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Physicochemical Assessment of Effluent Discharged from Tannery and Textile Industries on Water Quality and Aquatic Ecosystem of Sharada Kano

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Abstract

Industrial development, urbanization, and growth in the agricultural sector due to human needs have resulted in the widespread use of chemicals that significantly increased the rate of water pollution through the discharge of effluents. The present study aimed to determine the extends of physicochemical parameters levels in the effluents released by tannery and textile industries at Sharada Industrial Area, Kano, Nigeria. This can pose a health risk to humans and other aquatic organisms. Effluent samples were collected in July and August and digested using nitric acid (HNO_3). Effluent samples were analyzed for concentration standard limits of heavy metals (Cd and Pb) using the spectrophotometer for atomic absorption (Buck Scientific with the model 210VGP). Effluent samples were further also studied for the pH level, temperature and dissolved oxygen (DO). Furthermore, other parameters such as nitrites, biochemical oxygen demand (BOD), Phosphate and electrical conductivity (EC). The results showed that all the heavy metals (Cd and Pb) studied were elevated at different levels compared to those previously studied in normal samples and those recommended by WHO, EU, and NAFDAC concentration limits. Furthermore, the results of the study also show that samples collected in July revealed that the mean value of temperature, Phosphate, Lead, and Cadmium exceeded the permissible levels of the WHO, EU, and NAFDAC, whereas those in August revealed that the mean value of temperature, Phosphate, Lead, pH, and Cadmium also elevated above the same permissible limits set by WHO, EU, and NAFDAC. Two-sample T-test results revealed a significant relationship in the mean concentration of EC, pH, BOD, Nitrate, and Lead between tannery and textile industries in July, while pH, EC, BOD, Nitrate, lead, DO, temperature, and Phosphate showed a significant correlation difference between tannery and textile in August. The results further showed that the tannery industry had the most contaminated effluents, and August had the highest mean level of contaminated effluents. Therefore, these effluents are likely to pose serious risks of diseases and deterioration of health conditions of the humans using it as a source of water and adversely affect the quality of life of the aquatic organisms in the sewage, drainage, and dams. It could further pose a risk of transmission of diseases to plants during irrigation and affects the fruits and vegetables quality and nutrition. Thus, there is a need for serious monitoring.

Keywords: Physicochemical, parameters, effluents, Tannery, Heavy metals

INTRODUCTION

Industrial development, urbanization, and growth in the agricultural sector due to human needs have resulted in the widespread use of chemicals that significantly increased the rate of water pollution (Rehman & Anjum, 2010). Effluents are discharged industrial wastewater or domestic used water, treated or untreated, that causes harm and affects both aquatic and terrestrial ecosystems with adverse long-term health consequences (Joshi & Santani, 2012; Fitzpatrick *et al.*, 2017). Industrial discharged effluents may contain some elements and heavy metals such as chlorides, Phosphate, oil, grease, Nitrate, and heavy metals, among other substances with exceeded acceptable levels (Olayinka & Alo, 2004; Ekiye & Zejiao, 2010). The tannery and textile industry's major production is the conversion of raw materials such as hides and skin into finished products such as leather, fabrics, clothes, and shoes using volatile chemicals and inorganic salt cations such as Fe^2, Zn^2, Na^2, Cu^2, and anions such as NO_3 and PO_4 respectively (Baba *et al.*, 2021).

Effluents from textile industries are composed of different chemical compositions, including dyes, oils, solvents, heavy metals, and inorganic salts that are often used to alter the physical color of their products, resulting in the physical and biochemical changes in the water bodies with fluctuating pH levels (Hannan *et al.*, 2011; Ali *et al.*, 2020). These effluents continue to cause pollution and contamination of water, soil, and air, leading to a heavy disease burden to the communities around the industries after several efforts by the Nigerian Government to control and provision of the disease-free environment (Helmer & Hespanhol, 1997; Santhosh *et al.*, 2016; Rhouati *et al.*, 2022). Heavy metals mostly found in industrial effluents are carcinogenic to humans and other animals when present at high levels (Tamburlini *et al.*, 2002; Valent *et al.*, 2004; McDonald *et al.*, 2008; Rahman *et al.*, 2009; Westra, 2012).

Kano is the most populated city with available industries in northern Nigeria. Most of the industries are tannery and textile (Akan *et al.*, 2009). Furthermore, previous works have found that effluents released from these industries in Kano have serious effects on humans, irrigated plants, and animals due to the presence of mutagenic chemicals that are genotoxic, which may pose a public health risk of disease emergencies (Binns *et al.*, 2003; Olukoju, 2004; Khadija & Ibrahim, 2019; Abdullahi *et al.*, 2021; Koko *et al.*, 2023). Hence, this work aimed to study the concentration levels of effluents released by tannery and textile industries in Sharada, Kano, and its potential health risk.

MATERIAL AND METHODS

Area of Study

Sharada industrial area of Kano State, the study area is located in Kano central municipal Local Government Area of Kano State Nigeria. It is located at (11˚59.981N, 008˚ 31.491E). It covers an area of 24sqkm with an Altitude of 486.5m, the largest populated industrial city in Nigeria (Koko *et al.*, 2023).

Sample Collection

Effluents were collected from July to August 2023. The effluent samples were immediately transferred to a plastic bottle with screwed caps after collection and transported to the laboratory. The container was well labelled, and clearly indicated the date, time, and area of the effluent collection.

Determination of Physical and Chemical Parameters

Temperature

The dipping method was adopted using a thermometer dipped into the water in situ according to the method of (Sial *et al.*, 2006).

pH

pH is also measured based on the procedure of (Hannan *et al.*, 2011) using an H1255 combined meter where the pH meter pointer was dipped into the sample until a fixed reading on the meter is achieved.

Electrical Conductivity

This is also obtained following the methods of (Hannan *et al.*, 2011) in which the meter probe for the EC was dipped into the sample and obtained fixed results on the meter screen.

Dissolved Oxygen (DO)

Dissolve oxygen (DO) analysis was conducted with the H19146 Dissolved Oxygen meter adopted by (Hannan *et al.*, 2011), where the probe was dipped into the sample. Reading was taken in ppm according to the manufacturer's instructions.

Biochemical Oxygen Demand (BOD)

The biochemical demand of oxygen was conducted after incubating the effluent sample for a minimum of 5 days at a temperature of 20˚C. Readings were obtained on the 5th day on the dark bottle container, where oxygen emission evolved as expected because of the destruction of the dead organic matter by microbes present with the effluent (Rice *et al.*, 2012).

$BOD=DO_1-DO_5$. DO_1=Dissolved Oxygen concentration prior to incubation. DO_5=Dissolved Oxygen concentration after 5 days incubation

Nitrate

Phenol di-sulphuric acid method was adopted in the determination of Nitrate using the following: Spectrophotometer, hot water bath, glass wares, and other reagents such as Phenol di-sulphuric acid; 235ml of conc H_2SO_4 was divided into two, in one part, 150ml of conc H_2SO_4 was added white phenol measuring 25g and allow to stand. Another concentrated H_2SO_4 at 85ml was also added and heated in a dark container for 2 hours. Nitrite was obtained by dissolving 0.722g of anhydrous potassium nitrite in distilled water to obtain 1ltr of stock solution containing1.00mg NO_3 N/L (or 443mg NO_3 ions/liter) (Ewaid *et al.*, 2020).

Procedure

About 25ml of the effluent sample was subjected to dryness through evaporation in a water bath with 0.5ml phenol di-sulphuric acid (Reagent A). In 1.5ml of potassium hydroxide, 5ml of distilled water was added and termed as (reagent B). The solution is thoroughly mixed, and yellow coloration indicates the presence of Nitrite. Absorbance was read at 410nm, while Nitrite was recorded in mg/l (Tumolo *et al.*, 2020).

Determination of Phosphate

About 25ml of the effluent sample was evaporated to dryness in an Erlenmeyer heating flask. The effluent residue was then cooled and allowed to dissolve in 1mL hydrochloric acid (Reagent A). The content of the flask was further heated to become colorless and allowed to cool. Two (2) drops of Phenolphthalein indicator were added to the 10ml distilled water (Reagent B). Sodium hydroxide was titrated against reagent A and reagent B (Reagent C) to obtain a pink color. Furthermore, 25ml of water sample was placed in an Erlenmeyer flask and heated to evaporate to dryness. The residue was also allowed to cool and dissolved in 1 ml of perchloric acid (reagent A).

furthermore, the flask was then heated gently so that the contents would become colorless. It is then allowed to cool. Ten (10ml) of distilled water was then added together with 2 drops of phenolphthalein indicator (reagent B). Reagents A and B were titrated against sodium hydroxide solution (reagent C) until the solution changed to a pink color. The volume of the solution was raised to 25mL by adding distilled water. Furthermore, reagent D (ammonium molybdate) was added by 1mL and 3 drops of reagent E (stannous chloride solution was further added. Blue coloration ensures the presence of Phosphate and absorbance is read at 690nm and measured in mg/L (Ewaid *et al.*, 2020).

Determination of Heavy Metals (Cd and Pb)

Cadmium (Cd) and Lead (Pb) heavy metals were determined by atomic absorption spectrometer (Buck scientific with model 210VGP) based on the method adopted by Elboughdiri., (2020)

Sample preparation for Heavy Metals Detection

About (100ml) of the effluent samples were heated and evaporated to 25ml and filtered. 75ml distilled water then added to increase the volume to 100ml and digested with 5ml concentrated HNO_3 (for metal digestion) (Yilmaz & Kartal, 2012).

Heavy Metals Analysis

Using an atomic absorption spectrometer, heavy metals were determined in this study using (Buck scientific model 210VGP). A specific wavelength was set for each heavy metal. Galvanometer reading obtained in 1-2mins. The levels of the heavy metals concentration were calculated according to the standard of measurement based on the method adopted by Elboughdiri, (2020).

$y=mx+c$ (straight line quadratic equation).

$y= mx$, $x= y/m$

Where : y= Absorbance , M= Slope, X= Concentration

Statistically Analysis

Data obtained were analyzed based on the software of statistics, SPSS version 15.0, for mean, standard error, and two-sample t-tests.

RESULTS

The result of the physicochemical analysis conducted shows that the concentrations of Temperature (27.36 °C), Phosphate (1.07 mg/L), Lead (0.68 mg/L), and Cadmium (0.30 mg/L) (Table 1) have exceeded the permissible limits set by WHO, NAFDAC, and EU while pH (9.50), EC (36.41μsm), DO (3.43 mg/L), BOD (2.18 mg/L), and Nitrate (0.67 mg/L) were all below the permissible set limits in Tannery industry (Table 1). In the Textile industry, only Phosphate (0.89 mg/L) and Lead (0.31 mg/L) were above the permissible limits while Temperature (24.48), DO (5.16), EC (11.04μsm), BOD (36.41), pH (6.16), Nitrate (0.63) and Cadmium (0) have been found to be lower than the limits set to be permissible WHO, EU and NAFDAC (Table 1). Welch two sample t-test result of physic-chemical parameters for July revealed a significant difference in the mean concentration of EC, BOD, Nitrate, and Lead both in Tannery and Textile at $p<0.05$ (Table 1). In July, the result revealed no significance in the mean values for pH, Temperature, Phosphate, DO, and Cadmium (Table 1) between Tannery and Textile at $p<0.05$.

Table 1: Mean value concentrations of physicochemical parameters of Tennery and Textile industries collected in July 2018

Parameters	Sites		Limits		
	Tannery	Textile	WHO	EU	NAFDAC
Temperature °C	27.36±0.33[a]*	24.48±0.71[a]	25°C *	-	-
pH	9.50±0.63[a]	6.16±0.23[b]	6.5-8.5	6.5-9.5	6.5-8.5
EC μsm	36.41±1.49[a]	11.04±0.57[b]	1000	2500	1000
DO mg/l	3.43±0.24[a]	5.16±0.30[a]	10	-	-
BOD mg/l	2.18±0.34[a]	2.60±0.15[b]	8-10	-	-
Phosphate mg/l	1.07±0.04[a]*	0.89±0.02[a]*	0.1 *	-	-
Nitrate mg/l	0.67±0.04[a]	0.63±0.02[b]	50	50	10
Lead mg/l	0.68±0.18[a]*	0.31±0.06[b]*	0.01 *	0.05 *	0.01*
Cadmium mg/l	0.30±0.02 *	ND	0.003 *	0.025 *	-

Note: Mean value with different alphabets is significantly different at p<0.05. Mean values with (*) had exceeded permissible limits. Mean values are n=6 replications

The result of concentrations of heavy metals (Cadmium and Lead) mentioned above in August 2018 (Table 2) shows that the mean value of Temperature (27.65 °C), Phosphate (1.09 mg/L), Lead (0.26 mg/L), pH (11.10) and Cadmium (0.26 mg/L) were higher than the permissible limits set by WHO, EU, and NAFDAC While EC (35.15μsm), DO (3.28 mg/l), BOD (1.91 mg/L) and Nitrate (0.73 mg/L) were all below the permissible limits set by WHO, EU, and NAFDAC in Tannery industry (Table 2). Furthermore, the results of the physicochemical analysis of the effluents released from the Textile industry also show that Temperature (26.53 °C), Phosphate (0.89 mg/l), and Lead (0.35 mg/l) exceeded the permissible limits set by WHO (2008), EU (2011) and NAFDAC (2013) (Table 2). Moreover, the results of pH (9.04), EC (10.84μsm), DO (3.84 mg/L), BOD (1.88 mg/L), Nitrate (0.60 mg/l) and Cadmium (0) were all found to be within the permissible limits set by WHO, EU and NAFDAC respectively (Table 2). Welch two sample t-test result of physicochemical parameters in August revealed a significant difference in the mean value of Temperature, pH, Phosphate, EC, DO, BOD, Nitrate, and Lead between Tannery and Textile at p<0.05 (Table 2). However, no significant difference was found in the mean value of Cadmium (Table 2) between Tannery and Textile at p<0.05

Table 2: Mean value concentrations of physicochemical parameters of Tennery and Textile industries collected in August 2018

Parameters	Sites		Limits		
	Tannery	Textile	WHO	EU	NAFDAC
Temperature °C	27.65±0.39[a]*	26.53±0.41[b]*	25°C*	-	-
pH	11.10±0.22[a]*	9.04±0.20[b]	6.5-8.5*	6.5-9.5*	6.5-8.5*
EC μsm	35.15±0.95[a]	10.84±0.67[b]	1000	2500	1000
DO mg/l	3.28±0.40[a]	3.84±0.40[b]	10	-	-
BOD mg/l	1.91±0.28[a]	1.88±0.21[b]	8-10	-	-
Phosphate mg/l	1.09±0.01[a]*	0.89±0.09[b]*	0.1*	-	-
Nitrate mg/l	0.73±0.01[a]	0.60±0.01[b]	50	50	10
Lead mg/l	0.26±0.04[a]*	0.35±0.06[b]*	0.01 *	0.05*	0.01*
Cadmium mg/l	0.26±0.02*	ND	0.003 *	0.025*	-

Note: Mean value with alphabets is significantly different at p<0.05. Mean values with (*) had exceeded permissible limits. The mean value is for n=6 replication.

DISCUSSION

The present study evaluates physicochemical parameters and heavy metals of Cadmium and lead in the tannery industries in Kano Municipal Local Government Area. The concentrations of Cadmium in the tannery industry studied in this work were found at 0.030mg/L and 0.26mg/L in the study sites, were considered maximum to the acceptable limits according to WHO and EU standards of < 0.003 mg/l and 0.025 mg/l respectively (WHO, 2002, 2004; Adah *et al.*, 2013; Ojekunle *et al.*, 2015). These standard values were set by WHO and EU following the previous study comparison in Peshawar, Pakistan, for tannery and textile industries effluents (Tariq *et al.*, 2006).

Cadmium is present in air, food, and water in low quantities. However, prolonged exposure to Cadmium could lead to kidney diseases and other potential public health emergencies, such as respiratory diseases and weak bones (Rehman et al., 2018; Satarug & Phelps, 2020).

Lead concentrations in this study was found at 0.68mg/L, 0.26mg/L in tannery industries, and 0.31mg/L,0.35mg/L in textile industry. These results show a higher elevation than the standard recommended limit set by WHO, EU, and NAFDAC at 0.01mg/L, 0.05mg/L, and 0.01mg/L, respectively. Furthermore, long-term exposure to Lead was also proven to result in acute or chronic damage to sense organs and the central nervous system in humans (Islam *et al.,* 2015; Shahbazi *et al.,* 2016; Sanusi *et al.,* 2017; Mathaiyan *et al.,* 2021). Furthermore, pH values in this study were shown to be within and little above the WHO recommended limits of 7.5-8.5, which were founds in the tannery site within the range of 9.5 to 11.1 and that of the textile at the range of 6.16 to 9.04. These were acceptable as compared with the acceptable values of the water quality of 6.5-8.5 for drinking water, domestic use and other contact recreation (WHO, 2002, 2004). Moreover, it was also within the EU pH acceptable limits of 6.5-9.5 for fisheries and other aquatic life, respectively. The pH value of 11.10 of the tannery industry recorded in this study was higher compared with the acceptable maximum limit of 9.5 previously reported for Nigeria water by EU (Fatoki *et al.,* 2003; Davies *et al.,* 2006; Wakawa *et al.,* 2008; Ajayi *et al.,* 2009; Wogu & Okaka, 2011).

Temperature values of 27.36^{0}C and 27.65^{0}C obtained at the tannery and 24.48^{0}C and 26.53^{0}C at the textile were all above the permissible limits of 25^{0}C recommended by WHO as a guideline for water quality. These temperatures rise above the standard limit and have effects on the balance in the water environment, which adversely affects the life of the fauna and flora in the water ecosystem. Consequently, the 24.48^{0}C value in the textile was within the acceptable WHO limits (Talaiekhozani *et al.,* 2016; Nayar, 2020; Shmeis, 2018). The electrical conductivity of a water sample was an indicator that determines salinity and total levels of salt content in a given water, which makes it healthy and suitable for consumption (Veelen, 2002). This shows that the electrical conductivity obtained in this work on the two different sites at 36.41µsm and 35.15µsm in the tannery and 11.04µsm, and 10.84µsm in the textile were found within the acceptable limits of WHO, EU, and NAFDAC of 1000µsm, 2500µsm, and 1000µsm respectively. Dissolved oxygen is also a crucial parameter in the life of aquatic environment where it determines the survival of aquatic organism in fresh water. It further maintains the life of biological systems in the body (Alam et al., 2020). The oxygen demand (DO) values were found to be at 3.43mg/L, 3.28mg/L at the tannery, and 5.16mg/L, 3.84mg/L at textile, which shows below standard for drinking purposes set at 6mg/L and for sustaining fish and aquatic life was 4-5mg/L for good aeration of water and supported life (Yilmaz & Kartal, 2012). These further show that the effluent of the studied sites was poorly aerated, polluted, and unhealthy for drinking and domestic consumption.

Biological oxygen (BOD) serves as a measure that shows the presence of pollution effects, and it also shows the required oxygen demand by microbes to degrade and break down organic matter in the water environment. The higher the micro-organisms in the effluent samples, the lower the DO and BOD values. The biological oxygen demand (BOD) values obtained in this study were 2.18mg/L,1.91mg/L at the tannery, and 2.60mg/L, 1.88mg/L at the textile. The observed BOD levels were within the acceptable limit of 8-10mg/L recommended by WHO (WHO, 2002, 2004). These shows that the presence of large amounts of biodegradable materials and debris from plants could cause harm to the aquatic animals in the lakes, rivers, and streams due to the poor dissolved oxygen in the water, leading to oxygen depletion that eventually leads to the death of the animals and creates unpleasant odor and damage to the overall water quality (Devi *et al.,* 2017; Malik *et al.,* 2020). The Nitrate level present in effluents was drive from the several components of the nitrogen-containing chemicals present in the proteinaceous materials in the effluents (Akan *et al.,* 2009). The observed Nitrate level tested in this work was found to be within the acceptable limits of EU, WHO, and NAFDAC of 50mg/L, 50mg/L, and 10mg/L, respectively. This shows that the nitrate levels measured of 0.67mg/L, 0.73mg/L at the tannery and 0.63mg/L, 0.60mg/L at the textile were all safe and would not cause any health threat for any domestic use.

Furthermore, high phosphate content affects water quality and causes high algal growth, changing the physical and chemical composition of the water and making it unsafe for use. The phosphate measure values obtained in this work were 1.07mg/L, 1.09mg/L at the tannery and 0.89mg/L, 0.89mg/L at the textile.

These phosphate concentration values were found to be above the maximum recommended limit by WHO (2000). This makes the effluents unsafe for domestic use. Also, these high values can cause an imbalance in the water, leading to the accumulation of harmful toxins that could be harmful to health and destroys aquatic species (Garg *et al.*, 2022; Sahu *et al.*, 2024).

Finally, this study considers that the concentrations of Temperature, pH, Phosphate, Lead, and Cadmium in the site tannery were above the recommended permissible set limits by WHO, EU, and NAFDAC. Hence, these results were higher than the permissible recommended limits observed in Peshawar, Pakistan, for Tannery effluents as the standard (Shafiq *et al.*, 2017; Shakil *et al.*, 2023). Also, the value of Temperature, Lead, and Phosphate obtained in the textiles site was above the permissible limits. Thus, these untreated effluents were considered harmful and unsafe for both aquatic and terrestrial life.

CONCLUSION

Effluents discharged from tannery and textiles industries studied in this work show that the concentrations of Cadmium and Lead were found to be above the recommended limits set by EU NAFDAC and WHO. The concentration levels of DO, BOD, and Phosphate tested show a clear indication of poor water quality that demands the need for awareness to the general public and consideration for regulation by the authority on the potential health risk of emergence of diseases. Finally, there is a high need for regular monitoring of the heavy metal concentrations and treatment of the water before discharge to avoid disease outbreaks that could lead to public health emergencies.

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