European Journal of Agriculture and Forestry Research
Vol.9, No.2, pp. 14-25, 2021
Published by ECRTD-UK
Print ISSN: ISSN 2054-6319 (Print),
Online ISSN: ISSN 2054-6327(online)

IRRIGATION WATER QUALITY ASSESSMENT OF INDUSTRIAL EFFLUENTS USED FOR IRRIGATING CROPS IN SEMI-ARID ECOLOGICAL ZONE OF NIGERIA

[1]Sani, A., [1]Garba, M.D., [1]Almu, H., [2]Sanda, A.R., [1]Abdulkadir, N.A., [3]Musa, M.U and [2]Idris, R.
[1]Soil Science Department, Kano University of Science and Technology, Wudil, Nigeria.
[2]. Soil Science Department, Kebbi State University of Science and Technology, Aliero, Nigeria.
[3]. Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria

ABSTRACT: *Provision of quality treated wastewater effluents in form of irrigation water will potentially be an option to augment the water needs in agricultural irrigation. However, if the effluents did not meet the irrigation quality standards, their application will be detrimental to the receiving soils, consequently leading to soil and crop quality deterioration. The aim of this study is to assess if Sharada industrial effluents are fit for irrigation application. The irrigation water quality assessment was carried out in three phases (Phases I, II and III) of the industrial locations. Findings indicated that the concentration of the major key irrigation water quality parameters; Electrical conductivity (EC), pH, Exchangeable sodium (Na), Calcium (Ca), Magnesium (Mg) and Total dissolved solids (TDS) were of good quality and suitable for irrigation regardless of phases. However, the concentration of bicarbonate (HCO_3), Chlorides (Cl), Potassium (K) and Nitrate (NO_3-N) values detected in the samples were 488, 305, 305meq/l, 177.50, 159.75, 124.25meq/l, 18.99, 17.72, 13.50mg/l, and 119.09, 59.54, 31.53mg/l respectively. These values were high and of poor quality, thus, unfit for irrigation. Moreover, NO_3-N and HCO_3 in all irrigation effluents recorded high significant difference ($P<0.05$) in phase I compared to other phases while, Cl and K were highly significant ($P<0.05$) in phases I and II in comparison to phase III. Overall, the result when tested for irrigation quality compliance using International Standards revealed that compliance was achieved with reference to pH, EC, Na, Ca, Mg and TDS, while noncompliance was recorded for other irrigation water quality indices indicating that the effluents will be suitable for irrigation under careful, adequate and very effective proper management including improved irrigation system and schedule, soil with good permeability, infiltration and internal drainage, and use of good salt tolerant crops. The importance of this research lies in the fact that the effluents could not be a reliable and effective potential source of irrigation water rich in nutrients capable of increasing soil fertility and crop quality as is the practice of the farmers in the area.*

KEYWORDS: crop quality, water quality, soil quality, irrigation, effluents

INTRODUCTION

Application of treated wastewater for agricultural irrigation or otherwise is becoming an imperative global method of replacing high and continuous demand on natural sources of fresh water (Almuktar et al., 2018; Sani et al, 2020). Some of the advantages attached to the effluents application include nutrients supply to agricultural crops, protecting the environment from direct waste water pollution impact and saving farmer’s income of buying inorganic fertilizers (Bichai et al., 2012). Investigations have shown that application of effluents from conventional and non-conventional treatment technologies from industrial sources or domestic have impacted positively to soil fertility concomitantly with crop growth. For instance, in the review carried out by Qadir et al. (2007), the authors stressed that untreated and or partially treated wastewater effluents from conventional and unconventional treatment facilities have been applied to agricultural lands and replenished the soil with essential nutrients and increased crop yield. However, some studies, reported that changes in soil hydrological behavior, reduced porosity and raised bulk density (Aello et al., 2007), change in organic matter content, phosphorus, pH and EC (Mojiri, 2011) were apparent after irrigation with the wastewater. Comparably, in their study, Almuktar et al. (2015, 2018) have expounded high concentration of soil nutrients, improved soil quality and increase in crop yield with no health risks when effluents from unconventional treatment sources were applied as irrigation amendments. Furthermore, the authors reported that the irrigation water quality parameters from the applied effluents complied with irrigation standards, and high market economic return from the sold crops was also recorded.

Agricultural water sources must be of good quality before it is acceptable for a given use (Wong, 2010). Pertaining irrigation, several scientists have advocated and expounded that water quality parameters for evaluating irrigation water quality include salinity hazard, water infiltration rates (sodium hazard), pH, carbonate and bicarbonates, and specific ion toxicities (Bauder et al., 2011), and concluded that irrigation water quality is evaluated based upon total salt content, sodium and specific ion toxicities. Thus, assessing the composition of the effluent waters is very imperative, and helps in ascertaining the suitability of the effluent for irrigation purpose.

Though, depending on the sources, industrial effluents have been reported to contain high amount of salts and solids which when applied in irrigation water to soils clog the soil pores, restrict air and water movement, affect the hydraulic conductivity and water permeability, consequently, abate the water absorption by the crops (Al-Isawi et al., 2016). However, some studies reported low amount of salts and solids in the industrial effluents and within irrigation permissible limits (Sani et al., 2020). Contrastingly, Almuktar et al. (2018) stated that irrigation water irrespective of its amount of chemical substances in solution has the potential to degrade the quality of the soils and reduce crop yield provided it is not compliant to irrigation standards.

For any Irrigated agriculture to be effective and efficient, the assessment of the water quality is one of the most important aspects, because water quality has direct effect on crop growth and development as well as soil itself. For instance, Bouksila et al.(2013) documented that human activities that involved urbanization, agricultural activities, over use of fertilizers or chemicals, inadequate management of land use and sewage disposal have directly or indirectly affected the quality of water and makes it unsuitable for irrigation as a result of excess salts and other pollutants being present in the water. Hence, continuous application of irrigation water without effective irrigation water quality assessment gives rise to salts and other pollutants accumulation in the soil which will generally affect the growth and development of crops.

This study may give advantageous information to environmental, agricultural and related soil and water authorities with proved interpreted data leading to understanding of effluent constituents relevant to irrigation quality, that will allow them to justify if possible, the use of these effluents in their wastewater management, and their successful application as irrigation water for long-term agricultural production, soil and water quality improvement with concomitant environmental protection.

Many studies were carried out on industrial effluents (Olayinka and Alo 2004; Essoka and Ummaru, 2006; Ebiyare and Luv, 2010; Abdulmumini et al., 2015; Amoo et al., 2018) particularly on their quality. In Northern Sudan Savannah Ecological Zone however, few concerted efforts on the evaluation and assessment of industrial effluents particularly from tannery and textile industries were made (Akan et al., 2009; Danazumi and Bichi, 2010; Abdulmumini et al., 2015), while some focused on underground water and mixture of the industrial effluents (Isa and Jimoh, 2015; Amoo et al., 2018; Sani et al., 2020). Yet, despite these numerous investigations, there is a gap in knowledge and understanding as very little information is available about the irrigation quality assessments of these effluents to justify their application as irrigation amendments in agricultural irrigation using international standards. Therefore, the aim of this paper was to evaluate irrigation water quality of industrial effluents in Sharada industrial area and assess whether they comply with permissible irrigation quality standards. The key objectives were to

- To evaluate the irrigation water quality parameters of the industrial effluent;
- To assess the suitability of the effluents for agricultural irrigation using international standards.

MATERIALS AND METHODS

Research Area Description

This research was carried out in Sharada industrial area of Kano metropolis, Kano State, Nigeria. The area covered about 600 Km^2 and is located between longitude 8º and 9ºE and latitude 10º and 12ºN (Sani et al., 2020). The industrial area is divided into three phases; phase I, II and III. In each phase, there are certain number of industries ranging from sacks and nylon, oil and gas, textiles, tanneries and plastic industries among others. The released effluents from these industries mix with a little component of domestic waste water and drain into gutters, and empty into a concrete open sink, from which the farmers in the area use them for the irrigation of vegetables, cereals, tubers and fruits according to Sani et al. (2020). The climate of the research area was reported (Dan Azumi and Bichi, 2010) to be tropical wet and dry type with dry season between for 4 - 5 months and wet season between May and September while the temperature was 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).

Vol.9, No.2, pp. 14-25, 2021
Published by ECRTD-UK
Print ISSN: ISSN 2054-6319 (Print),
Online ISSN: ISSN 2054-6327(online)

Water Collection and Sampling

Effluent samples were sampled using plastic containers from the collection sink, a confluence of Phase I, II and III industrial discharged effluents between February and March, 2019. Three (3) samples were collected randomly to ensure accuracy by replication. Before sampling, the plastic bottles were washed with detergent and rinsed 3 times with distilled water and then with the sample effluents. 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 (Sani et al., 2020).

Irrigation Water Quality Determination

Water quality analysis followed (APHA, 2005) standard procedures for variables including total dissolved solids (TDS), Electrical Conductivity (EC), chloride (Cl_2), nitrate-nitrogen (NO_3-N), Carbonates (CO_3) and Bicarbonates (HCO_3). pH and EC were measured with sensION+Benchtop Multi-Parameter Meter (Hach Lange, Düsseldorf, Germany) respectively, while Calcium (Ca) and magnesium ions were determined by Atomic Adsorption Spectrophotometer (AAS), sodium (Na) and potassium (K) ions were determined by flame photometry.

Statistical 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.

RESULT AND DISCUSSION

Assessment of Irrigation Water Quality of the Industrial effluents

Comparison of Salinity effects Parameters (pH, EC, Na, Ca and Mg)

Overall mean values with regards to irrigation water quality parameters was shown in Table1 including the salinity effects variables. The result shows that, all phases recorded pH values within the recommended irrigation quality standard advocated by FAO and WHO regulatory authorities. The overall mean pH concentrations for phase II was higher than phases I and III but were all statistically similar ($P>0.05$) as shown in Table 2.

The pH concentration of any irrigation water quality is evaluated based on acidity or basicity of that irrigation water and is expressed as pH (< 7.0 acidic; > 7.0 basic). The overall pH concentrations obtained from this research were generally within the irrigation application standards recommended by regulatory agencies of 6.5-8.5 (FAO, 2003; WHO, 2008) in all phases. When the pH concentration in irrigation water is acidic (<6.5), gradually, that leads to corrosion of the irrigation system while basic pH concentration (>8.5) makes some nutrients such as heavy metals and sodium more soluble in the effluent, subsequently, leading to high sodium absorption ratio (SAR), high electrical conductivity (EC) and salinity concentrations. Consequently, this leads to poor soil texture and structure (Bauder et al., 2011). The concentration of EC recorded in this research was low and within the threshold standard for irrigation water quality by regulatory agencies (Table 1) regardless of phases. On statistical assessment, Table 2 indicated that, there was a significant difference observed ($P<0.05$) between EC concentrations and different phases in the industrial effluents with phase I recording highest values than phase II but statistically similar and higher than values recorded in phase III. This difference could be attributed to confluence of abundant discharge of effluents from the industries and domestic sewage, municipal, dirt and suspended inorganic matter that might have led to the high observed concentration in the former phase compared to other phases in the industrial area (Sani et al., 2020). EC has been referred as the most important irrigation water quality guideline, index of salinity hazard, and use to evaluate the impact of saline irrigation water on crop production (Bauder et al., 2011).

Table 1 Overall Mean Values of Industrial Effluents Irrigation Water Quality Parameters and their Irrigation Quality Standard Limit in Different Industrial Phases

Parameters	Phase I	Phase II	Phase III	Irrigation Quality Standard
pH (-)	7.04	7.12	7.01	6.0-8.5acd
EC(ds/m)	0.62	0.58	0.45	0-3.0ab
Mg (mg/l)	58.07	53.02	52.27	0-60ab
Ca (mg/l)	131.15	155.74	122.95	0-400ab
HCO_3 (me/l)	488.00	305.00	305.00	0-10ab
K (mg/l)	18.99	17.72	13.50	0-2abc
Na (mg/l)	12.77	12.27	11.11	0-920ab
Cl (me/l)	177.50	159.75	124.25	<3.00ab
TDS (mg/l)	337.00	353.00	275.00	0-2000e
NO_3-N (mg/l)	119.09	59.54	31.53	0-30ad

Note, EC, electrical conductivity, Mg, magnesium, Ca, calcium, HCO_3, K, potassium, Na, sodium, Cl, chloride, TDS, total dissolved solids, a, FAO 1994, b, FAO 2003, c, Pescod 1992, d, WHO 2008 and e, USEPA 2004

Furthermore, the authors expounded that high concentration of EC in irrigation water leads to shortage of water absorption by crops and subsequent yield reduction.The irrigation water quality threshold values for EC recommended by regulatory bodies was set to be 0.7-3.0ds/m (FAO, 1994, 2003) and all phases were compliant. Variety of crops comprising of vegetables, fodder, grain crops and fruits have been reported in many studies to grow within the range of 0-3ds/m (Abdullahi et al., 2010; Tsado et al., 2014) as obtained in the current experiment. Na, Ca and Mg are additional important parameters used to assess salinity status of irrigation water. According to Table 1, all concentrations of Na, Ca and Mg in the Sharada effluents were high but complied with the standard threshold values of 0-920mg/l, 0-400mg/l and 0-60mg/l respectively recommended by FAO (1994, 2003; Almuktar and Scholz, 2016).

For Na, the results showed that values of 12.58, 12.82 and 12.04 (mg/l) were recorded for Phase I, II and III respectively and no significant differences ($P>0.05$) observed between the locations

(Tables 1 and 2), and all the concentrations of Na recorded in the irrigation effluents in all phases did not exceed the standard of irrigation water of 920mg/l (FAO, 1994, 2003; Almuktar and Scholz, 2016). High amount of Na in irrigation water causes the water to be sodic. Whenever irrigation water becomes sodic, the Na concentration dominates that of Mg and Ca leading to dispersion of aggregate stability and soil aggregates, poor soil structure and texture, soil pores sealing with subsequent decrease in permeability to water flow (Bauder et al., 2011).

There was a significant difference in the concentration of Ca (P<0.05) among the sampling locations with phase II having the highest value of Ca concentration (Table 2) compared to other phases that were statistically similar. Though phase I recorded high concentration of 131.15mg/l, phase II 155.74mg/l and phase III 122.95mg/l, but they all achieved compliance of 0-400mg/l recommended by FAO (1994, 2003) and Almuktar et al. (2018).

Table 2 Overall Statistical Differences Between Irrigation Water Quality Parameters of the Sharada Industrial Effluents and Different Phases 2019

Parameters	Phase I	Phase II	Phase III	SE+/-
pH (-)	7.040^{NS}	7.120^{NS}	6.917^{NS}	0.095
EC(ds/m)	0.621^{a}	0.599^{a}	0.447^{b}	0.014
Mg (mg/l)	57.95^{a}	55.20^{b}	51.64^{b}	1.914
Ca (mg/l)	132.2^{b}	158.1^{a}	124^{b}	3.86
HCO_3 (me/l)	477.7^{a}	305.3^{b}	305^{b}	6.21
K (mg/l)	19.54^{a}	20.90^{a}	13.39^{b}	2.276
Na (mg/l)	12.58^{NS}	12.82^{NS}	12.04^{NS}	0.646
Cl (me/l)	177^{a}	159.3^{a}	125.9^{b}	2.319
TDS (mg/l)	338.0^{a}	355.7^{a}	281.3^{b}	8.53
NO_3-N (mg/l)	119.34^{a}	59.58^{b}	33.90^{c}	1.985

Note: NS, not significant and means followed by the same letter are not significantly different from each other, while those with different letters are at ≤5% level of significance.

On the other hand, the plausible reason for the significant difference recorded between the different phases could be probably due to abundant and rich concentration of limestone and other calcium-rich wastes in the effluents discharge of phase II that lead to the high observed concentration of Ca in the effluents (Tsado et al., 2014). Mg concentrations in the effluents recorded 58.07mg/l in Phase I, 53.02mg/l in phase II and 52.27mg/l in Phase III respectively (Table 1). All these recorded values were compliant to the recommendation standard of 0-60mg/l set by FAO (1994, 2003) in all Phases. On statistical assessment, Table 2 indicated that phase I recorded highest concentration of Mg with a significant difference (P<0.05) compared to phase II and phase III that were statistically similar accordingly. High concentration of Ca and Mg above permissible limit in an irrigation water leads to toxicity of these elements in soil and when subsequently consumed by humans via food chain, their normal function of maintaining borne structure, muscle and nerve function control and blood stream (A-Isawi et al., 2016) is affected. Moreover, they are complementary parameters when combined with Na in sodium absorption ratio determination

(SAR), an important measure of assessing irrigation water sodicity (Bauder et al., 2011, Almuktar et al., 2018).

Comparison of Permeability Effects Parameters (HCO_3 and TDS)
Overall mean values of HCO_3 recorded in this experiment indicated that phase I has concentration of 488 me/l while phases II and III have 305me/l and 305me/l respectively in their irrigation effluents (Table 1). All these recorded values exceeded the irrigation water quality recommended standard of 0-10 me/l set by FAO (1994, 2003). With regards to statistical analysis, Table 2 has shown that phase I recorded the highest concentration with significant difference ($P<0.05$) compared to Phases II and III that were statistically similar accordingly. The plausible reason for this significant difference could be ascribed to confluence of solids and different types of wastes rich in bicarbonate sources from both the industries and domestic sewage in the catchment that could have triggered the high observed concentration and has been affirmed by other studies elsewhere (Tsado et al., 2014; Abdulmumini et al., 2015).

Irrigation water with high concentration of bicarbonate can trigger the concentration of pH to be above 8.5. This situation makes some nutrients such as heavy metals and sodium more soluble in the irrigation effluents, subsequently, high SAR, high electrical conductivity (EC) and salinity concentrations leading to poor soil texture and structure (Bauder et al., 2011, Al-Isawi et al., 2016; Almktar et al., 2018), infiltration and permeability. The concentration of TDS according to Table 1 was high in all phases but compliant to irrigation quality standard of 2000mg/l recommended by regulatory agencies (FAO, 1994, 2003) and United State Environmental Agency (USEPA, 2004). The summary of statistical differences between the TDS concentrations recorded and different phases, Table 2 revealed that phase II recorded the highest values than phase I but were significantly and statistically similar ($P<0.05$), and higher than phase III.

Excess TDS in irrigation effluent 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 concentrations with high TDS concentration (Sani et al., 2020). The high concentration of TDS above irrigation standard recorded in this research could be attributed to confluence of more particles via leaching from inorganic fertilizers such as nitrogenous, refuse dumping and other domestic wastes (FAO, 2003; Sani et al., 2020) from the catchments and disposed into the water courses leading to the observed solids concentration. Furthermore, effluents of industrial sources containing high amount of solid particles (Sani, 2015; Wu et al., 2015; Almuktar et al., 2018; Sani et al., 2020) above irrigation quality standards have been reported.

Comparison of Other Parameters (Cl, K and NO_3-N)
The overall mean effluent concentrations of all phases with reference to chloride indicated that, all phases recorded very high concentrations and non-compliant to irrigation water quality standard advocated by regulatory agencies (Table 1). FAO (1994, 2003) set 0-3me/l as the recommended threshold value of Cl in irrigation water. However, 177.5 me/l concentration of Cl in phase I

irrigation effluent was highly significant (P<0.05) than Phase II but statistically similar and exceeded the set recommended value (Table 2). Furthermore, Table 2 indicated that Phase II recorded significant higher concentration than phase III (P<0.05) with corresponding values of 159.75me/l and 129.25me/l respectively, and were also non-compliant to the aforementioned set standard by regulatory authorities.

Irrigation effluent rich in Cl and above irrigation water quality standard causes toxicity to sensitive crops and when applied as irrigation amendment using sprinkler irrigation method causes crops leaf burn (Bauder et al., 2011). Furthermore, the authors concluded that crops generally are safe only when chlorides in irrigation water did not exceed 0.7 me/l. The high concentration of Cl observed in the irrigation effluent above the allowable limit in all phases could be ascribed to high chloride discharge from tanneries industries located in the industrial phases and this has been confirmed previously elsewhere (Abdulmumini et al., 2015)

Potassium concentration was high and exceeded the threshold limit of 0-2mg/l for irrigation water quality recommended by regulatory authorities (Pescod, 1992, FAO, 1994, 2003) regardless of phases (Table 1). Phase I recorded the highest value of 18.99mg/l than phase II (17.72mg/l) and phase III (13.50mg/l) respectively. With respect to statistical differences (Table 2), phases I and II were statistically similar but significantly (P<0.05) higher than phase III. The possible reason for this high observed concentration of K in the effluents could be due to intrusion of K-rich wastes in the effluents discharge in the effluent (Tsado et al., 2014).

In irrigation water, K is less important compared to other cations and anions in-terms of irrigation water quality assessment (Mahmud et al., 2007; Getahun et al., 2014). Moreover, it is a trace element needed in small quantities. However, when found in excess in the irrigation water, leads to abnormal growth such as excessive foliage production in vegetables particularly when in association with excess nutrients (Al-muktar et al., 2014). The NO_3-N effluent concentrations in all phases were high and all above irrigation quality standards (Table 1) advocated by FAO (1994, 2003). The statistical table 2 indicates that industrial effluent high in NO_3-N result in a statistically significant (P<0.05) difference in Phase I compared to phases II and III respectively. Application of untreated or poorly treated effluents with high NO_3-N concentration above quality irrigation standard on agricultural soils, degrades soil quality, delays crop growth and prolong maturity. 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; Sani et al., 2020).

The observed high nitrate concentration of the industrial effluents in this study could be attributed to poor treatment of the effluent containing nutrients from industrial treatment facilities and confluence of high sewage, animal wastes, leached nitrogen fertilizers from nearby urban and agricultural catchments (Danazumi and Bichi, 2010; Paul, 2011; Sani, 2015; Sani et al., 2020) and has been confirmed previously elsewhere (Abdulmumini et al., 2015; Sani et al., 2020).

Limitation of the Study

This paper represents a partly incomplete picture on the irrigation water quality assessment of industrial effluents application for irrigation, because microbiological parameters were not studied. However, many studies have indicated that microbial contamination of vegetables is improbable owing to long distance between the crops and the potential contaminated soil (Cirelli et al., 2012). Furthermore, some key irrigation water quality parameters such as SAR and ESP were not directly investigated. However, they were tacitly measured using TDS concentration, since it has been reported that TDS, ESP and SAR were positively correlated (Bauder et al., 2011; Almuktar et al., 2018). In addition, the result of this paper is based on three months data. Nevertheless, recently, Amoo et al. (2018) and Sani et al. (2020) conducted their studies in the same environment and within a short period of time, and were reported to demonstrate results contributing to scientific knowledge, and therefore accepted by scientific community.

CONCLUSION AND RECOMMENDATION

The main objective of this paper was to assess the irrigation water quality and suitability of the Sharada industrial effluents for irrigation agriculture. Based on the guidelines for the interpretation of water quality for irrigation, the results of analysis and assessments of water quality show that the major irrigation water quality parameters in the effluents; EC, pH, Na, Ca, Mg and TDS achieved compliance for application in irrigation agriculture as recommended by regulatory agencies in comparison with HCO_3, Cl, K and NO_3-N that exceeded the threshold. This implied that the industrial effluents based upon the evaluated aforementioned irrigation water quality parameters could be considered suitable for irrigation under proper care and management such as improved irrigation system and schedule, soil with good infiltration and internal drainage and good salt tolerant crops. Water quality should be used as a guideline to define appropriate management practices in irrigated agriculture to maintain existing soil productivity with the benefits of high crop yield under irrigation.

Overall, this research indicated that Sharada industrial effluents produced by the industries are not qualitative enough to be qualified as a solely source of irrigation water to be applied as soil and water amendments to improve soil quality and fertility, and produce crops as being a practice by the farmers residing in the area, unless under careful management and adequate quality assessment prior to application.

The current research will be continued to assess the accumulation of metals and other pollutants as well as their toxicity in the effluents and soil, and microbiological contamination will also be studied. Further research with vegetable crops receiving the effluents from the industrial discharge should also be undertaken to evaluate their concentration and effect. All industries in Sharada should be directed by authorities to avoid direct discharge of their effluents without thorough quality investigation, and farmers should also be educated to periodically monitor and assess the irrigation water quality of the effluents prior to application as irrigation

Print ISSN: ISSN 2054-6319 (Print),
Online ISSN: ISSN 2054-6327(online)

amendment. Furthermore, to fully enforce and encourage the practice, these industries should be allowed to discharge only following an environmental impact assessment.

REFERENCES

Abdullahi, A.S., Funtua, I.I., Dewu, B. B. M. and Alagbe, S. A. 2010. Study of suitability of ground water for household and irrigation purposes in parts of Adamawa State, North-eastern Njgeria. Int. Archive of Applied Sci. Tech, 1(2): 48 – 56

Abdulmumini, A., Abubakar, I. K., Magaji, L., Sani, M.G., Ayuba, A.M., Shehu, H., and Isa, B.K. (2015). A Review on Industrial Effluents as Major Sources of Water Pollution in Nigeria.

Amoo, A.O., Gambo, Y.H., Adeleye, A.O and Amoo, N.B. (2018). Assessment of groundwater quality in Sharada industrial area of Kano, North-Western Nigeria. FUW Trends in Science and Technology Journal, Vol. 3 No. 2A pp. 407 – 411e-ISSN: 24085162; pISSN: 20485170hemistry Journal 1, (5), 159-164

Aiello, R., Cirelli, G.L., Consoli, S. (2007). Effects of Reclaimed Wastewater Irrigation on Soil and Tomato Fruits: A Case Study in Sicily (Italy).” Agricultural Water Management 93: 65–72.

Akan J. C., Ogugbuaja V. O., Abdulrahman F. I. and A yodele J. T. (2009) Pollutant level in effluent samples from tanneries and and textile of Kano industrial Areas, Nigeria. Global Journal of Pure and Applied Sciences 15(3): 343-352.

Al-Isawi, R., Scholz, M., and Alfaraj., F. (2016). Assessment of diesel-contaminated domestic wastewater treated by constructed wetlands for irrigation of chilies grown in green house. Environmental Science and Pollution Research. DOI 10.1007/s11356-016-7706-x

Almuktar SAAAN, Abed, S. N., Scholz M (2018).Wetlands for wastewater treatment and subsequent recycling of treated effluent: a review Environmental Science and Pollution Research https://doi.org/10.1007/s11356-018-2629-3

Almuktar SAAAN, and Scholz M (2016). Experimental assessment of recycled diesel spill contaminated domestic wastewater treated by reed beds for irrigation of Sweet Peppers. InternationalJournalofEnvironmentalResearchandPublicHealth13:208.https://doi.org/10.3390/ijerph13020208

Almuktar, S. A. A. A. N., Scholz, M., Al-Isawi, R. H. K, and Sani, A. (2015). Recycling of domestic wastewater treated by vertical-flow wetlands for irrigating chillies and sweet peppers. Agricultural Water Management, 149, 1-22

American Public Health Association (APHA) (2005). Standard methods for the examination of water and wastewater (21st ed.). Washington, DC: American Public Health Association (APHA), American Water Works Association, and Water and Environment Federation.

Bauder, T.A., Waskom, R.M., Sutherland, P. and Davis, J.D. (2011). Irrigation Water Quality Criteria Crop Series Irrigation module. Fact Sheet No. 0.506. Colorado State University, Extension, USA

Bichai, F., Polo-Lopez, M. I., Ibanez, P. F., 2012.Solar disinfection of wastewater to reduce contamination of lettuce crops by Escherichia coli in reclaimed water irrigation. Water research. 46,6040-6050

Bouksila, F., Bahri, A., Berndtsson, R., Persson, M., Ro-zema, J. and VanderZee, S.E. (2013)
Assessment of soil salinization risks under irrigation with brackish water in semi-arid Tunisia.

Cirelli, G.L., Consoli, S., Licciardello, F., Aiello, R., Giuffrida, F., Leonardi, C., (2012). Treated municipal wastewater reuse in vegetable production. Agricultural Water Management. 104, 163–170

Ekiye, Ebiyare, and Luv Z. (2010) Water quality management in Nigeria: case study of Nigerias' industrial cities. Journal of American Science 6(4): 22-28.

Ensink, H.H., Mahmoud, T., Vand der Hoeck, W., Raschid-Sally, L., Amerasinghe, F.P, F.P., (2004). A nation-wide assessment of wastewater uses in Pakistan: an obscure activity or a vitally important one? Water Policy 6, 197–206.

Environmental and Experimental Botany,92, 176-185 http://dx.doi.org/10.1016/j. envexpbot.06.0

Essoka P. A. and Umar J. M. (2006) Industrial effluent andwater pollution in Kakuri area, Kaduna South, Nigeria Journal of industrial pollution and control 22(1)

FAO (2003) User's manual for irrigation with treated wastewater. Food and Agriculture Organization (FAO) of the United Nations. FAO Regional Office of the Near East, Cairo

FAO (2005). "Global Network on Integrated Soil Management for Sustainable Use of Salt Affected Soils. FAO Land and Plant Nutrition Management Service, Rome.

FAO, 1994. The State of Food and Agriculture. Food and Agriculture Organization (FAO) of the United Nations, FAO Agriculture Series Number 27, Rome, Italy.

Getahun, K., Heluf, G., and Tena., A. (2014). Assessment of Irrigation Water Quality and Suitability for Irrigation in the Fincha'a Valley Sugar Estate, Nile Basin of Western Ethiopia. Science, Technology and Arts Research Journal, 3(1), 64-73

Isa Baba Koki and Jimoh W.L.O. (2015) Assessment of heavy metals in tannery solid waste from Challawa Industrial Estate, Kano State, Nigeria, International Journal of Research in Environmental Studies. 2, 33-40.

Mahmud, R., Inoue, N. and Sen, R. (2007). Assessment of Irrigation Water Quality by Using Principal Component Analysis in an Arsenic Affected Area of Bangladesh. Journal of Soil of the Nature 1(2): 08-17

Mojiri, A. (2011). Effects of Municipal Wastewater on Physical and Chemical Properties of Saline Soil. Journal of Biological Environmental Science. 5(14), 71-76

Nuruddeen, Z. O., Adamu, A. and Ibrahim, F.B (2016). Quality assessment of irrigation water of Kano river irrigation project (Kadawa sector). Gashua Journal of Irrigation and Desertification Studies, Vol. 2. No. 1 ISSN: 2489 – 0030

Olayinka K. O. and Alo B. I. (2004) Studies on Industrial pollution in Nigeria: the effects of textile effluent on the quality of ground water in some parts of Lagos. Nigerian Journal of Health and Biomedical Sciences 3(1): 44-50

Pescod, M.B., 1992. Wastewater treatment and use in agriculture. In: FAO Irrigation and Drainage Paper Number 47. FAO. From http://www.fao.org/docrep/T0551E/T0551E00.htm (Retrieved on 4 April, 2020)

Qadir, M., Sharma, B. R, Bruggeman, A., Choukr-Allah, R and Karajeh, F. (2007) Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries. Agricultural Water Management 87 2-22

Sani, A. 2015. Treatment Performance Assessments of Different Wetland Mesocosms. Unpublished PhD Thesis. University of Salford Manchester, UK.

Sani, A., Ahmad, R.S., Mohamed, U.M., Uzaifa, K.A and Abdulkadir, N.N. (2020). Discharged Industrial Effluents Quality Appraisal and Its Uses for Agricultural Production in Sudan Savannah Ecological Zone, Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), 13(3), 45-51

Tsado, P. A., Lawal, B. A., Eze, P. C., Afolabi, S. G., Saidu, O. I.,and Igwe, C. A. (2014). Assessment of the suitability of water quality for irrigation in Minna, Niger State. International Journal of Research in Agriculture and Forestry, 1(2), 13–17.

USEPA (2004) Guidelines for water reuse. United States Environmental Protection Agency (USEPA), Washington\

WHO (2008).Guidelines for Drinking Water Quality, 3rd Edition Incorporation the First and Second Agenda Vol. 1 Recommendations, World Health Organizations Geneva

Wong, K. H. (2010). U.S. Patent No.7,673,418. Washington, DC: U.S. Patent and Trademark Offic