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## Chapter

# Perspective Chapter: Environmental Assessment on the Effect of Chemical Waste from Dyeing Industries in Zaria

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## Abstract

The research study was done on groundwater obtained from waste wells, well around the waste wells and wells about 5 km from the dyeing sites of Zaria, in Kaduna state of Nigeria. The objectives were to assess the status of pollution on local dyeing areas, the occupational hazard associated with this activity and the impact on the residents of the area. Parameters such as pH, coli form bacteria, conductivity, colour, DO, BOD, COD, chlorides, total available nitrogen, cadmium, chromium, lead, mercury and alkalinity were determined and statistical analysis carried out to evaluate the Significant difference of pollutants in the area studied.

**Keywords:** groundwater, dyeing industry, Zaria metropolis, heavy metals, pollution

## 1. Introduction

Water is essential to maintain and sustain human life, animals and plants [1], this is because it constitutes to a large extent, the major solvent in which many of the body's proteins and other substances are dissolved. It enables many metabolic activities of the body to take place [2]. Water is essential for growing food, for domestic uses and as a critical factor in industries, tourism and cultural purpose as it helps in sustaining the earth's ecosystem. According to Ajibade et al., [3] 90% of the population in Nigeria depends largely on hand dug wells and boreholes [4]. Rapid growth in urban populations, industrial activities, commercial and agricultural developments result in an increase in the search for potable water. The preference of groundwater as a source of drinking water in rural areas is because of its relatively better quality than that of river water [5]. Historically, the point of rural settlement was being determined by water source such as stream, river and spring [6]. The inhabitants of rural settlements relied on groundwater often within a few meters of the surface which they exploited by digging wells. Access to safe drinking water is a basic human need and a fundamental human right that is crucial for poverty reduction [7].

According to a report [8] this situation forces people to consume untreated water from rivers and ponds and represents a high risk to their health [9].

Kaduna State was famous for its traditional indigo dyeing pits, during the Trans Sahara trade in Northern part of the country. Local industries like the dyeing industry, proved vital to Nigeria's socio-economic development, apart from providing employment to a good number of people; it serves as source of tourist attraction. These local industries used a local technology of dyeing and discharge of waste. Ideally citing industries should strike a balance between socio-economic and environmental considerations. This was not the case with local dyeing industries in Zaria; which were mostly located within the city walls and surrounded by settlements. The mode of disposal was usually in pits dug for that purpose. Previous studies, when the dyeing activities were functional, have shown contamination of ground water in close proximity to the dye wastes well in Zaria [10]. The findings show environment-related ailments ranging from skin and eye problems to cancerous tumours and methaemoglobinaemia in children which were attributed to the disposal of dye wastes in these areas. Even though most of these dyeing pits have long been abandoned, their impacts on the settlements around them are still persisting.

## **2. Research methodology**

### **2.1 Sample collection**

Samples were collected from local dyeing areas located in northern Nigeria namely, Zaria a major city in Kaduna state (**Figure 1**). The dye wastes are normally disposed in waste wells dug around these local dyeing industries. Each well is approximately 3.5 m deep. Samples were collected in February 1998 and August 1998, which represents the peaks of dry and wet seasons in these areas respectively.

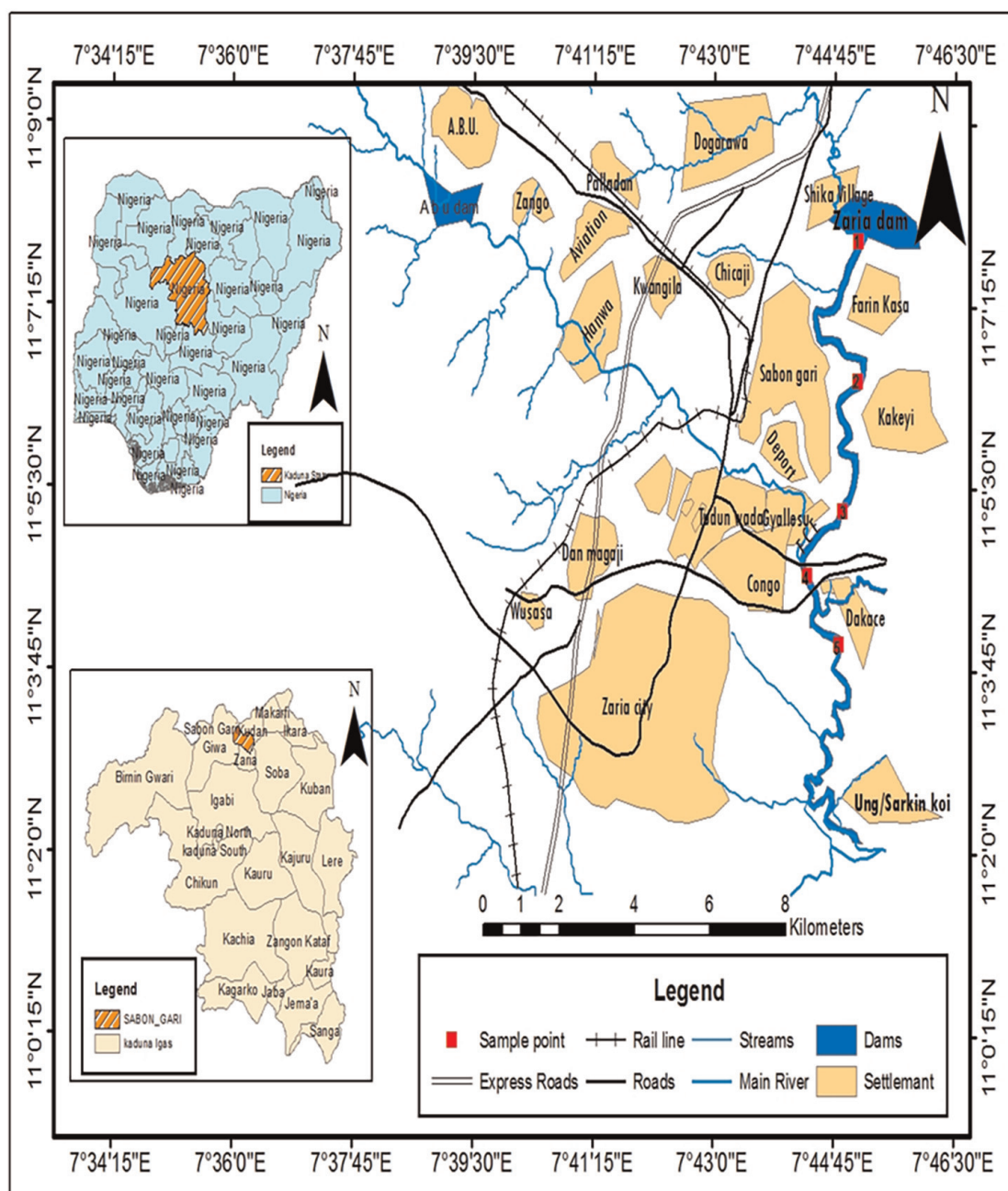
Samples of wastewater (about 2 litres) were collected using plastic containers. Samples were also collected from wells at a depth of approximately 15 m, 30 m, and 45 m radius from the waste wells. All the samples were stored in an airtight screw capped plastic bottles. Samples were also collected from wells located about 5 km away from local dyeing industries (**Table 1**). All the water samples collected were coded with reference to their site of collection as:

### **2.2 Measurements of physicochemical parameters**

The physicochemical properties of water, plays a vital role in determining the extent to which heavy metal pollution of water occurs. Standard methods as recommended by relevant authorities such as World Health Organisation (WHO), United States Environmental Protection Agency (US-EPA), etc. were employed for the preparation of reagents and determination of all water quality parameters.

### **2.3 Determination of pH**

The pH of the water samples was determined using a portable pH meter after being standardised with buffers of pH 4.0 and pH 9.2 [11].



**Figure 1.**  
 Map of Zaria and its environment.

Code	City	Location of dyeing industry
ZA <sub>1</sub> , ZA <sub>2</sub> and ZA <sub>3</sub>	Zaria	Karofin Bakin Kasuwa
ZB <sub>1</sub> , ZB <sub>2</sub> and ZB <sub>3</sub>	Zaria	Karofin Mabuga
ZC <sub>1</sub> , ZC <sub>2</sub> and ZC <sub>3</sub>	Zaria	Karofin Karanka
ZN	Zaria	5 km away from dyeing industry

**Table 1.**  
 Location of dyeing industry and representative codes used in the study.

## 2.4 Determination of colour

Colour was determined by visual comparison using Lovibond colour disc (Pt-Co). The disc consists of different colours which is graduated. Sample was placed on disc and observed to see colour changes, and then the reading was taken for the colour which it corresponds with [12, 13].

## 2.5 Determination of conductivity

Conductivity of the surface water and the underground water samples was determined using the standard procedure approved by AOAC (1998). The conductivity meter (Hach model CO150) was used. The power key and the conductivity key of the conductivity meter was switched on, and the temperature of the meter adjusted; the instrument was calibrated with 0.001 M KCl to give a value of 14.7mS/m at 25°C. The probe was dipped below the surface of both samples. Time was allowed for the reading to be stabilised and the reading was recorded [14].

## 2.6 Determination of dissolved solids

Water sample (100 cm<sup>3</sup>) was quantitatively transferred into an evaporating dish that has been previously weighed and dried in an oven for one hour and cooled in desiccators. The content of the dish was evaporated to dryness on a water-bath to a constant weight. The residue was dried in an oven between 103 and 105°C for two hours; then cooled in a desiccator and the difference in weight calculated using the following equation [12, 15].

$$DS \text{ (mg/L)} = \text{difference in weight} \times 1000 \text{ ml of sample} \quad (1)$$

## 2.7 Determination of chemical oxygen demand (COD)

The COD of the surface water and the underground water samples was determined using the standard method described by Ademoroti [11]. 0.4 cm<sup>3</sup> of H<sub>2</sub>SO<sub>4</sub> was placed in a refluxing flask. About 20 cm<sup>3</sup> of the samples was diluted with 20 cm<sup>3</sup> of distilled water. Exactly 10 cm<sup>3</sup> standard solution of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> was then added to glass leads already heated to 600°C for 1 hour. The flask was then attached to the reflux condenser and about 30 cm<sup>3</sup> of concentrated H<sub>2</sub>SO<sub>4</sub> containing Ag<sub>2</sub>SO<sub>4</sub> was added through the open end of the condenser. The resulting solution was thoroughly mixed by switching. The mixture was refluxed for 1 hour, cooled and the condenser was washed with about 25 cm<sup>3</sup> of distilled water. The mixture was diluted with 150 cm<sup>3</sup> of distilled water and cooled to room temperature. About 3 drops of (0.10–0.15 cm<sup>3</sup>) ferroin indicator was added. The mixture was the titrated with Fe(NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub> taking as the end point the sharp colour change from blue-green to reddish brown. In the same manner a blank containing 20 cm<sup>3</sup> distilled water was refluxed together with the reagent.

$$\text{COD} \frac{\text{mg}}{\text{l}} = (a - b) \times M \times 8000 \text{ ml of sample} \quad (2)$$

Where a = cm<sup>3</sup> Fe (NH<sub>4</sub>)<sub>2</sub> (SO<sub>4</sub>)<sub>2</sub> used as blank,

b = cm<sup>3</sup> Fe (NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub> used for sample and M = Molarity of Fe (NH<sub>4</sub>)<sub>2</sub> (SO<sub>4</sub>)<sub>2</sub>.

## 2.8 Determination of dissolved oxygen

The azide modification of the Winkler's method was used to determine dissolved oxygen (DO) and biological oxygen demand (BOD). 250 cm<sup>3</sup> of the sample was introduced into a stopped dark bottle and 2 cm<sup>3</sup> of manganese sulphate solution and 2 cm<sup>3</sup> alkali-iodide-azide reagent was added well below the surface of the liquid and mixed by inverting the bottle several times. Then 5 cm<sup>3</sup> of conc. H<sub>2</sub>SO<sub>4</sub> was added immediately precipitate settled. The bottle was then shaken to ensure distribution of iodine, until titrant changed to pale-straw colour. 25 cm<sup>3</sup> of the mixture with 5 cm<sup>3</sup> of starch indicator was then titrated against 0.01 M sodium thiosulphate.

Titration continued until first disappearance of the blue colour. The titration was carried out three times and average titre value obtained was the equivalent value of dissolved oxygen (DO).

## 2.9 Determination of biological oxygen demand (BOD)

A fresh sample was incubated at 20°C for five days and the above procedure for the determination of dissolved oxygen was then repeated. The difference between DO for incubated sample and DO not incubated was determined [13].

$BOD_5 \text{ mg/L} = DO(0) - DO(5) \text{ dilution factor}$ .

Dilution factor = no of days ml of sample.

Where DO (5) = demand oxygen at day five and DO (0) = dissolved oxygen before incubation.

## 2.10 Determination of nitrate, phosphate and sulphate

The HANNA multi parameter logging spectrophotometer (HI83200) was used to digitally determine the nitrate, phosphate and sulphate in the surface water and ground water samples. The concentration of nitrate, sulphate and phosphate was determined using standard procedure. Sulphate was determined using Sulfa Ver methods 8051. Phosphate was determined using direct reading from HI 83200 HANNA multi parameter.

## 2.11 Determination of total alkalinity

Water sample (100 cm<sup>3</sup>) was transferred into a conical flask, two drops of phenolphthalein indicator was added and the solution titrated with H<sub>2</sub>SO<sub>4</sub> to the end point. Again, two drops of methyl orange was added to the titrated mixture and titration was continued to methyl orange end point [12].

$$\text{Total Alkalinity, mg CaCO}_3 \text{ A} \times \text{B} \times 1000 \text{ ml of sample} \quad (3)$$

Where A = Vol. of standard H<sub>2</sub>SO<sub>4</sub> and B = Titre of standard acid.

## 2.12 Digestion of water sample

The determination of heavy metals in water is often regarded as the movement of total suspended and dissolved metals (soluble metals). In such cases consistent and dependable digestion procedures must be used so that data derived for total metal content is reliable. The water was immediately digested after sampling to prevent

changes in composition of water samples according to standard procedures of the American Public Health Association [16].

### 2.13 Procedure for water digestion

Water samples ( $100\text{ cm}^3$ ) were transferred quantitatively into beakers containing concentrated  $\text{HNO}_3$  acid ( $10\text{ cm}^3$ ) and concentrated  $\text{HCl}$  ( $5\text{ cm}^3$ ) in ratio (2:1) and heated on a hot plate making sure the sample did not boil, until the volume was reduced to about  $15\text{ cm}^3$ . The samples were then allowed to cool, filtered and quantitatively transferred into a  $100\text{ cm}^3$  standard volumetric flask and made up to mark with distilled water and further analysed using AAS.

## 3. Results and discussion

The chemical analysis of samples from the three local dyeing industries namely; Bakin Kasuwa, Mabuga and Karauka and surrounding wells was done and results can be discussed in the following order (Tables 2–4).

Except for the wastewater sample in Karofm Mabuga which has a pH value of  $9.02 \pm 0.16$  during the dry season all pH values in the three dyeing industries; Bakin Kasuwa, Mabuga and Karauka fall within the accepted level of between 7.0 and 8.5. It could be inferred here that for the three places pollution is insignificant with regards pH values. The high pH value of  $\text{ZB}_3$ , during dry season could be as a result of high-alkalinity, the alkalinity of this waste well water is to the tune of  $6600 \pm 50\text{ mg/L}$ .

$\text{ZA}_3$  has alkalinity value of  $300 \pm 8.50$ ,  $\text{ZA}_2$ ,  $200 \pm 5.65\text{ mg/L}$  during dry and wet seasons respectively and a location where no dyeing activity took place has  $300 \pm 8.50\text{ mg/L}$ . Others are  $\text{ZB}_2$ , with  $300 \pm 5.00$ ,  $\text{ZB}_3$  with  $300 \pm 10.11\text{ mg/L}$  and also  $\text{ZC}_2$ ,  $300 \pm 5.76$ ,  $\text{ZC}_3$   $300 \pm 4.87\text{ mg/L}$ . All these values are below the permissible level of  $500\text{ mg/L}$  of alkalinity and are obtained during the wet season. All other values were found to be higher than the acceptable level. The lower values during the wet season are obtained due to dilution of underground water by penetration and increase in volume by rain water. The lower values can also be inferred from low values of conductivity and pH. This was found to be higher than those of WHO standard.

Considering the permissible level, the likelihood of pollution is imminent since the colour unit of more than 5 Hazen unit is unacceptable in drinking water and water for domestic purposes. All the waste water samples for the three areas (Bakin Kasuwa Mabuga and Karauka) have greatly exceeded this limit both during dry season and wet season, though higher values are obtained during wet season,  $\text{ZC}$ , well has  $5500 \pm 500$  Hazen,  $\text{ZB}$ , has  $12,500 \pm 500$ . These are the highest values for waste wells recorded during wet season. The well water samples have values within acceptable levels with the exception  $\text{ZA}$ , and  $\text{ZC}_3$  with  $10 \pm 0.0$  Hazen respectively during the wet season. Colouration during the wet season may not be unconnected with presence of suspended particles as a result of movement of soil particles by penetration of rain-water. Comparing these values with that of the control site there is a certain degree of agreement in both dry and wet seasons.

Conductivity values of the wastewater samples in the three industries in Zaria ( $\text{ZA}_3$ ) are high exceeding the levels permitted. This shows the presence of soluble, once and other dissolved solids. However, well water samples especially  $\text{ZA}_1$ ,  $\text{ZA}_2$ ,  $\text{ZB}_3$  and  $\text{ZC}_1$ , all during dry season have concentrations slightly higher than the acceptable value [17, 18].

Parameter	Unit	Dry season samples				Wet season samples			
		ZA <sub>1</sub>	ZA <sub>2</sub>	ZA <sub>3</sub>	Z <sub>N</sub>	ZA <sub>1</sub>	ZA <sub>2</sub>	ZA <sub>3</sub>	Zn
pH		8.49 ± 0.11	8.28 ± 0.01	8.37 ± 0.01	7.65 ± 0.02	7.05 ± 0.02	7.03 ± 0.11	7.00 ± 0.07	7.05 ± 0.05
Coliform count	*MPN	7.00 ± 1.40	2	2	2	7.00 ± 1.60	5.00 ± 0.40	ND	2,00 ± 0.59
Conductivity x 10 <sup>2</sup>	mS/m	75 ± 5.00	20.00 ± 2.31	21.00 ± 1.29	10.2 ± 1.33	18.5 ± 2.3	17 ± 2.00	1.20 ± 0.2 1	8.50 ± 0.68
Colour	Hazen	1500 ± 250.00	5	5	5	1500 ± 50.50	10.00 ± 7.07	5	5
DO	mg/L	3.00 ± 0.01	8.00 ± 1.00	5.00 ± 1.00	10.00 ± 0.10	4.00 ± 1.00	9.00 ± 1.00	10.00 ± 1.00	12.00 ± 1.00
BOD	mg/L	2.40 ± 0.06	3.20 ± 0.07	2.28 ± 0.61	3.20 ± 1.25	4.80 ± 0.15	2.08 ± 0.10	3.68 ± 0.10	3.80 ± 0.25
COD	mg/L	144.00 ± 4.31	100.00 ± 0.39	92.00 ± 0.22	12–00 ± 0.03	120.00 ± 0.57	76.00 ± 1.97	64.00 ± 4.30	36.00 ± 2.01
NO <sub>2</sub> <sup>-</sup> N	mg/L	37.50 ± 1.11	43.00 ± 0.61	11.50 ± 0.67	17.50 ± 0.15	26.00 ± 0.12	37.00 ± 4.30	11.00 ± 2.40	15.00 ± 0.76
Chlorides	mg/L	351.00 ± 0.20	280.13 ± 0.01	209.21 ± 0.01	280.13 ± 38. 90	336.87 ± 32.90	3540.0 ± 0.02	3540 ± 0.01	531.10 ± 5.66
**TAN	mg/L	72.00 ± 0.05	74.00 ± 0.51	25.00 ± 0.23	30.00 ± 0.76	34.00 ± 5.67	46.00 ± 5.03	25.0 ± 1.4	31.00 ± 2.22
Cd	mg/L	2.10 ± 0.01	3.00 ± 0.01	3.50 ± 0.01	1.60 ± 0.26	1.90 ± 0.1 8	2.50 ± 0.01	2.20 ± 0.01	2.30 ± 0.21
Cr	mg/L	2.20 ± 0.21	1.9 ± 0.01	1.40 ± 0.01	2.40 ± 0.01	1.70 ± 0.21	15.00 ± 0.03	1.80 ± 0.11	2.20 ± 0.12
Pb	mg/L	2.60 ± 0.01	2.50 ± 0.00	2.60 ± 0.01	1.25 ± 0.12	3.20 ± 0.01	3.50 ± 0.01	2.00 ± 0.04	1.50 ± 0.11
Hg	mg/L	0.90 ± 0.12	1.10 ± 0.02	1.000 ± 0.001	1.20 ± 0.15	ND	1.00 ± 0.02	1.30 ± 0.07	1.10 ± 0.03
Alkalinity	mg/L	7600 ± 3610	1300 ± 10	300.00 ± 8.50	700 ± 8.43	1300.00 ± 80.50	900.00 ± 6.78	200.00 ± 5.65	300.00 ± 8.50

\*Most probable number.  
 \*\*Total available nitrogen.  
 ND—not detected.

**Table 2.**  
 Results from Zaria (Karofin Bakin Kasuwa).



Parameter	Unit	Dry season samples				Wet season samples			
		ZC <sub>1</sub>	ZC <sub>2</sub>	ZC <sub>3</sub>	Z <sub>N</sub>	ZC <sub>1</sub>	ZC <sub>2</sub>	ZC <sub>3</sub>	Z <sub>N</sub>
pH		9.02 ± 0.16	8.04 ± 0.01	8.18 ± 0.66	7.65 ± 0.02	7.46 ± 0.15	5.73 ± 1.67	7.37 ± 0.71	7.05 ± 0.05
Coliform count	*MPN	9.00 ± 1.50	9.00 ± 1.00	2.00 ± 0.50	2	6.00 ± 1.67	4.00 ± 1.10	4.00 ± 0.80	2.00 ± 0.59
Conductivity x 10 <sup>2</sup>	mS/m	52.50 ± 0.90	19.00 ± 0.70	21.0 ± 0.90	10.00 ± 1.33	450.00 ± 3.45	6.00 ± 1.66	18.00 ± 0.59	8.50 ± 0.18
Colour	Hazen	1000 ± 115.00	5	5	5	12,500 ± 500.00	10.00 ± 5.00	5	5
DO	mg/L	4.00 ± 1.50	8.00 ± 1.11	5.00 ± 2.20	10	6.00 ± 1.80	8.00 ± 1.12	9.00 ± 1.30	12.00 ± 1.00
BOD	mg/L	3.60 ± 0.60	1.60 ± 1.21	3.20 ± 1.11	3.20 ± 1.25	6.00 ± 1.20	3.20 ± 0.87	1.80 ± 0.92	3.80 ± 0.25
COD	mg/L	156.00 ± 2.39	92 ± 8.09	84 ± 6.06	12.00 ± 0.03	180.00 ± 2.39	20.00 ± 1.17	40.2 ± 1.80	36 ± 2.00
NO <sub>2</sub> <sup>-</sup> N	mg/L	13.00 ± 5.50	130 ± 0.90	10.00 ± 1.19	17.50 ± 0.15	21.00 ± 0.40	20.00 ± 0.44	9.00 ± 1.26	15 ± 0.76
Chlorides	mg/L	138.29 ± 8.0 8	138.29 ± 0.50	138.29 ± 0.89	280.13 ± 3.89	141.84 ± 0.5 9	138.29 ± 0.89	124.11 ± 0.56	531.90 ± 5.66
**TAN	mg/L	35.0 ± 5.60	27.00 ± 2.42	19.00 ± 2.05	30.00 ± 0.76	39.00 ± 5.66	37.00 ± 0.72	21.00 ± 0.45	31.00 ± 2.22
Cd	mg/L	2.00 ± 0.16	ND	1.70 ± 0.09	1.60 ± 0.26	2.10 ± 0.04	1.60 ± 0.06	1.80 ± 0.02	2.30 ± 0.02
Cr	mg/L	1.80 ± 0.10	2.40 ± 0.03	2.50 ± 0.02	2.40 ± 0.01	1.80 ± 0.10	2.50 ± 0.03	2.60 ± 0.01	2.20 ± 0.21
Pb	mg/L	3.25 ± 0.02	2.50 ± 0.11	1.90 ± 0.11	1.25 ± 0.12	2.45 ± 0.05	1.75 ± 0.05	1.25 ± 0.04	1.50 ± 0.11
Hg	mg/L	1.20 ± 0.07	1.09 ± 0.01	1.00 ± 0.03	1.20 ± 0.15	1.10 ± 0.05	1.00 ± 0.09	0.95 ± 0.04	1.10 ± 0.03
Alkalinity	mg/L	6600 ± 50	800 ± 46.00	1700.00 ± 80.90	700.00 ± 8.43	8000 ± 100	300 ± 5.00	300.0 ± 10.1	300.00 ± 8.50

\*Most probable number.

\*\*Total available nitrogen.

ND—not detected.

**Table 3.**  
Results from Zaria (Karofin Mabuga).

Parameter	Unit	Dry season samples				Wet season samples			
		ZB <sub>1</sub>	ZB <sub>2</sub>	ZB <sub>3</sub>	Z <sub>N</sub>	ZB <sub>1</sub>	ZB <sub>2</sub>	ZB <sub>3</sub>	Z <sub>N</sub>
pH		7.68 ± 0.29	7.65 ± 0.30	8.03 ± 0.67	7.65 ± 0.02	7.57 ± 0.66	7.63 ± 0.24	7.92 ± 0.11	7.05 ± 0.05
Coliform count	*MPN	6 ± 1.00	6.00 ± 0.50	ND	2	2.00 ± 0.60	6	2	2.00 ± 0.59
Conductivity x 10 <sup>2</sup>	mS/m	61.00 ± 17.14	20.00 ± 10.14	8.59 ± 0.49	10.00 ± 1.33	20.00 ± 0.80	17.00 ± 0.74	18.0 ± 1.7	8.50 ± 0.16
Colour	Hazen	1000	5	5	5	5500 ± 500.00	10	10	5
DO	mg/L	12 ± 2	8.00 ± 0.12	6.00 ± 2.10	10 ± 0	10 ± 0	9.00 ± 1.40	10.0 ± 1.0	12 ± 1.0
BOD	mg/L	3.20 ± 1.47	3.68 ± 1.20	2.28 ± 1.11	3.20 ± 1.25	7.00 ± 1.17	2.88 ± 0.03	2.68 ± 0.12	3.80 ± 0.25
COD	mg/L	208.00 ± 62.79	104.0 ± 31.4	92.00 ± 6.06	12.00 ± 0.03	156.00 ± 9.09	72.00 ± 1.02	84.00 ± 1.96	36 ± 2.00
NO <sub>2</sub> <sup>-</sup> N	mg/L	12.00 ± 3.70	9.00 ± 2.10	11.00 ± 1.18	17.50 ± 0.15	20.00 ± 0.06	13.00 ± 3.66	11.00 ± 3.3	15.00 ± 2.21
Chlorides	mg/L	138.29 ± 0.50	138.29 ± 1.90	138.29 ± 0.89	280.13 ± 38.9	3540.0 ± 13.8	177.30 ± 5.36	141.84 ± 0.04	531.90 ± 5.66
**TAN	mg/L	22.00 ± 6.74	16.00 ± 2.45	22.00 ± 0.76	30.00 ± 0.76	38.00 ± 2.06	25.00 ± 0.30	27.00 ± 0.66	31.00 ± 2.21
Cd	mg/L	3.00 ± 0.08	2.00 ± 0.06	2.10 ± 0.26	1.60 ± 0.26	3.70 ± 0.16	2.30 ± 0.02	2.90 ± 0.12	2.10 ± 0.02
Cr	mg/L	1.70 ± 0.06	1.80 ± 0.08	1.80 ± 0.01	2.40 ± 0.01	2.00 ± 0.11	2.30 ± 0.11	1.90 ± 0.10	2.20 ± 0.21
b	mg/L	2.40 ± 0.08	1.50 ± 0.06	1.75 ± 0.05	1.25 ± 0.12	3.25 ± 0.05	1.25 ± 0.05	1.90 ± 0.05	1.50 ± 0.11
Hg	mg/L	0.95 ± 0.01	1.50 ± 0.02	0.95 ± 0.15	1.20 ± 0.15	1.10 ± 0.09	1.06 ± 0.07	1.00 ± 0.02	1.10 ± 0.03
Alkalinity	mg/L	6900 ± 253	1200 ± 535	700.00 ± 7.67	700.00 ± 8.43	600.00 ± 5.64	300.00 ± 5.76	300.00 ± 4.87	300.00 ± 8.50

\*Most probable number.

\*\*Total available nitrogen.

ND—not detected.

**Table 4.**  
 Results from Zaria (Karofin Karauka).

The rest fall below the acceptable level, the fact that those that exceeded the acceptable value were only during dry season shows that ions are more concentrated during dry season because of the absence of dilution by rainwater.

The three respective areas studied in Zaria showed that the waste water wells, drinking water wells and wells in a location where no dyeing activity took place have all exceeded the possible level of 0.01 mg/L cadmium concentration [19, 20]. The only exception is ZB<sub>3</sub>, with non-determinable value during the dry season. These showed slight variations with those of WHO standard.

The maximum permissible level of chromium is 0.05 mg/L [21, 22]. The three respective areas have high chromium concentrations when compared to this standard.

Lead concentration of 0.1 mg/L is the concentration permissible in drinking water. Lead concentrations in the three respective areas of Zaria have all exceeded this level. The highest concentration was found in well ZA<sub>2</sub> during dry season with  $3.50 \pm 0.05$  mg/L and the lowest is ZC<sub>2</sub> during wet season with  $1.25 \pm 0.05$  mg/L. The lead concentration in wells from Kano and Katsina fall between the higher and the lower values here. This signifies little variation and high lead toxicity since the tolerance level has been exceeded [23, 24].

ZA, wastewater well is the only well with a non-determinable value of mercury concentration during the wet season in the three areas under study. All other wells here exceeded the permissible level of 0.0001 mg/L [25]. The environmental threat here associated with mercury is very significant for all the three areas. Concentrations of mercury as high as  $1.50 \pm 0.02$  mg/L were obtained.

If the permissible level of chlorides concentration of 200 mg/L as reported by Ayoade is considered then, all the wells in Karofm Bakin Kasuwa have exceeded this level. However, in Karofin Mabuga only the well in the neutral location exceeded this level during dry and wet season with a concentration of  $280.13 \pm 3.89$  and  $531.90 \pm 5.66$  mg/L respectively. This may be due to the underlying soil structure as having less salt content as compared to Zaria Karofin Bakin Kasuwa. Apart from the well in the neutral location only one well ZC, during the wet season exceeded the level with a concentration of  $3540 \pm 13.83$  mg/L. The reason for this variation may also be due to the soil texture and composition. The threat of chlorides can only be significant in the area of Karofin Bakin Kasuwa. Generally, values here are not as high as those found in Kano and Katsina [26–28]. This may also be due to variation in soil texture and composition.

The waste wells, the well in a location where no dyeing activity took place and the drinking water wells for both seasons in all the three areas (Bakin Kasuwa, Mabuga and Karauka) have all not exceeded the Nitrate permissible level of 45 mg/L [29].

Water quality can be indicated by DO values. DO values are between  $12 \pm 1.00$  mg/L for the neutral well water wells and 3 mg/L for the ZA, waste water well during dry season. It could be seen that wastewater wells have lower DO values than the other wells. This may be due to chemical and biochemical demand because of the presence of organic and biological materials in the waste samples. However, it is noted that DO values are higher for all the three areas (Bakin Kasuwa, Mabuga and Karauka) during the wet season. This is because there may be more dissolved oxygen in rainwater, which eventually finds its way to the underground well waters through percolation.

BOD values for Bakin Kasauwa, Mabuga and Karauka waste wells during the wet season i.e. ZA<sub>1</sub>, ZB<sub>1</sub>, and ZC<sub>1</sub>, are  $4.80 \pm 0.15$ ,  $6.0 \pm 1.2$  and  $7.00 \pm 1.17$  mg/L. The ZC<sub>1</sub>, exceeded the acceptable level of 6.0 mg/L BOD and ZB, slightly exceeding the level. However, not all other values for wastes and drinking water samples exceeded the permissible level. This shows in the wastewater wells outlined above, that

biochemical activity is prominent during the wet season. This can be further enhanced by humid and other favourable conditions that are obtained during wet season. Therefore, coliform bacteria may be more prominent as the only surviving organism showing significant activity in all the samples here.

COD values should not exceed 10 mg/L standard. However, all the results for Bakin Kasuwa, Karauka and Mabuga have exceeded this level in all seasons. The only well close to this is the neutral well during the dry season with  $12 \pm 0.03$  mg/L. There is no clear variation as to the content of the COD during wet and dry season for all the three areas. It is therefore noteworthy that many organic materials may be found herein.

#### **4. Conclusion**

The research agrees with what the medical examinations in the literature assert, which shows that local dye workers at Bakin Kasuwa, Mabuga and Karauka exhibited clear signs of lung and skin diseases notably, contact dermatitis and other fungal diseases like eczema. The skin diseases could have been caused by contact with organic dye materials that might have absorbed UV radiations from the sunlight. In addition, concentrations of heavy metals like chromium could have also contributed to causing dermatitis. Lung diseases could be associated with chromium and high lead concentrations, which could have led to lung damage and ultimately cancer. Other diseases such as gastroenteritis, evidenced in some of the local dye workers as also reported in the literature could have been because of coliform bacteria, which were significantly present in the water of the well.

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