Physicochemical Quality and Genotoxic Potential of Wastewater Generated by Canteen Complex

Ebenezer O. Dada, Chioma M. Agu and Modupe O. Akinola

Department of Cell Biology and Genetics, Environmental Biology Unit, Faculty of Science, University of Lagos, Akoka, Yaba, Lagos, Nigeria

Abstract—Canteens generate high volumes of wastewater that should constantly be subjected to physicochemical and genotoxicity screening. In this study, the wastewater generated by a canteen complex was screened for physicochemical properties and genotoxic potential using standard procedures and *Allium cepa* chromosome assay. Results showed that the wastewater had total suspended solids, total dissolved solids, and total hardness concentrations of 120.70 mg/l, 554.50 mg/l, and 500.00 mg/l, respectively. The chloride concentration of the wastewater (7873.60 mg/l) was much higher than the recommended limit of 250 mg/l. The wastewater inhibited root growth in *A. cepa* at 0.1%, 1%, 10%, 25%, 50%, and 100% concentrations but promoted root growth at 2% and 5% concentrations. The wastewater was highly mitodepressive, with mitotic inhibition generally increasing with rising concentrations. The major chromosomal aberrations observed in *A. cepa* exposed to different concentrations of canteen wastewater were vagrant, sticky, and bridged chromosomes. No chromosomal aberration was observed in onion roots exposed to water (control). The differences in total chromosomal aberrations across wastewater concentrations were not statistically significant ($P > 0.05$). In view of these results, the practice of discharging untreated canteen wastewater into drainage canals may not be environmentally sustainable.

***Index Terms*—Chromosomal aberration, Environment, Mitodepressive, Pollution.**

I. Introduction

Catering or food service is an essential but complex system that provides food and beverages away from home (Davies et al., 1998; Fusi et al., 2016). A component part of the catering system is the canteen service. A canteen prepares and serves food and drink to its customers. In canteen services, meals are usually cooked and served on premise, but many canteens also offer takeaway and food delivery services.

Canteen wastewater is the water that has been used for cleaning meats and vegetables, washing dishes and cooking utensils, or cleaning the floor and other associated substances. Canteens use high volumes of water in food preparation and generate correspondingly high volumes of contaminant-bearing wastewater. Canteen wastewater can be both a useful resource and an environmental burden. Canteen wastewater contains plant growth-promoting nutrients and may possibly be used for farming irrigation to aid crop production after undergoing preliminary treatments to reduce fats, oils, and greases and other pollutants. However, in most situations, canteen wastewater negatively impacts communities and ecosystems. Even if canteen wastewater is used for irrigation, the nutrients may leach down the soil to pollute groundwater after sometime (Mahmood and Maqbool, 2006). Canteen wastewater is typically associated with contaminants and other environment-polluting parameters such as organic compounds, biological oxygen demand (BOD), suspended solids, oil and grease, chemical oxygen demand (COD), proteins, carbohydrates, and a host of others (Mohamed et al., 2015; Ying et al., 2011).

Since the services that canteens and other catering services provide are crucial to basic and daily human needs, a huge number of canteens and food outlets are usually found in cities and towns. In many countries, wastewaters from catering and food services constitute the largest source of domestic wastewater (Mohamed et al., 2015). The wastewater generated and discharged, on daily basis, by these vast number of canteen and other food outlets usually constitutes an enormous burden to the environment and public health (Chen et al., 2000). The wastewater composition of canteens varies from culture to culture and from one ethnic group to another. Even for a particular canteen, the composition of wastewater generated may vary from time to,time because the food served for breakfast, lunch, and dinner may vary.

Unlike in many developed countries, where catering service is effectively and efficiently regulated such that canteens and cafeteria must, of necessity, install wastewater treatment facilities to reduce fats, oils, and greases in wastewater (Rainwater, 2004; Mohamed et al., 2015), in Nigeria and some other developing countries, canteens are less regulated, do not

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Corresponding author's e-mail: eodada@unilag.edu.ng

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install any wastewater treatment facility, and consequently dispose of their wastewater untreated in gutters and drainage canals. Such direct discharge of wastewater down the drain by canteens constitutes enormous extra load to the receiving environment. Among other adverse effects, the oil and grease components of the wastewater may aggregate and break down to generate unpleasant odor. Although studies have shown that some physicochemical qualities of canteen wastewater such as organic compounds, BOD, suspended solids, oil and grease, COD, proteins, carbohydrates, and metals are capable of inducing environmental pollution (Chen et al., 2000; Mahmood and Maqbool, 2006; Ying et al., 2011; Mohamed et al., 2015; Fusi et al., 2016), more research attention needs to be focused on the genotoxic potential of these wastewaters.

Genotoxicity is the ability of a substance to interact with the DNA and/or the cellular mechanisms that maintain the stability of the genome. Genotoxicity tests are used for the prediction of carcinogenicity, and their outcomes are often reliable in interpreting carcinogenicity studies. Onions (*Allium cepa*) are among the plants that are used for short-term environmental mutagen studies. *A. cepa* assay is sensitive and reliable short-term chemical mutagen-induced chromosomal aberration tests. *A. cepa* tests are cheap, and the results can easily be analyzed, unlike other short-term tests (Feretti et al., 2007; Leme and Marin-Morales, 2009). This study aimed to assess the genotoxic potential of wastewater generated by a canteen complex.

II. Materials and Methods

A. Collection of Samples

The approximately equal sized and healthy looking bulbs of *A. cepa* (onions) used for this study were purchased from Oyingbo Market (latitude 6º45'N and longitude 3º.39'E), Lagos Mainland Local Government Area of Lagos State, Nigeria. The canteen complex whose wastewater was used for the study is located within the main campus of the University of Lagos, Nigeria. There are 12 canteens that make up this complex, with each serving different foods to under- and post-graduate students. The wastewater was collected from the drainage canal into which every canteen in the complex discharged its effluent. The wastewater was collected in a 5-L plastic container in the morning at about 9.00 am local time, when cooking activities were always at its peak, and was immediately taken to the laboratory for physicochemical analyses and genotoxicity test.

B. Physicochemical Analyses of Canteen Wastewater

Canteen wastewater was analyzed for physicochemical properties including color, pH, electrical conductivity, turbidity (nephelometric turbidity unit [NTU]), total suspended solids (TSS), total dissolved solids (TDS), nitrate (NO_3^-P), phosphate (PO_4^{3-}P), dissolved oxygen (DO), BOD, COD, total alkalinity, total acidity, total hardness, and metals (Zn, Pb, Cd, and Cr). The tests were carried out using the methods described by the American Public Health Association (1998) and as done by Dada et al. (2017). Some of the tests are briefly described.

Color

The color of wastewater was determined using HACH DR 2000 direct reading spectrophotometer method 8025. Each sample was first filtered and measured against previously filtered deionized water as blank at a wavelength of 455 nm.

Test for pH

The pH of the wastewater was estimated using test-2 pH meter. The meter was first standardized against buffer solutions pH 4, 7, and 9.2 after which samples were tested in turn.

Electrical conductivity (EC) and TDS

The electrical conductivity and TDS of the wastewater were measured using portable combined electrical conductivity/TDS/temperature meter (HM Digital COM-100). The meter was standardized with 342-ppm sodium chloride calibration solution testing.

Turbidity (NTU)

The turbidity of the wastewater was measured using HACH DR 2000 direct reading spectrophotometer method 8237. The turbidity of the sample was estimated against deionized water as a blank at a wavelength of 450 nm.

TSS

TSS was measured using HACH DR 2000 direct reading spectrophotometer method 8006. The TSS of each sample was estimated against deionized water as blank at a wavelength of 810 nm.

Nitrate (NO_3^- N)

The nitrate concentration of the wastewater was determined using the HACH DR 2000 direct reading spectrophotometer method 8039. The HACH NitraVer 5 Nitrate Pillow was used in 25 ml of water sample against the sample not treated with NitraVer 5 reagent as blank at a wavelength of 500 nm.

Phosphate (PO_4^{3-} P)

The phosphate concentration of the wastewater was determined using the HACH DR 2000 direct reading spectrophotometer method 8048. The HACH PhosVer 3 Phosphate Powder Pillow reagent was used in 25 ml of the water sample against deionized water as blank at a wavelength of 890 nm.

DO

The DO of each water sample was determined using a portable Orion-3 DO meter. The DO meter was calibrated with water saturated with air after which the different water samples were tested in turn.

BOD_5^{20}

The BOD of the wastewater sample was determined using the Winkler method. The method involves estimating the DO content of the water sample on day 0 (day of sampling) and then the 5th day of the 5-day incubation, at 20°C in the dark against a blank.

COD

To determine the COD of wastewater sample, 0.4 g of $HgSO_4$ was placed in a reflux flask and 20 ml of water

sample was added and mixed properly. Thereafter, 10 ml of 0.25 N $K_2Cr_2O_7$ solution, four seeds of anti-bumping granules, and 30 ml of H_2SO_4-Ag_2SO_4 reagent were added. The flask was then connected to the condenser and slowly heated. The mixture was refluxed for 2 h and then cooled. The walls of the condenser were washed down into the flask with distilled water. The resulting mixture was diluted to 150 ml and titrated with 10 N ferrous ammonium sulfate (FAS) solution using ferroin as an indicator. A color change from blue green to wine red indicated the end point. A blank experiment with distilled water in place of sample was also performed. The procedure was repeated for each sample and the COD value computed is given below.

$$\text{COD in mg / l} = \frac{(V1 - V2) \times N \times 800}{X} \quad (1)$$

Where,
V1 = Volume of FAS for blank
V2 = Volume of FAS for water
N = Normality of FAS
X = Volume of sample taken.

Alkalinity

The alkalinity of the wastewater sample was determined by the acid-base titrimetric method. Aliquot portion of each water sample was titrated with standard solution of sulfuric acid (0.05 M) using methyl orange as indicator.

Acidity

Two drops of phenolphthalein indicator was added to 50 cm^3 of each wastewater sample. Each was then titrated with 0.02 N NaOH until the color changed to faint pink, characteristic of pH 4.5.

$$\text{Acidity as Mg / l}CaCO_3 = \frac{A \times N \times 500 \times D}{\text{Volume of sample}} \quad (2)$$

Where,
A = Volume of NaOH used at end point
N = Normality of NaOH
D = Dilution factor.

Total hardness

To determine the acidity of the wastewater sample, 100 cm^3 of the sample was measured into a 250 cm^3 conical flask and 2.0 ml buffer solution was added and mixed properly. Eight drops of Eriochrome black T indicator were introduced, followed by titration with 0.01 M EDTA solution. A color change from wine red to pure blue indicated the end point. The entire procedure was carried out for each of the water samples. Total hardness for each sample was then computed.

$$\text{Total hardness in mg / L } CaCO_3 = \frac{\text{ml of EDTA} \times M \times 100 \times 1000}{\text{ml of sample}} \quad (3)$$

C. Determination of Metals

To determine the concentrations of metals, the wastewater sample was first digested. Wastewater sample was first thoroughly shaken, after which 100 ml was transferred into a beaker and 5 ml of concentrated nitric acid was added. The beaker was placed on a hot plate and evaporated to dryness. It was then cooled and another 5 ml concentrated nitric acid was added. Heating was continued until a light-colored residue was observed. Then, 1 ml of concentrated nitric acid was added and the beaker was warmed slightly to dissolve the residue. The walls of the beaker were then washed with distilled water. The volume was adjusted to 50 ml. Zinc, Pb, Cd, and Cr were determined in the digested samples using the atomic absorption spectrophotometer.

D. Procedure for A. cepa Genotoxicity Assay

Genotoxicity test was adapted from Adegbite and Olorode (2002), Olorunfemi et al. (2011), and Dada et al. (2017; 2018). The onions used for this test were first sun-dried for 1 week, after which the dry ones were selected for the test. The outer scales and the dried roots present at the base of the sun-dried onions were carefully peeled off with a sharp razor blade to expose the fresh meristematic tissues (primordial). The peeled bulbs were placed in distilled water during the cleaning procedure to prevent the fresh meristematic tissues (primordial) from drying up. The onions were thereafter grown in distilled water at room temperature (25–31°C) for 24 h. When the roots were about 1–2 cm long, they were exposed to eight concentrations of canteen wastewater (0.1%, 1%, 2%, 5%, 10%, 25%, 50%, and 100%) prepared using distilled water as diluents and control, for 24, 48, and 72 h. The test substrates were changed daily. Six onion bulbs were set up for each concentration, of which the best five were selected for morphological (root growth inhibition) and cytological (chromosomal aberration) evaluations.

To determine the root growth inhibition by canteen wastewater, the root lengths of the onions exposed to each wastewater concentration and the ones exposed to distilled water (control) were measured at 24, 48, and 72 h of exposure. Mean root length, percentage root length, and percentage root length inhibition were calculated according to the equations indicated below.

$$\text{Mean root length (cm)} = \frac{\text{Summation of root lengths}}{\text{Total number of root lengths counted}} \quad (4)$$

$$\%\,\text{Root length} = \frac{\text{Root length in test solution}}{\text{Root length in control}} \times 100 \quad (5)$$

$$\%\,\text{Root length inhibition} = \frac{\text{Root lenth in control} - \text{Root length in test solution}}{\text{Root length in control}} \times 100 \quad (6)$$

Chromosomal aberration study was carried out by the squash technique for onion root as described by Adegbite and Olorode (2002). At the end of the exposure periods, the roots of onion bulbs with the best growth at each concentration were removed with forceps and fixed in 1:3 aceto-alcohol. Chromosome samples were taken from the root tips containing actively growing cells. One root tip was squashed on each slide and stained with acetocarmine for 10 min. Coverslips were carefully lowered onto the slide to exclude air bubble. To prevent the possible drying out

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of the preparation, the coverslips were sealed on the slides with clear fingernail polish. Each prepared slide was viewed under the ×40 objective of the light microscope (Leica 2000 Phase Contrast Microscope) to observe its mitotic stages. Data on total cells, total dividing cells, and cells carrying chromosomal aberrations were taken from five microscope fields for each of the different concentrations and the control (Fiskesjo, 1985).

The mitotic index was calculated by expressing the number of dividing cells as a percentage of total cells counted for each of the treatments and the control.

$$\text{Mitotic index} = \frac{\text{Number of dividing cells}}{\text{Total number of cells}} \times 100 \quad (7)$$

$$\%\,\text{Mitotic inhibition} = \frac{\text{Mitotic index in control} - \text{Mitotic index in test solution}}{\text{Mitotic index in control}} \times 100 \quad (8)$$

The frequency of chromosomal aberrations was calculated by expressing the number of aberrant cells as a percentage of total dividing cells for each treatment. Scoring of chromosomal aberrations was taken from five microscopic fields for each of the different wastewater concentrations (Fiskesjo, 1985).

$$\%\,\text{Chromosomal aberration} = \frac{\text{Number of total chromosomal aberrations}}{\text{Total number of dividing cells}} \times 100 \quad (9)$$

E. Statistical Analysis of Data

The total number of chromosomal aberrations across all canteen wastewater concentrations was analyzed by one-way analysis of variance. Mean differences were compared for significance by the least significant difference *post hoc* test. All analyses were carried out by SPSS (Version 22).

III. Results

A. Physicochemical Properties of Canteen Wastewater

The result of the physicochemical analysis of canteen wastewater as presented in Table I showed that the wastewater had TSS, TDS, and total hardness concentrations of 120.70 mg/l, 554.50 mg/l, and 500.00 mg/l, respectively. The DO and BOD of the wastewater were 19.00 mg/l and 110.20 mg/l, respectively. The chloride concentration of the wastewater (7873.60 mg/l) was much higher than the recommended limit of 250 mg/l set by the Lagos State Environmental Protection Agency. All the metals assessed were present in lower concentrations than the recommended limits except Zn whose concentration of 27.10 mg/l was higher than the recommended limit of 5.0 mg/l.

B. Effect of Canteen Wastewater on the Root Growth of A. cepa

At the end of 24-h test period, there was no visible damage to the root tips of onions in the control and in test solutions.

TABLE I
Physicochemical Properties of Canteen Wastewater

Canteen wastewater qualities	Concentrations	
	Canteen wastewater	LASEPA limits
Physical		
Temperature (0°C)	26.80	na
pH	4.54	5.5–9.0
Color	Cloudy	na
Turbidity (NTU)	109.72	na
Conductivity(μS/cm^3)	1109.00	na
Total suspended solids mg/l	120.70	100.0
Total dissolved solids mg/l	554.50	2,100.0
Chemical		
Total hardness mg/l	500.00	na
Total alkalinity mg/l	25.00	na
Total acidity mg/l	50.00	na
BOD mg/l	110.20	50.0
COD mg/l	180.00	na
Dissolved Oxygen mg/l	19.00	2.0
Chloride mg/l	7,873.60	250.0
Nitrate mg/l	29.50	na
Sulfate mg/l	2.00	na
Phosphate mg/l	12.10	na
Metals		
Zinc mg/l	27.10	5.0
Lead mg/l	0.024	0.1
Cadmium mg/l	0.001	0.02
Chromium mg/l	0.004	0.036
Biological		
Bacteria	3.40×10^5	na
Coliform	1.10×10^2	na
Yeast	nd	Na

LASEPA: Lagos State Environmental Protection Agency, nd: Not detected, na: Not available. NTU: Nephelometric turbidity unit, BOD: Biological oxygen demand, COD: Chemical oxygen demand

At 48 h and 72 h, there was a slight darkening in the root tip of onions in 50% and 100% canteen wastewater. However, canteen wastewater inhibited root growth in *A. cepa* at 0.1%, 1%, 10%, 25%, 50%, and 100% concentrations. Canteen wastewater of 100% concentration induced the highest root growth inhibition of 34.82% and 59.56% in *A. cepa*, respectively, at 24 and 72 h of exposure. Canteen wastewater of 50% concentration induced the highest onion root growth inhibition of 44.95% at 48 h of exposure. Canteen wastewater of 1% concentration induced the least root growth inhibition of 12.83%, 14.80%, and 16.04% at 24, 48, and 72 h of exposure, respectively.

On the other hand, canteen wastewater also promoted root growth in *A. cepa* at 2% and 5% concentrations. Relative to the control, canteen wastewater of 2% concentration induced more growth in *A. cepa* roots by 27.23%, 40.82%, and 49.01% at 24, 48, and 72 h of exposure, respectively (Table II).

C. Mitotic Activity in A. cepa Exposed to Canteen Wastewater

The mitotic activity in *A. cepa* exposed to different concentrations of canteen wastewater showed that the number of dividing cells and the percentage mitotic index decreased with increasing concentrations at 24, 48, and 72 h of

exposure, whereas the percentage mitotic inhibition increased with rising concentrations. The number of dividing cells and percentage mitotic index also decreased with increasing period of exposure, whereas percentage mitotic inhibition increased with period of exposure. At 24 h of exposure, 100% canteen wastewater induced the highest percentage mitotic inhibition of 91.52%. At 48 and 72 h of exposure, the lowest percentage mitotic inhibitions of 87.31% and 91.03%, respectively, were induced by 2% canteen wastewater (Table III).

C. Chromosomal Aberrations Induced by Canteen Wastewater

The chromosomal aberrations observed in *A. cepa* exposed to different concentrations of canteen wastewater in this study were vagrant, sticky, and bridged chromosomes. Sticky chromosomes were the most frequent (370). C-mitosis was observed only in one root cell. No chromosomal aberration was observed in onion roots exposed to water (control). Canteen wastewater of 5% concentration induced the highest chromosome aberration of 99, whereas canteen wastewater of 2% concentration induced the least, 44. However, the differences in total aberrations across wastewater concentrations were not statistically significant ($P > 0.05$).

The percentage chromosome aberration induced by canteen wastewater in onion roots increased with rising concentrations except for 2% wastewater that deviated from this pattern by inducing the least percentage aberration of 29%. Canteen wastewater of 100% induced the highest aberration of 96.1%, whereas 0.1% wastewater induced percentage aberration of 34. 0%. Canteen wastewater of 10% and 50% concentrations induced 61.0% and 76.7% chromosomal aberrations, respectively (Table IV). Representative photomicrographs of normal and aberrant chromosomes are shown in Figures 1-8.

IV. Discussion

Nutrition is a basic biological function of life. The increasing human population has brought about global awareness for the need to create more raw and cooked foods but with only little attention paid to the environmental impact of rising food production. This is more so in developing countries, where food outlets, including cafeteria and canteens, may be set up without installing any wastewater treatment facility and without carrying out an adequate environmental impact assessment.

Some physicochemical parameters of the canteen wastewater under the study, including conductivity, BOD, and chloride, were high or above regulatory limits but were relatively lower than those assessed in some previous studies (Chen et al., 2000; Mohamed et al., 2015). However, some other parameters of the wastewater (including pH, TSS, BOD) were not only lower than those assessed in previous studies but were also below or within regulatory limits. The very high conductivity of the canteen wastewater must have been occasioned by the equally very high chloride concentration. The high chloride concentration in the wastewater may indicate greater use of table salt and salt-containing spices in different canteens contained within the complex.

TABLE II
Effect of Canteen Wastewater on The Root Growth Of *A. cepa*

Canteen W/water conc.	Mean root growth			% Root growth			% Root growth inhibition		
	24 h	48 h	72 h	24 h	48 h	72 h	24 h	48 h	72 h
Ctr	2.6±1.06	2.6±1.29	3.0±1.44	100	100	100	0	0	0
0.1%	1.8±0.84	2.0±1.26	1.9±1.98	69.63	77.04	61.98	30.37	23.00	38.02
1%	2.2±0.88	2.2±0.88	2.2±1.07	87.17	85.20	83.96	12.83	14.80	16.04
2%	3.2±1.33	3.7±1.72	4.6±2.30	127.23	140.82	149.01	−27.23	−40.82	−49.01
5%	2.7±0.97	2.7±1.15	4.0±2.77	105.76	102.81	130.54	−5.76	−2.81	−30.60
10%	1.9±0.83	1.9±0.92	1.7±1.11	72.51	71.43	56.70	27.49	28.57	43.30
25%	1.9±0.86	1.7±1.00	1.8±0.74	72.51	65.82	57.80	27.49	34.18	42.20
50%	1.9±48	1.4±0.66	1.3±0.69	74.35	55.05	41.75	25.64	44.95	58.24
100%	1.7±0.85	1.7±0.85	1.2±0.80	65.18	63.52	40.44	34.82	36.48	59.56

W/water: Wastewater, Conc: Concentration, Ctr: Control, Hrs: Hours, *A. cepa: Allium cepa*

TABLE III
Mitotic Activity in *A. cepa* Exposed to Canteen Wastewater

CW conc	Total cells counted			Number of dividing cells			Mitotic index (%)			Mitotic inhibition (%)		
	24 h	48 h	72 h	24 h	48 h	72 h	24 h	48 h	72 h	24 h	48 h	72 h
Ctr	1000	1000	1000	513	513	513	51.30	51.30	51.30	0	0	0
0.1%	965	932	921	57	52	41	5.91	5.58	4.45	88.50	89.12	91.33
1%	942	918	873	68	46	36	7.22	5.01	4.12	85.93	90.23	91.97
2%	948	875	848	53	57	39	5.59	6.51	4.60	89.10	87.31	91.03
5%	916	887	832	51	39	24	5.57	4.40	2.89	89.14	91.43	94.37
10%	903	852	809	46	33	21	5.09	3.87	2.60	90.08	92.46	94.93
25%	885	831	783	43	35	16	4.86	4.21	2.04	90.53	91.79	96.02
50%	874	828	765	40	29	17	4.58	3.50	2.22	91.07	93.18	95.67
100%	851	813	741	37	27	13	4.35	3.32	1.75	91.52	93.53	96.59

CW: Canteen wastewater, Conc: Concentration, Ctr: Control, Hrs: Hours, *A. cepa: Allium cepa*

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TABLE IV
CHROMOSOMAL ABERRATIONS INDUCED IN *A. CEPA* ROOT CELLS EXPOSED TO DIFFERENT CONCENTRATIONS OF CANTEEN WASTEWATER

CW conc.	Chromosomal aberration type										
	Sticky			Vagrant			Bridged anaphase			Total Abr.	% Abr.
	24 h	48 h	72 h	24 h	48 h	72 h	24 h	48 h	72 h		
0.1%	5	8	11	3	11	3	6	3	1	51	34.0
1%	17	15	17	5	2	2	0	1	0	59	39.3
2%	11	11	15	7	0	0	0	0	0	44	29.5
5%	23	18	13	2	5	7	15	13	3	99	86.8
10%	14	15	20	1	7	1	3	0	0	61	61.0
25%	23	21	18	0	0	0	7	4	1	74	78.7
50%	18	19	14	4	7	2	0	2	0	66	76.7
100%	25	10	9	11	15	4	0	0	0	74	96.1
Total		Sticky			Vagrant			Bridged anaphase		528	
		370			99			59			

CW Conc: Canteen wastewater concentration, Abr: Aberration. The differences in total aberrations across wastewater concentrations were not significant ($P>0.05$). *A. cepa: Allium cepa*

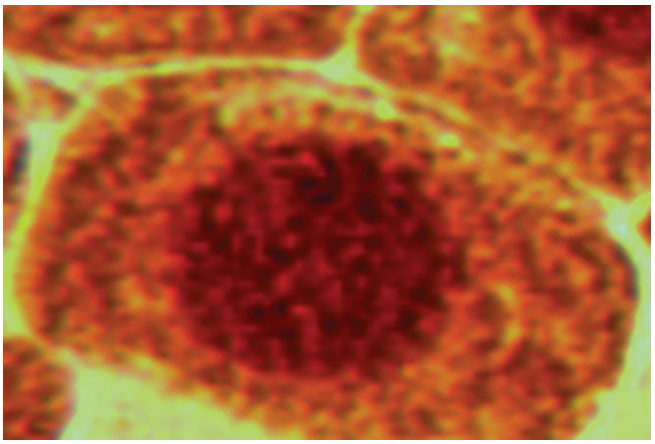

Fig. 1. Normal prophase.

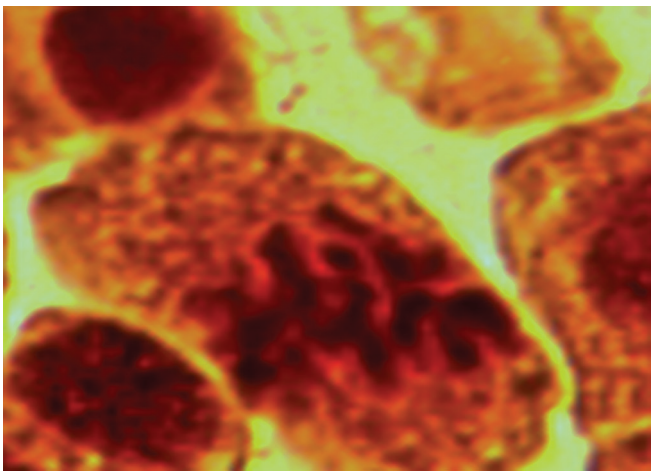

Fig. 2. Normal metaphase.

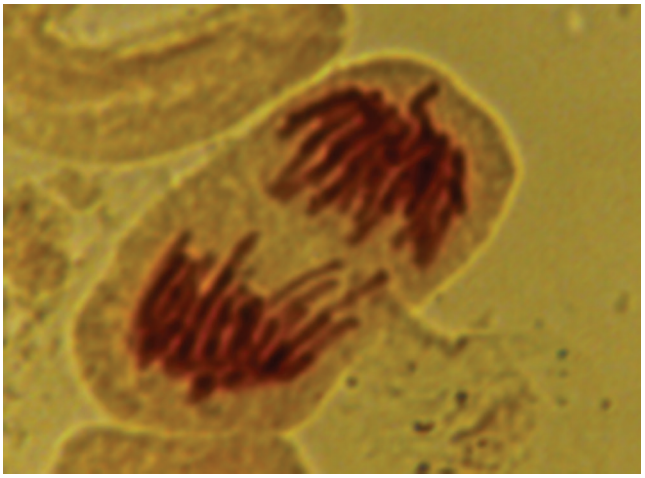

Fig. 3. Normal anaphase.

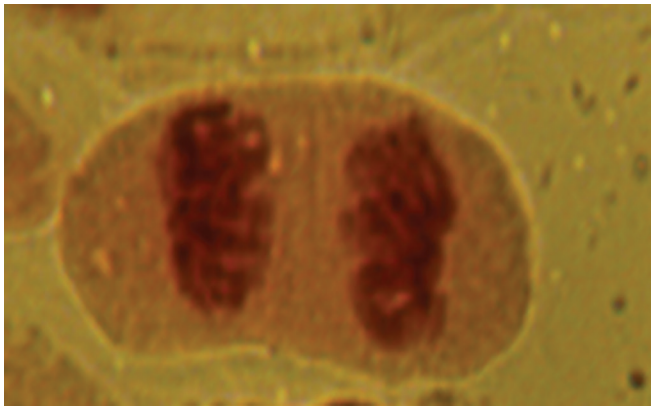

Fig. 4. Norma telophase.

The effects produced on the root growth of *A. cepa* in this study require attention. First, root growth inhibition was neither directly nor inversely proportional to increasing wastewater concentration. Second, although the canteen wastewater inhibited root growth at most of its concentrations, it also promoted root growth at 2% and 5% concentrations. The inhibition in root growth of *A. cepa* by some concentrations of canteen wastewater implies that the metals and other parameters such as BOD, total hardness, and conductivity in the wastewater were harmful to *A. cepa* roots at those concentrations. On the other hand, the fact that canteen wastewater promoted root growth at 2% and 5% concentrations, suggesting that it contains some nutrients that may promote plant growth at appropriate concentrations. Such growth-promoting nutrients may likely include organic compounds such as proteins, carbohydrates, and essential micronutrients such as Zn and Cu (Yasin et al., 2017).

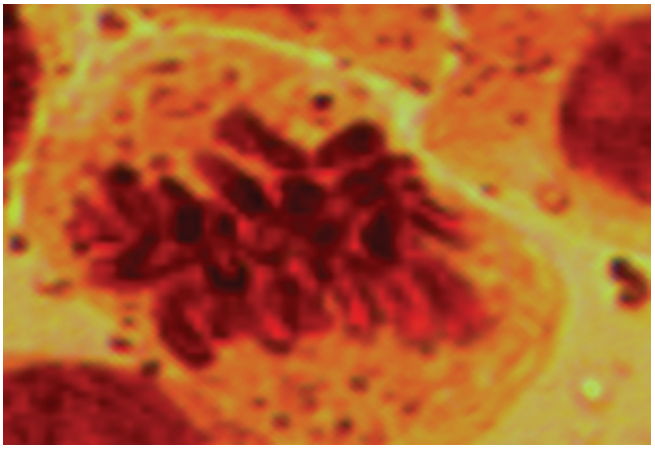

Fig. 5. Sticky anaphase.

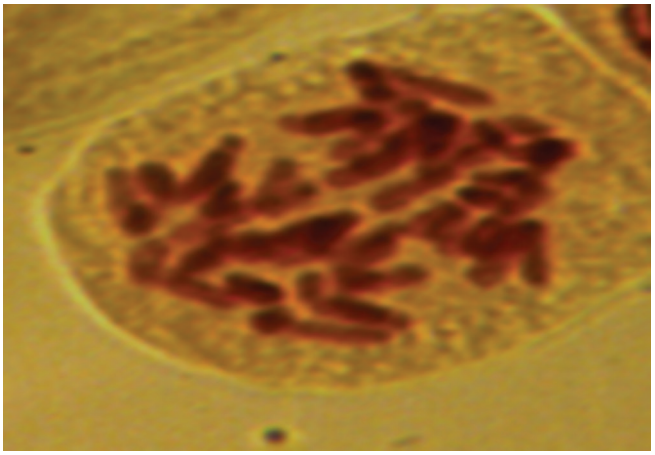

Fig. 6. Vagrant anaphase.

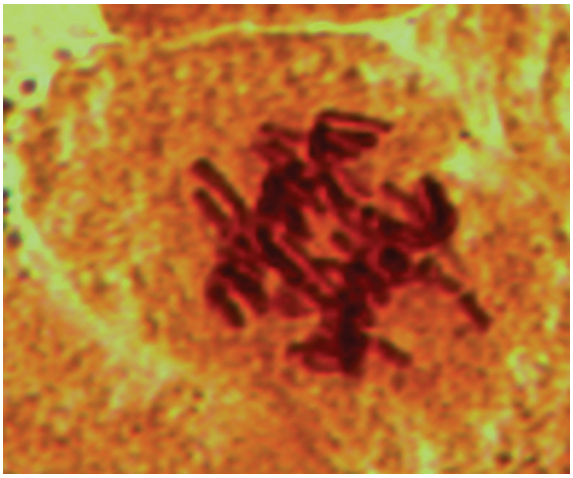

Fig. 7. Bridged anaphase.

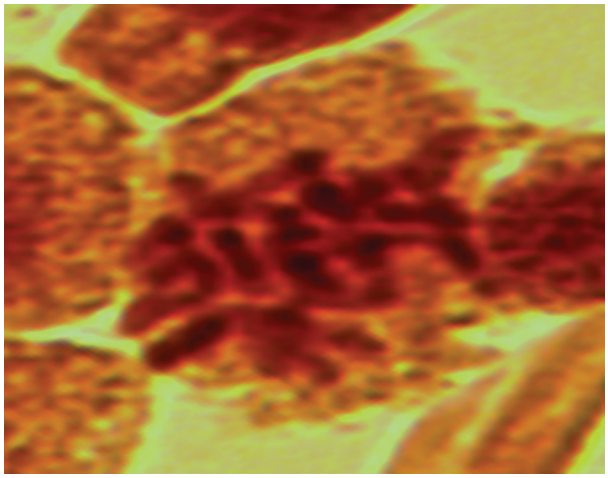

Fig. 8. C-mitosis.

Canteen wastewater was observed to be highly mitodepressive in *A. cepa* roots with mitotic inhibition increasing with rising concentrations. Mitotic index is considered a reliable indicator for the presence of cytotoxic pollutants (Kaymak and Goc-Rasgele, 2009). The decreased mitotic index and increased mitotic inhibition are also likely associated with the presence of metals and other parameters such as BOD, total hardness, conductivity, and perhaps, other parameters are not assessed in this study. These contaminants must have either disrupted DNA synthesis or completely halted metabolic activities, thereby preventing the cells from entering mitosis (Metin and Burun, 2008).

Only few chromosomal aberrations (mainly sticky, vagrant, and bridged) were observed. Nevertheless, chromosomal aberrations, irrespective of types or numbers, are generally signs of toxicity resulting from the presence of genotoxic materials. Chromosome bridges result from chromosome and/or chromatid breaks, indicating clastogenic effect (Leme and Marin-Morales, 2009). C-mitosis, the least frequent aberration in this study indicate a risk of aneuploidy. Sticky and vagrant chromosomes, which were the most frequent aberrations observed, result from chromatin dysfunction or spindle failure. Chromosome stickiness may result from improper folding of chromatin fiber into single chromatid and chromosome, which consequently hinder free chromosome separation (Klasterska et al., 1976). Prominent stickiness of the chromatin matrix is indicative of toxicity which often results in abnormal metaphases and anaphases. Sticky chromosomes are associated with a disturbance in the balance of the quantity of histones or other proteins responsible for controlling the proper structure of nuclear chromatin. Stickiness is considered a common sign of toxic effects on chromosomes that may lead to cell death (Kuras, 2004; Metin and Burun, 2008).

Typical of most non-corporate canteens in Nigeria, the canteens that generated the wastewater under study are not fitted with wastewater treatment facilities. Rather, untreated wastewaters are discharged through a drain channel. In view of the pollutant load and the genotoxic potential of canteen wastewater as found in this study and the fact that canteens generate high volumes of wastewater, the practice of discharging untreated canteen wastewater may not be environmentally sustainable. Such untreated wastewater eventually increases the pollution loads of the receiving soil and water environments. In addition, increasing volumes of untreated canteen wastewater may also constitute pollution threat to groundwater.

V. Conclusion

As found in this study, canteen wastewater has genotoxic properties likely brought about by its substantially high pollutant load. The practice of discharging untreated canteen wastewater into drainage canals may not be environmentally sustainable. Nevertheless, canteen wastewater also promoted root growth at low concentrations. Where and when possible, canteen wastewaters that have undergone proper treatment may be converted to productive uses like farm irrigation.

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