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Discharged Industrial Effluents Quality Appraisal and Its Uses for Agricultural Production in Sudan Savannah Ecological Zone, Nigeria.

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Abstract: *Industrial Effluents entering the water and soil bodies, and occasionally used as irrigation water to improve soil and crop productivity, can be one of the major sources of soil and environmental pollution depending on their quality. Properly treated industrial effluents can potentially supply nutrients vital for soil and crop quality improvement and augment the high water needs for irrigation from natural fresh water sources. The aim of this study is to assess if treated effluents from different industries in Sharada industrial estate can be recycled for irrigation. Findings indicate that the key water quality parameters; chemical oxygen demand (COD), orthophosphate phosphorus (PO_4-P), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_4-N), turbidity (TBD) and total dissolved solids (TDS) recorded high concentration above allowable limits (300-360mg/l), (17-26mg/l), (32-119mg/l), (91-154mg/l), (5-31mg/l) and (275-353mg/l) respectively regardless of phases when tested for and irrigation re-use standards using Nigerian Federal Environmental Protection Agency (FEPA), World health Organization (WHO), Food and Agricultural Organization (FAO) and other related agencies. However, only biochemical oxygen demand (BOD) and pH complied with discharge and re-use permissible limits indicating the toxicity of the effluents. This implies that the effluents could not be relied as effective potential source of irrigation water rich in nutrients as assumed by some farmers that can increase soil fertility, crop quality and protect water environment. Overall outcome of this research may give useful scientific rationalization for not using and applying the effluents as irrigation amendment for agricultural production.*

Keywords: *water quality, soil quality, industrial effluent, irrigation, environment*

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I. Introduction

Release of industrial effluents into soil and water bodies is one of the major cause of environmental pollution globally. The impact of these released effluents is not restricted only to drinking water quality deterioration but also has harmful effect on soil micro flora and aquatic ecosystems (Kaur et al., 2010).Furthermore, these pollutants deteriorate surface waters, the soils and ground waters (Tamburline et al., 2002; Abdulmumini et al., 2015), and if directly consumed or applied as irrigation amendments for crop production becomedetrimental to the end users by impacting their carcinogenic and mutagenic effect.

Industrial effluents are liquid wastewaterdischarged from industrial facilities either treated, untreated or partially treated to surface waters and soil bodies. Depending on the sources, these effluents contain substances ranging from chlorides (Cl), phosphates (PO4-P), nitrates (NO_3-N), hydrocarbons (H), total dissolve solids(TDS), suspended solids (SS), heavy metals (HM), chemical oxygen demand (COD), biochemical oxygen demand (BOD), electrical conductivity (EC), among others(Kaur et al; Abdulmumini et al., 2015).

The increase in global population and industrialization has resulted in the increase in production of industrial effluents (Abdulmumini et al., 2015), and all are disposed in the soil and water bodies leading to negative impacts such as reduction in aggregate stability with poor soil structure and texture, susceptible to wind and water erosion, reduced soil organic carbon and nitrogen on soil ecosystem respectively (Sani, 2015; Almuktaret al., 2018)causing soil degradation (Alkhais, 2001) and inhibit the growth of plants on one hand, while causing hydrophobicity, fish kills, reduced dissolved oxygen in water ecosystem leading to environmental pollution on the other hand (Almuktar et al., 2018).In addition, depending on the sources and constituents, if these effluents are not treated and managed properly, the farmers using them as irrigation water source and as for soil amendments will be exposed to different types of health risks. For instance, in heavy metals containing effluents, Cadmium (Cd) alone is carcinogenic, mutagenic, teratogenic and causes renal failure and chronic anaemia, Chromium (Cr) causes hair loss, Copper (Cu) causes brain and Kidney damage, liver cirrhosis and chronic anaemia, Mercury (Hg) causes Anxiety, depression, insomnia, ulcers and damage to brain, kidney and lungs, while Lead (Pb)causes problems in children such as impaired development, reduced intelligence, loss of short-term memory, learning disabilities and coordination problems, among others (Ali et al., 2013).

Reuse of urban wastewater as a marginal quality water for agricultural production has been a disposal mechanism for centuries in advanced countries. For example, the practice is common in America (Asano and Levine, 1996; Pedro et al., 2010), United Kingdom, Italy, Germany and France (AATE, 2004; Pedero e al., 2010). However, this process is recently gaining acceptance in Asian and African countries (Einsink et al., 2004; Keraita and Drechsel, 2004; Pedero et al., 2010) particularly water scarce ones (Qadir et al., 2007) because of the realization that the effluents have the advantage of supplying nutrients to agricultural crops, environmental protection from direct waste water pollution and economically save farmers cost of buying inorganic fertilizers in addition to saving portable clean water sources (Bichi et al., 2012).

Conversely, discharge of effluents from different industries in urban areas above permissible limits have been reported (Mohsen and Jaber, 2002; Danazumi and Bichi, 2010; Kaur et al., 2010; Kanu et al., 2011; Abdulmumimi et al., 2015) in many studies causing negative impacts to thereceiving ecosystems**.** For instance, a study in Uganda to assess water pollution by industrial effluents revealed that due to poor designed effluent treatment plants or lack of them by industries has led to major pollution of water resources in the country and made humans vulnerable to toxic substances through drinking water (Lake Victoria Environmental Management Project (LVEMP, 2002; Paul, 2011). Industrial effluent’s COD, BOD, pH, TSS and TDS of textile and sugar industries were found above permissible limit in a research conducted in India by Kaur et al. (2010) and when applied as irrigation amendment deteriorated the soil quality, consequently making the soil infertile. Similarly, research conducted by Mohsen and Jaber (2002) in Jordan on industrial effluent’s quality and their potential reuse in agricultural production expounded that the industrial effluents are qualitatively poor and reusing them for irrigation is dangerous because they are far above Jordan’s irrigation reuse threshold limit. Furthermore, it has been reported recently in a study conducted in Nepal on soil quality assessment posed by industrial effluents reuse findings indicated that the agricultural soils were severely and negatively affected (Ojha and Chaudry, 2017). However, some studies in UK argued that if the effluents were properly treated, they compliant of discharge standard and could be reused for irrigation and protect the environment (Almuktar et al., 2015, 2018; Sani, 2015).

This research may give useful information to environmental, agricultural and related soil and water authorities with established interpreted data leading to understanding of effluent constituents andtheir discharge processes, allowing them to justify if possible, the use of industrial effluents in their waste water management for successful recycling into agricultural production, soil and water qualityimprovement simultaneously protecting the environment.

In Nigeria, many studies were conducted on the impact of industrial effluent on water quality. For example, Olayinka and Alo (2004) and Ebiyare and Luv (2010) evaluated the effect of industrial effluent on the quality of ground water and its management respectively in the southern part of the country. In Northern part of the country, Essoka and Umaru (2006) assessed the impact of industrial effluents on water pollution of a receiving river in Kakuri area, Kaduna south, they attributed the pollution of these water bodies is as a result of and improper discharge of untreated or partially treated effluents from industries.Although, in Kano, many concerted efforts were made on the evaluation and assessment of industrial effluents particularly from tannery and textile industries (Akan et al., 2009; Danazumi and Bichi, 2010;Abdulmumini et al., 2015; Isa and Jimoh, 2015; Amoo et al., 2017), however, very little information is available about the quality assessmentsof these effluents, their discharge standard and possible reuse threshold limit for agricultural irrigation using both national and international standards. Therefore, the aim of this paper was to evaluate quality of various industrial effluents in Sharada industrial area and assess whether they comply with permissible discharge and irrigation reuse limit. The key objectives were to;

1- evaluate the quality of various industrial effluents in Sharada industrial area
2- compare the discharge and reuse quality of the effluents with the Nigerian and other International standards

II. Materials and Methods

Study Area Description

The study wasconducted in Sharada industrial area of Kano metropolis which has an area of about 600 Km^2 located between longitude 8º and 9ºE and latitude 10º and 12ºN. Industries of Kano are concentrated in three industrial estates which are: Bompai, Challawa and Sharada. The climate area of Kano is the tropical wet and dry type with dry season between for 4 - 5 months and wet season between May and September (Dan Azumi and Bichi, 2010). Sharada is one of the popular industrial area located in Kano Municipal Local Government and Kumbotso Local Government areas of Kano State, Nigeria.Thetemperature of the research area is 26^oC with the 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 industrial effluents comprise of waste water from sacks and nylon manufacturing companies, oil and gas, textiles and tanneries, plastic industries and little component of domestic waste water whichare located in three phases; phase I, II and III respectively. The industrial effluents released 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 the irrigation of vegetables, cereals, tubers and fruits.

Water Collection and Sampling

Samples were collected in plastic containers from Phase I, II and III in Sharada industrial sites between February and March, 2019. At each point of collection in each phase; 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**.**

Water quality analyses

Standard water quality analysis procedures (APHA, 2005) were applied for variables including chemical oxygen demand (COD), ammonia-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), orthophosphate-phosphorus (PO_4-P) and total dissolved solids (TDS). The five-day biochemical oxygen demand (BOD_5) was determined in all water samples with the OxiTop IS 12-6 system, a manometric measurement device, supplied by the Wissenschaftlich-TechnischeWerkstätten (WTW), Weilheim, Germany. Nitrification was suppressed by adding 0.05 mL of 5 g/l N-Allylthiourea (WTW chemical solution No. NTH600) solution per 50 ml of sample water. pH and turbidity (TBD) were measured with sensION+Benchtop Multi-Parameter Meter (Hach Lange, Düsseldorf, Germany) respectively.

Data analysis

Data collected were subjected to analysis of variance (ANOVA) using SPSS Statistical package. The treatment means were separated using least significant difference (LSD) at 5% level of probability.

III. Result and Discussion

Assessment of Discharge and Re-Use Water quality of the Industrial effluent

Oxygen demand variables (COD and BOD):

Overall mean values with regards to water quality parameters was shown in table1 including the chemical and biological oxygen demand variables. The result shows that, all phases demonstrated high COD but low BODeffluent concentrations.

The overall mean COD and BOD concentrations for phase I was higher than phases II and III which were statistically similar with the former, while higher in phase III comparedto phases I and II in the latter. This difference was statistically significant ($P<0.05$) as shown in Table 4which shows a significant difference between effluent water quality parameters in the three different industrial phases using one way Anova. Despite exceeding permissible discharge standard, the high COD values recorded in Phase I compared to other phases could be attributed probablyto much recalcitrant chemicals that escape biodegradation in the Phase I released wastewater in comparison to other phases (Abdulmumini et al., 2015).

Table1 Overall mean values of water quality Parameters of the Sharada Industrial Wastewater in different Phases 2019

Parameters	Symbols	Units	Phase I	Phase II	Phase III
Chemical Oxygen Demand	COD	mg/l	360.00	300.00	330.00
Biological Oxygen Demand	BOD_5	mg/l	1.00	0.28	2.00
Ammonia-Nitrogen	NH_4-N	mg/l	63.05	154.11	91.07
Nitrate-Nitrogen	NO_3-N	mg/l	119.09	59.54	31.52
Orthophosphate Phosphorus	PO_4-P	mg/l	26.26	21.47	17.10
Alkalinity/Acidity	pH	-	7.04	7.12	7.01
Total Dissolved Solids	TDS	mg/l	337.00	353.00	275.00
Turbidity	TBD	NTU	5.56	30.70	5.00

High concentration of BOD and COD in wastewater above discharge limit, leads to sunlight abstraction and oxygen depletion in water bodies, consequently impacting negatively on fish and aquatic life. On soil body however, application of wastewater with much concentration above threshold value leads to nutrient toxicity and excessive morphological growth in crops(Almuktar etal., 2015, 2018).The UK and Nigerian standards for COD and BOD concentrations from secondary wastewater is 125 and 150 mg/l for COD, 50 and 25 mg/l for BOD_5respectively for environmental discharge (UK Government, 1994; FEPA, 1991). All phases were none compliant with reference to COD but were compliant to BOD (Table 2). The high concentration of COD reported in this study could be attributed to much recalcitrant chemicals that were not efficiently removed from the industries water treatment plants and has been confirmed elsewhere(Abdulmumini et al., 2015; Sani, 2015).

The irrigation water quality threshold values for COD and BOD recommended by regulatory bodies for urban wastewater recycling were set to be 0-146mg/l (Radaideh et al, 2009) and 0-30mg/l (USEPA, 2004) respectively. All filters were BOD compliant but were not for COD.

Nutrients variables (NH_4-N, NO_3-N and PO_4-P)

The overall effluent concentrations of all phases with reference to ammonia-nitrogen were high and all above discharge standard to the environment (Tables 1and 2).The statistical table 4 indicates that effluent waste water high in NH_4-N results in a statistically significant ($P<0.05$) difference in Phase II compared to phases III and I respectively probably due to confluence of high sewage, animal wastes and leached nitrogenous containing ammonium fertilizers from urban and agricultural sources (Paul, 2011) with effluents in the former phase compared to the latter phases.

Application of untreated or partially treated high concentration of NH_4-N wastewater above maximum threshold values to water and soil bodies leads to eutrophication of the water bodies on one hand and soil quality degradation leading to poor crop growth (Al-muktar et al., 2015, 2018) on the other hand.

Table 2 Overall mean values of industrial effluents from different industrial phases and their recommended threshold discharge limit

	Sharada Industrial Phases			
Parameters/Unit	Phase I	Phase II	Phase III	Discharge limit
COD (mg/l)	360.00	300.00	330.00	0-125a/150f
BOD_5 (mg/l)	1.00	0.28	2.00	0-25a
NH_4-N (mg/l)	63.05	154.11	91.07	0-20b
NO_3-N (mg/l)	119.09	59.54	31.52	0-50ad
PO_4-P (mg/l)	26.26	21.47	17.10	0-2a
pH (-)	7.04	7.12	7.01	6.5-8.5c
TDS (mg/l)	337.00	353.00	275.00	250d
TBD (NTU)	5.56	30.70	5.00	0-5ad

A typical standard by UK regulations (Sani et al., 2013) set 0-20mg/l (Table 2) as a discharge standard limit for ammonia-nitrogen variable concerning secondary wastewater treatment. All phases were non-compliant. Comparably, none of the phases (Table 3) complied with irrigation re-use recommended values of 0-5mg/l (FAO, 2003). The high concentration of the NH_4-N in the industrial wastewater is in agreement with many findings in the literature (Paul, 2011; Sani, 2015; Wu et al., 2015) who reported that poorly treated or untreated industrial effluents are associated with high nutrients concentration including NH_4-N above discharge and irrigation standard limits (Almuktar et al., 2015, 2018).

UK Government, (1994), Sani et al. (2013), Almuktar et al. (2015), WHO (2006), WHO (2000), FEPA (1991)The NO_3-N and PO_4-P effluent concentrations in all phases were high and all above discharge and irrigation reuse standards except for NO_3-N that showed compliance of discharge to the environment in phase III (Tables 1, 2 and 3). The statistical table 4 indicates thatindustrial effluent high in NO_3-N and PO_4-P result in a statistically significant ($P<0.05$) difference in Phase I compared to phases II and III respectively.

Untreated or poorly treated wastewater with nitrate and phosphorus above permissible limit have been reported to exhibit eutrophication of receiving watercourses, delayedreactions to light and sound stimuli of aquatic creatures (Robillard et al.,2003) and can cause methaemoglobinemia in children upon skin contact (Fatoki, 2003), while in agricultural irrigation reuse, degrades soil quality, surfeits crop growth and prolong maturity.

Table 3 Overall mean values of industrial effluents from different industrial phases and their recommended threshold irrigation reuse limit

	Sharada Industrial Phasess			
Parameters/Unit	Phase I	Phase II	Phase III	Irrigation reuse limit
COD (mg/l)	360.00	300.00	330.00	6-142a
BOD_5 (mg/l)	1.00	0.28	2.00	0-30b
NH_4-N (mg/l)	63.05	154.11	91.07	0-5c
NO_3-N (mg/l)	119.09	59.54	31.52	0-30c
PO_4-P (mg/l)	26.26	21.47	17.10	0-2c
pH (-)	7.04	7.12	7.01	6.5-8.5d
TDS (mg/l)	337.00	353.00	275.00	500-2000b
TBD (NTU)	5.56	30.70	5.00	Na

Radaideh et al. (2009), USEPA(2004)FAO (2003), Na, not available and WHO (2008), In contrast, when applied in appropriate proportion, improves soil quality and fertility, shortens growing season in crops with qualitative yield improvement (Almuktar et al., 2015).

The high nutrients concentration observed in the industrial wastewaters could be attributed to improper treatment of the effluent containing nutrients from industrial treatment facilities and confluence of high sewage, animal wastes, leached nitrogen and phosphorus fertilizersand runoff from urban and agricultural catchments (Danazumi and Bichi, 2010; Paul, 2011; Sani, 2015) and has been confirmed previously elsewhere (Abdulmumini et al., 2015).

Solids variables (TDS and TBD)

The concentration of TDS recorded in the industrial effluent was high and above discharge limit set by environmental regulatory agencies (Table 2). However, it is within the irrigation reuse limit (Table 3). On statistical assessment, Table 4 indicated that there was statistical significant difference recorded ($P<0.05$) between the different phases and TDS concentration (Table 4) with phase II recording highest value than phase I but statistically similar and higher than values recorded in phase III. On the other hand, TBD concentration was higher in phase II and above discharge and irrigation reuse standards compared to other phases that recorded lower values and achieved compliance (Tables 2 and 3). However, statistically, highly significant difference was recorded in phase II compared to other phases that were statistically similar (Table 4).

Excess solids in wastewater cause soil pores clogging and changes in soil hydrological properties (Aello et al., 2007; Al-Isawi et al., 2016) restricting water absorption by the growing crops. Moreover, positive correlation has been reported between high EC, SAR and salinity with high solids concentration (Bauder et al., 2011). Theregulations (WHO, 2006) set a value of 250 mg/l forTDS discharge threshold limits, while 500-2000mg/l was set for irrigation reuse limit (USEPA, 2004). All phases were non-compliant for discharge standard but compliance was achieved with regards to irrigation reuse standard.

Table 4 Overall statistical differences between water quality Parameters of the Sharada Industrial Wastewater and different Phases 2019

Parameters	Symbols	Phase I	Phase II	Phase III	SE+/-
Chemical Oxygen Demand	COD	369.30^{a}	311.70^{b}	338.30^{b}	14.64
Biological Oxygen Demand	BOD_5	1.026^{b}	0.31^{c}	2.097^{a}	0.055
Ammonia-Nitrogen	NH_4-N	62.20^{c}	151.70^{a}	91.10^{b}	2.045
Nitrate-Nitrogen	NO_3-N	119.34^{a}	59.58^{b}	33.90^{c}	1.985
Orthophosphate Phosphorus	PO_4-P	26.42^{a}	21.76^{b}	17.55^{c}	0.340
Alkalinity/Acidity	pH	7.04^{NS}	7.12^{NS}	6.97^{NS}	0.095
Total Dissolved Solids	TDS	338.00^{a}	355.70^{a}	281.30^{b}	8.53
Turbidity	TBD	5.64^{b}	31.17^{a}	4.96^{b}	0.858

Note: NS (Not significant), Means followed by the same letter are not significantly different from each other at ≤5% level of significance.

Effluents of industrial sources are reported to contain high amount of solid particles (Al-Isawi et al., 2015, 2016; Sani, 2015; Wu et al., 2015; Almuktar et al., 2018) above discharge and irrigation reuse standards. The high concentration recorded in this research could be attributed probably to confluence of more particles via leaching from inorganic fertilizers such as nitrogenous, refuse dumping and other domestic wastes (FAO, 2003)from the catchments and disposed into the water courses leading to the observed solids concentration.

Acidity or Alkalinity (pH)

The acidity or basicity of irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). The pH concentrations obtained from this study are generally within the discharge and irrigation reuse standards recommended by regulatory agencies of 6.5-8.5 (Almuktar et al., 2015) and (WHO,2008) respectively. Furthermore, no significant difference ($P>0.05$) observed between pH and different phases as indicated in Table 4.

Low pH's (<6.5) in effluents leads to accelerated irrigation system corrosion while high pH's above 8.5 makes some nutrients such as heavy metals and sodium more soluble in the wastewater, subsequently, leading to high sodium absorption ratio (SAR), high electrical conductivity (EC) and salinity concentrations. Hence, poor soil texture and structure (Bauder et al., 2011).

Limitation

In this research, the results presented to some extent incomplete depiction on the reuse of industrial wastewater for irrigation, because some key irrigation water quality parameters such as EC, SAR were not

directly valuated. However, they are tactfully measured through TDS concentration, since they are highly correlated positively (Bauder et al., 2011).
Moreover, the result of the research is based on three months' data. However, some studies conducted based on similar environment (Amoo et al., 2018) were reported to demonstrate results contributing to scientific knowledge, and therefore accepted by scientific community.

IV. Conclusion And Recommendations For Further Research

The prime objective of this research was to assess the quality and suitability of the Sharada industrial effluents for irrigation agriculture. Findings show that the major water quality parameters in the effluents; COD, NH_4-N, NO_3-N and PO_4-P exceeded the standard limit of both discharge and reuse in irrigation agriculture as recommended by regulatory agencies. Furthermore, results indicated that the industrial effluents are not fit for recycling in irrigation agriculture and cannot improve soil and crop quality, and protect the environment due to toxicity of the water quality indices.

Overall, this research indicated that Sharada industrial effluents produced by the industries are polluted and cannot be applied as soil and water amendments to produce crops as being a practice by the farmers residing in the area, because of the deleterious effects the effluents can cause such as diseases to both humans and animals upon consumption of the harvested crops, soil and water quality degradation, crop growth and quality alteration.

Pertaining recommendations, all industries in Sharada should be directed by authorities to discharge their effluents to the sewer system not through irrigation or discharge directly to the environment as some of them do. Furthermore, to fully enforce and encourage the practice, these industries should be allowed to discharge only following an environmental impact assessment. This scheme will reduce industrial discharge of both organic and inorganic pollutants in the wastewater. In addition, researchusing the wastewater be conducted on the impact on soil quality and fertility using some test crops to fully ascertain adequate assessment of the effluents effect on soil quality and fertility, and their relationship to different types of crops growth and development.

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