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Effect of Brewery Sludge Effluent on Soil Quality

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This study reports the residual effect of Ama Brewery effluent sludge discharge on the soil quality of the recipient soil environment in Amaeke Ngwo Community of Udi Local Government Area of Enugu State Nigeria. Samples were collected in triplicates in two sites, control and test sites and analyzed the physical and chemical properties of the soils. The result of analysis showed that some soil chemistry parameters such as phosphorus, calcium, potassium, magnesium, organic matter, organic carbon, cation exchange capacity and exchangeable bases occurred at higher levels of concentration in the test soil site than the control site. This study therefore indicates that the Ama Brewery sludge effluent has not impacted on the soil quality of the test site adversely but has improved it for agricultural purposes. The distribution of the measured soil chemistry parameters is such that the top soil contains the highest concentration. The study also revealed that the movement and distributions of these parameters down the soil profile could be modeled *via* predictive models that would however require to be validated with data from other field studies.

Keywords: Brewery, Macro and Micronutrients, Sludge effluent, Soil chemistry, Soil quality.

INTRODUCTION

Soil is an environmental or ecological indicator that serves the purpose of assessing conditions of the environment, monitoring trends in conditions over time, providing an early warning signal of changes in the environment and diagnosing the cause of an environmental problem [1,2]. The study of soil quality is very important as it is the resource base of the biosphere's nutrients. These nutrients especially the macronutrients derivable from soils are made available for plant absorption through such processes as mineral weathering and the decomposition of organic matter into inorganic minerals [3-6].

The varied properties of the soil could be used to characterize a given soil for its quality classification could be altered by land use types [7,8]. The Brewery industry in Nigeria is quite big and commands a prime place in sub-Saharan Africa. Nigeria Brewery Plc is Nigeria's largest brewing company and enjoys a market share of about 65 % of all produced lager in the country. Ama Brewery produces several product brands namely: Star, Gulder and Heineken Lager Beer, Maltina and Amstel Malta. Brewing raw materials generally include barley or sorghum, maize, hops, yeast and water [9]. The major waste materials generated in breweries including Nigeria Breweries Limited are mainly waste water, spent grain, waste yeast, spent hops, *etc.* [10,11]. These wastes are usually released in large volumes (given the high throughput nature of brewery industry) hence an understanding of their effects on the receiving environment would assist in proffering strategic solutions for effective environmental management.

The modification or alteration of soil quality as a result of the intrusion of brewery effluent has led to various studies. There are several reports on the effects of brewery effluents on soil quality with some indicating the beneficial effects and others the adverse effects.

The continuous application of brewery wastewater has been reported to have the potential of improving soil physical and chemical characteristics and increase the contents of organic carbon and nitrogen with beneficial effects on soil quality more evident on poorly developed soils – sandy soils [12-16]. Continuous effluent application on soil can also lead to an increase in level of sodium and consequently the electrical conductivity of the soil [13,15]. The application of effluents to the soil has been demonstrated to decrease bulk density and increase porosity and water holding capacity by same authors. With soil pH directly linked to nutrient availability, the effects on soil pH can vary from decrease to slight increases [12,15].

Several studies have been conducted to know the ability of industrial sludge effluent to supply the soil with nutrients without adversely affecting the ecosystem. In this regard, some studies have indicated that some sludge effluents such as paper industry sludge would require to be treated before using them for improving soil quality while others (such as sewage plant treatment sludge effluents) even though have high nutrient value contains high concentration levels of heavy metals and therefore would still be treated before application [16,17].

Given the wide array of possibilities with respect to how brewery effluent can affect soil quality, it is necessary to investigate the soil quality of the study site to ascertain the extent of alteration (if any) due to Ama Brewery sludge effluent with respect to some given soil quality parameters. The study is also expected to generate some useful predictive mathematical models that could predict the outcome of similar brewery sludge discharge to soils of similar characteristics as the study area.

The main objectives of this study are: (a) To compare the soil quality of the site that has received the Ama Brewery sludge effluent with that which never received the sludge effluent so as to determine whether there is adverse or beneficial alteration in soil quality in the study area with respect to the use of the site for agricultural purposes; (b) Determine how any soil quality change may have varied with the soil profile of the study area and determine the aspect of the soil profile that is most affected; (c) Understand how the soil quality parameters are distributed along the soil profile within the time the effluent was discharged and the study period so as to attempt generating predictive models for such distributions.

EXPERIMENTAL

Study area: The Nigeria Breweries Plc (also known as Ama Breweries as will be referred to in this study) is located along Umuezeani-Eke Oghe Road in Amaeke Ngwo Community in Udi Local Government Area (LGA) of Enugu State. The study site is located opposite Ama Brewery, along the Amaeke-Eke Oghe Road in Amaeke Ngwo Community of Udi Local Government Area (LGA) of Enugu State. The map of Enugu State showing Udi LGA and the map of the study site showing sampling points are as shown in Figs. 1 and 2, respectively.

Sampling techniques: Soil samples of 200 g each were collected from the sampling points at various depths of 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and 60-75 cm using auger borer. Test soil samples were collected at the land area that received sludge discharge at a distance of 10 m away from each point of collection while soil samples collected from a location that did not receive the sludge effluent served as control and is 200 m away from the test site. Thirty samples were collected for each of the sites (test and control sites).

Laboratory determination of soil quality parameters: Prior to analyses, the soil samples collected from the study area were air-dried and made to pass through a 2 mm sieve. The fine earth was then used for analyses. The following soil quality parameters were determined for each soil sample: particle size distribution, pH, organic carbon, total Nitrogen, available phosphorus and exchangeable cations (Na, K, Ca, Mg, Mn). Soil texture was also used to characterize the project area.

The description of the methods used for the different analyses carried out on the soil samples are:

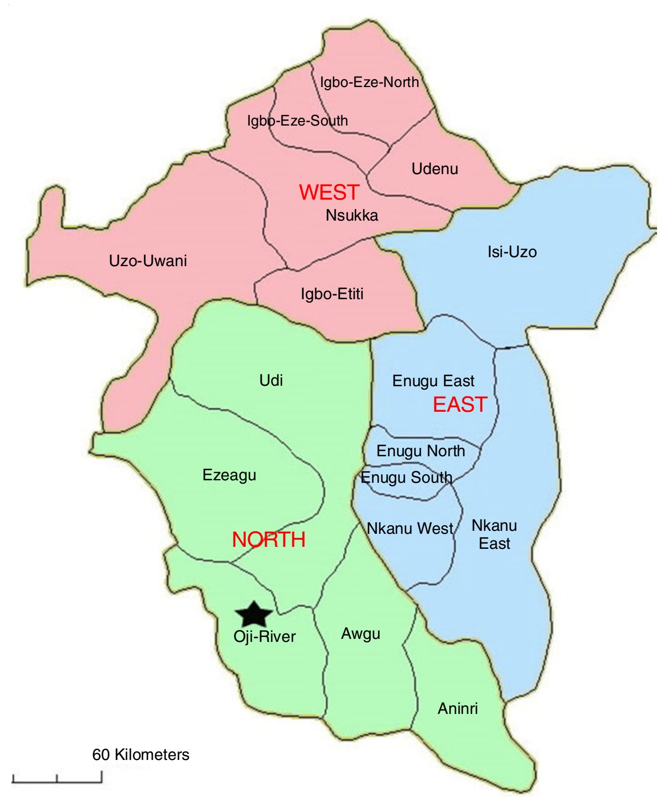

Fig. 1. Map of Enugu state showing Udi LGA where Ama Brewery and study site is located

Particle size destribution: The particle size distribution was determined using hydrometer method as described by Bouyoucos [18].

Soil pH: The pH value of the soils and sediments in water and KCl were determined using Kent EIL 7020 pH meter.

Organic carbon: The method for organic carbon determination as described by Walkley and Black [19] was adopted.

Exchangeable cations: 1 N ammonium acetate solution was used as extractant in the exchangeable cation determination. Ammonium acetate (1N, 25 mL) was added to 3 g of finely ground soil sample and the mixture was agitated on a mechanical shaker for 1 h, before centrifuging at 2000 rpm for 10 min. A clear supernatant was decanted into a volumetric flask. The supernatant was used for the determination of sodium and potassium by flame photometry [Gallenkamp Flame Analsyer, FGA-330-3C] while magnesium and calcium were determined by atomic absorption spectrophotometry.

Cation exchange capacity (CEC): The cation exchange capacity of soil samples was determined by following the standard ammonium acetate method [20].

Available phosphorus: Bray-1 extracting solution (0.03 N NH_4F in 0.1 N HCl) was used to determine the available phosphorus in the soil samples. Air dried soil sample (1 g) was treated with 20 mL of the above extractant and shaken for 1 min and filtered immediately using Whatman No. 42 filter paper equivalent. The filtrate was used for the development of molybdenum blue colour using 2 % of ascorbic acid solution (1 mL) and ammonium molybdate-sulphuric acid reagent (mixture of 150 mL conc. H_2SO_4 in 150 mL deionized water and 100 mL of a solution of 10 g crystalline ammonium molybdate in 100 mL of deionized water). The optical density of developed blue

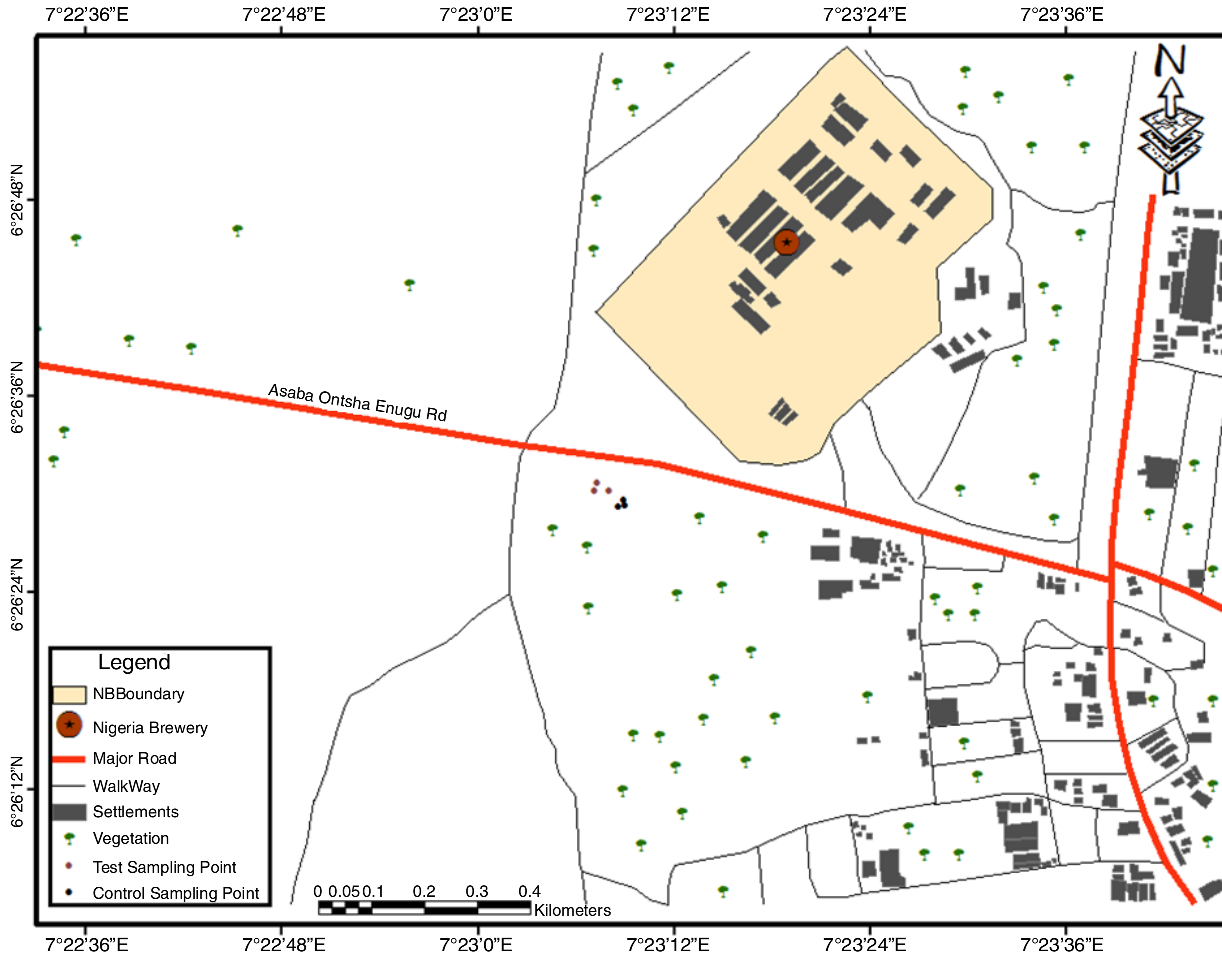

Fig. 2. Map of the project site around Ama brewery showing the sampling points

colour was read at 660 nm using a VP 1012 Jowan, spectrophotometer and calculated after reference to a standard curve.

Statistical analysis: Mini Tab version 17 statistical software was used in this study for all statistical analysis. Student t-test was employed to test for significant difference in soil quality between the soil that received the brewery effluent and the control soil that did not receive the effluent. Analysis of variance (ANOVA) was used for testing whether there was any significant difference in soil quality among the soil profile. The distribution of the soil quality parameters along the soil profile was described using regression models that could be predictive in nature after due validation which was not covered in present study. The use of parametric statistics was informed by large sample size that formed the basis for assumption of normality.

RESULTS AND DISCUSSION

Soil quality of the test site compared with the control site: The mean and p values of each of the measured soil chemistry parameters with respect to the test and control sites are as presented in Table-1 while the physical properties of the soils are presented in Table-2.

The p values reported in Table-1 are for the 2-sample t-test at 95 % confidence interval (CI). Here, the mean value of

TABLE-1
SOIL CHEMISTRY PARAMETERS MEAN AND p VALUES AT 95 % CONFIDENCE INTERVAL

Parameters	Site 1 (test site)		Site 2 (control site)		p value
	Mean value	Standard error mean	Mean value	Standard error mean	
Available phosphorous (ppm)	66	1.6	5.6	0.32	0.007
Total nitrogen (%)	0.07	0.012	0.067	0.012	0.35
Organic matter (%)	4.9	0.71	1.7	0.22	0.047
Organic carbon (%)	2.92	0.41	1.1	0.21	0.032
Cation exchange capacity (meq/100 g)	13.63	0.98	8.67	1.8	0.104
Base sat (%)	89	3.3	58	6.6	0.043
Mg^{2+} (meq/100 g)	4.4	0.35	0.93	0.18	0.012
Ca^{2+} (meq/100 g)	6.97	0.75	3.3	0.66	0.036
K^+ (meq/100 g)	0.22	0.037	0.07	0.015	0.085
Na^+ (meq/100 g)	0.166	0.013	0.146	0.024	0.52

TABLE-2
SOME PHYSICAL PROPERTIES OF THE SOIL SAMPLES

Sample description	Texture class	Particle size (%)				pH value*	
		Clay	Silt	Fine sand	Coarse sand	H_2O	KCl
A_1T	S	6	6	20	60	6.8	6.1
A_2T	LS	6	8	30	56	7.1	6.4
A_3T	S	6	6	32	56	7.2	6.8
B_1C	SL	18	14	22	46	5.5	4.1
B_2C	SL	14	12	29	45	5.2	4.1
B_3C	LS	10	11	33	46	5.7	4.3

*pH is included here for convenience. It is actually soil chemical property.
A_1T, A_2T and A_3T = Soil samples from test site; B_1C, B_2T, B_3T = Soil samples from control site S = sandy; L = loamy.

each soil parameter (top soil) for the test site was compared with the control site to ascertain if there is any statistical significant difference. For parameters with p values less than 0.05, it is concluded that the difference is statistically significant at 95 % confidence interval.

The concentration of phosphorus at the test site have been affected by the sludge effluent as the difference in the concentration of phosphorus in the control site and that of the test site is significant (Table-1; p value = 0.007). This result is consistent with several other results from the work of other authors [21]. The critical value of phosphorus required by plants for tropical soil has been reported to be in the range of 15-20 ppm [22,23]. This critical value is far higher than the concentration of phosphorus for soil samples collected at the control site whereas it is far lower than those collected at the test site indicating that Ama Brewery sludge effluent has fertilized the study site with respect to phosphorus. Phosphorus is a major plant nutrient and its occurrence in soils is influenced mainly by soil parent material. It is rendered available mainly in soils of pH between 6 and 7. It is therefore not surprising that the top soil samples of the test soil site with pH of about 7 correspondingly have the highest concentration of available phosphorus (Tables 1 and 2). At the two extremes of low and high pH, the availability of phosphorus is drastically reduced due to the formation of phosphate compounds that are not soluble. The available phosphorus of untreated paper industry sludge is abysmally low but only increases to the level of those reported in this work after bioconversion *via* aerobic composting and vermicomposting. The available phosphorous reported in this study therefore compares favourably with the available phosphorous resulting from aerobic composting and vermicomposting of paper industry sludge as reported by Sahariah *et al*. [24]. The available phosphorus in sewage treatment plant sludge is quite high but the sludge cannot be applied directly without treatment due to the high level of toxic metals [25]. Hence, the brewery sludge which could be applied without treatment offers an advantage for enhancing soil fertility with respect to available phosphorous.

The concentration of Nitrogen at the test site appears not to have been affected by the sludge effluent considerably as the difference in nitrogen concentration at the control site and that of the test site is not significant (Table-1; p value = 0.35). Generally, the % abundance of organic matter and organic carbon is higher for the test site than the control site (Table-1). The difference in abundance for both organic matter and organic carbon for the two sites (test and control sites) are significantly different at 95 % confidence interval (Table-1). This indicates that the Ama Brewery effluent discharge at the study site contains relatively high organic matter. Organic matter has some beneficial impacts on soil quality ranging from enhanced water holding capacity, soil structure improvement, soil erosion prevention to cation exchange capacity [26]. Studies have also shown that there is a strong relationship between organic matter or organic carbon and cation exchange capacity [26]. The cation exchange capacity at the study test site appears to have been affected by the sludge effluent as the difference in cation exchange capacity in the control site and that of the test site is evident (Table-1). However, the p value of 0.104 (Table-1) is an indication that the cation exchange capacity in the test site is not significantly different from the control site statistically. The % base saturation at the study test site appears to have been affected by the sludge effluent as the difference in % base saturation of the control site and that of the test site is substantial (Table-1). Percentage base saturation indicates the extent to which cation exchange complexes are occupied by base forming cations. High base saturation implies high concentration of nutrient cations on the cation exchange site. The high value of percentage base saturation is desirable for adequate plant and vegetative growth. The cation exchange complexes of the soil at both the control and test sites are composed of predominantly divalent cations such as calcium and magnesium. Despite the dominance of these divalent cations in the study sites, their concentration level is low for the control site with mean values of 0.93 and 3.3 mE/100 g (Table-1) for magnesium and calcium ions respectively. There is however a significant increase in the concentration of these cations at the test site as the concentration of magnesium and calcium ions has gone up to 4.4 and 6.97 meq/100 g respectively. The p value of 0.012 and 0.036 for Mg^{2+} and Ca^{2+} respectively indicate that these two exchangeable bases are significantly different for the two sites whereas the p value of 0.085 and 0.52 for K^+ and Na^+ respectively indicate that there is no significant difference for the two exchangeable bases in the two sites (Table-1). The dominance of calcium ion over the other basic ions is desirable for plant growth. As a matter of fact, plant growth is adversely affected when exchangeable magnesium exceeds the exchangeable calcium. There is an increase in the concentration of K^+ as we move from control to test site (Table-1) although the difference is not significant statistically at 95 % confidence interval. The mean concentration of potassium ion in the test soil is only marginally higher than that of sodium. This is also the situation for the control site. It is desirable for potassium ion to be higher than sodium ion to avoid a situation whereby the sodium ion may partially substitute for potassium ion and end up having a depressing effect on crops in addition to other adverse effects such as soil dispersion and degradation that eventually hinders nutrient uptake by plants and water penetration. The marginal dominance of potassium ion over sodium ion is therefore highly desirable as found at the test site (Table-1).

The selected soil chemistry parameters for the soil profile: 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and 60-75 cm and the ANOVA generated R-square values are as presented in Table-3.

In the test site, there is no significant difference between profile A and B for phosphorous concentration whereas there is significant difference between profile A and either of the other profiles. For all the other parameters in the test site, soil organic matter, organic carbon, calcium ion and magnesium ion, their concentrations in profile A differ significantly from those of profiles B, C, D and E. The ANOVA generated R-square (adjusted) values for the test site indicate that there is a good strength of relationship between the profile and parameter concentration levels whereas the converse is true for the control site (Table-3). In order to generate predictive models, these parameters and their values for the test site were used for regression analysis. The plots from where regression equations were derived are presented in Figs. 3-7.

There is strong relationship between the profile and concentration of all the parameters, namely, phosphorus, soil organic matter, organic carbon, calcium ion and magnesium ion (Figs. 3-7). The distribution of the soil chemistry para-

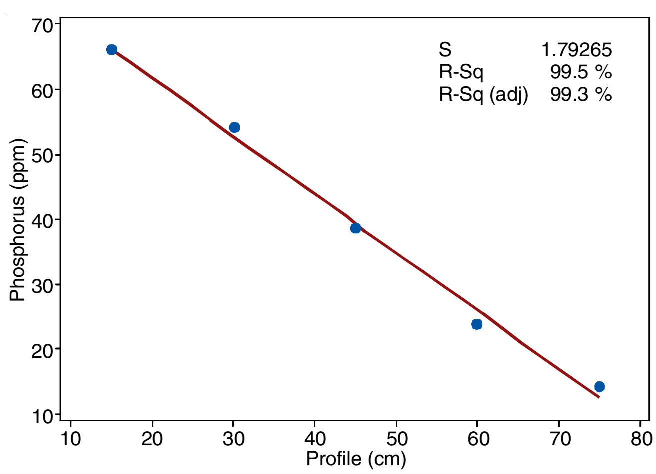

Fig. 3. Regression of phosphorus concentration on profile at the test site

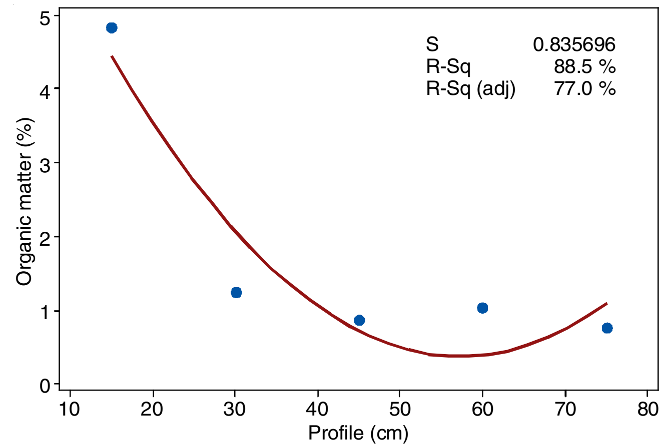

Fig. 4. Regression of organic matter concentration on profile at the test site

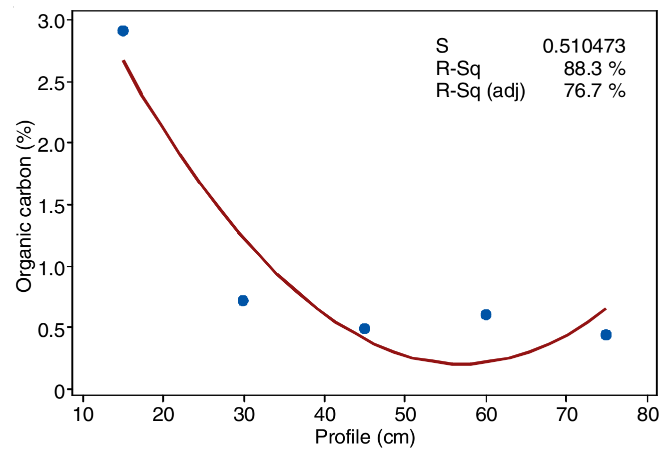

Fig. 5. Regression of organic carbon concentration on profile at the test site

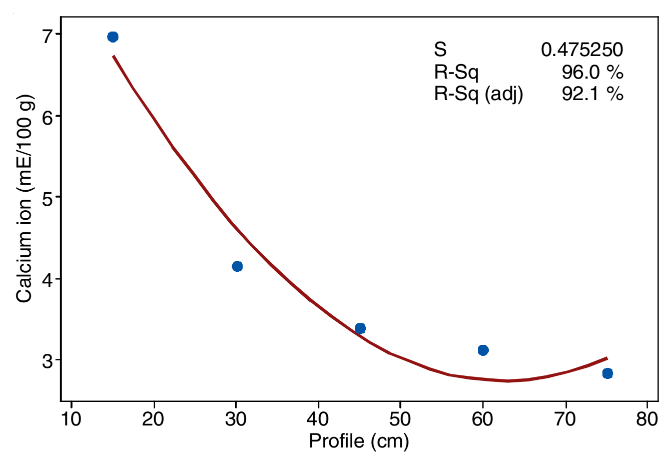

Fig. 6. Regression of calcium ion concentration on profile at the test site

TABLE-3
SELECTED SOIL CHEMISTRY PARAMETERS FOR ALL THE SOIL PROFILE AND THE ANOVA GENERATED R SQUARE (adj) VALUES. TABLE VALUES ARE REPORTED AS MEAN

Parameter	Profile (test site)					R^2 (adj) (%)	Profile (control site)					R^2 (adj) (%)
	A	B	C	D	E		A	B	C	D	E	
Phosphorus (ppm)	66	54.1	38.5	28.7	14.7	88	3.14	1.87	1.6	1.58	1.33	8.81
Soil organic matter (%)	4.8	1.22	0.85	1.03	0.75	87	1.87	1.4	1.62	1.87	1.23	0.00
Organic carbon (%)	2.91	0.72	0.6	0.68	0.44	90	1.07	0.83	0.95	1.05	0.72	0.00
Calcium ion (mE/100 g)	6.97	4.13	3.38	3.1	2.8	85.5	3.3	3.2	3.1	2.9	2.6	0.00
Magnesium ion (mE/100 g)	4.4	2.53	2.4	2.3	2.33	81.3	0.93	0.93	0.9	1.4	1.53	16.5

A = 0-15 cm; B = 15-30 cm; C = 30-45 cm; D = 45-60 cm; E

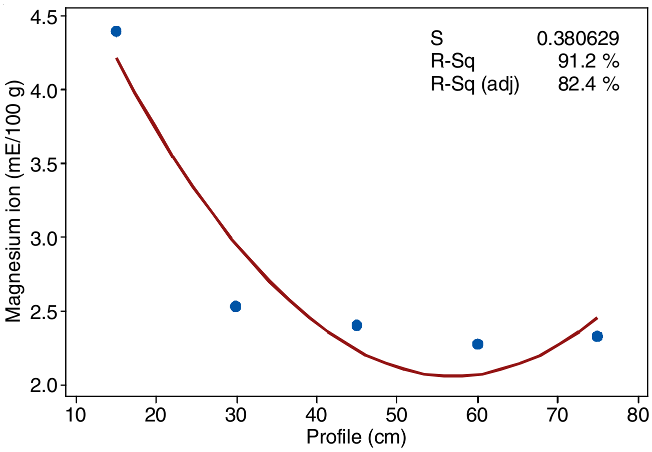

Fig. 7. Regression of magnesium ion concentration on profile at the test site

meters such as phosphorus among the soil profiles of the test site is such that the concentration was relatively high down to the 3rd profile (30-45 cm). For the second (15-30 cm) and third (30-45 cm) profiles, about 85 % and 60 % respectively of the phosphorus found in the first profile (0-15 cm) exist. However, for the other parameters such as organic matter and organic carbon, the second and third profiles hold only about 30 and 25 %, respectively of the abundance in the first profile. The distributions of exchangeable bases appear to fall somewhere between the two extremes, hence the concentration of the exchangeable bases in the second and third profiles occur in the range of 40-55 % and 30-40 % respectively of the concentration in the first profile. This seemingly differences in the distributions of these chemical parameters among the soil profile appear to account for why we have different types of regression equations.

Conclusion

Among the soil chemical parameters studied, there were significant changes in the top soil concentration of phosphorus, organic matter, organic carbon, magnesium and calcium as we move from control site to the test site. However, there had not been any significant changes in the concentration of sodium and nitrogen in the top soil of the test site in comparison to the control site. Consequently, it could be inferred that the soil quality of the study test site with respect to the afore-stated parameters had been altered by reason of the discharge of the Ama Brewery sludge effluent. The distributions of phosphorus among the profiles of the soil test site fit into a linear regression model with strong and high predictive ability evidenced by very high R-square value. In contrast, the distributions of the exchangeable bases and organic matter among the soil profile fit into polynomial regression models with fairly good predictive ability. This study indicates that Ama Brewery sludge effluent has not impacted the soil quality of the test site adversely but has improved it for agricultural purposes. The study has also revealed that the movement and distributions of these parameters down the soil profile could be modeled *via* predictive models that would however require to be validated with data from other field works.

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