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IMPACT OF INDUSTRIAL EFFLUENTS ON SOIL QUALITY OF SUDAN SAVANNA ALFISOLS IN SEMI-ARID TROPICAL ZONE OF NIGERIA

[1]Abdulkadir Sani, [1]Nasiru Ahmed Abdulkadir, , [1]Hamisu Almu, [2]Uzaifa Adamu Karfi and [3]Musa Mohamed Umar
1 Soil Science Department, Kano University of Science and Technology, Wudil, Nigeria.
2 Soil Science Department, Federal University, Dutse, Nigeria
3- Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria

ABSTRACT: *With increase in industrialization, threat of industrial pollution has been troubling the human world for many years causing environmental pollution including agricultural soils, which are adversely affected when untreated or partially treated industrial effluents are applied on them as irrigation amendments. The aim of this study was to evaluate the effect of industrial effluents on the quality of soils irrigated with the effluents in Sharada industrial area by measuring different physico-chemical quality parameters. The soil samples were collected from three different phases of the industrial area and analyzed using standard laboratory procedures. Findings indicated that application of industrial effluents on soil caused changes in the physico-chemical profile of the soil with parameters like pH, organic carbon (OC) , nitrogen (N), phosphorus (P), exchangeable sodium (Na) and potassium (K) recording mean values ranging from 6.6-7.2, 1.0-2.2%, 0.1-0.2%, 9.0- 14.0mg/Kg, 0.1-0.5Cmol/Kg and 0.6-0.7Cmol/Kg respectively. These values were different from the normal range of fertile and qualitative soil according to standards, and no significant differences were recorded among the sampling sites (P>0.05). Furthermore, the study revealed that the soil texture was sandy loam and loamy sand, while the cation exchange capacity (CEC), electrical conductivity (EC) exchangeable calcium (Ca) and magnesium (Mg) recorded mean values in the range of 4.6-6.8Cmol/Kg, 0.3-1.0dS/m, 1.6-3.7Cmol/Kg and 1.0-2.0Cmol/Kg in that order with significant variation among the sampling sites (P<0.05) indicating the moderate impact of industrial effluents on the soil quality.* ***Overall, the research findings indicated that Sharada industrial effluents have impacted relatively on the soil quality of the surrounding soils in the area and their application should be discontinued for irrigation unless with careful monitoring and guarded improvement in the quality of the industrial wastewater as well as application of inorganic and organic amendments that will improve the fertility and quality of the soils of the study area.***

KEYWORDS: soil quality, pollution, industrial effluent, irrigation, environment

INTRODUCTION

Having the potential characteristics of reducing pressure demand on natural fresh water resources coupled with supply of rich needed nutrients for proper soil and crop quality improvement when adequately and accurately treated, industrial effluents are now one of the preferred choice for irrigation amendment (FAO, 2012; Almuktar et al., 2018; Sani et al., 2020) in agricultural irrigation particularly in arid and semi-arid counties. Moreover, they have the potential of saving farmers economic cost of buying both organic and inorganic fertilizers, and concurrently protecting the environment from direct pollution. However, when the reverse was the case, they deteriorate soil quality and fertility with consequent crop quality and yield reduction (Almuktar et al., 2018).

The potential concern over these pollutants are their absorption by soil and the crops grown on them, and can easily bio-accumulate in different parts of human body impacting their deleterious effect upon consumption even if consumed in small concentration, since human bodies don’t have their effective elimination system (Arora et al., 2008; Garcia-Delgado et al, 2012). However, some studies argued that at low concentration, the effluents enhanced soil quality and provided a conducive soil environment that promoted better growth of crops and subsequent increase in yield (Akinyemi et al., 2015).

Some industrial effluents depending on the sources, types and constituents, when applied to soil environment inform of irrigation amendment beyond the assimilation capacity of the soil plant system, can make the constituents of the effluents available and readily leachable (Megason and Wang, 2003; Balkhair, 2016) by disrupting soil aggregate stability (Almuktar et al., 2018; Sani et al., 2020) leading to eutrophication of water bodies and ground water quality degradation. Conversely, when adequately and properly applied, can enhance both soil quality and fertility, increase aggregate stability with apparent increase in organic carbon concentration (Whalen and Chang, 2002) leading to decrease in global warming, as well as improvement in soil physical, chemical and hydrological parameters (Mohawesh et al., 2013).

This research will be useful to environmental and agricultural industries with provision of established interpreted data leading to understanding the impact of different constituents in industrial effluents and their potential effect when applied as irrigation amendments particularly on agricultural soils and crops because depending on their concentration, they can improve or degrade the soils and crops quality resulting to increase or decrease in yield of agricultural production with concomitant environmental protection.

Considering the negative implication of these industrial effluents to soil quality and irrigation agriculture, human health and environment, this study is aimed to evaluate the impact of these effluents on soil quality of Sudan Savannah Alfisols. Though, few numerous investigations on soil quality posed by industrial effluents were carried out in south and eastern parts of Nigeria (Akinyemi et al., 2015; Odoabuchi et al., 2020), none or few if any were ever conducted in semi-arid tropic zone of Northern Nigeria (Abdulmumini et al., 2015; Pantami, 2019; Sani et al., 2020), particularly focusing on whether the impacted soil quality parameters were compliant to standards or not. Hence, this notable gap needs to be addressed by identifying the concentration and compliance status of these parameters to fully understand their role in soil, crop and overall environmental quality improvement. Therefore, the overall aim of this study was to assess the soil quality irrigated with discharged industrial effluents in Sharada industrial estate, Kano state, semi-arid tropical zone of Nigeria with the following objectives;

- Assess the concentration of soil quality parameters irrigated with Sharada industrial discharged effluents.
- Compare the observed concentration of the analysed parameters with recommended standard for compliance.

MATERIALS AND METHODS

Study Area Description

Sharada industrial area is in Kano metropolis, Kano state, semi-arid tropical zone of Nigeria. The area covered about 600 Km^2, located between longitude 8º and 9ºE and latitude 10º and 12ºN in the Semi-arid ecological Savannah zone of the country. The research area has the climate of tropical wet and dry type, with dry and wet season months in between November to May, and June to October respectively. Furthermore, the temperature of the area is 26ºC with the maximum value of 39ºC occurring in the month of April/May and the lowest of 14ºC in December (Nuraddeen et al., 2016). The industries in Sharada are located in three phases; phase I, II and III respectively. The industrial effluents comprise of waste water from various industries ranging from battery production factories, sacks and nylon manufacturing companies, oil and gas, textiles and tanneries, plastic industries and little component of domestic waste water. The released effluents from these industries drain into gutters through the industries discharge outlets and empty into a concrete open sink, where the farmers in the area use them for their soil irrigation.

Soil Sampling

Soil samples were collected from three different locations (Sharada phase I, II and III), in each phase, three representative soil samples were collected and bulked from the surrounding farms at a depth of (0-30cm) using soil auger, making a total of six (6) composite samples. All samples were kept in a well label polythene bags for laboratory analysis.

Laboratory Analyses

Soil pH and EC were determined using pH and conductivity meters respectively, Cation Exchange Capacity (CEC) was determined using neutral pH_7 in NH_4OAC saturation method as described by Anderson and Ingram (1993), Organic Carbon was determined by the dichromate oxidation method as detailed by Nelson and Sommers (1982) while Mechanical Analysis was by standard hydrometer method as outlined by Gee and Bauder (1986). Total Phosphorus was determined by acid digestion as outlined by Murphy and Relay (1962), Total Nitrogen content was determined using the micro-Kjeldhal technique as described by Bremmer (1982) while The exchangeable bases of Na and K were determined using the flame photometer; Mg and Ca were determined using atomic absorption spectrophotometer**.**

Statistical analysis

To assess the contamination level of the soil quality indices in different phases and their corresponding differences, data mean values of the concentration in each phase were subjected to analysis of variance (ANOVA) using SPSS Statistical package. The treatment means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS AND DISCUSSION

Soil Salinity, Permeability and Infiltration Parameters

Comparison of Soil Texture

Overall mean values with regards to soil texture analysis was shown in Table 1. The results showed variability in the soil textural classes through particle size distribution of soil samples from soils irrigated with industrial effluents. The distribution of the soil particles indicated that

Sharada phase I, II and III recorded particle size distribution values of sand 88%, silt 4% and clay 8%; sand 78%, silt 8% and clay 14% and sand 62%, silt 20% and clay 18% respectively. Broadly, soils irrigated with industrial effluents in Sharada phase II and III could be categorized as sandy-loam while that of Phase I as loamy-sand indicating low concentration of clay fractions compared to sand and loam.

Findings of Anova using DMRT indicated that there was no significant ($P>0.05$) variation (Table 1) in the distribution of the sand, silt and clay fractions across all soils in different phases. The plausible reason for the high sand fraction in comparison to other fractions could be attributed to high amount of particles from the industrial effluents (Almuktar et al., 2018; Sani et al., 2020) that might have dominated and elevated the proportion of sand soil particles compared to other particles in the textural class, making the clay and silt fractions very low leading to reduction of exchangeable nutrients concentration in the soil indicating weak aggregate stability and its overall productivity (Brady and Weil, 2005). Many studies have reported reduction in soils aggregate stability, porosity, hydraulic conductivity and high bulk density as well as poor texture and structure as a result of irrigating soils with industrial effluents containing high amount of sand particles (Sani, 2015; Sani et al., 2020). The result of soil texture of this study compares well with the data reported in literature (Awoteye et al., 2011).

Comparison of pH

The result of soil pH in the soil samples collected from the soils irrigated with industrial effluent was also presented in table 1. The range of the pH was between 6.55 and 7.18 in all the three phases. The result also indicated that no significant difference was recorded ($P>0.05$) between the soils of the three different phases and H^+ concentrations (Table 3). Soil pH is one of the most important soil quality parameter. It affects mineral nutrients mobility and distribution. Under decreased soil pH condition, most desirable crop nutrients become less available while others, often undesirable, become more available and can reach toxic levels (Sani et al., 2020). Considering the recorded pH values, the soils could be considered neutral according to the ratings of Esu (1991), and the possible reason for that could be ascribed to high amount of exchangeable bases in the industrial effluent used for irrigation, which cancels the acidification potentials of the heavy use of nitrogenous fertilizers. A similar result has been confirmed elsewhere by Dawaki et al. (2013).

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Table 1: Comparison of mean values concentration of soil Salinity, Infiltration and permeability Parameters of Soils Irrigated with Sharada Industrial effluents

Location	%Sand	%Silt	%Clay	Textural Class	EC (dS/m)	Ca (Cmol/Kg)	Mg (Cmol/Kg)	K (Cmol/Kg)	Na (Cmol/Kg)
Phase I	88 NS	4 NS	8 NS	Loamy sand	1.0065	1.62	1.01	0.63	0.46
Phase II	78 NS	8 NS	14 NS	Sandy loam	0.2960	2.52	1.73	0.67	0.30
Phase III	62 NS	20 NS	18 NS	Sandy loam	0.2760	3.69	1.91	0.61	0.12

Note, for soil textural classes, means having the same letters in the same column are not significant under 5% level of probability using DMRT

Comparison of Electrical Conductivity

Electrical conductivity (EC) is a term used as an indicator of salinity status of either soil or water medium and also serves as irrigation water quality (Bauder et al., 2011) index. The findings of the soil EC in all the phases were depicted in table 1. The results indicated that the mean EC values were significantly different ($P<0.05$) in different phases with the highest value recorded in Phase I (1.0065), while Phase II (0.2960) and III (0.2760) were statistically similar (Table 3). The possible reason behind this high record of EC values in the former phase compared to the latter phases could be due to high amount of solid particles in the effluents of phase I industries that were applied as irrigation water to the soils in the phase I soils likely due to the intrusion of domestic or agricultural waste water containing high amount of solids and might have led to the higher concentration of the EC values observed (Maradi et al., 2013). However, all the values of the EC values recorded complied with recommended threshold values of 0-4dS/m advocated by FAO (1993). The data of the EC values obtained in the present study was in conformity with the results reported by Binns et al. (2003) and Dawaki et al. (2013).

Comparison of the Exchangeable Bases (Ca, Mg, K and Na)

The result of exchangeable bases was also depicted in table 1. Concentration of Ca and Mg was highly variable but stable for K and Na with highest values recorded in phase III compared to other phases for the former cations with apparent significant ($P<0.05$) difference while no difference was recorded significantly ($P>0.05$) with different phases with the latter cations (Table 3).

According to the recommendation set by regulatory agencies (Esu, 1991), the exchangeable Ca and Mg concentration of the soils ranged from medium to low in PhaseIII and Phase I respectively, while exchangeable K and Na concentration were within the range of low to medium in that order. Inequity of exchangeable Na relative to Ca and Mg in soil matrix results in water permeability and infiltration problems (Bauder et al., 2011; Sani et al., 2020). However, considering the concentration of these exchangeable bases (Table 1), the soil quality was not affected negatively with the applied industrial effluents and crops could be grown without any threat of infiltration and permeability problems (Sani et al., 2020). Similar results were reported by Binns et al. (2003) and Dawaki et al. (2013).

Soil Major Fertility Parameters

Comparison of Organic Carbon

Soil organic carbon (SOC) concentration is an index of soil quality and influences aggregate size distribution and stability (Whalen and Chang, 2002). According to table 1, SOC concentration was higher in phase II followed by Phases III and I but statistically ($P>0.05$) recorded no difference (Table 3). However, all the phases had SOC concentration above very low class and within low classes of fertility ratings according to regulatory agencies (Esu, 1991) of 0.4% and 0.4-1.00% respectively.

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COD and BOD in wastewater when applied to soil medium as irrigation amendment lead to organic carbon accumulation in the soil. However, when they are in high concentration above threshold limit can lead to soil OC toxicity and soil quality degradation with subsequent excessive growth of the crops grown in the soil medium (Almuktar et al., 2014, 2018).

Nevertheless, according to Sani et al.(2020), the COD concentration of the Sharada industrial effluent was above discharge limit, but considering the result of this research (Table 1), the concentration of the OC from the soil being irrigated with the effluents was low, which is surprising. However, the plausible reason for this could be attributed to rapid decomposition and mineralization of organic materials due to high temperatures prevalent in the semi-arid tropical region (Sharu et aI., 2013) that might have degraded the already accumulated OC leading to the observed low concentration in the soils irrigated with the industrial effluents.
The result of OC found in the current study was comparable to data reported by Dawaki et al. (2013).

Location	pH	O.C.%	TN%	P (mg/Kg)	CEC (Cmol/Kg)
Phase I	7.180	0.978	0.1225	8.50	4.616
Phase II	6.515	2.214	0.2100	14.09	5.645
Phase III	6.705	1.007	0.2450	13.79	6.800

Table 2: Comparison of mean values concentration of Key Soil Quality Parameters of Soils Irrigated with Sharada Industrial Effluents

Comparison of Total Nitrogen

Nitrogen is another soil quality and fertility index. According to table 1, the result showed that all the phases recorded low concentration of nitrogen with phase I recording the highest values compared to other phases. Furthermore, statistically, no significant differences were recorded (P>0.05) between the nitrogen concentration in the soils and the different phases (Table 2)The major sources of nitrogen from wastewater are ammonium and nitrate nitrogen, and when applied in appropriate concentration increase nitrogen content of the soil within the crops requirement, however, in contrast, if applied in high concentration above the capacity of soil-plant absorption, it leads to soil nitrogen toxicity, soil acidification and harmful effect to the crops grown in the affected soils (Sani et al., 2020).

Despite recording low nitrogen concentration according to recommended values set by regulatory authorities (Esu, 1991), phase III recorded the highest values in comparison to other phases probably due to influx of human and animal faces (Nuruddeen et al., 2016), and excess nitrogenous compounds in the industrial effluents from domestic and agricultural sources as a result of nitrogenous fertilizers over usage by the farmers in the area (Sani et al., 2020) which might when applied have triggered the observed high values of nitrogen concentration in the latter phase soils of the industrial area. The result of TN obtained in the current study was dissimilar with the data reported by Dawaki et al. (2013) in their soil quality assessment using industrial wastes application. This contradicting result obtained, could be attributed possibly to differences in the chemical compositions of the industrial wastes and the effluents (Sani et al., 2020).

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Table 3 Statistical Significant Differences Between the Soil Chemical and Physical Parameters and Sharada Industrial Phases

Sharada Industrial Phases			
Soil Parameters	I	II	III
pH (-)	7.180[NS]	6.515 [NS]	6.705 [NS]
EC (dS/m)	1.0065[a]	0.2960[b]	0.2760[b]
Ca (mg/kg)	1.62[b]	2.52 [ab]	3.69[a]
Mg (mg/kg)	1.01[b]	1.73 [a]	1.91 [a]
K (mg/kg)	0.63[NS]	0.67[NS]	0.61[NS]
Na (mg/kg)	0.46[NS]	0.30[NS]	0.12[NS]
OC (%)	0.978 [NS]	2.214 [NS]	1.007 [NS]
TN (%)	0.1225 [NS]	0.2100 [NS]	0.2450 [NS]
CEC (cmol/kg)	4.616[b]	5.645[b]	6.800[a]
P (mg/kg)	8.50 [NS]	14.09 [NS]	13.79 [NS]

Means having the same letters in the same column are statistically the same, NS = Not significantly different, and Means were separated using DMRT at 5% level of significance.

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Comparison of Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) is a fertility and soil quality indicator that assess the amount of cations to be retained on soil particle surfaces. The variability in CEC concentration of the soils is presented in table 2. Findings indicated that highest CEC values were recorded in phase III than phases II and I respectively, and the difference was statistically significant ($P<0.05$) as depicted in the analysis of variance (ANOVA) statistical table (Table 3). However, despite these significant differences in the concentration of CEC observed, all the recorded values were low according to recommended threshold limit set by regulatory authorities (Esu, 1991) probably due to small percentage of clay particles, OC, TN and P in the industrial effluents applied to the irrigated soils because they are responsible for retaining the exchangeable cations (Lickaz and Penny, 2001) hence, if they are much in the effluents, they increase the CEC and vice-versa. Many studies have reported positive correlation between soil P, OC and TN with subsequent increase in CEC (Hao et al., 2004; Sani, 2009), while on the other hand, it was reported that industrial effluent contaminated soil accumulates potentially toxic elements (PTE) that reduce CEC and slight alteration in the pH concentration (Willet, 1994) of the affected soils confirming data of the current study.

Comparison of Phosphorus

Phosphorous (P) nutrient is very essential in plant growth and early root formation, and growth development. It also improves the quality of many cereal crops, fruits and vegetables (Ojha and Chaudhary, 2017). The concentration of soil phosphorus (P) irrigated with industrial effluents was depicted in table 1.The result indicated that P concentration was higher in phase II compared to other phases, and were all statistically similar ($P>0.05$) (Table 3). Though there was no significant difference across the phases, all the P concentrations recorded were within the low (<10mg/kg) and medium (10-20mg/kg) quality and fertility classes recommended by regulatory authorities (Esu, 1991) considering the recorded concentrations of 8.5, 14.09 and 13.79 (mg/kg) across the phases. Despite being within the low and medium range of quality and fertility class, the highest values recorded in phase II in comparison to other phases could be attributed to high P in the phase II industrial wastewater (Sani et al., 2020), that might have raised the observed high values in the irrigated soils confirming the findings of Toze (2006) and Dawaki et al. (2013) who found very high levels of N and P association between domestic and industrial wastewaters.

CONCLUSION AND RECOMMENDATION

The aim of the current study was to assess the quality of soils impacted by industrial wastewater irrigation. Different soil samples collected from various agricultural sites in different phases of Sharada industrial area were found to have variation in physico-chemical parameters. Findings also indicated that the the major soil quality indicators; OC, TN, CEC and Exchangeable bases were non-compliant to the standard limit of both quality and fertility classification of agricultural soils as recommended by regulatory agencies since they were within the low to medium ranges, whereas EC and pH were compliant to the standard.

Overall, this study indicated that Sharada industrial effluents applied as soil and water amendments to produce crops as being a practice by the farmers residing in the area have relatively and slightly affected the soil quality by altering different soil parameters from its normal range of fertility, which could lead to soil quality degradation and subsequent crop growth and quality alteration.

Concerning recommendations, all industries in Sharada industrial area should be directed and enforced by authorities to discharge effluents only after wastewater quality assessments, while the farmers apply the effluents for agricultural irrigation only following irrigation water reuse quality check and frequent organic matter addition to the soil of the study area. Furthermore, research using the wastewater irrigation with some test crops and their reciprocal relationship to soil quality assessment are highly recommended.

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