations and prepared for laboratory studies according to Anderson and Ingram (1993) procedures. Plant leaf and shoot samples were also collected for analysis.

II. Soil Chemical and Physical Properties

Soil pH was measured in a 1:1 soil-water suspension using glass electrode pH meter (MaClean, 1982). Exchangeable acidity (AI^{3+}, H^+) were extracted with IN KCl (Thomas, 1982) and determined by titration with 0.05 Na0H using phenolphthalein as indicator. Organic carbon was determined by wet dichromate acid oxidation method (Nelson and Sommers, 1982). Total nitrogen was determined by the Micro-Kjedahi method (Bremner, 1982). Available phosphorus was extracted with Bray-P1 solution and measured by the molybdenum blue method on the technician auto analyzer as modified by Olsen and Sommers (1982). Exchangeable cations (Ca, Mg, Na and K) were extracted within 1N NH_4OAc. pH 7.0 (ammonium acetate), K and Na were determined with flame emission photometer while Ca and Mg were determined with atomic absorption spectrophotometer (Anderson and Ingram, 1993). Effective cation exchange capacity (ECEC) was calculated by the summation of exchangeable bases and exchangeable acidity (Anderson and Ingram 1993; Okalebo *et al*., 2002). Particle size distribution was determined by the hydrometer method according to Okalebo *et al.* (2002). The soils were dispersed with sodium hexamethaphosphate solution.

III. Statistical Analysis

All the data obtained were analyzed using analysis of variance (ANOVA), mean comparison was carried out using least significant difference (LSD) at 5% probability level (Frank and Althoen, 1995).

IV. Results and Discussion

Experimental Soil and Effluents

The chemical properties of the different effluents and that of the experimental soil are shown in Table 1. The experimental soil was slightly acidic in reaction, low in organic carbon, total nitrogen, exchangeable potassium, calcium, magnesium and available phosphorus. The soil was therefore deficient in plant nutrients. Chemical analysis of the effluents indicated that they are inherently low in exchangeable Mg, Ca and P but high in exchangeable K, total N and organic carbon. Fish pond effluent had the lowest nutrient contents compared to the other effluents. Poultry effluent used for the study was found to contain higher exchangeable Ca, organic carbon, total N and available P compared to others.

Soil Chemical Properties

Table 1 shows the chemical properties of the soil after effluent treatment and maize harvest. Average soil pH increased from 5.47 (strongly acidic) in the control treatment to a range of 5.52 (strongly acidic) to 5.62 (medium acidic) in effluent treated soils (Table 2). This shows a gradual increase in son reaction due to effluent effect. Soil organic carbon increased from 10.00 g/kg to a range of 10.10 to12.20 g/kg. Organic carbon was highest in soils treated with poultry effluent, followed by abattoir and POME treatments. The range shows that effluent treated soils had higher organic carbon relative to the control. Total N of the soil was significant compared to the control with poultry effluent treatment; total N increased from 0.50 g/kg in untreated soil to 1.00 g/kg due to poultry effluent treatment. Other effluent treatment had no significant effect on soil N compared to the control. Palm oil mill effluent decreased soil N slightly but the decrease was highest with fish pond compared to other effluents and the control. Effluent application was significant on soil available P content; available P in the surface soils remained low at a range of 2.90 mg/kg to 6.76 mg/kg compared to 2.82 mg/kg in soils of the control. Exchangeable Ca and Mg increased significantly from 2.28 cmol/kg and 0.15 cmol/kg in untreated soil to 4.25 cmol/kg and 2.09 cmol/kg in effluent treated soils respectively. The increases were highest with poultry effluent. However, fish pond, POME, and abattoir effluent applications had no significant effect on exchangeable Ca compared to the control. But for exchangeable Mg, only POME had no significant effect on exchangeable Mg. The levels of exchangeable K in effluent treated soils were slightly increased by POME, poultry and cassava effluents. Despite the increase, the level of K remained very low in the treated soils. Exchangeable Na in effluent treated soils declined significantly from a range of 0.13 cmol/kg to

0.15 cmol/kg relative to 0.22 cmol/kg in untreated soil. ECEC of the effluent treated soils was significantly different from the control with the exception of POME treatment. The ECEC of the soils increased from 2.94 cmol/kg in the untreated soil to 6.34 cmol/kg in the treated soils. ECEC was highest in soils treated with cassava effluent, followed by poultry, abattoir and fish pond effluents in decreasing order.

Soil N correlated positively with soil P and K but was negatively correlated with available P. The relationship were however not significantly different, but correlated positively with Ca, Mg and K; and was negatively correlated with pH and clay. The positive and significant correlation is attributed to higher Ca and Mg supplied by the effluents. Effluents increased Ca and Mg highly and above the critical level of 3.8 and 1.90 cmol/kg. The ECEC correlated negatively and significantly with soil clay (r = -0.71113), significantly positive with Ca (r = 0.94546) and Mg (r = 0.94139) respectively. The positive and significant correlation is attributed to higher Ca and Mg supplied by effluent; effluent increased Ca and Mg highly and above the critical level of 3.8 cmol/kg. Effective cation exchange capacity correlated positively with soil N (r = 0.37280) and P (r = 0.58136) but was not significant. Clay correlated positively and significantly with P (r = 0.67088) and K (r = 0.65730) but significantly negative with Mg (r = -0.62194) and Ca (r = -0.66993). Though clay was lowest as a result of poultry effluent treatment, Ca attained maximum concentration relative to other effluent used. Low soil clay and ECEC may affect nutrient content of the soil and its exchange.

Organic carbon correlated negatively with available K and total N; this indicates that organic carbon derived from the applied effluent had low contribution to soil K and N. Organic carbon had positive correlation with Ca, Mg, P and ECEC but was significant with Ca. Organic carbon resulting from the effluents and its breakdown contributed more to P, ECEC, Mg and Ca. The contribution was highest with poultry waste and cassava effluents. The increase in soil nutrients suggests the fertilizer value of the effluents through the addition of nutrients such as N, P and K as well as the enhancement of organic carbon and its release of soil nutrients.

Ehiagbonare *et al*. (2009) reported that cassava mill effluent improves the soil chemical and biological properties of soils in Okada, Edo state. They found that cassava mill effluent increased soil pH, available P and organic carbon significantly. Iwara *et al*. (2011) reported that the proportions of Ca, Mg, K and Na in POME treated soil increased and concluded that the increment shows enrichment of the soil. Okwute and Isu (2007) reported similar result and attributed the increase to the addition of effluent to the soil which increased the levels of exchangeable bases. The increase in pH to near neutrality in POME soil has also been reported in several raw POME is discharged, the pH is acidic but seems to gradually increase to alkaline as biodegradation takes

Table 1 Properties of the experimental soil and effluents used for the experiment.

Parameter	Soil	Poultry waste	Cassava ←	POME mg/l	Abattoir	Fish pond →
pH (H_2O)	5.50	6.00	7.25	4.70	5.50	5.60
Total N g/kg	0.60	2.08	1.34	1.13	3.72	0.62
OC g/kg	10.30	22.00	30.00	25.00	28.00	40.00
Exch. Cations (cmol/kg)						
Exch. Ca	2.48	2.8	5.80	2.60	5.60	4.80
Exch. Mg	0.24	1.16	0.76	0.21	0.13	0.15
Exch. Na	0.24	0.55				
Exch. K	0.05	1.09	1.27	0.93	1.35	0.88
Exch. H^+	0.20	0.60				
Exch. Al^{3+}		0.30				
E C E C	3.21	6.50				
P mg/kg	7.85	16.13	0.31	0.16	0.14	0.35
Particle Size (g/kg)						
Sand	93.3					
Silt	2.2					
Clay	4.5					
Texture	Sand					

Table 2 Effects of effluents on soil chemical properties after harvest

Effluents	pH	OC	N	P	Na	K	Ca	Mg	H^+	ECEC
		← g/kg		mg/kg	←		cmol/kg			→
Control	5.47	10.00	0.50[bc]	2.82[c]	0.22[a]	0.06[c]	2.28[c]		0.23	2.94[c]
Poultry	5.58	12.20	1.00[a]	5.71[ab]	0.14[b]	0.10[a]	4.25[a]	2.09[a]	0.02	6.16[a]
Cassava	5.52	10.80	0.80[ab]	4.62[abc]	0.14[b]	0.09[ab]	4.05[ab]	1.72[ab]	0.34	6.34[a]
Pome	5.62	11.10	0.40[bc]	2.90[c]	0.13[b]	0.11[a]	2.53[bc]	1.06[bc]	0.31	4.14[bc]
Abattoir	5.52	11.20	0.70[ab]	3.76[bc]	0.14[b]	0.08[abc]	3.09[abc]	1.82[ab]	0.06	5.19[ab]
Fish pond	5.55	10.20	0.20[c]	6.76[a]	0.15[b]	0.07[bc]	2.87[abc]	1.29[ab]	0.45	4.83[ab]
L S D	Ns	ns	0.04	2.5	0.04	0.03	1.53	0.91	Ns	1.86

Means followed by the same letter(s) are not significantly different at 5%

Table 3 Matrix of correlation between soil chemical properties after effluent application

	N	P	K	ECEC	pH	Clay	OC	Ca	Mg
N	1.00	0.167	0.34	0.37	-0.14	-0.29	-0.65	0.069	0.36
P	0.16	1.00	-	0.58	0.03	-0.67	0.13	0.51	0.54
K	0.34	-0.04	1.00	0.55	0.35	-0.65	-0.01	0.50	0.55
ECEC	0.37	0.58	0.55	1.00	-0.19	-0.71	0.37	0.94	0.94
pH	-0.14\	0.03	0.35	-0.19	1.00	-0.26	-0.10	-0.21	0.03
Clay	-0.29	-0.67	-0.65	-0.71	-0.26	1.00	-0.01	0.66	-0.62
OC	-0.64	0.13	-0.01	0.37	-0.10	-0.01	1.00	0.60	0.41
Ca	0.06	0.51	0.50	0.94	-0.21	-0.66	0.60	1.00	0,85
Mg	0.36	0.54	0.55	0.94	0.03	-0.62	0.41	0.85	1.00

Correlation Table value = 0.666

place. This therefore, implies that POME increases soil pH which in effect increases the values of major nutrients (nitrogen, potassium and phosphorus) in the soil, thereby promoting high crop yields. Increase in soil pH from acidic to neutral was also reported by Isitekhale and Mba (1995) as a result of poultry manure treatment in eastern Nigeria soils.

Patterson (1999) found that exchangeable Ca and Mg decreased slightly throughout the soil profile while exchangeable K increased marginally when soils were treated with paper mill effluent. Calcium, Mg and K increase in these soils disagree with the above findings as a result of the higher organic matter and exchangeable bases in the different effluents relative to paper mill effluent. Sodium decline as a result of effluent application was similar to Patterson (1999) who earlier reported a decline in Na concentrations in the surface soil after paper mill effluent treatment. Controlled application of effluents increases soil pH, Ca, K, Mg and organic carbon (Onyia *et al*., 2001).

The total organic carbon obtained was slightly above values reported by Oviasogie and Omoruyi (2007). Total organic carbon is a measure of organic content in soils (Yun, 2003) and contributes significantly; to acidity through contributions from organic acids and biological activities. The total nitrogen ranged from 0.40 to 1.00 g/kg. These values are in the same range with the values reported by Osemwota (2009), but relatively higher than the values reported by Oviasogie and Omoruyi, (2007) in soils around foam manufacturing industry. The total nitrogen obtaineded was probably due to nitrogen mineralization as a result of organic matter (Jadhav and Savant, 1975). This is consistent with the views of Goi and Kurchara, (1987) as cited by Jadhav and Savant, (1975) following the analysis of total nitrogen in urban wastes. Nitrogen is one of the elements needed by plant for healthy growth.

V. Conclusion

As a result of effluent treatment, soil available P, K Ca, Mg and ECEC were increased significantly while organic carbon and soil pH were however not increased significantly when compared to the control. Therefore, the application of effluents enhances soil chemical properties and is good nutrient sources for plant growth. Poultry and abattoir effluents are preferred to the use of fish pond, POME and cassava effluents due to their enhancement of soil chemical properties.

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