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RIVER WATER QUALITY ASSESSMENT AND SUITABILITY FOR IRRIGATION IN NORTHERN SUDAN SAVANNA, ECOLOGICAL ZONE OF NIGERIA

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ABSTRACT: *Good river water quality management and reusing the water appropriately in irrigation agriculture can decrease complete soil and crops toxicity, and serve as a potential feasible options to potable water as well as improvement of natural water resources shortages. This study was carried out between May and July, 2019 to investigate the discharge and irrigation reuse quality of Wudil River effluents in Kano State, Nigeria. The research was conducted in three locations of the river; locations A, B and C respectively. Water quality parameters; pH, COD, BOD5, nutrients (NO_3-N, NH_4-N and PO_4-P), EC and SS were determined in different water samples obtained from the different locations. Data obtained were subjected to statistical analyses of variance (ANOVA). No significant variations ($P>0.05$) existed in all the chemical variables among the sampled locations. Comparison of the investigated parameters at the various locations of the river with the standard limit of discharge and irrigation reuse revealed that all the locations achieved compliance except for NH_4-N and PO4-$_P$ variables that polluted the river using Food and Agricultural Organization (FAO), World Health Organization (WHO), United States Environmental Protection Agency (USEPA) and other related international standards. Hence, the need for a drastic move towards both discharge and irrigation water quality improvement of the river as well as environmental conservation through sustainable development and cleaner technology approach within the research area is highlighted*.

KEYWORDS: Irrigation, water quality, River effluents, soil quality, wastewater

INTRODUCTION

Surface waters including rivers are among the major sources of irrigation water in developing countries particularly in arid and semi-arid regions. Good river water quality management and reusing the water appropriately in agriculture can decrease complete soil and crops toxicity, can be a potential feasible options to potable water for agricultural irrigation as well as improvement of natural water resources shortages (Almuktar et al., 2018; Sani et al., 2020).

However, climate change, speedy growth population coupled with slapdash industrialization and extension of urbanization combined with improper sanitation management, resulted in quality degradation of these water resources (Tsado et al., 2014; Al-Isawi et al., 2016) by dint of massive upsurge in release of extensive assortment of organic and inorganic pollutants including petroleum hydrocarbons, biological oxygen demand (BOD), chemical oxygen demand (COD), total

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dissolved solids (TDS), total suspended solids (TSS), turbidity, nitrogen compounds, toxic metals and fecal coliforms from domestic, agricultural and industrial sources. These pollutants are carcinogenic and mutagenic, causing deleterious effects on the different components of the water environment including fisheries, thus making such water unsuitable for drinking, irrigation and aquatic life. Moreover, these pollutants are conveyed with the water inform of irrigation water to farm lands and remain behind in the soil after water evaporates or consumed by the growing crops affecting the soil and crop quality respectively (Almuktar et al., 2018).

Literature has documented that wastewater can only be of good quality and suitable for irrigation when both the water quality indices (Morari and Giadini, 2009; Al-Isawi et al., 2015, 2016) and irrigation water quality variables (Bauder et al., 2011; Tsado et al., 2014) are within the recommended threshold limits set by environment, health and agricultural agencies respectively. Several publications have also reported that river waters with good quality indices and their subsequent reuse in irrigation led to increase in soil quality and crop yield (Qadir etal., 2007; Tsado et al., 2014), while the reverse was the case particularly in river waters with poor water quality (Danazumi and Bichi, 2010; Al-Isawi et al., 2016).

For example, application of river water as an irrigation amendment in UK has been reported to improve the growth of vegetables with no apparent deformation in the growth of agronomic parameters of the grown crops. Furthermore, highest yield was associated with the vegetables grown under the river effluents in comparison with other type of wastewaters (Al-Isawi et al., 2016). In another investigation, Selvi et al (2007) indicated that unpolluted river will be a potential source of irrigation water suitable for crop production and soil quality improvement compared to polluted sources which can deteriorate growth media quality and impede crops growth.

Application of polluted river water directly as irrigation amendment to the agricultural soils could be hazardous and impact negatively on soil and crop quality if not adequately and properly treated. For instance, river water polluted with high chemical and biological oxygen demands (COD and BOD), nutrients and other conventional pollutants above discharge and irrigation quality standards can lead to sunlight impediment and oxygen diminution in water bodies with consequent negative impact on fish and aquatic life (Sani et al., 2020), nutrient toxicity in soil media and subsequent alteration in morphological growth and yield of crops (Almuktar et al., 2014, 2018). Comparably, river water containing high amount of heavy metals (HMs) or hydrocarbons (HC) above discharge and irrigation reuse limits when applied as soil amendment, can impede crop growth by deteriorating soil quality and subsequently cause cancer and other related diseases to animals and humans upon consumption of the crops grown on the affected soils (Chopra et al., 2009; Ali et al., 2013; Sani et al., 2020). In addition, they can reduce soil aggregate stability, porosity and hydraulic conductivity, increased bulk density leading to poor texture and structure (Alkhais, 2001), increased soil salinity, electrical conductivity (EC), organic matter (OM), exchangeable cations, phosphorus (P), micronutrients and decrease in pH (Mojiri, 2011; Khaskhoussy et al., 2015; Sani et al., 2020).

Benefits of applying river wastewater for agricultural purposes are widely known. However, in Nigeria, their appropriate assessment and management to improve soil quality and crop production keeping the environment safe remains thinly implemented (Danazumi and Bichi, 2010; Tsado et al., 2014). Furthermore, instead of using expensive drinking water in agriculture, river wastewater streams might be suitable for the successful irrigation of crops. The presence of contaminants including nutrients in such waters might reduce the need for fertilizer application. The overall aim of this study is to evaluate the quality of Wudil river water and assess if the water is qualified for irrigation. The objectives are to assess (a) river water quality parameters, (b) irrigation water quality indices suitability for crop production and soil quality improvement.

MATERIALS AND METHODS

Study Area Description

The study was conducted in Wudil Local Government area of Kano State, Nigeria, located between longitude 8.85^0 E and latitude 11.81^0 N, with an area coverage of $362Km^2$ (Olofin, 2008). The climate is tropical wet and dry type with dry season in the month of May and wet season in September (Dan Azumi and Bichi, 2010), and temperature of 26^oC with maximum value of 39^oC occurring in the month of April/May and the lowest of 14^oC in December (Nuruddeen et al., 2016). The river is situated in the middle of Wudil city, receiving water from Tiga Dam from the west bordering with Dawakin Kudu local government and extended up to Jigawa State at the boarder of Gaya local government from the east. The river water gets confluence of waste water from domestic, grey, laundry, livestock, little component of industrial, abattoir, and other type of wastewaters from non-point sources from Wudil local government area and her inhabitants. The farmers in the area use the water for drinking, fishing, laundry, domestic use and irrigation of vegetables, cereals, tubers and fruits. Examples of the common vegetables grown in the area are lettuce, spinach, onions, cabbage, tomatoes, peppers etc. maize, millet, sorghum and rice are the only cereal crops grown, the tubers comprise of carrots and sweet potatoes while the fruits are sweet and lime oranges. Most of these crops and the vegetables cultivated in this area are supplied to the wholesale general market within Wudil metropolis and the rest enter the nearby local markets.

Water Collection and Sampling

Before water collection and sampling, the total length of the river was divided into three locations; beginning of the river (A), mid of the river (B) and end of the river (C). Samples were collected in plastic containers from each of the location between May and July, 2019. At each point of collection, three (3) samples were collected randomly to ensure accuracy by replication. The plastic bottles used for the sample collection were washed with detergent and rinsed 3 times with distilled water and then with the sample water. The technique of random sampling was applied in collecting the samples to make one composite sample because of numerous contaminants that could alter the quality of the water. All water samples were stored at a cool temperature of 4^0c to inhibit the activities of microorganisms

Laboratory analysis

Water quality sampling was carried out according to American Public Health Association (APHA; 2005) unless stated otherwise. The spectrophotometer DR 2800 Hach Lange (www.hach.com) was used to determine variables including chemical oxygen demand (COD), ammonia-nitrogen (NH_4-

N), nitrate-nitrogen (NO_3-N), orthophosphate-phosphorus (PO_4-P) and suspended solids (SS). The biochemical oxygen demand (BOD) was determined in all water samples with the OxiTop IS 12-6 (Wissenschaftlich Technische Werkstatten (WTW), Weilheim, Germany). Nitrification was suppressed by adding 0.05 ml of 5 g/L N-Allylthiourea (WTW Chemical Solution No. NTH 600) solution per 50 ml of sample water. pH was measured with a sensION+Benchtop Multi-Parameter Meter (Hach Lange, Düsseldorf, Germany).

Statistical Analysis

To assess the quality level of pollutants concentration in different locations and their corresponding differences, data mean values of the concentration in each location 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.

RESULT AND DISCUSSION

Discharge and Irrigation re-use Quality Assessment of the River water.

Oxygen demand variables (COD and BOD)

Overall assessment with regards to river water quality parameters was shown in table1 including the chemical and biological oxygen demand variables. The result shows that, all the locations demonstrated conspicuously low COD and BOD concentration values. The overall mean COD and BOD concentrations for location C were higher than those for locations A and B (Tables 1 and 2). The recorded values of COD variable was compliant to discharge and irrigation quality standards of 0-125mg/l (UK government, 1994) and 0-146mg/l (Radeideh et al., 2009). Equally, BOD variable also achieved compliance for both discharge and irrigation quality standard of 0-25mg/l and 0-30mg/l respectively as advocated by UK government (1994) and USEPA (2004). Though, all the oxygen demand variables were within the permissible limit of discharge and irrigation, their values were high in location C compared to other locations probably due to high amount of inorganic and organic substances in the location C released wastewater into the river water in comparison to other locations indicating that all the discharged wastewater released to the river from all the locations contain low organic and inorganic substances, thus, leading to the low observed concentration indicating low pollution of the river water (Clair et al., 2003).

The result obtained for oxygen demand variables within the range compliant to discharge and irrigation reuse limit in this study is comparable to numerous studies reported in the literature (Kotti et al., 2005; Laraba, 2016).

High BOD and COD concentration in river water above discharge limit, can lead to sunlight blockage and oxygen depletion in the water body, consequently impacting negatively on fish and aquatic life (Sani et al., 2020). On soil body however, irrigation with river water containing high amount of oxygen demand variables above irrigation reuse standard can result to nutrient toxicity and excessiveness in morphological growth parameters in crops (Almuktar et al., 2014).

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Nutrients variables (NH_4-N, NO_3-N and PO_4-P)
The overall mean values of the river water quality in all locations with reference to ammonia-nitrogen were relatively variable; lower in location A and discharge limit compliant according to the recommended threshold value of 0-20mg/l advocated by regulatory authorities (Sani et al., 2013) but higher in locations B and C (Table 1) probably due to high effect of excessive release of domestic waste such as kitchen and house waste water into the river (Bindraban, et al., 2015) in the latter locations.

The statistical table 3 indicates that river water effluent in all locations results in no statistically significant (P>0.05) difference on ammonia-nitrogen concentration.
A typical standard by FAO regulations (FAO, 2003) set 0-5mg/l for ammonia-nitrogen variable for irrigation reuse, and none of the locations complied (Table 2). The findings of Al-Isawi et al.(2016) reported high values of NH_4-N concentration in their river effluents and were found to be noncompliant to irrigation standard which is in conformity with the result of the current study.
Application of effluents rich in ammonia nitrogen concentration above permissible discharge and irrigation standard to water and soil bodies can lead to eutrophication of water bodies, soil quality degradation and subsequent alteration of the crops grown on the soil media (Al-muktar et al., 2014).

Table 1 Overall mean River water quality from different River Locations and Threshold Standard Discharge Limit.

River Locations				
Parameters/Unit	A	B	C	Discharge allowable limit
COD (mg/l)	16.30	21.80	45.400	0-125a
BOD_5 (mg/l)	8.05	9.20	15.01	0-25a
NH_4-N(mg/l)	14.015	22.765	31.520	0-20b
NO_3-N(mg/l)	21.015	22.765	28.025	0-50a
PO_4-P(mg/l)	25.370	41.175	25.095	0-2a
SS (mg/l)	16.03	18.05	11.75	0-35a
pH (-)	7.415	6.805	6.635	6.5-8.5c

[a]UK Government, (1994), [b]Sani et al.(2013), [c]Almuktar et al.(2014)

The overall mean values of nitrate-nitrogen of the river effluents were relatively low in all locations with high concentration recorded in location C, followed by B and A respectively (Tables 1and 2). This difference was not statistically significant (P>0.05) (Table 3). Furthermore, all the recorded values achieved discharge and irrigation quality compliance of 0-50mg/l and 0-30mg/l accordingly as advocated by regulatory agencies (UK government, 1994) and USEPA (2004) in all the locations.

Comparable findings of river effluents containing nitrate-nitrogen concentration compliant to both discharge and irrigation quality standards within the range recorded in the current study have been reported elsewhere (Kotti et al., 2005;Tsado et al., 2014).

The plausible reason for the high difference in concentration of river effluents in location C in comparison with locations B and A could be attributed to confluence of sewage, nitrogenous compound fertilizers and other wastes in the former location river effluents that might have elevated the concentration of the NO_3-N variable compared to the river effluents in the latter locations (Paul, 2011; Sani et al., 2020).

Irrigation of river effluents with high nitrate-nitrogen concentration above permissible limit can lead to eutrophication of receiving watercourses, slow reactions to light and sound stimuli of aquatic organisms, and can cause methaemogloobinemia in children upon skin contact (Fatoki, 2003; Sani et al., 2020), while in soil, degrades its quality, delays crop growth and prolongs maturity.

The results of PO_4-P concentration was also depicted in table 1. The mean river effluent values in location B recorded higher values in comparison to values registered in locations C and A. This difference was not statistically (P>0.05) significant between the river effluents and the different locations (Table 3). Furthermore, all the recorded concentrations of ortho-phosphate phosphorus variable were non-compliant to both discharge and irrigation reuse standards of 0-2mg/l as recommended by UK government (1994) and FAO (2003) regulatory agencies respectively (Table 2).

Table 2 Overall mean River water quality from different River Locations and Threshold Standard Irrigation reuse Limit

Locations				
Parameters/Unit	A	B	C	Irrigation allowable limit
COD (mg/l)	16.30	21.80	45.400	0-146a
BOD_5 (mg/l)	8.05	9.20	15.01	0-30b
NH_4-N(mg/l)	14.015	22.765	31.520	0-5c
NO_3-N(mg/l)	21.015	22.765	28.025	0-30c
PO_4-P(mg/l)	25.370	41.175	25.095	0-2c
SS (mg/l)	16.03	18.05	11.75	0-30b
EC (ds/m)	0.060	0.045	0.070	0-3d
pH (-)	7.415	6.805	6.635	6.5-8.5e

[a]Radaideh et al.(2009), [b]USEPA(2004)[c]FAO (2003) [d]Bauder et al. (2011) and [e]WHO (2008)

The values of PO_4-P in the river effluents in all the locations obtained under the current study was high, and non-compliant to discharge and irrigation quality standards. Moreover, the result was in disagreement with some reported data in the literature (Morrison et al., 2001) who reported lower values that were compliant to discharge and irrigation reuse standards. In contrast, the reverse was the case in some studies reported elsewhere with recorded values within the range found in the present research (Tsado et al., 2014; Al-Isawi et al., 2016). The possible reason for the contradicting values above discharge and irrigation reuse limit could be attributed to the composition of the wastewater constituents; organic and inorganic substances entering the river (Morrison et al., 2001).

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Irrigation water containing high amount of ortho-phosphate phosphorus causes eutrophication of water bodies, soil and crop quality deterioration (Al-muktar et al., 2018; Sani et al., 2020).
The high ortho-phosphate phosphorus concentration observed in the river effluents above discharge and irrigation reuse quality standards could be attributed to confluence of animal wastes, leached phosphorus fertilizers and runoff from urban and agricultural catchments of Wudil populace (Paul, 2011; Sani, 2015; Sani et al., 2020).

Comparison of particles

The overall mean river effluent values for SS in all locations were within the acceptable concentration of discharge and irrigation reuse standards (Tables 2 and 3) of 0-35mg/l (UK, government, 1994) and 0-30mg/l (USEPA, 2004) respectively. Though, SS values recorded in location B was higher in concentration in comparison to locations A and C, the difference was not significant (P>0.05) statistically (Table 3).

Results concerning SS variable assessment for discharge quality and irrigation reuse compliance (Almuktar et al., 2014; Al-Isawi et al., 2016; Al-muktar et al., 2018; Sani et al., 2020) has been reported. Findings indicated that the mean values of SS concentration was comparable and within the range of the SS variable found in the current study.

Numerous studies have indicated that irrigation of crops with river effluents containing excess SS concentration can cause soil pores clogging and changes in soil hydrological properties (Aello et al., 2007; Al-Isawi et al., 2016) limiting water absorption by the growing crops. Furthermore, positive correlation has been reported between high EC, SAR and salinity concentrations with high SS concentration (Bauder et al., 2011).

Comparison of EC concentration

The concentration of EC as shown in table 1 was very low in all the locations and compliant to irrigation quality standard of 0-3ds/m as recommended by regulatory agencies (Bauder et al., 2011). This implies that the river effluents were not salt affected and was fit for irrigation as far as salinity effect is concerned. Moreover, the EC concentration indicated that the river effluents contained tiny amounts of solids that could not be a threat to soil clogging and permeability, hence, free from negative impact of restricting the movement of soil nutrients from the soil matrix to crops via their roots (Bauder et al., 2011; Sani et al., 2020).

Table 3 Statistical Significant Differences Between Some Key River Water Quality Variables and Different Locations

Parameters				
Locations	NH_4-N	NO_3-N	PO_4-P	pH
A	14.015	21.015	25.370	7.415
B	22.765	22.765	41.175	6.805
C	31.520	28.025	25.095	6.635
Significance	NS	NS	NS	NS
DMRT	0.316	0.427	0.363	0.316

A-C= River locations= 1-3, NS= Not Significant at 5% level of probability, *=Significant at 5% level of probability

Application of irrigation water high in EC concentration has been reported to negatively affect crop production. The crops grown become weak and unable to withdraw the soil nutrients for their normal growth and production consequently leading to substantial yield reductions (Bauder et al., 2011; Sani et al., 2020).

Comparison of Acidity and Basicity

The acidity or basicity of irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). The normal pH range for irrigation water is from 6.5 to 8.5 and all the locations complied (Table 1). Irrigation with river effluents recording low pH's (<6.5) can lead to accelerated corrosion of irrigation system while high pH above 8.5 makes some nutrients such as heavy metals and sodium more soluble in the wastewater, subsequently, high sodium absorption ratio (SAR), high electrical conductivity (EC) and salinity concentrations leading to poor soil texture and structure (Bauder et al., 2011). The pH values for all the locations recorded no significant (P>0.05) and were within the normal range recommended for discharge to receiving water courses and irrigation reuse respectively (Tables 1 and 2) as advocated by regulatory agencies (Almuktar et al., 2014) and WHO (2008).

Limitation of the Research

The research presented to some extent incomplete depiction on the reuse of wastewater for irrigation, because some key irrigation water quality parameters such as , SAR and exchangeable sodium percentage (ESP) were not directly estimated. However, they are indirectly evaluated through SS concentration, since it has been reported that they are highly correlated positively (Bauder et al., 2011; Sani et al., 2020).

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CONCLUSION AND RECOMMENDATIONS FOR FURTHER RESEARCH

The prime objective of this research was to assess the quality and suitability of the Wudil river effluents for irrigation agriculture. Findings revealed that the major water quality parameters in the effluents; COD, BOD_5, NO_3-N, SS and pH achieved compliance to standard limit of both discharge and reuse in irrigation agriculture as recommended by regulatory agencies, while NH_4-N and PO_4-P variables were non-compliant. Furthermore, results indicated that the EC of the river effluents was also within the allowable limit for irrigation.

Overall, this research indicated that river Wudil effluents are polluted with ammonia and phosphorus and can lead to eutrophication of the river water with subsequent negative impact to soil and crop quality when applied as irrigation amendment. Despite achieving compliance by some key water quality parameters, the river effluents are not entirely safe and fit for irrigation application, as a result, cannot be relied solely and applied as soil and water amendments to produce crops as being a practice by the farmers residing in the area unless proactive water quality improvement measures are applied.

Concerning recommendations, authorities should regularly enforce and encourage farmers to irrigate crops with the river effluents only following irrigation quality impact assessment. This scheme will reduce the potential negative impact of ammonia, phosphorus and other pollutants in the wastewater that might otherwise pollute the soil and cause soil and crop quality degradation.

In addition, research using the impact of the river effluents be conducted on the soil quality and fertility using some test crops to fully ascertain adequate assessment of the effluents, and their relationship to different types of crops growth and development.

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