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Original Article

Characterization and cytogenotoxicity of water samples from Challawa River in Kano, Northwest Nigeria

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Abstract

This study assessed the cytogenotoxicity of water samples obtained at the discharge site and about 1.5 km downstream of the discharge site of a textile factory along Challawa River, Kano, Nigeria. After physicochemical and microbial characterizations, water samples were used to grow 20 *Allium cepa* bulbs divided into two equal groups for 72 hrs. A control group was similarly conducted, but was grown over deionized water. Root-tips of the bulbs were then examined for chromosomal aberrations. Physicochemical analysis showed that the levels of Ca, Cd, Cr, Pb, DO, BOD, COD, turbidity, and nitrate in both water samples were not within WHO standards. Only the bacterial loads of samples from 1.5 km distance were abnormal in the microbial analysis. A significant ($p<0.05$) reduction in mitotic index and bi-nucleated cells, sticky and vagrant chromosomes were observed in the treated bulbs. These findings showed that the water samples could be toxic.

Keywords: bi-nucleated cells, BOD, cytogenetics, microbes, mitotic index

1. Introduction

Rivers are a major determinant of human settlement because water is necessary for growth and development (Bindu & Mohamed, 2016; Silva, Serdoura, & Pinto, 2006). Water is essential for agriculture and provides a conducive environment for humans, other animals, and plants (Pimentel *et al*., 2004). River banks are used for leisure and sport events as well as tourism (Srinivas, 2016). Some industries are also sited close to rivers because they need water for production as well as to discharge wastes. These multifunctional roles of water increase the liveability of communities along rivers; however, many activities also pollute and degrade rivers. Solid wastes, chemicals, and sewage from homes, industries and agricultural runoffs are discharged into rivers, affecting water quality and compromising the suitability of water resources for drinking, consumption and other domestic uses. In Kano, Nigeria, socioeconomic activities along Challawa River are observed to pollute the water body.

Notable among industries that use water from the Challawa River and discharge wastewaters into the river are textile, plastic, and tin factories. Challawa River is a major source of water in Kano for domestic use and irrigation and is a beehive of fishing activities. Thus, contamination of the river may have a wide impact on the residents, hence constant monitoring of the river is necessary. Though some studies

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have characterized water samples from the river, the results are inconsistent. For instance, while Akan, Abdulrahman, Ayodele, and Ogunbuaja (2009) and Egila, Dauda, Iyaka, and Jimoh (2011) detected elevated levels of some physicochemical parameters in water samples from the river, Waziri, Zakaria, and Audu (2015) and Udiba, Oko, and Anyim (2018) did not find such. Moreover, none of these studies evaluated the toxicity of water samples from the river in biological systems, especially the cytogenetic effects, which may be transmitted to generations unborn. Cytogenotoxicity studies, particularly *Allium cepa* toxicity test, have been used consistently in environmental monitoring since 1940s because it is cheap and gives accurate results in both plant and animal test subjects (Leme & Marin-Morales, 2009; Olorunfemi, Duru, & Okieimen, 2012). It is easy to carry out, takes a little time, and does not require much reagents and laborious preparations of test substances (Leme & Marin-Morales, 2009). This study, therefore, used *A. cepa* assay test to determine the cytogenotoxicity of water samples obtained from Challawa River in Kano, Nigeria.

2. Materials and Methods

2.1 Description of the study site

Challawa River originates from the Challawa Gorge dam in Challawa village, Kano, Northwest Nigeria. The river flows through Sharada Industrial Estate, which includes a notable textile factory as well as plastic, tin and other factories at about 1.5 km from the textile factory. The land around the mentioned areas is used for washing, animal grazing, fishing and irrigation of plants such as tomatoes, peppers, and leafy vegetables. Kano is the capital of Kano State at 11° 59' 18.3" N and 08° 32' 05.8" E (Figure 1). The state is 418 m above the sea level (Akan, Ogunbuaja, Abdulrahman, & Ayodele, 2007) and bordered by Kaduna State in the south, Katsina State in the west, Jigawa State in the east, and Niger Republic in the north. Kano State has a land mass of about 43, 285 km^2, representing about 4.69% of Nigeria's total land area (Mustafa & Yakudima, 2008). The people of the state are predominantly farmers, artisans and animal breeders. Kano residents also engage in trading, and the city is host to one of the largest textile markets in West Africa.

The vegetation of Kano State is Sudan savannah (Oyewole & Ojeleye, 2015), but long-term human activities and natural environmental degradation have changed the original vegetation of the state. The state has an annual rainfall between 800 to 1,000 mm (Nabegu, 2014), which begins in May and ends in October (Abaje, Ndabula, & Garba, 2014). According to Olofin (2008), the mean annual temperature of the state is about 26 °C.

2.2 Collection of water samples

Samples of Challawa River water were collected in duplicate at the discharge site and about 1.5 km downstream of the discharge site of a textile factory at different times of the day between March and June 2018. The sampling on Challawa River was done randomly on the bottom and surface in the middle and the bank of the river. Water samples were collected in sterilized plastic containers, covered tightly, and moved to the laboratory where they were stored in a refrigerator at about 4 °C before analysis.

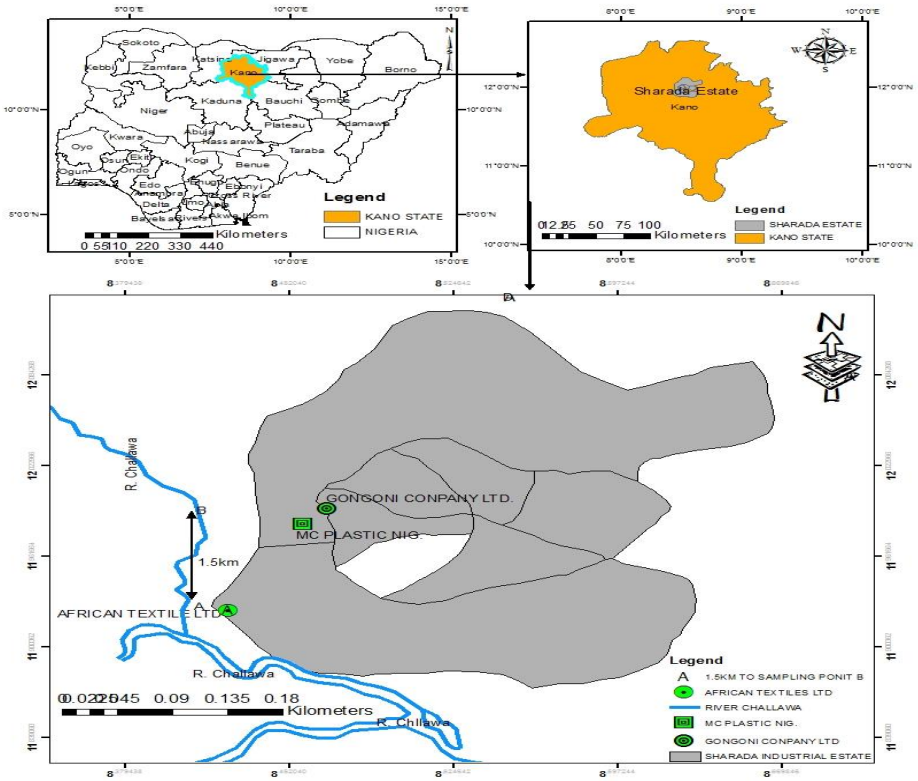

Figure 1. Challawa River and locations of some factories in Sharada Industrial Estate, Kano, Nigeria

2.3 Physicochemical analysis

Guidelines for measuring water quality parameters as described by APHA (2002) were used to determine the physicochemical parameters of the water samples. For accuracy, time sensitive parameters, including temperature, pH and electrical conductivity (EC), and total dissolved solids (TDS) were measured on-site with a mercury-in-glass thermometer, Pye Unicam pH and conductivity meter model 292, and HM Digital TDS meter model TDS-4, respectively. Other parameters such as turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) as well as sulphate and nitrate concentrations were measured in the laboratory. These parameters were measured using TU5 Series Turbidimeter model 400sc, Clark DO Sensors model 5500, HACH BOD instrument model 25638018, as well as Perkin Elmer UV spectrophotometer model lambda 45 HACH, respectively. Elements in the water samples, including calcium (Ca), magnesium (Mg), iron (Fe), cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), and manganese (Mn) were determined using UNICAM Atomic absorption spectrometer model 969.

2.4 Microbial analysis

Microbial populations in the water samples, including the total bacteria, coliform, and fungi counts were determined using the membrane filtration technique described by Brock (1983). One hundred (100) ml of each sample was passed through a sterile cellulose filter, after which the filter was placed on a nutrient agar plate and incubated for about 24 hrs at 35 ℃. The total bacteria colonies formed on the plate were then estimated using a colony counter. The coliform colonies were estimated using the two-step enrichment procedure in which the filters containing bacteria were placed on an absorbent pad saturated with lauryl tryptose broth and incubated at 35 ℃ for 2 hrs. The filters were then transferred to an absorbent pad saturated with M-Endo media and incubated for 22 hours at 35 ℃. Sheen colonies were seen and then estimated with a colony counter. To estimate the fungal populations, the nutrient agar was used, but the agar nutrient was supplemented with an antibiotic to prevent bacterial growth (Babič *et al*., 2017).

2.5 Collection of *Allium cepa* bulbs and Cytogenotoxicity test

The *A. cepa* toxicity test described by Fiskesjo (1988) was used to determine the cytogenotoxic effects of the water samples. Sixty (60) *A. cepa* bulbs weighing between 30 and 32 g each were obtained from the market in December 2018. The *A. cepa* bulbs were air-dried for 14 days, after which thirty (30) viable bulbs were selected for the study. The bulbs were subjected to surface sterilization, after which they were divided into three groups of ten each. Group 1 contained the control samples and was grown over beakers containing 100 ml deionized water under ambient temperature and humidity for 72 hrs. Groups 2 and 3 contained the test samples and were grown under the same conditions as the control over water samples obtained from the two sampling points, respectively. The root length of the *A. cepa* bulbs were recorded during the experiment, after which the roots were cut and fixed instantly in Aceto-alcohol in the ratio 1:3. The root tips of each bulb were macerated in drops of 1 N HCl at 60 ℃ for three minutes and then stained with Carbol Fuchsin (Koa, 1975). The mixture was later squashed in a 2% Aceto-orcein in 45% acetic-acid. Permanent slides were made and mounted on Canadian turpentine for identification of chromosomal abnormalities. Chromosomal abnormalities were determined and calculated by examining one thousand (1000) cells in each slide.

2.6 Data analysis

Data were expressed as mean ± standard error of mean (SEM). The statistical difference between the control and test groups was analyzed using one-tailed student's *t*-test. The value of $p \leq 0.05$ was considered significant.

3. Results

3.1 Physicochemical parameters

Table 1 shows the physicochemical parameters of the water samples collected at the discharge site of the textile factory versus water samples collected at about 1.5 km downstream of the first collection site. The concentrations of Ca, Cd, BOD, COD, DO, turbidity and nitrate in the water samples collected from the first sampling point were not within the respective WHO permissible limits for wastewaters. In the water samples obtained from the second sampling point, the levels of Ca, Cd, Cr, Pb, BOD, COD, turbidity and nitrate were also not within the permissible limits. However, the concentrations of other tested parameters, including pH, Mg, Fe, Mn, Ni, EC, TDS and sulphate in the two water sample groups were within the normal ranges. Significant differences ($p<0.05$) exist between the two water sample groups in the concentrations of EC, TDS, Ca, Mg, Pb, Ni, DO, COD, and nitrate.

3.2 Microbial loads

The microbial loads of the two water sample groups are revealed in Table 2. The bacteria and fungi loads of the water samples collected from the first sampling point did not exceed the WHO limits, and coliforms were not detected. Similarly, the microbial loads of the water samples collected at the second sampling point did not exceed the permissible limits, except the bacteria load, which was as much as 290,000 CFU/ml.

3.3 Root length increase of the exposed *A. cepa*

Table 3 compares the root length of the *A. cepa* bulbs grown over the two water sample groups with the control. Water samples significantly retarded ($p<0.05$) the root length of the *A. cepa* bulbs compared with the control, with the bulbs grown over water samples collected from the second sampling point being the most significant. While the control group gained 1.31 cm at the end of the treatment, the bulbs treated with water samples from the first and second sampling points lost 0.66 and 0.80 cm, respectively.

Table 1. Physicochemical parameters of water samples obtained at the discharge site and 1.5 km downstream of the discharge site of a textile factory along the Challawa River, Kano, Nigeria

Parameter	Water sample 1	Water sample 2	WHO Limit
Temp (°C)	$23.42^{a} \pm 1.02$	$23.32^{a} \pm 1.04$	25^{0}
pH (-)	$6.80^{a} \pm 0.01$	$6.02^{a} \pm 0.02$	6.0 - 9.0
EC (µS/c^{3})	$800.02^{a} \pm 10.02$	$25.12^{b} \pm 2.02$	1,000
TDS (mg/l)	$567.17^{a} \pm 15.17$	$189.53^{b} \pm 8.24$	2,000
Turbidity (NTU)	AL*	AL*	5.0
Ca (mg/l)	$*1.02^{a} \pm 0.17$	$*2.18^{b} \pm 0.10$	0.01
Mg (mg/l)	$10.37^{a} \pm 2.01$	$30.53^{b} \pm 4.27$	60.0
Fe (mg/l)	$1.54^{a} \pm 0.21$	$1.37^{a} \pm 0.17$	5.0
Cd (mg/l)	$*0.03^{a} \pm 0.01$	$*0.03^{a} \pm 0.01$	0.01
Cr (mg/l)	$0.04^{a} \pm 0.01$	$*0.07^{a} \pm 0.01$	0.05
Pb (mg/l)	$0.01^{a} \pm 0.00$	$*0.07^{b} \pm 0.01$	0.02
Ni (mg/l)	$0.01^{a} \pm 0.00$	$0.03^{b} \pm 0.01$	0.2
Mn (mg/l)	$0.03^{a} \pm 0.01$	$0.04^{a} \pm 0.01$	0.2
DO (mg/l)	$*0.06^{a} \pm 0.02$	$1.95^{b} \pm 0.01$	1.0
BOD (mg/l)	$*192.20^{a} \pm 10.02$	$*104.46^{a} \pm 9.27$	60.0
COD (mg/l)	$*925.10^{a} \pm 20.10$	$*1,485.13^{b} \pm 31.10$	150.0
Nitrate (mg/l)	$*10.89^{a} \pm 1.20$	$*21.98^{b} \pm 2.50$	1
Sulphate (mg/l)	$122.03^{a} \pm 11.06$	$176.07^{a} \pm 9.01$	750

Values were expressed as Mean ± SEM; AL = above limit; values along the same row with different superscripts 'a' and 'b' are statistically different at $p<0.05$; values with an asterisk (*) are not within WHO acceptable limits; Water sample 1 = water obtained at the discharge site of the textile factory; Water sample 2 = water collected at 1.5 km downstream of the discharge site of the textile factory; WHO = World Health Organization

Table 2. Microbial loads of water samples obtained at the discharge site and 1.5 km downstream of the discharge site of a textile factory along the Challawa River, Kano, Nigeria

Microbe (CFU/mL)	Water sample 1	Water sample 2	WHO limit
Bacteria	$8.17^{a} \pm 1.40$	$*290{,}000.00^{b} \pm 1000$	< 1,000
Coliform	0.000 ± 0.000	11.17 ± 2.20	< 400
Fungi/yeast	$10.18^{a} \pm 1.70$	$11.00^{a} \pm 1.90$	< 1,000

Values were expressed as Mean ± SEM; values along the same row with different superscripts 'a' and 'b' are statistically different at $p<0.05$; values with an asterisk (*) are not within WHO acceptable limits; Water sample 1 = water obtained at the discharge site of the textile factory; Water sample 2 = water collected at 1.5 km downstream of the discharge site of the textile factory; WHO = World Health Organization

Table 3. Root length of the *A. cepa* bulbs grown over water samples obtained at the discharge site and 1.5 km downstream of the discharge site of a textile factory along the Challawa River, Kano, Nigeria

Period of Treatment (hour)	Control	Period of Treatment (hour)	Control
0	1.01 ± 0.01	1.70 ± 0.07*	1.03 ± 0.02
24	1.22 ± 0.03	1.52 ± 0.12*	0.95 ± 0.11*
48	2.21 ± 0.05	1.11 ± 0.18*	0.55 ± 0.10*
72	2.32 ± 0.06	1.04 ± 0.20*	0.23 ± 0.24*

Values were expressed as Mean ± SEM; values with asterisk (*) are significantly different from control at $P<0.05$; Control = deionized water; Water sample 1 = water obtained at the discharge site of the textile factory; Water sample 2 = water collected at 1.5 km downstream of the discharge site of the textile factory

3.4 Chromosomal aberrations detected in the exposed *A. cepa* bulbs

Table 4 shows the numbers and types of chromosomal aberrations detected in the *A. cepa* bulbs grown over the water samples obtained from the first sampling point. The number of dividing cells found in the control was 30, while the number of dividing cells in the treated decreased from 23 on day 0 to 15 after 24 hours, later to 13 after 48 hours and finally to five cells after 72 hours. The mitotic index (MI) of the treated group was also significantly reduced ($p<0.05$) after 72 hours compared to the control. The MI of the control was 3.0, while the MI of the treated are 2.3, 1.5, 1.3, and 0.5 on day 0, 24 hours, 48 hours, and 72 hours, respectively.

Chromosomal aberrations detected in the bulbs treated with water samples collected from the second sampling point are presented in Table 5. Thirty-four (34) dividing cells were seen in the control, whereas the treated samples had 26 cells at day 0, 15 cells after 24 hours, 11 cells after 48 hours, and 3 cells after 72 hours. A significant difference ($p<0.05$) exists between the MI of the control and the treated group. While the MI of the control was 3.0, the MI of the treated group was 2.6, 1.5, 1.1, and 0.03 on day 0, 24th, 48th, and 72nd hour, respectively.

Figure 2 (a-e) shows the chromosomal abnormalities found in the root tip cells of the exposed and non-exposed bulbs. Normal metaphase was seen in the control group (Figure 2a), while bi-nucleated cells (Figure 2b) as well as anaphase bridge and sticky chromosomes (Figure 2c) were observed in the bulbs grown over water samples collected from the first sampling point. Vagrant chromosomes (Figure 2d) and sticky chromosomes (Figure 2e) were detected in the cells of the bulbs grown over water samples obtained from the second sampling point.

Table 4. Chromosomal aberrations in the *A. cepa* roots grown over water samples collected at the discharge site of a textile factory along the Challawa River, Kano, Nigeria

Control/Treated over time	TCN	ND	ST	CM	BF	VG	LG	BC	TA (%)	MI	MI ± SEM
Control (72 hours)	1,000	30($P_8M_{13}A_6T_3$)	0	0	0	0	0	0	0	3.0	3.0 ± 0.16
0	1,000	23($P_1M_8A_{12}T_2$)	2	0	2	1	1	0	26.09	2.30	2.30±0.40*
24 hours	1,000	15 ($P_6M_5A_3T_1$)	2	0	1	2	1	0	40.0	1.50	1.50±0.33*
48 hours	1,000	13 ($P_4M_6A_2T_1$)	2	3	1	2	2	0	76.92	1.30	1.30±0.22*
72 hours	1,000	5($P_1M_1A_3T_0$)	2	1	0	0	1	1	80.0	0.50	0.50±0.18*

Values were expressed as MEAN ± SEM; control = deionized water; values with asterisk (*) are significantly different from control at P<0.05; TCN = Total Cell Number; ND = Number of dividing cells; ST= Stickiness; CM = C-mitosis; BF = Bridges fragment; VG = Vagrant; LG = Laggard; BC= Bi-nucleated cell; TA = Total aberrations; SEM = Standard error of mean; MI = Mitotic index; P = Prophase; M = Metaphase; A = Anaphase; T= Telophase.

Table 5. Chromosomal aberrations in the *A. cepa* roots grown over water samples collected at 1.5 km downstream of the discharge site of a textile factory along the Challawa River, Kano, Nigeria

Control/Treated over time	TCN	ND	ST	CM	BF	VG	LG	MA	TA (%)	MI	MI ± SEM
Control (72 hours)	1,000	34($P_{10}M_{13}A_6T_5$)	0	0	0	0	0	0	0	3.4	3.±0.13
0	1,000	26($P_7M_8A_{10}T_1$)	2	0	3	1	0	0	23.08	2.60	2.30±0.80*
24 hours	1,000	15 ($P_5M_6A_4T_0$)	3	0	1	1	0	0	33.33	1.50	0.50±0.33*
48 hours	1,000	11($P_3M_6A_1T_1$)	2	3	0	0	1	0	54.55	1.10	1.20±0.42*
72 hours	1,000	3($P_1M_1A_1T_0$)	1	0	0	1	0	0	66.67	0.03	0.20±0.15*

Values were expressed as MEAN ± SEM; control = deionized water; values with asterisk (*) are significantly different from control at P>0.05; TCN = Total Cell Number; ND = Number of dividing cells; ST= Stickiness; CM = C-mitosis; BF = Bridges fragment; VG = Vagrant; LG = Laggard; BC= Bi-nucleated cell; TA = Total aberrations; SEM = Standard error of mean; MI = Mitotic index; P = Prophase; M = Metaphase; A = Anaphase; T= Telophase

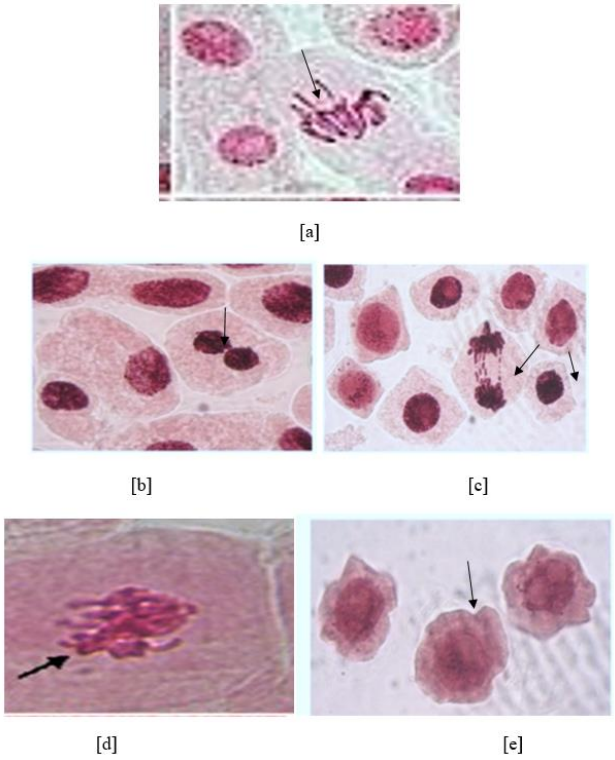

Figure 2. Chromosomal aberrations detected in the root cells of the control and treated *A. cepa*: a = control *A. cepa* showing normal metaphase (x 40). b = A. cepa grown over water samples collected at the discharge site of the textile factory showing bi-nucleated cell (x 40). c = *A. cepa* grown over water samples collected at the discharge site of the textile factory showing anaphase bridge and sticky chromosome (x 40). d = *A. cepa* grown over water samples collected at 1.5 km downstream of the discharge site of the textile factory showing vagrant chromosomes (x 40). e = *A. cepa* grown over water samples collected at 1.5 km downstream of the discharge site of the textile factory showing sticky chromosomes (x 40).

4. Discussion

The cytogenotoxicity of water samples obtained at the discharge site and about 1.5 km downstream of the discharge site of a textile factory along Challawa River in Kano, Nigeria were determined in this study. At the discharge site and about 1.5 km downstream of the discharge site, Ca, Cd, BOD, COD, DO (discharge site only), turbidity and nitrate as well as Pb and Cr concentrations (1.5 km only) were not within the WHO permissible limits for wastewaters (Table 1). Appreciable levels of Mg, Fe, Mn, Ni, EC, TDS and sulphate were also detected at the two sampling points. These results agree with Egila *et al*. (2011) who found elevated levels of Cr, Cu, Pb and Zn above the permissible limits in samples of wastewaters collected at the discharge site of a textile factory in Kano, Nigeria. Ogunlaja & Ogunlaja (2009) also reported abnormal levels of some physicochemical parameters in samples of wastewater collected from a textile factory in Lagos, Nigeria. Moreover, in Table 1, the concentrations of EC, TDS, Ca, Mg, Pb, Ni, DO, COD, and nitrate in the samples collected at 1.5 km downstream of the discharge site were significantly higher than the samples collected at the discharge site of the factory. This suggests more pollutants have been introduced into the river at the said distance. The river receives more waste discharges from some plastic and tin companies at the mentioned distance, which could have raised the concentrations of some pollutants. Additionally, there were farming and laundry activities along this distance, which could contribute to decreases in the water quality. In the microbiological characterization, the relatively low microbial population of the water samples from the discharge site of the textile factory (Table 2) could be due to low DO of the samples. This is contrary to the findings of Prabha, Gogoi, Mazumder, Ramanathan, & Kuma (2017) that isolated high populations of microbes in textile wastewaters. The abnormally high concentrations of bacteria in the water samples collected at 1.5 km downstream of the discharge site could be attributed to its high nutrient content, particularly nitrate and calcium. According to Singh (2013), nitrate is among the major nutrients needed by microorganisms for their physiological processes. In a study that investigated the effects of dietary nitrate addition on ruminal microbial populations in goats, *Streptococcus bovis* and *Streptococcus ruminantium* concentrations were significantly increased (Asanum N, Yokoyama S, & Hino, 2015). The growth of a wall-less, L-form of *Escherichia coli* has also been shown to require calcium (Onoda *et al*., 2000). Collectively, the physicochemical and microbiological characteristics of the water samples suggest the water could be toxic to biological systems. Through irrigation, pollutants in the water can accumulate in the leafy vegetables, tomatoes, peppers and other plants grown around the textile factory and at least up to 1.5 km downstream of the textile factory along the Challawa River. The health of the residents could be affected through the food chain and domestic use of the river water. The pollutants can also accumulate in the body of the fish and grazing animals and transfer to humans through their meat and dairy products.

The potential toxicity of the water samples is evident in the reduced root growth of the exposed *A. cepa* bulbs compared with the control (Table 3). Yakasai, Abubakar, and Abba (2015) observed similar findings among potted tomatoes and peppers watered with effluent obtained from a textile company in Kano. Growth retardation was also reported by Hayyat, Mahmood, Hassan, and Rizwan (2013) who grew sorghum plants in potted soil containing textile effluent. The reduced growth rate showed that some chemicals in the water samples such as Pb and Cd retarded cell division and elongation of the treated bulbs. According to Wang, Vinocur, and Altman (2003), heavy metals can induce oxidative damage in plants, causing membrane alteration as well as reduced root and shoot elongation. Heavy metal exposure has also been demonstrated to cause fetal and neonatal growth restriction (Gardner *et al*., 2013; Sabra, Malmqvist, Saborit, Gratauos, & Roig, 2017). Water samples were very turbid, which could affect light penetration, reducing photosynthesis and growth. The high bacterial populations noticed in the water samples collected at 1.5 km downstream of the discharge site could also contribute to the growth retardation observed. According to Ivanov, Bartosch, and Isaguliants (2017), bacterial infections can induce oxidative stress, which can cause several pathologies, including cell death and growth retardation. Chromosomal abnormalities observed in the root cells of the exposed bulbs (Tables 4 and 5 and Figure 2) further proved the toxicity of the water samples. The observed cytogenetic effects could be linked to the heavy metals and bacteria detected in the water samples. Jadhav, Sarkar, and Tripathi (2006) demonstrated that sub-chronic exposure to Pb, Hg, Cd, Cr, Mn, As, Fe, and Ni through drinking water induced genotoxicity in rat bone marrow and spleen cells. Also, several bacteria and fungi species may induce reactive oxygen species, causing double-strand breaks in host plant DNA (Song & Bent, 2014).

5. Conclusions

The findings of this study showed that the water samples collected at the discharge site and about 1.5 km downstream of the discharge site of a textile factory along the Challawa River in Kano, Nigeria contained high concentrations of some heavy metals, particularly Pb, Cr and Cd. Some quantities of bacteria, fungi and coliform were also present in the water samples, and bacterial population was particularly abnormally high in the samples collected at 1.5 km downstream of the discharge site of the textile factory. The study also showed that the water samples were cytotoxic and genotoxic to biological systems, which are evident in the reduced root growth and mitotic index of the exposed *A. cepa* root tips. The toxic nature of the water samples was further demonstrated by the chromosomal abnormalities detected in the root cells of the exposed *A. cepa* bulbs. The high levels of the BOD, COD, turbidity, and nitrate of the water samples also suggest the water could be ecotoxic. Therefore, there is the need to treat water from the river before it can be deemed safe for agricultural and domestic purposes.

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