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### Research Article

## Bacteriological and Physicochemical Assessment of Tannery Effluents from Chalawa Industrial Area, Kano State, Nigeria

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### ARTICLE INFO: ABSTRACT

#### Keywords:

Bacterial load,  
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parameters,  
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This study assessed bacterial load and physicochemical parameters of tannery effluents in Chalawa industrial area, Kano State, Nigeria, and compared findings with WHO/NESREA standards. Effluent samples were analyzed for bacterial counts, pH, temperature, BOD, DO, TDS, TSS, and heavy metals (Cr, Cd, Pb, Ni) using standard procedures. Bacterial counts ranged from  $3.7 \times 10^4$  to  $5.1 \times 10^4$  CFU/ml, while a control fish pond effluent recorded  $4.1 \times 10^6$  CFU/ml. Physicochemical analyses revealed alkaline pH values up to 12.10, Cr concentrations of 20.45–29.37 mg/L, Cd up to 0.009 mg/L, Pb up to 0.136 mg/L, and Ni up to 0.484 mg/L, all exceeding WHO/NESREA limits. These findings indicate significant environmental and health risks associated with untreated tannery effluents, highlighting the need for advanced treatment technologies and stricter policy enforcement.

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## INTRODUCTION

The tanning industry is a significant contributor to economic development in many countries, but it is also one of the most polluting industries due to the discharge of untreated or partially treated effluents (Pundir *et al.*, 2024). Tannery effluents contain a complex mixture of organic and inorganic pollutants, including heavy metals, salts, and chemical additives used during leather processing (China *et al.*, 2020). These effluents, when released into the environment without adequate treatment, pose a severe threat to aquatic ecosystems, soil quality, and public health (Ilyas *et al.*, 2019). A comprehensive bacteriological and physicochemical assessment is crucial to understanding the extent of pollution, evaluating the risks, and devising effective mitigation strategies (Wang *et al.*, 2022). Such assessments involve analyzing the effluents' chemical composition, physical properties, and microbial load to determine their environmental impact (Ilyas *et al.*, 2019).

The physicochemical parameters of tannery effluents are critical indicators of their quality and potential environmental hazards. Parameters such as pH, chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), and the concentration of heavy metals like chromium, lead, and cadmium are commonly analyzed (Tadesse, 2020). Tannery effluents are often highly alkaline or acidic due to the use of lime and acids in the tanning process, which disrupts the natural pH balance of receiving water bodies (Singh *et al.*, 2023). High BOD and COD values indicate the presence of organic pollutants that can deplete dissolved oxygen levels, causing harm to aquatic life (Management *et al.*, 2020). Heavy metals, particularly chromium in its hexavalent form, are of significant concern due to their toxicity, persistence, and bioaccumulation potential in the food chain (Ray & Vashishth, 2024).

The documented bacteriological assessments of tannery effluents do focus on identifying the microbial communities present and their potential risks to human and environmental health (Oruko *et al.*, 2021). Effluents often harbor pathogenic bacteria, such as *Escherichia coli*, *Salmonella spp.*, and *Vibrio cholerae*, which originate from animal hides or contamination during processing (Brauge *et al.*,

2024). The presence of these pathogens in effluents discharged into water bodies can lead to waterborne diseases, affecting nearby communities that depend on these water sources (Yeboah *et al.*, 2024). Additionally, the effluents may contain antibiotic-resistant bacteria, which can exacerbate the public health threat by contributing to the global issue of antimicrobial resistance (Samreen *et al.*, 2021). Also tannery effluents harbor *Bacillus species* in most cases due their ability to withstand harsh conditions that is always possible because of their potential to produce spores. Bacteriological analysis not only provides insights into the health risks but also helps in understanding the biodegradation potential of the effluents.

The combined physicochemical and bacteriological assessment of tannery effluents is essential for designing effective treatment solutions (Abate *et al.*, 2021). Conventional treatment methods, such as coagulation, sedimentation, and filtration, can reduce the levels of TSS and heavy metals but may not effectively address organic pollutants or microbial contamination (Ayach *et al.*, 2024). Advanced treatment technologies, such as membrane filtration, advanced oxidation processes, and biological treatments using microbial consortia, are gaining attention for their ability to target complex pollutants (Babu Ponnusami *et al.*, 2023). Phytoremediation and constructed wetlands have also shown promise as eco-friendly alternatives for treating tannery effluents (Kumar *et al.*, 2023). Regular monitoring and assessment of effluent quality, coupled with stringent regulatory frameworks, are necessary to ensure that tanneries comply with environmental standards and minimize their ecological footprint (Moktadir *et al.*, 2023). The bacteriological and physicochemical assessment of tannery effluents does provide a comprehensive understanding of their environmental and health impacts (Singh *et al.*, 2023). The insights gained from these assessments are instrumental in developing effective treatment technologies and regulatory policies. While the tanning industry remains a vital economic sector, its sustainability hinges on adopting cleaner production techniques, improving waste management practices, and investing in advanced effluent treatment systems (Thakur and Kumar, 2024). Collaborative efforts among industry stakeholders, researchers, and policymakers

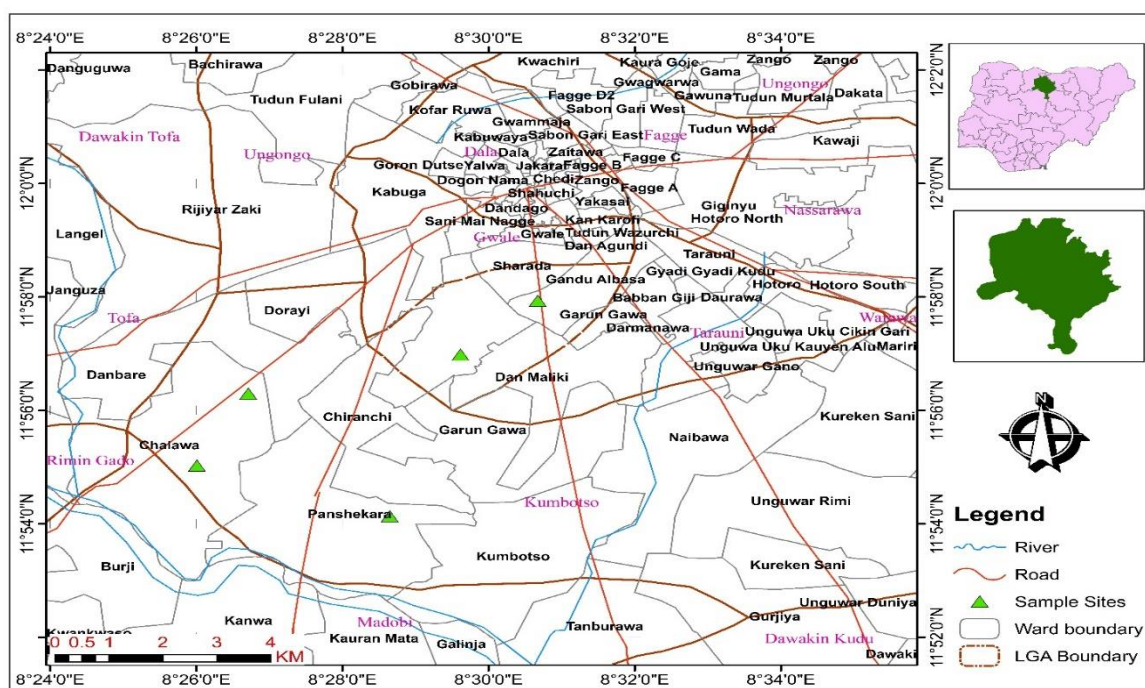
are essential to address the challenges posed by tannery effluents and to protect the environment and public health from their adverse effects (Moktadir *et al.*, 2023). Therefore, this study was designed to determine the bacterial load and physicochemical characteristics of tannery effluents from Chalawa industrial area, and to compare the results with international standards (WHO/NESREA) to evaluate potential environmental and public health risks

## MATERIALS AND METHODS

### Study Area

The area of the study is Chalawa industrial area of Kano metropolis, Kano State Nigeria. Kano is located in the Northwestern part of Nigeria. The state was characterized by

lengthy seasonal variation with rainfall annually, cold and dry winters as well as rainy season. Kano is a commercial centre of northern Nigeria and was for long known in having certain popular areas where residents have been practicing tanning process as their only source of income as reported by Umar *et al.* (2017) within the old Kano metropolis. Chalawa industrial area is one of the area where modern tannery activities are happening which is located within Kumbotso are of Kano state (Figure 1). During the process, large volumes of waste water (effluents) are being discharged into the soil environment leading to environmental pollution sewage and land (Rabah and ibrahim, 2010).



**Figure 1:** Map and Location of Sampling Area

**Source:** Map Room, Geography Department, New Site, Bayero University Kano, Nigeria

### Sample Collection

Tannery waste polluted samples were collected in triplicates with sterile sample bottles from the four different tannery sites of Chalawa industrial area. The samples were immediately transported to the laboratory for further analysis.

### Bacteriological Analysis

#### Enumeration of Bacterial Loads in the Tannery Samples

A stock solution for serial dilution was made by dispensing 1 mL of effluents into 9ml of distilled water and shaken thoroughly and transferring one (1) ml into a test tube containing 9ml of sterile distilled water and subsequently making a serial dilution of up to  $10^5$ . Using the spread plate method technique, 0.1 ml of

the suspension from dilution of  $10^3$ ,  $10^4$  and  $10^5$  were plated aseptically on a prepared Nutrient Agar (NA) and incubated at  $30^\circ\text{C}$  for 24 hours. The results were determined by multiplying the number of counts with the dilution used and expressed as colony forming units per gram (cfu/ml) of effluents and the isolates were also subcultured in nutrient agar (Rabah and Ibrahim, 2010).

#### **Physicochemical Analysis of the Effluent Samples**

Physicochemical analysis of the effluent samples was carried out based on the effluent's properties such pH, and temperature in accordance to the procedure employed by Umar *et al.* (2017). The pH was measured using (Jenway pH meter) and temperature was measured using thermometer. Other physicochemical parameters such as BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), DO (Dissolved Oxygen), TDS (Total Dissolved Solid) and TSS (Total Suspended Solid) were determined in accordance with the procedure of Umar *et al.* (2017).

##### **i. pH**

After allowing the samples to equilibrate for three minutes in a 250 ml conical flask, the pH was measured using a pH/Temperature meter and recorded in accordance to the procedure of Adamu, (2012).

##### **ii. Temperature**

By inserting a pH/Temperature meter into the effluent samples in a 250 ml conical flask and allowing it to equilibrate for 4 minutes, the temperature of the effluent was also obtained. The reading was taken to the nearest degree Celsius ( $^\circ\text{C}$ ) (Adamu, 2012).

##### **iii. Determination of dissolved oxygen (DO) and biological oxygen demand (BOD)**

Dissolved oxygen (DO) and biological oxygen demand (BOD) were also measured using a Hanna water quality meter (Model HI 9813-6) in accordance to the methodology used by Adamu (2012). As soon as the samples were collected, the instrument's electrode was put into the effluent to estimate the DO. The BOD was calculated after the sample had been kept in opaque vials, covered in black polyethylene, and covered in aluminum foil for five days. By placing the electrode of the instrument into the bottle and deducting the initial DO from the final result, the BOD was calculated. The

measurements were made in milligrams per litre (mg/L) values.

##### **iv. Electrical conductivity (E/C)**

According to Adamu (2012), the electrical conductivity was measured by inserting a conductivity probe (Hanna instrument Model HI 9813-6) into the sample in a 250 ml conical flask, allowing the sample to equilibrate for about three minutes, and recording the electrical conductance in miliSiemens per centimeter (mS/cm).

##### **v. Determination of Total Suspended Solids (TSS)**

In order to prepare the glass fiber filters for sample, they were first soaked in distilled water, dried at  $100^\circ\text{C}$ , and weighed. Glass fiber filters were weighed and then put onto a filtering flask with the wrinkled side facing up after the sample bottles had dried. Water was then placed onto the pump after the sample bottle had been shaken. Depending on the water's characteristics, a different volume of water may need to be filtered. Filtering was done using paper with a 0.8 mm porosity and a 100 ml sample. Volume of water that was filtered was recorded. A temperature range of 100 to  $105^\circ\text{C}$  was used to dry the filter paper before it was weighed. It was weighed again after drying. Up until the filter's weight became constant, this was done repeatedly. The total end weight was noted. (APHA, 2001)

##### **vi. Determination of Total dissolved solids (TDS)**

By drying the waste sample samples to a dry state, total dissolved solid (TDS) was calculated (AOAC, 1990). In this approach, 50 ml of material was put to an evaporating dish that was weighed, heated for one to two hours at  $180^\circ\text{C}$ , and then evaporated to dryness to a consistent weight. A total dissolved solid was calculated as follows:

$$\text{mg/l of TDS} = \frac{\text{mg residue}}{\text{ml sample}} \times 1000$$

##### **vii. Heavy metals concentration (zinc, cadmium, lead and nickel) from textile effluents**

The heavy metals (chromium, cadmium, lead, and nickel) were examined in all samples. An atomic absorption spectrophotometer was used to determine the amounts of heavy metals (APHA, 2001).

## RESULTS AND DISCUSSION

### Enumeration of the Bacteriological Load of the Tannery Effluents Sample

The assessment of bacterial colony counts in effluent samples serves as a critical indicator of microbial contamination and environmental impact as well the toxic effect of heavy metal content especially chromium within the chemical used in the tannery industry. In this study, tannery effluent samples from various sites (A, B, C, and D) were analyzed for bacterial load, with a fish pond effluent serving as a positive control (Site E). Table 1 shows the mean bacterial counts ( $\times 10^4$  CFU/ml) and their standard deviations provide insights into the microbial dynamics across these sampling sites. The bacterial load observed in the tannery effluent samples ranged between  $3.7 \times 10^4 \pm 0.86$  CFU/ml (Site A) and  $5.1 \times 10^4 \pm 1.60$  cfu/ml (Site C). Site E, representing fish pond effluent, demonstrated a significantly higher bacterial load of  $4.1 \times 10^6 \pm 0.31$  cfu/ml. The bacterial counts at Sites B and D were similar, with values of  $4.1 \times 10^4 \pm 0.21$  CFU/ml and  $4.5 \times 10^4 \pm 0.86$  CFU/ml, respectively. Site A exhibited the lowest bacterial count among tannery effluents, which might indicate less contamination or a reduced nutrient load conducive to bacterial proliferation. Site C, with the highest bacterial count, and could be linked to increased organic or chemical waste discharge from tannery operations. Such variations in bacterial counts from sample A to D and being lower counts compared to sample E might be due to the fact that tannery chemicals contained heavy metals that are toxic microbial load and can greatly affect bacterial biodiversity as reported by Fardami and Abdullahi (2024). The presence of chromium in leather tanning chemicals was

reported by Arellano-Sánchez *et al.* (2022) as it was emphasized that Chromium-tanning of leather involves the use of chromium salts, particularly chromium alum and chromium (III) sulfate. The collagen fibers are cross-linked by the chromium, which stabilizes the leather. The low bacterial count of the tannery effluents samples might also be linked to the waste management practices and environmental factors influencing microbial growth. The fish pond effluent (Site E) demonstrated bacterial counts approximately two orders of magnitude higher than tannery effluent samples. This elevated bacterial load could be attributed to the nutrient-rich environment in fish ponds, driven by organic matter from feed and fish excreta, which promotes microbial proliferation (Sana *et al.*, 2019). In contrast, tannery effluents may contain antimicrobial agents such as chromium or high salinity levels that limit bacterial growth (Abdel-Raouf *et al.*, 2012; Dixit *et al.*, 2015; Kumar *et al.*, 2017).

This finding of the result of tannery effluent bacterial colony counts within  $3.1 \times 10^4$  to  $5.1 \times 10^4$  cfu/ml is in conformity with the finding of Chukwu *et al.* (2016) who worked on microbiological and antimicrobial analysis of hospital wastewater discharged into the soil environment. The finding also agreed with the findings of El-Bestawy and Kashmeri (2017) in their research titled enhanced treatment of contaminated domestic wastewater using bacterial consortium biofilm. The result of the bacterial count within the tannery effluent samples in this finding had slightly disagreed with that Ramírez, *et al.* (2019) in a finding titled investigation of pilot-scale constructed wetlands treating simulated pre-treated tannery wastewater under tropical climate.

**Table 1:** Mean Aerobic Heterotrophic Bacterial Counts of Tannery Effluents Samples

Sampling Sites	Mean Bacterial Count (CFU/ml) $\pm$ S.D
A	$3.7 \times 10^4 \pm 0.86$
B	$4.1 \times 10^4 \pm 0.21$
C	$5.1 \times 10^4 \pm 1.60$
D	$4.5 \times 10^4 \pm 0.86$
E (Control)	$4.1 \times 10^6 \pm 0.31$

**Key:** S.D. = Standard deviation

### Physicochemical Properties of the Tannery Effluents

The analysis of the physical and chemical characteristics of tannery effluents is crucial in understanding their potential environmental and health impacts. Tannery effluents are known to contain high levels of pollutants, including suspended solids, organic matter, other chemical contaminants and heavy metals. Parameters such as pH, chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), and the concentration of heavy metals like chromium, lead, and cadmium are commonly analyzed (Tadesse, 2020). In this study, various parameters were assessed to evaluate the quality of the effluents and their potential environmental and health impacts (Table 2), the Figures are Tukey–Kramer multiple comparison test plot comparing Parameters across the four sampling sites (A, B, C, and D), The horizontal bars show the 95% confidence intervals for each mean. If confidence intervals of two sites overlap substantially, it suggests no significant difference between them and the green diamonds represent Tukey–Kramer simultaneous comparison intervals. Overlap between diamonds indicates no significant difference between those groups. The Average temperatures range from 27.0°C to 28.15°C. National Environmental Standards and Regulations Enforcement Agency (NESREA), Recommend industrial effluents should not exceed 35–40°C to prevent thermal pollution. The results also revealed that there is no significant differences ( $P < 0.05$ ) in temperature among the sites. This means that, while there are variations in the temperature values, these differences are not statistically significant (Figure 1). Since all sites are well below the threshold, the risk of thermal stress on aquatic life is minimal, aquatic organisms and microbes have temperature-dependent metabolic rates. Extreme fluctuations can alter biodiversity, favoring thermo-tolerant species while suppressing others. These temperatures fall within the optimum range for microbial degradation of organic matter. The finding of this study had disagreed with the findings of Kamalakkannan *et al.*, 2024 which reported tannery effluent temperatures exceeding 35°C, which can negatively affect aquatic life by reducing dissolved oxygen levels.

The pH results in this research ranges from 7.35 to 12.10. The pH at Site A ( $12.10 \pm 0.14$ ) has highly alkaline effluent and exceeded the acceptable range of 6–9, suggesting a strong presence of alkaline tanning agents such as Sodium Hydroxide (NaOH) –which is Highly alkaline, used for liming and pH adjustment, also Magnesium Oxide (MgO) Slightly alkaline, used to regulate pH in process, while the other sites are within range. Sites C and D are not statistically significant from each other, and also site B and C, indicating that, they are not statistically significant (Figure 2). Previous studies reported by Mayank Kumar, 2023 found similar High pH values in raw tannery wastewater due to lime and sodium sulfide use in processing which is in conformity with the present study.

The result of Electrical conductivity values ranged from 3.27 to 7.26 ms/cm exceed the permissible limit (1 ms/cm), indicating high ion concentration suggesting high dissolved salts and potential soil salinity risks. Site A and Site D are not statistically significant from each other but are significantly lower than Site C (Figure.3).The findings align with study conducted by Shaibu and Audu (2019) evaluated physicochemical parameters of tannery effluents from different companies in the Challawa and Sharada industrial areas of Kano State, Nigeria, reporting EC values between 3.0–12.0 mS/cm in untreated tannery wastewater, reflecting the significant ionic load typical of such effluents. Total dissolve solid (TDS) results ranges (1220–1989 ppm) significantly exceed the permissible limit (500 ppm), Statistically, Site A significantly differ from the other sites (B, C, and D). Site B it is also significantly different from Sites C and D, while there is not significant different between Site C and D (Figure 4). The results indicate contamination risks for groundwater and this had disagreed with the finding of Previous research by Bhagawati *et al.*, 2024 who found TDS levels  $> 20000$  ppm in untreated effluents.

The Biological oxygen demand (BOD) values of this research ranges (0.75–1.15 mg/L) are much lower than the limit (50 mg/L). Figure 5, shows the Statistical differences between the sites which revealed that, there are no statistically significant differences in BOD values among the sites ( $P < 0.05$ ). Previous study conducted by Mahmud *et al.*, (2024)



which is with disagreement with this present research, found BOD levels between 70–610 mg/L in untreated tannery effluent, suggesting high organic load. The lower BOD in this research may indicate Low organic Pollution.

The average result of Dissolve Oxygen (DO) ranges (2.10–2.60 mg/L) are below the standard (5 mg/L), suggesting poor water quality. Statistical significant differences in dissolved oxygen levels among the sites at ( $P < 0.05$ ), revealed that, they are not significant (Figure 6). Slightly Similar result revealed in a study conducted in Bangladesh assessed surface water quality around tannery effluent discharge areas and reported dissolved oxygen (DO) concentrations ranging from 0.5 to 1.6 mg/L. These findings highlight the detrimental impact of untreated tannery effluent on aquatic ecosystems, emphasizing the need for effective wastewater treatment to maintain adequate DO levels and protect aquatic life. The Low DO levels of this research indicate oxygen depletion, which can harm aquatic organisms. The results of the Total Solids (TS) in mg/L from the tannery effluents at different sites revealed that Site A has the highest Total Solids concentration of 85.00 (mg/L), Site B shows a lower level of 25.00 mg/L, which is moderate contamination compared to Site A. while Sites C (13.00 mg/L) and D (16.00 mg/L) have the lowest Total Solids concentrations. The statistical significant differences in Total Solids levels among the sites at ( $P < 0.05$ ) indicate that Site A has the highest Total Solids concentration, which is significantly differ from the other sites (B, C, and D). Site B significantly differ from Sites C and D. Sites C (13.00 mg/L) and D (16.00 mg/L) are not significant (Figure 4.7).

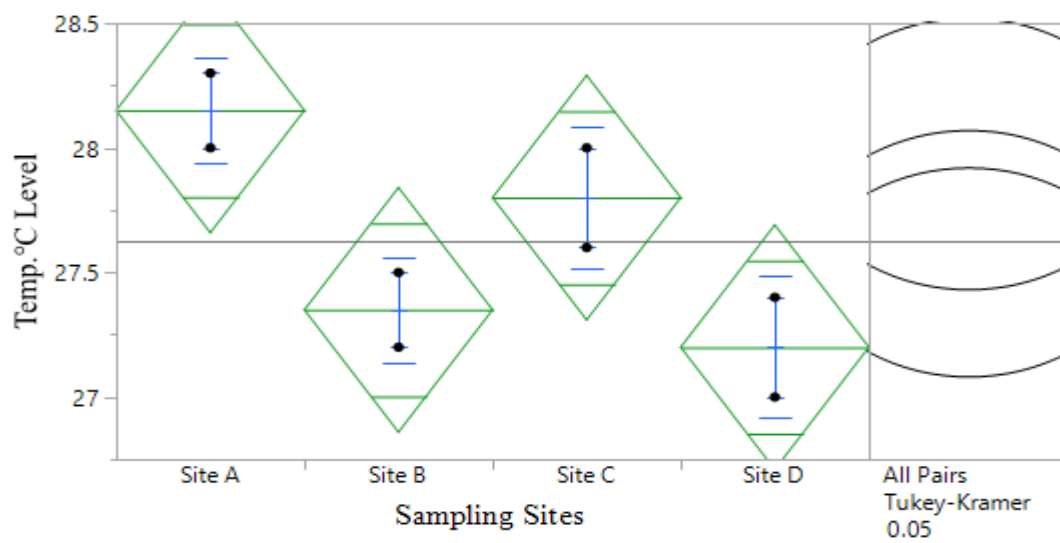
Average Phosphate concentrations obtained in this research tannery ranged between 0.19 mg/L and 0.27 mg/L, which are well within the permissible limit of 5.0 mg/L set by regulatory bodies and statistically there is significant difference between the all sites at ( $P < 0.05$ ) (Figure 4.8). Phosphates in tannery wastewater typically originate from detergents, processing chemicals, and certain leather treatment agents. Although phosphates are essential nutrients for aquatic ecosystems, excessive concentrations can lead to eutrophication, a condition that promotes excessive algal growth and subsequent oxygen depletion in water bodies. Furthermore, the results align with findings from other study on treated tannery effluents, by Begum *et al.* (2021), which reported phosphate concentrations in the range of 0.1–1.0 mg/L in compliant effluents.

Potassium Oxide ( $K_2O$ ) No permissible limit is provided, but your values (5.04–24.49 mg/L) show significant variation. The result of Potassium Oxide ( $K_2O$ ) in the tannery effluent samples ranged from 5.04 mg/L to 24.49 mg/L, Figure 10 shows the statistical difference of  $K_2O$  between the sites which revealed that, there is significant difference between the all sites at ( $P < 0.05$ ). The variability between the sites is likely influenced by differences in tanning processes, chemical formulations used, and wastewater treatment efficiency across the sampling sites. Other study found tannery effluent contributing to potassium enrichment in soils, potentially affecting plant growth (Kumar *et al.*, 2018) which is in conformity with this study.

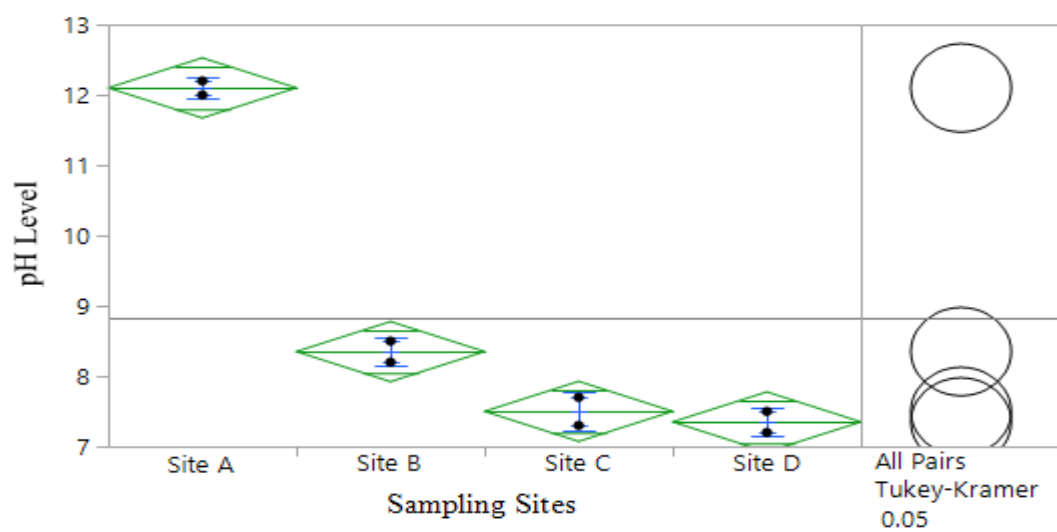
**Table 2:** Physical and Chemical Characteristics of the Tannery Effluents

Parameters	Site A (Mean±S.D.)	Site B (Mean±S.D.)	Site C (Mean±S.D.)	Site D (Mean±S.D.)	WHO & NESREA Permissible Limits
Temp.°C	28.15±0.21 <sup>a</sup>	27.35±0.2 <sup>a</sup>	27.8±0.28 <sup>a</sup>	27.0±0.28 <sup>a</sup>	40
pH	12.10±0.14 <sup>a</sup>	8.35±0.2 <sup>c</sup>	7.5±0.28 <sup>bc</sup>	7.35±0.21 <sup>b</sup>	6-9
EC ms/cm	6.57±0.35 <sup>c</sup>	3.27±0.09 <sup>b</sup>	7.26±0.09 <sup>a</sup>	6.68 ±0.02 <sup>c</sup>	1
TDS ppm	1989±9.19 <sup>a</sup>	1524±6.27 <sup>d</sup>	1234±6.27 <sup>b</sup>	1220±6.27 <sup>b</sup>	500
BOD mg/L	1.15 ±0.07 <sup>a</sup>	0.75 ±0.21 <sup>a</sup>	1.10 ±0.14 <sup>a</sup>	1.05 ±0.07 <sup>a</sup>	50
DO mg/L	2.50±0.14 <sup>a</sup>	2.60±0.28 <sup>a</sup>	2.10±0.14 <sup>a</sup>	2.20 ±0.14 <sup>a</sup>	5-6
TS mg/L	85.00±2.82 <sup>a</sup>	25.00±1.4 <sup>b</sup>	13.00±1.41 <sup>c</sup>	16.00±1.41 <sup>c</sup>	25
PO <sub>4</sub> mg/L	0.22±0.004 <sup>a</sup>	0.27±0.004 <sup>d</sup>	0.19±0.002 <sup>b</sup>	0.25±0.004 <sup>c</sup>	5
NO <sub>3</sub> mg/L	68.65±0.04 <sup>b</sup>	110.67±0.008 <sup>c</sup>	229.77±0.014 <sup>a</sup>	195.70±0.014 <sup>d</sup>	20
K <sub>2</sub> O mg/L	24.49±0.003 <sup>a</sup>	17.29±0.12 <sup>b</sup>	5.04±009 <sup>c</sup>	15.25±0.005 <sup>d</sup>	-

Mean values with different superscript alphabet in a row differ significantly ( $P < 0.05$ ).

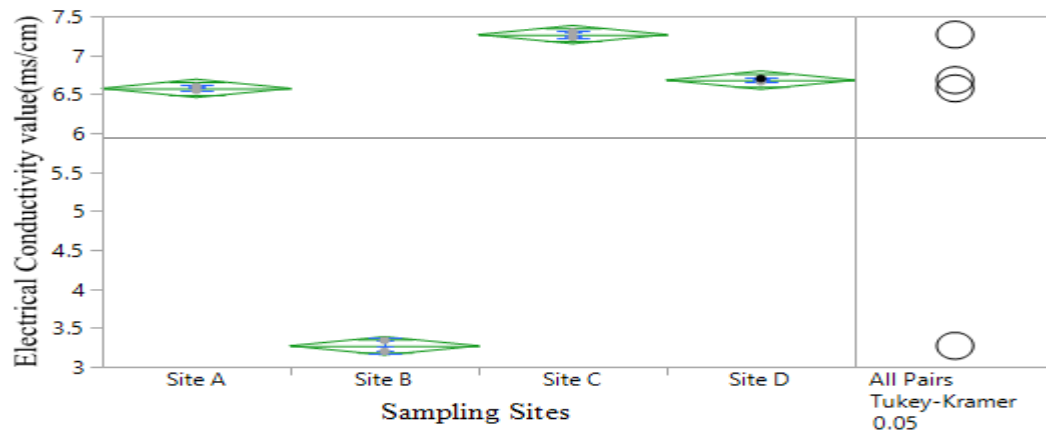


**Figure 2:** Significant of Temperature level across Sampling Sites

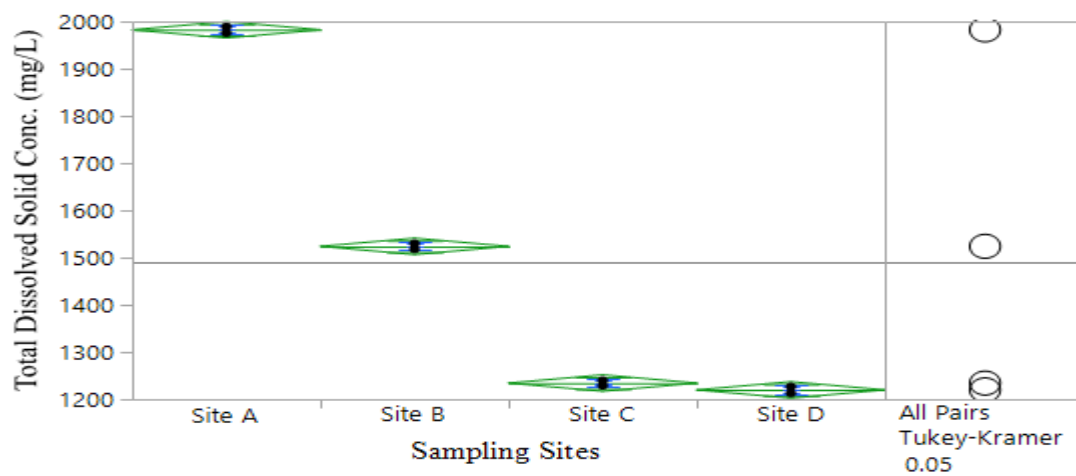


**Figure 3:** Significant of pH Level across Sampling Sites

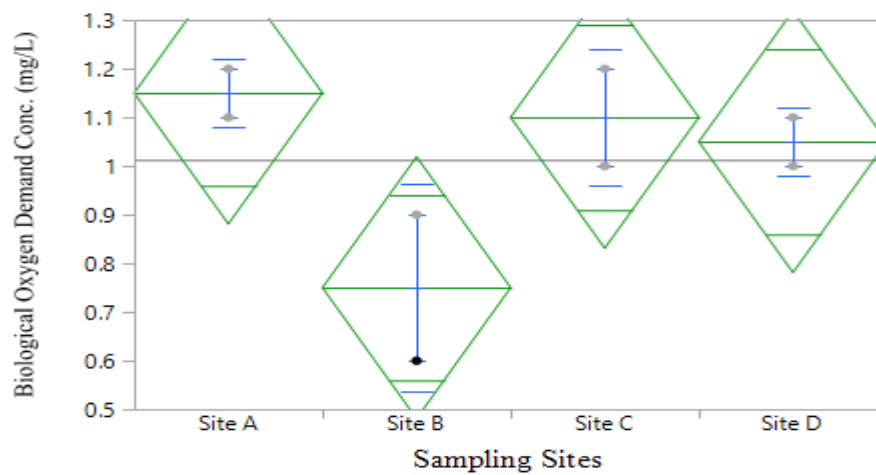




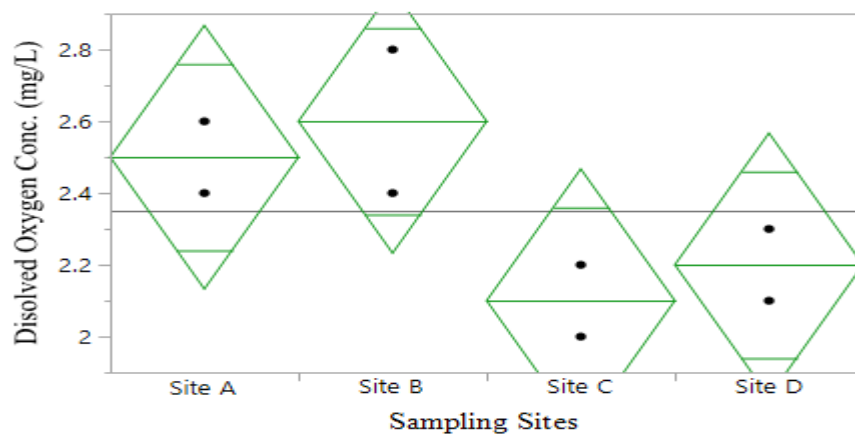
**Figure 4:** Significant of Electrical Conductivity Level across Sampling Sites



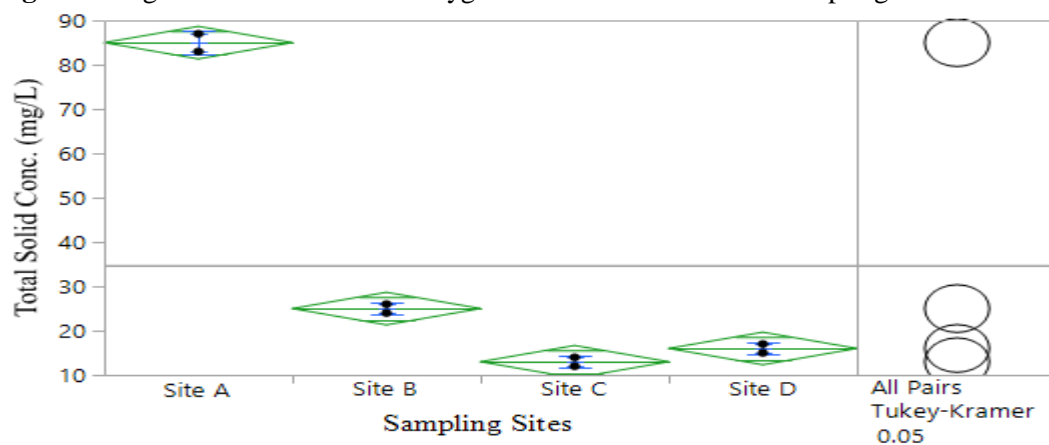
**Figure 5:** Significant of Total Dissolved Solid Concentration across Sampling Sites



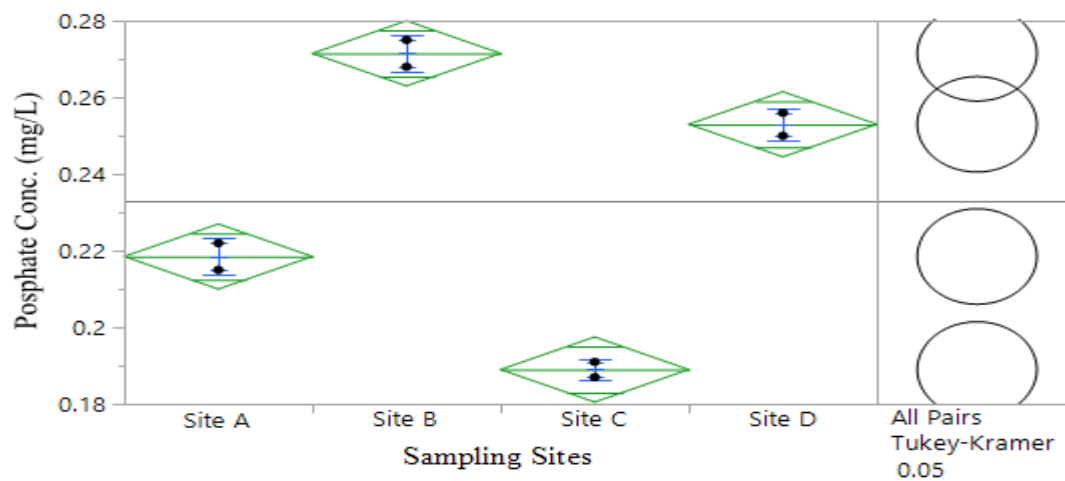
**Figure 6:** Significant of Biological Oxygen Demand level across Sampling Sites



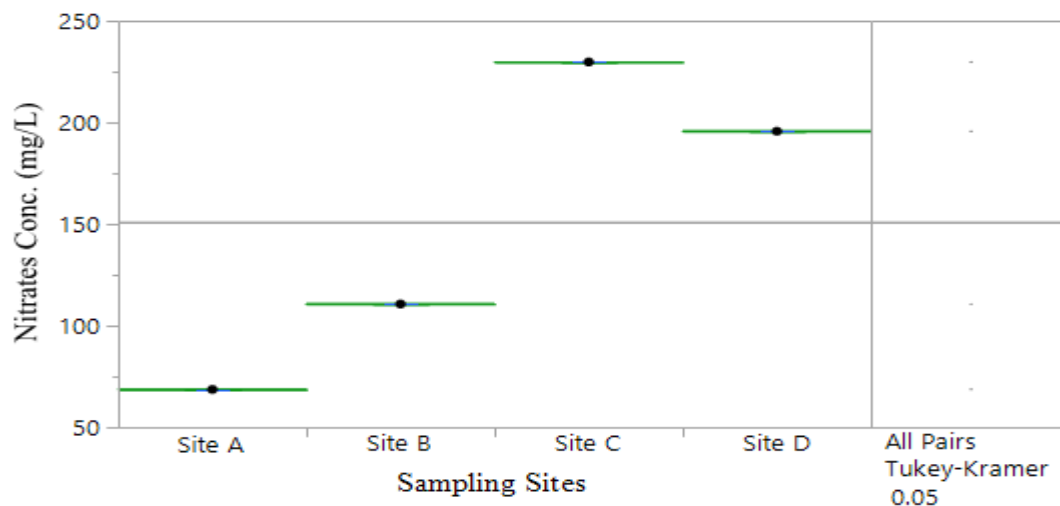
**Figure 7:** Significant of Dissolved Oxygen Concentrations across Sampling Sites



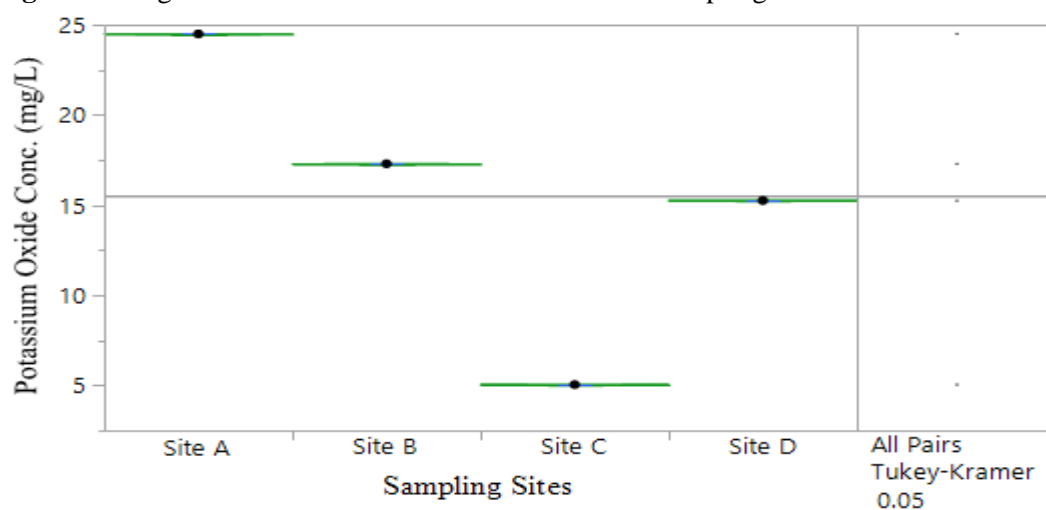
**Figure 8:** Significant of Total Solid Concentration across Sampling Sites



**Figure 9:** Significant of Phosphate Concentration across Sampling Sites



**Figure 10:** Significant of Nitrates Concentration across Sampling Sites



**Figure 11:** Significant of Potassium Concentration across Sampling Site

### Heavy Metals Concentration of the tannery Effluents

Table 3 revealed the result of heavy metals concentration of chromium, cadmium, lead, and nickel within the tannery effluents samples from four sites in the Challawa industrial area of Kano State, Nigeria. These values are compared to the permissible limits established by the World Health Organization (WHO) and the National Environmental Standards and Regulations Enforcement Agency (NESREA). The Chromium result, showed mean concentrations ranging from  $20.45 \pm 0.021$  mg/L at Site A to  $29.37 \pm 0.068$  mg/L at Site C. All sites far surpass the permissible limit of 0.5 mg/L. Statistically Site A, is significantly different with other sites, while Sites B, C, and D showed no significant difference (Figure 12). Such high levels of chromium, a toxic heavy metal often linked to industrial processes, which can pose severe health risks,

including respiratory problems, skin irritation, and long-term carcinogenic effects. This highlights the urgent need for stricter control measures and advanced effluent treatment methods in tannery operations, and the results align with the findings of Oladoja *et al.* (2022), who reported higher chromium concentrations, working on untreated tannery wastewater in Nigeria. Such high levels of chromium, a toxic heavy metal often linked to industrial processes, can pose severe health risks, including respiratory problems, skin irritation, and long-term carcinogenic effects (Hossini *et al.*, 2022). This highlights the urgent need for stricter control measures and advanced effluent treatment methods in tannery operations. The chromium concentrations reported by Hossini *et al.*, 2022 is notably lower than this current findings while exceeding permissible limit.

Cadmium concentrations, though relatively low, show site-specific variations, with Site B exhibiting the highest mean value of  $0.009 \pm 0.0007$  mg/L, closely approaching the permissible limit of 0.01 mg/L. Meanwhile, Sites C and D recorded slightly lower values of  $0.003 \pm 0.0014$  mg/L and  $0.004 \pm 0.0007$  mg/L, respectively, Figure 15 shows the statistical difference between the sampling sites, Site B is significant with the other sites, while Sites A, C, and D did not differ significantly. Cadmium is particularly hazardous as it accumulates in living organisms, potentially leading to kidney damage and bone demineralization. The marginal differences among sites indicate localized variability in effluent composition but underscore a consistent environmental and public health concern that warrants continuous monitoring and remediation.

Lead and nickel concentrations further amplify the environmental burden posed by these tannery effluents. Lead levels exceeded the permissible limit of 0.1 mg/L at Sites A, B, and D, with Site A recording the highest value of  $0.136 \pm 0.034$  mg/L. Statistically there is significant difference between Site C and the other sites (A, B, and D), while Sites A, B, and D did not differ significantly (Figure 14). Nickel concentrations were even more concerning, with values between  $0.198 \pm 0.013$  mg/L at Site A and  $0.484 \pm 0.011$  mg/L at Site C, all far above the allowable limit of 0.1 mg/L, there is statistical difference between site A and other sites (B, C, and D) and also C and other sites (A, B, and D) while Site B and

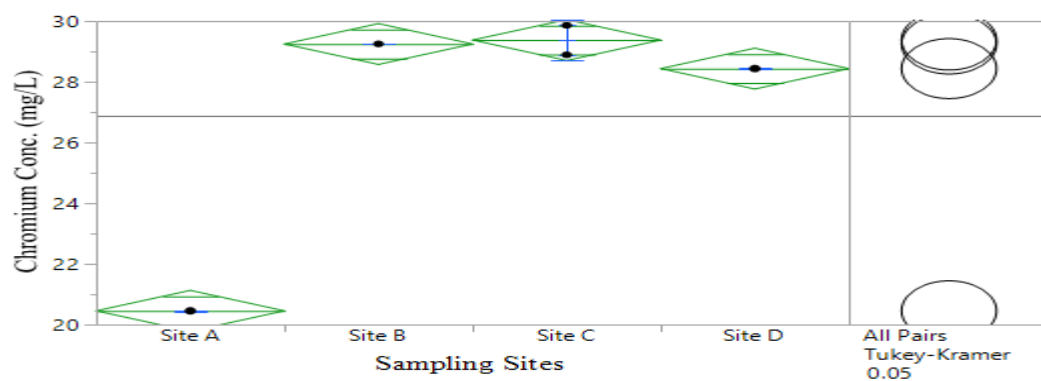
D are not significant (Figure 15). Both metals are notorious for their toxicological impacts, including neurological damage, cardiovascular issues, and reproductive toxicity (Mitra *et al.*, 2022). These findings indicate that the tannery industry poses a critical threat to aquatic ecosystems and nearby communities, necessitating immediate intervention through policy enforcement and sustainable industrial practices.

The findings reveal significant contamination of the effluents Heavy metals, particularly with chromium and nickel, underscoring the environmental and public health concerns associated with untreated or inadequately treated tannery discharges. More so, the findings highlight a critical gap in compliance with regulatory standards for industrial wastewater discharge in the Challawa industrial area. The excessive concentrations of chromium and nickel, along with elevated lead levels, demonstrate the urgent need for stricter enforcement of environmental regulations. The lack of adequate treatment facilities or processes exacerbates the risk of contaminating nearby water bodies and soil, which can affect agriculture and human health. Long-term strategies should focus on adopting cleaner production techniques, regular monitoring, and community awareness programs to mitigate the impact of tannery effluents. Research into cost-effective and sustainable treatment technologies should also be prioritized to address this pressing environmental challenge.

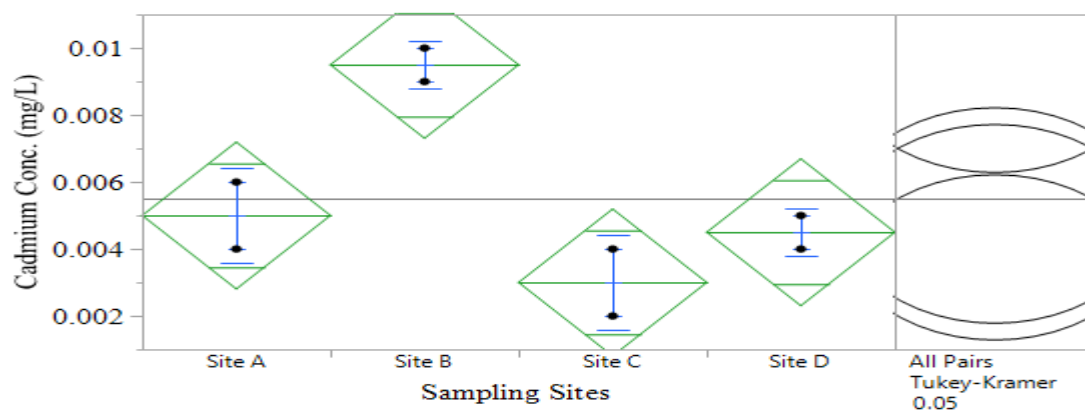
**Table 3:** Heavy Metals Concentration of the tannery Effluents

Parameters	Site A (Mean±S.D.)	Site B (Mean±S.D.)	Site C (Mean±S.D.)	Site D (Mean±S.D.)	WHO & NESREA Permissible Limits
Chromium	$20.45 \pm 0.021^a$	$29.24 \pm 0.007^b$	$29.37 \pm 0.068^b$	$28.43 \pm 0.021^b$	0.5 mg/L
Cadmium	$0.005 \pm 0.0014^{ab}$	$0.009 \pm 0.0007^a$	$0.003 \pm 0.0014^b$	$0.004 \pm 0.0007^b$	0.01 mg/L
Lead	$0.136 \pm 0.034^a$	$0.125 \pm 0.005^a$	$0.012 \pm 0.004^b$	$0.119 \pm 0.001^a$	0.1 mg/L
Nickel	$0.198 \pm 0.013^{aa}$	$0.324 \pm 0.006^{ab}$	$0.484 \pm 0.011^b$	$0.318 \pm 0.004^{ab}$	0.1mg/L

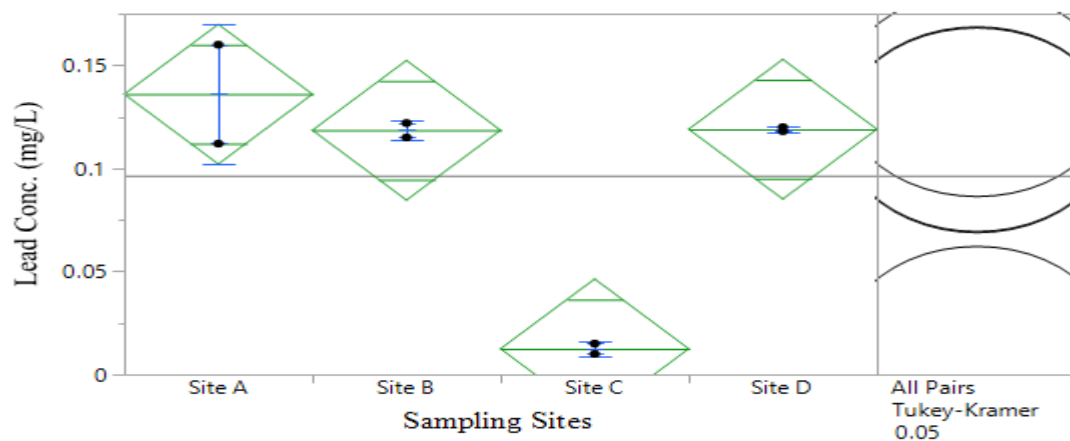
Mean values with different superscript alphabet in a row differ significantly ( $P < 0.05$ ).



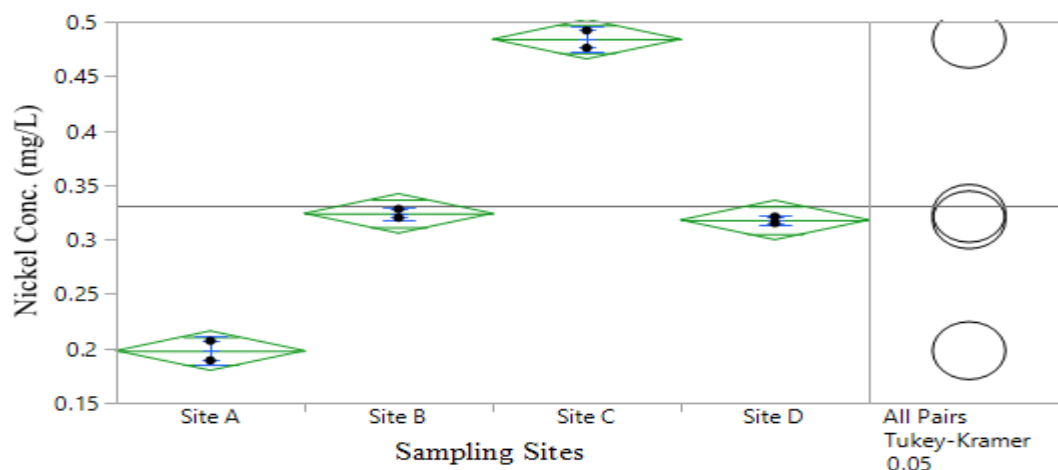
**Figure 12:** Significant of Chromium Concentrations across Sampling Sites



**Figure 13:** Significant difference of Cadmium Concentrations across Sampling Sites



**Figure 14:** Significant of Lead Concentrations across Sampling Sites



**Figure 15:** Significant of Nickel Concentrations across Sampling Sites

## CONCLUSION

This study demonstrated that tannery effluents in Chalawa contain elevated heavy metals (Cr, Ni, Pb) and highly alkaline pH values above permissible limits, along with reduced bacterial load compared to natural controls. These results highlight serious ecological and public health risks, emphasizing the urgent need for effective effluent treatment, stricter regulatory enforcement, and promotion of sustainable industrial practices.

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