

# EFFECTS OF LOCAL DYEING ACTIVITIES ON GROUNDWATER QUALITY IN KANO METROPOLIS, KANO STATE, NIGERIA

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## ABSTRACT

This study examined the effects of dyeing activities on groundwater quality in selected areas of Kano Metropolis. Three hand-dug wells and three boreholes were purposively selected based on their proximity to the dyeing sites and frequency of use. The sampling points were designated as BH1, BH2, BH3, HDW1, HDW2, and HDW3. The concentrations of physicochemical parameters, like temperature (T°C), pH, Total Dissolved Solids (TDS), were measured with the aid of calibrated thermometer, the Hanna instrument H1 2020 model, Turbidity with data loggings spectrophotometer CDR/2400model, Alkalinity, Chloride (Cl), Sulphate (SO<sup>4-</sup>), while Calcium (Ca), Magnesium (Mg), Cadmium (Cd), and Chromium (Cr) was done using the Atomic Absorption Spectrometer (PerkinElmer PinAAcle 900H model). The results revealed that the levels of physicochemical parameters - temperature, pH, and Total Dissolved Solids (TDS)- were high compared to the maximum permissible limits of 29 °C, 7, and 500mg/l set by the World Health Organization (WHO) and the Standard Organization of Nigeria (SON). The average concentrations of Cadmium (Cd) and Chromium (Cr) exceeded the maximum permissible limits of 0.01 mg/L and 0.003 mg/L, respectively, as defined by both WHO and SON. The elevated concentrations of Cadmium (Cd) and Chromium (Cr) may be attributed to the leaching of these heavy metals into the groundwater from nearby dyeing activities and waste disposal practices. This indicates that the water has been contaminated with Cadmium (Cd) and Chromium (Cr), rendering it unsafe for consumption. Furthermore, the results revealed a significant variation in the physicochemical parameters between hand-dug well water and borehole water. In conclusion, the water poses a potential health risk. It is imperative to address this issue promptly to ensure the safety and well-being of individuals relying on these water sources.

**Keywords:** local dyeing; groundwater quality; traditional practice; local textiles; kofar mata dye pit

## INTRODUCTION

Dyeing is a fundamental process that involves adding color to various materials, including textile fibers, yarns, and fabrics. This process ensures that the coloring matter becomes an integral part of the dyed material (Jayanth *et al.*, 2011). It is a traditional, skillful practice used to enhance the appearance of clothes by applying color or dye to fiber stock, yarn, or fabric.

Dye, whether natural or synthetic, is a substance specifically designed to add color to various items, such as textiles or hair. Typically, it is applied in liquid form (Kuberan *et al.*, 2011). Dyes are colored soluble compounds that impart their characteristic hues (Ara, 2015). The dyeing process typically involves immersing the material in a specialized solution containing dyes and other

chemicals. After dyeing, the dye molecules form strong chemical bonds with the fiber molecules, resulting in a lasting coloration. However, it is important to note that approximately 10-20% of the dye remains in the dye bath, along with other residual chemicals, which are discharged as exhausted dye wastewater (Sajjala *et al.*, 2008).

Dyeing in the dye pit is a long-standing craft institution in Kano, the heart of the Hausa land in Sub-Saharan Africa. However, in recent years, a new dyeing practice has emerged in urban Kano. The introduction of local textiles processing in Kano dates back to the fifteenth century when Moroccan traders brought their expertise, leading to the establishment of the renowned Kofar Mata dye pit in 1498 (Liman, 2015).

Traditionally, dyed cloth in Kano is predominantly associated with indigo (Baba). However, the growing prevalence of secondary dyeing processes is raising concerns among the local population. The desire to change the colour of one's textile material is a personal preference, as individuals have varying color preferences (Kamat & Kamat, 2015).

Human actions and activities often have significant environmental consequences, with the magnitude of these consequences varying across locations. The discharge of untreated dye wastewater is a major contributor to severe pollution problems worldwide. Approximately 10 - 25% of textile dyes are lost during the dyeing process, with 2-20% directly released as aqueous effluents into different environmental components (Baban *et al.*, 2010). The discharge of dye-containing wastewater into aquatic environments is particularly harmful, not only because of its visible coloration but also because many dyes and their breakdown products are toxic to living organisms. These dyes often contain carcinogens such as benzidine, naphthalene, and other aromatic compounds (Suteu *et al.*, 2009).

The expansion of Local Dyeing Activities (LDA) in urban Kano has brought about significant socio-economic development. However, this growth has come at a cost, as dyeing activity now poses a serious threat to the environment and the health of humans and other living organisms through complex ecological interactions (Muhammad *et al.*, 2020).

One of the major environmental issues arising from these activities is the contamination of surface and groundwater sources (Odjegba & Bamgbose, 2014). The wastewater generated by the dyeing process is highly toxic, characterized by its high Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and suspended solids (Yusuf & Sonibare, 2004; Sharma *et al.*, 2014). The toxic nature of the wastewater poses a significant risk to both ground and surface water sources, leading to a detrimental alteration in water quality.

According to the World Health Organization (1996), about 80% of human diseases are caused by water. Once water is contaminated, its quality cannot be restored easily. Groundwater is an essential

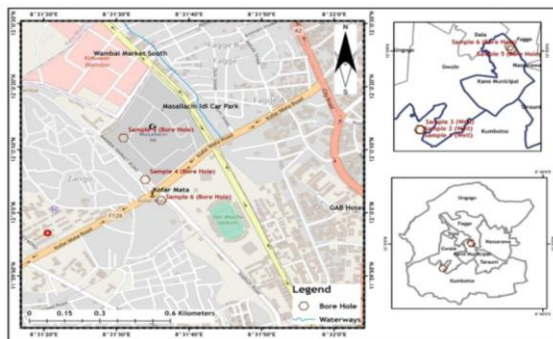
resource, and it exists almost everywhere under most landscapes. It is one of the sources of freshwater and constitutes about 0.3% of usable water; though in small amounts, groundwater is the source of safe water supply for many parts of the world (Godwill et al., 2015). Water should be clear, colourless, tasteless, odourless, and devoid of suspended matter or turbidity.

Therefore, ensuring access to a reliable, secure, safe, and sufficient source of fresh water is not only crucial for survival but also for the well-being and socio-economic development of humanity (Tebbutt, 1990).

**MATERIALS AND METHODS**

**Study Area**

Kano Metropolis is officially made up of eight (8) Local Government Areas: Dala, Fagge, Gwale, Municipal, Nassarawa, Tarauni, Kumbotso, and Ungogo. The metropolis covers about 499 square kilometers at an altitude of 472 meters above sea level and lies between latitude 11 ° 05 'N to 12°07'N and longitude 8°23'E to 8°47'E. Kano Metropolis is bounded to the north-east by Minjibir LGA and the east by Gezawa LGA, and to the south-east by Dawakin Kudu LGA and to the west by Madobi and Tofa LGAs. Kano metropolis is Nigeria's second-largest commercial center after Lagos, and the largest urban center in Hausaland. Its growth has been phenomenal, driven by trade, industry, and population expansion, making it the most influential commercial town in the Sudan region, with a long-standing sedentary population within an organized emirate (Boyi et al., 2017). Recent estimates suggest that the population of Kano Metropolis has grown significantly. As of 2021, projections based on an annual growth rate of 3.5% put the population of Kano Metropolis at over 4.5 million (World Bank, 2021; NPC, 2021). The city lies in the tropical wet-and-dry zone typical of the Sudan savanna belt, with the wet season lasting 4 to 5 months, from May to September (Olofin & Tanko, 2002). During the hot months, average daytime temperatures typically range between 30°C and 32°C, though peak temperatures can be higher, especially in March, April, and May before the rains arrive (Adzandeh et al., 2014). Kano Metropolis lies within the Sudan Savanna region of Nigeria and is underlain by basement complex rocks of Precambrian age (Umar et al., 2019).



**Figure 1:** Kofar Mata Dye Pit Area Source: GIS Lab BUK, 2024

**Acquisition of Field Data**

The research was conducted in two stages, providing a thorough examination of the dyeing activities and their impact on groundwater quality. This two-stage approach provided a comprehensive understanding of the subject matter, which helped in the meaningful conclusion and recommendations:

- i. Reconnaissance survey of dyeing sites
  - ii. Acquisition of field data (collection of water samples)
- Data were acquired through direct sampling of groundwater from hand-dug wells and boreholes within a 100m radius of the dyeing sites. The choice of distance is based on the fact that contaminant plumes from waste disposal sites are governed by site-specific conditions such as the hydrogeological properties of the aquifer, groundwater flow velocity, and the nature of the contaminants. These plumes can migrate significant distances, often hundreds of meters, depending on aquifer permeability and contaminant persistence (Johnson, 2016). A total of six (6) samples of groundwater were collected for physicochemical analysis in the laboratory. This was achieved due to their proximity to the dyeing site. Each sample was accurately coded and marked on the sampling bottles using a permanent marker at two distinct locations. To ensure clarity and prevent any potential confusion or errors, all relevant information, such as the name of the sampling location, source, and date of collection, was diligently recorded in the field book

**Table 1:** Location of the Sample Sites of Hand dug wells and Boreholes

S/N	SITE	CORDINATES	
		Longitude	Latitude
1	HDW1	11.946102	8.471280
2	HDW2	11.9457422	8.4711701
3	HDW3	11.945598	8.472030
4	BH1	12.0014594	8.5260991
5	BH2	12.003299	8.5252736
6	BH3	12.0005483	8.5267109

HDW – Hand Dug Well

BH – Borehole

**Laboratory Analysis**

**Table 2: Methods of Laboratory Analysis**

Parameters	Analytical Method APHA 2021	Equipment used
Temperature(°C)	Direct measurement using a calibrated thermometer	Calibrated Thermometer
pH	pH Meter	Hanna instrument HI 2020 edge hybrid model
Total Dissolved Solids (TDS)	Conductivity Method	Hanna instrument HI 2020 edge hybrid model
Turbidity	Formazine Suspension	Data log in Spectrophotometer CDR/2400model HACH Company
Alkalinity (as HNO <sub>3</sub> )	Titration with standard acid using HCl	Spectrophotometer
Chloride	Atomic Absorption Spectrophotometry (AAS)	Spectrophotometer
Sulphate	Atomic Absorption Spectrophotometry (AAS)	Spectrophotometer
Calcium	Atomic Absorption Spectrophotometry (AAS)	Perkin Elmer Pinaccl 900H
Cadmium	Atomic Absorption Spectrophotometry (AAS)	Perkin Elmer Pinaccl 900H
Chromium	Atomic Absorption Spectrophotometry (AAS)	Perkin Elmer Pinaccl 900H
Magnesium	Atomic Absorption Spectrophotometry (AAS)	Perkin Elmer Pinaccl 900H

**Physicochemical Characteristics of Groundwater around the Dyeing Site**

**Data Analysis**

The data collected were subjected to statistical analysis (percentages, charts, mean, and one-way ANOVA) to achieve the study's aim and objectives.

The physicochemical characteristics of groundwater around the dyeing sites are presented, including mean values and the recommended standards set by WHO and SON.

**RESULTS AND DISCUSSION**

**Table 3: Sample Result Comparison with Water Quality Guidelines**

	SAMPLE										WHO (2022)	SON (2003)
	Hand Dug Well					Borehole						
	BH <sub>1</sub> (mg/L)	HDW <sub>2</sub> (mg/L)	HDW <sub>3</sub> (mg/L)	Total	Mean	BH <sub>1</sub> (mg/L)	BH <sub>1</sub> (mg/L)	BH <sub>1</sub> (mg/L)	Total	Mean		
Temperature(°C)	31	31.1	31	93.1	31.03	31.8	32.4	31.5	95.7	31.90	29	Ambient
pH	6.8	7	7.2	21	7.00	7.8	7.4	6.9	22.1	7.37	6.5 – 8.5	6.5 - 8.5
Total Dissolved Solids (TDS)	711	705	771	2187	729.00	856	1137	1223	3216	1072.0	500	500
Turbidity	0	0	0	0	0.00	0	0	0	0	0.00	5	5
Alkalinity (HCO <sub>3</sub> )	18.3	122	48.8	189.1	63.03	36.6	67.1	73.2	176.9	58.97	120	100
Chloride	127.8	127.8	159.8	415.4	138.47	230.8	252.1	326.6	809.5	269.83	400	250
Sulphate	1.24	1.97	2.25	5.46	1.82	1.46	2.26	2.04	5.76	1.92	200	200
Calcium	0.389	0.014	0.159	0.562	0.19	0.122	0.738	0.035	0.895	0.30	75	100
Cadmium	0.0012	0.0002	0.0006	0.002	0.0007	0.0002	0.007	0.0015	0.0087	0.0029	0.003	0.003
Chromium	0.0175	0.0079	0.0156	0.041	0.01	0.0108	0.0215	0.0255	0.0578	0.02	0.05	0.01
Magnesium	0.0525	0.0371	0.0343	0.1239	0.04	0.015	0.0131	0.255	0.2831	0.09	50	200

**Note: HDW = Hand Dug Well**

**BH = Borehole**

**Temperature**

The temperature of hand-dug well water samples ranges from 31 °C to 31.1 °C, whereas borehole water temperatures vary from 31.5 °C to 32.4 °C. The temperature range for both the well and borehole samples is similar, although it exceeds the WHO's permissible limit. This may significantly affect groundwater quality.

**pH**

A pH meter was used to determine the acidity and alkalinity of the groundwater samples. The pH of the hand-dug well water varied from 6.8 to 7.2, with a mean of 7.0, whereas the pH of the borehole water ranged from 6.9 to 7.8, with a mean of 7.37. However, the pH values observed in this investigation from hand-dug wells and borehole samples were below the WHO-recommended range of 6.5 to 8.5 (WHO, 2018). Because water pH can influence water

treatment procedures, it indirectly affects human health. (Amin *et al.*, 2009)

#### Alkalinity (HCO<sub>3</sub>)

The alkalinity of hand-dug well water in the research area ranged from 18.3 to 122mg/L, whereas borehole water ranged from 36.6 to 73.2mg/L. The average alkalinity of water from hand-dug wells was 63.03 mg/L, while that from boreholes was 58.97 mg/L. These readings are less than the maximum limits specified by WHO and SON, which are 120 and 100, respectively. Although just one sample of Samegu well water exceeds the WHO and SON water quality recommendations for alkalinity. Clune *et al.* (2019) showed that alkalinity causes corrosion and alters chemical and biological responses. The elevated alkalinity and hydrogen carbonate readings might be the result of run-off entering the groundwater. Most of the wells are shallow, and the absence of casing or the presence of fractures in these wells may allow saltwater intrusion.

#### Turbidity

The turbidity value of all the hand-dug well and borehole water samples is 0 FTU. Turbidity should ideally be below 1(one) FTU.

#### Total Dissolved Solids (TDS)

TDS, which measures the concentration of dissolved minerals in water, ranged from 705 to 711 mg/L in hand-dug wells and from 856 to 1137 mg/L in boreholes. In general, Total Dissolved Solids were lower in hand-dug wells than in boreholes in the study area. However, the obtained levels were not within the limits set by WHO and SON. TDS in drinking water has a maximum allowable threshold of 500S/cm (WHO, 2022). The geology of the area may affect total solids levels in groundwater; however, high TDS readings may be related to dissolved solids from textile industry effluent discharge. (Geetha *et al.*, 2008). Total Dissolved Solid (TDS) found in water is mainly due to carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, nitrogen, calcium, sodium, potassium, and iron (Kannan *et al.*, 2005). High concentrations of these may affect humans, especially those suffering from kidney and heart disease (WHO, 2010). Excessive TDS in drinking water may also have widespread effects on the gastrointestinal system, produce an undesirable taste, and cause gastrointestinal irritation and corrosion (Gupta, 2004).

#### Calcium

Groundwater ionic species such as Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, HCO<sub>3</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup> and Cl<sup>-</sup> influence groundwater quality by determining its physical and chemical characteristics, as well as its suitability for drinking and other domestic, agricultural, and industrial uses (Sadashivaiah *et al.*, 2008). The calcium (Ca<sup>2+</sup>) ion varied from 0.014 to 0.562mg/L, with a mean of 1.82 mg/L (Table 3), whereas borehole water ranged from 1.46 to 2.04 mg/L, with a mean of 1.92 mg/L (Table 3). These readings are within the levels allowed by WHO and the SON, indicating that the calcium content is within the acceptable range.

#### Sulphate

The Sulphate ion concentration for hand-dug well water ranged from 1.97 to 2.25 mg/L, while those collected from boreholes ranged from 1.46 to 2.26 mg/L. The source of the sulphate ion may be attributed to chemicals used at dyeing sites. In unpolluted waters, chloride concentrations are usually lower than 10 mg/L (Chapman, 1996)

#### Chlorine

From the findings shown in Table 4.5, the Cl concentration in water samples taken from hand-dug wells ranged from 127.8 mg/L to 159.8 mg/L, with a mean of 138.47 mg/L, while the concentration in water samples taken from boreholes ranged from 230 mg/L to 326.6 mg/L, with a mean of 269.83 mg/L. While two of the borehole water samples fall within the SON and WHO permissible limit of 250 mg/L, the well water samples recorded values below the SON and WHO standards for drinking water quality. The low readings show that the study's groundwater complies with the allowed level of Cl<sup>-</sup>, which, according to WHO (2008), is 250 mg/L for drinking water, mostly due to taste considerations. Water hardness, however, can be caused by excessive levels of chloride and sulfate (Kannan *et al.*, 2005).

#### Magnesium

Its concentrations in the hand-dug well water samples in this study ranged from 0.0343 to 0.0525 mg/L, with a mean concentration of 0.04; meanwhile, concentrations in the borehole water samples ranged from 0.0131 mg/L to 0.255 mg/L, with a mean value of 0.09 (Table 3; Sample Result Comparison with Water Quality Guidelines).

#### Cadmium

Cadmium (Cd) was detected in water samples taken from both hand-dug wells and boreholes, while Cd concentrations of 0.002 obtained in borehole samples are below the maximum limit of WHO and SON of 0.003mg/L. Cd concentration in samples 1, 2, 3, 5, and 6 exceeded the WHO and SON standards. Cadmium is a very toxic heavy metal, which can devastate a child's immune system within a short period of exposure, and the risks of Cd in the water samples can be amplified by its ability to increase in concentration as it moves up the food chain (Michaela *et al.*, 2011).

#### Chromium

The concentrations were detected in all the water samples. Hand-dug well ranged from 0.0079 to 0.0175mg/L with a mean value of 0.01, while the concentration of Chromium ranged from 0.0108 to 0.0255mg/L with a mean value of 0.02. The borehole water sample exceeded the SON permissible limit of 0.01 mg/L but remained below the WHO guideline limit of 0.05 mg/L. Also, Samples 1 and 3 exceed the permissible limit of 0.01 by SON. However, adequate measures should be taken to prevent Chromium (Cr) contamination of groundwater, as ongoing activities may increase Cr levels in the environment. Ingestion of water with Cr concentration above 0.05 mg/L can lead to cancer or allergic dermatitis (Siyanbola *et al.*, 2011).

#### Variation among Physicochemical Parameters in Hand-dug Well and Borehole Water

To investigate the amount of variation in hand-dug well and borehole water samples, a One-Way Analysis of Variance was performed on the water samples at  $\alpha = 0.05$

**SUMMARY**

Groups	Count	Sum	Average	Variance
Hand Dug Well	3	264.71	88.23667	35.25853
Borehole	3	393.38	131.1267	534.3

**ANOVA**

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2759.32	1	2759.32	9.68935	0.03577	7.70864
Within Groups	1139.11	4	284.779			
Total	3898.44	5				

The ANOVA test compares the means of two or more groups to determine if there is a statistically significant difference between them. The descriptive statistics in the summary section indicate that the mean of the measured variable differs between the two groups. The average values for Hand Dug Well are 88.23667, while for Borehole are 131.1267. This suggests a potential difference in the outcome variable between the two types of wells.

The ANOVA table provides further insights into the significance of this difference. The between-groups analysis reveals a large F-statistic of 9.689357, indicating that the variability between the group means is much greater than the variability within each group. This is supported by the associated p-value of 0.035776, which is less than the conventional significance level of 0.05. According to Andrade (2020), such a small p-value indicates that the observed difference between group means is unlikely to have occurred by chance alone.

Additionally, the effect size, as measured by chi-squared ( $\eta^2$ ), is approximately 0.7086. According to Cohen (1988), this suggests a large effect size, indicating that the type of well explains a substantial portion of the variance in the measured variable.

**Conclusion**

The physicochemical characteristics of groundwater around the dyeing sites reveal concerning deviations from recommended standards. Despite similar temperature ranges observed in both hand-dug wells and borehole water samples, the values exceeded the WHO permissible limits, potentially adversely affecting water quality. pH levels are below the WHO's recommended range, which could affect water treatment procedures and indirectly impact human health. Alkalinity levels are generally within acceptable limits; however, elevated values recorded in some areas may be attributed to runoff, which could adversely affect groundwater quality. Turbidity levels are within the ideal range, but Total Dissolved Solids (TDS) exceed WHO's limits, possibly due to industrial effluent discharge. Ionic species such as calcium, sulphate, and chlorine were within acceptable levels; however, some samples contained toxic heavy metals, including Cadmium and Chromium, which exceeded safety thresholds, posing health

risks to consumers. Overall, these findings underscore the importance of monitoring and mitigating the environmental impacts of dyeing activities on groundwater quality. The investigation into variation in water quality between hand-dug wells and boreholes revealed a statistically significant difference between the two water sources. The physicochemical analysis of groundwater near dyeing sites reveals deviations from recommended standards and the presence of toxic heavy metals, underscoring the need for monitoring and mitigation of the environmental impacts of dyeing activities.

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