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Effects Of Distribution Pipes On The Quality Of Drinking Water From The Central Borehole At The Ugbowo Campus Of The University Of Benin, Benin City (Nigeria)

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ABSTRACT

The physico-chemical and microbial qualities of the drinking water at the central borehole at the Ugbowo Campus of the University of Benin was investigated and compared with the quality of the drinking water distributed from the borehole to different residential quarters and hostels in the campus. It was observed that significant changes occurred during distribution. The result showed significant increase/decrease for some parameters while some parameters showed no particular trend in the change. pH at the borehole was 5.01 while a range of 5.24 – 5.86 was observed at the residential quarters and hostels. Nitrate levels at the borehole (29.40 μg/l) were more than the levels observed at the quarters (ranged 9.40 – 23.08 μg/l). Parameters like phosphate showed no particular trend; while there was an increase at some quarters; decrease was observed at other quarters. Despite these changes, the overall quality of the water was within WHO and EU permissible limits and therefore fit for drinking and other domestic applications.

KEYWORDS

Benin City;
Low-mineralized;
University of Benin;
Remineralization;
Significant changes.

INTRODUCTION

Safe drinking water is a basic need for human development, health and well-being, and because of this it is an internationally accepted human right[1]. The healthcare of a people appears to start from the provision of good quality drinking water. Such water may be consumed in any desire amount without adverse effect on health. The water should be free from harmful levels of impurities: bacteria, viruses, minerals and organic substances. It should also be aesthetically acceptable, free of unpleasant impurities such as objectionable taste, colour, turbidity and odour[2].

Benin City, Nigeria, has limited sources of safe drinking water with the major reliable source being groundwater. Water is acquired from this source by drilling a borehole and the water piped to individual homes for domestic use. The integrity of the distribution pipes can affect the quality of the water supply at homes. Previous studies have attributed two potentially toxic metals, lead and cadmium to leaching from distribution pipes[3]. Another study has mentioned nickel as a potential contaminant from the plating of decorative plumbing fixtures[4]. Again, it has shown that corrosion products attached to pipes surfaces or accumulated as sediments in the distribution system can shield microorganisms from disinfectants[5]. These organisms can reproduce and cause problems such as bad tastes odours slimes, and leaching of certain metals[3].

The Ugbowo Campus of the University of Benin is located in Benin City with over 20, 000 students including staffs and their families resident within the campus[6]. The water need of this community is satisfied by a central borehole which distributes the water to staff quarters, students hostels and other buildings where water is needed. These buildings which are sited in different locations within the campus are serviced with different types of distribution pipes which ranged from asbestos-cement (A/C) pipes, galvanized iron pipes to PVC pipes. The integrity of the distribution system can have profound effect on the quality of the water supply.

Recent study has shown a relatively high total microbial load (TML) and total coliform count (TCC) at students hostels compared with the water at the central borehole[7]. The same study showed an increase in TML and TC as the water is piped to residential quarters. The study also indicated the development of odour and bad taste in some quarters especially students' hostels. No work has been done on the physico-chemical changes that occur along the distribution system. So this present study assesses the physico-chemical and microbial changes that occur during distribution in order to providing information to consumers and university authority about the quality of the water supply. The information will also be useful to other water consumers who rely on drinking-water from central boreholes and water piped to their homes using distribution pipes. It will also assist drinking-water agencies in taking precautionary measures that enhances the operational practices that will guarantee the safety of the water during distribution.

MATERIALS AND METHODS

Study Area

The study was carried out at the Ugbowo Campus of the University of Benin. The Campus is located in Benin City along the Ugbowo–Lagos expressway. Benin City is the capital of Edo State, Nigeria and is located in the south-south geopolitical zone of Nigeria. The City is bounded by latitudes 6°06'N, 6°30'N and longitudes 5°30'E, 5° 45'E.

Sampling

Water samples were taken randomly from ten residential quarters and the central boreholes between September and November 2005. Approximately two litres samples were collected in cleaned plastic bottles. The bottles were washed with cleaning mixture (potassium dichromate – sulphuric acid reagent), tap water, followed by distilled water several times. Before collection, each bottle was rinsed with the same water thrice and then filled with sample. All samples were stored in the refrigerator and analysis carried out within 24 hours.

Analysis

The temperature, pH, dissolved oxygen, bicarbonate, conductivity, turbidity and salinity were measured in situ using Horiba – U10 multimeter. The other physico-chemical characteristics: BOD_5, COD, phosphate, nitrate, nitrite, sulphate and chloride were analyzed according to APHA/AWWA Methods[8]. Calcium and magnesium were measured using flame photometer (corning). Iron, lead, cadmium, chromium, nickel, manganese were determined using Atomic Absorption Spectrometer AA689 Pie Unicam. Total level of N-nitroso compounds was analyzed for using the method developed by Telling and Dunnett[9]. The total coliform count was determined using APHA/AWWA's Standard Total Coliform Multiple Tube (MPN) tests methods[8].

RESULTS AND DISCUSSION

TABLE 1-3 show the results for the different quarters, hostels, health center and borehole. These tables indicated the mean values for the different sampling points. The mean values were supplemented with standard deviations so that the variation in data could be specified. Higher values of standard deviations at many places in the tables can be observed. This depicts a wide variation in the water quality characteristic. The mean values have also been compared with WHO and EU standards in TABLE 4.

pH

The pH of the water at the borehole is below the WHO desirable standard of 6.5 – 8.5 as shown in TABLE 4. The low value indicates that the water is corrosive[10]. A gradual significant increase in pH was observed as the water is piped from the borehole to different parts of the campus. This increase in pH may be due to interaction of the water with cement linings of the asbestos-cement pipes used for the distribution network. The increase may also be due to leaching of aromatic amines from PVC also used in the distribution network. Aromatic amines are used as antioxidants in PVC materials.

Physical characteristics

These include electrical conductivity, dissolved solids, suspended solids, dissolved oxygen and turbidity. These characteristics were observed to be below the WHO and EU standards as shown in TABLE 1 and 4. The low values of electrical conductivity and dissolved solids indicate that the water is soft and low mineralized[11]. Conductivity is an indirect measure of the total dissolved solids content of water. The softness of the water implies that the water is good for cooking, washing and preparation of beverages[2]. However, soft and low-mineralized water can lead to health problems due to loss of physiologic minerals[11].

Data for turbidity and suspended solids implies that the water was clear. This is important for aesthetic and health reasons. Suspended particles in drinking water can shield microorganisms from disinfectant[5], and also make consumer to source alternative sources of drinking water which may be expensive.

Dissolved oxygen is an indicator characteristic, as large declines in dissolved oxygen in water sources could indicate high levels of microbial activity [10]. The level of dissolved oxygen at the borehole is 5.20 mg/l and is above the WHO recommended standards. This high level of dissolved oxygen implies very low microbial activity and this indicates that the water is virtually free from organic contaminants. A comparison of these data at the various quarters and hostels with borehole shows an increase for conductivity and dissolved solids. This gradual increase for electrical conductivity and TDS may be due to leaching of various ions and metals from distribution pipes into the water. There was an increase in dissolved oxygen at some quarters and decrease at other points. This shows the oxygen was produced at some points in the distribution networks and consumed at other points. The increase may be due to photosynthetic reactions occurring within the water during storage. In some homes, water is piped into overhead storage tanks, from which it is distributed to the house. Photosynthesis can occur in such storage tank. The decrease in dissolved oxygen may be as a result of microbial action.

Chemical Characteristics

Compared with the WHO and EU standards, these parameters were very low as can be seen in

TABLE 1: pH and physical characteristics of drinking water at the borehole and quarters and hostels

	PH	Conductivity (μS/cm)	TDS (mg/l)	DO (mg/l)	Tempt. (°C)	Turbidity (FTU)	Salinity (%)	TSS (mg/l)
Bore hole	5.01±0.01	14.00±1.41	8.24±0.02	5.20±0.01	28.00±0.05	0.00±0.00	0.00±0.00	0.00±0.00
P - Quarters	5.24±0.09	14.00±0.63	8.07±0.58	5.30±0.04	28.00±0.06	0.00±0.00	0.00±0.00	0.00±0.00
A – Quarters	5.52±0.25	14.80±3.66	8.33±1.96	5.33±0.01	27.94±0.08	0.00±0.00	0.00±0.00	0.00±0.00
B – Quarters	5.59±0.23	18.66±3.14	11.92±3.73	5.28±0.05	27.96±0.05	0.20±0.40	0.00±0.00	0.00±0.00
Block of flats	5.65±0.18	21.00±4.52	11.78±2.63	5.31±0.03	27.90±0.11	0.00±0.00	0.00±0.00	0.00±0.00
Hall 1	5.78±0.01	15.00±0.89	8.40±0.02	5.26±0.01	27.90±0.09	0.00±0.00	0.00±0.00	0.00±0.00
Hall 2	5.86±0.02	12.00±0.89	6.96±0.02	4.28±0.01	28.20±0.05	0.00±0.00	0.00±0.00	0.00±0.00
Hall 3	5.58±0.02	13.00±1.79	7.41±0.01	5.29±0.01	28.20±0.07	0.00±0.00	0.00±0.00	0.00±0.00
Hall 5	5.45±0.02	14.00±0.63	8.12±0.02	5.32±0.01	27.70±0.10	0.00±0.00	0.00±0.00	0.00±0.00
ICB Hostel	5.66±0.02	25.00±0.63	14.75±0.02	5.30±0.01	27.90±0.05	0.00±0.00	0.00±0.00	0.00±0.00
New Health Centre	5.75±0.01	18.00±2.10	10.08±0.01	5.16±0.01	27.60±0.07	0.00±0.00	0.00±0.00	0.00±0.00

TABLE 2: Levels of SO_4^{2-}, Mg^{2+}, Ca^{2+}, Cl^-, HCO_3^- and some metals in the drinking water at the borehole and the quarters and hostels

	Cr (mg/l)	Cd (mg/l)	Ni (mg/l)	Mn (mg/l)	Zn (mg/l)	Pd (mg/l)	Fe (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	SO_4^{2-} (mg/l)	Cl (mg/l)	HCO_3^- (mg/l)
Bore hole	ND	ND	ND	ND	ND	ND	0.15±0.05	3.00±0.00	1.00±0.00	1.00±0.00	5.00±0.20	0.94±0.08
P – Quarters	ND	ND	ND	ND	ND	ND	0.16+0.08	3.00±0.00	1.04±0.08	1.32±0.32	5.78±0.39	1.00±0.47
A – Quarters	ND	ND	ND	ND	ND	ND	0.13±0.02	3.20±0.98	1.20±0.40	1.24±0.29	5.66±0.65	0.99±0.52
B – Quarters	ND	ND	ND	ND	ND	ND	0.20±0.07	4.20±0.98	1.48±0.41	1.28±0.39	6.14±0.23	1.30±0.59
Block of flats	ND	ND	ND	ND	ND	ND	0.21±0.04	4.00±1.00	1.25±0.43	1.55±0.35	6.25±0.11	1.26±0.75
Hall 1	ND	ND	ND	ND	ND	ND	0.10±0.00	3.00±0.00	1.00±0.00	1.20±0.40	6.30±0.25	0.94±0.08
Hall 2	ND	ND	ND	ND	ND	ND	0.15±0.05	2.00±0.00	1.00±0.00	1.80±0.40	6.20±0.25	0.48±0.04
Hall 3	ND	ND	ND	ND	ND	ND	0.20±0.00	3.00±0.00	1.00±0.00	0.80±0.40	4.40±0.20	1.96±0.05
Hall 5	ND	ND	ND	ND	ND	ND	0.15±0.05	3.00±0.00	1.00±0.00	1.80±0.40	4.10±0.20	1.94±0.05
ICB Hostel	ND	ND	ND	ND	ND	ND	0.07±0.015	4.00±0.00	2.00±0.00	2.00±0.00	7.20±0.25	1.98±0.04
New Health Centre	ND	ND	ND	ND	ND	ND	0.10±0.00	4.00±0.00	2.00±0.00	1.40±0.50	6.20±0.25	0.96±0.05

TABLE 3: Levels of N-nitroso compounds, BOD_5, COD, total coliform count, and nutrient, in the drinking water at the borehole and the quarters and hostels

	Nitrate (μg/l)	Nitrite (μg/l)	Phosphate (μg/l)	BOD_5 (mg/l)	COD (mg/l)	N-nitroso compound as NDELA* (μg/g)	Total coliform Count (MPN/100 ml)
Bore hole	29.40±1.36	7.40±0.49	7.40±0.49	0.03±0.01	0.04	ND	1
P - Quarters	11.88±3.60	3.96±0.94	3.96±0.94	0.02±0.01	0.04±0.007	ND	2
A - Quarters	23.08±8.84	7.88±4.00	7.88±4.00	0.02±0.01	0.04±0.007	ND	1
B - Quarters	15.80±4.59	5.44±0.90	5.44±0.90	0.04±0.02	0.06±0.03	ND	2
Block of flats	19.10±10.84	6.30±3.42	6.30±3.42	0.04±0.02	0.07±0.04	ND	2
Hall 1	19.60±0.49	6.20±0.40	6.20±0.40	0.03±0.01	0.04±0.02	ND	2
Hall 2	10.20±0.75	4.80±0.75	4.80±0.75	0.02±0.01	0.03±0.01	ND	1
Hall 3	9.40±0.49	2.40±0.49	2.40±0.49	0.02±0.01	0.03±0.01	ND	2
Hall 5	19.40±0.80	5.40±0.80	5.40±0.80	0.02±0.01	0.03±0.02	ND	2
ICB Hostel	20.60±0.49	6.40±0.49	6.40±0.49	0.02±0.01	0.03±0.01	ND	1
New Health Centre	20.20±0.75	7.20±0.75	7.20±0.75	0.02±0.01	0.03±0.01	ND	1

*NDELA is nitrosodiethanolamine

TABLE 4: WHO/EU drinking water standards

	WHO standards 1993	EU standards 1998
Suspended solids	No guideline	Not mentioned
COD	No guideline	Not mentioned
BOD	No guideline	Not mentioned
Oxidisability	-	5.0 mg/l 02
Grease oil	No guideline	Not mentioned
Turbidity	No guideline (1)	Not mentioned
pH	No guideline (2)	Not mentioned
Conductivity	250 micro S/cm	250 micro S/cm
Colour	No guideline (3)	Not mentioned
Dissolved Oxygen	No guideline (4)	Not mentioned
Hardness	No guideline (5)	Not mentioned
TDS	No guideline	Not mentioned
Cations (positive ions)		
Aluminum (AI)	0.2 mg/l	0.2 mg/l
Ammonia (NH4)	No guideline	0.50 mg/l
Antimony (Sb)	0.005 mg/l	0.005 mg/l
Arsenic (AS)	0.01 mg/l	0.01 mg/l
Barium (Ba)	0.3 mg/l	Not mentioned
Berillium (Be)	No guideline	Not mentioned
Boron (B)	0.3 mg/l	1.00 mg/l
Bromate (Br)	Not mentioned	0.01 mg/l
Cadmium (Cd)	0.003 mg/l	0.005 mg/l
Chromium (Cr)	0.05 mg/l	0.05 mg/l
Copper (Cu)	2 mg/l	2.0 mg/l
Iron (Fe)	No guideline (6)	0.2
Lead (Pb)	0.01 mg/l	0.01 mg/l
Manganese (Mn)	0.5 mg/l	0.05 mg/l
Mercury (Hg)	0.001 mg/l	0.001 mg/l
Molibdenum (Mo)	0.07 mg/l	Not mentioned
Nickel (Ni)	0.02 mg/l	0.02 mg/l
Nitrogen (Total N)	50 mg/l	Not mentioned
Selenium (Se)	0.01 mg/l	0.01 mg/l
Silver (Ag)	No guideline	Not mentioned
Sodium (Na)	200 mg/l	200 mg/l
Tin (Sn) inorganic	No guideline	Not mentioned
Uranium (U)	1.4 mg/l	Not mentioned
Zinc (Zn)	3 mg/l	Not mentioned
Anions (negative ions)		
Chloride (Cl)	250 mg/l	250 mg/l
Cyanide (CN)	0.07 mg/l	0.05 mg/l
Fluoride (F)	1.5 mg/l	1.5 mg/l
Sulfate (SO4)	500 mg/l	250 mg/l
Nitrate (NO3)	(see Nitrogen)	50 mg/l
Nitrite (NO2)	(see Nitrogen)	0.50 mg/l
Microbiological Parameters		
Escherichia coli	Not mentioned	0 in 250 ml
Enterococci	Not mentioned	0 in 250 ml
Pseudomonas aeruginosa	Not mentioned	0 in 250 ml
Clostridium perfringens	Not mentioned	0 in 250 ml
Coliform bacteria	Not mentioned	0 in 250 ml
Colony count 22°C	Not mentioned	100/ml
Colony count 37°C	Not mentioned	20/ml
Other parameters		
Acrylamide	Not mentioned	0.0001 mg/l
Benzene (C_6H_6)	Not mentioned	0.001 mg/l
Benzo (a) pyrene	Not mentioned	0.00001 mg/l
Chlorine dioxide (CIO2)	0.4 mg/l	
1, 2-dichloroethane	Not mentioned	0.003 mg/l
Epichlorohydrin	Not mentioned	0.0001 mg/l
Pesticides	Not mentioned	0.0001 mg/l
Pesticides – Total	Not mentioned	0.0005 mg/l
PAHs	Not mentioned	0.0001 mg/l
Tetrachloroethene	Not mentioned	0.01 mg/l
Trichloroethene	Not mentioned	0.01 mg/l
Trihalomethanes	Not mentioned	0.1 mg/l
Tritium (H3)	Not mentioned	100 Bq/l
Vinyl chloride	Not mentioned	0.0005 mg/l

Desirable: Less than 5 NTU
Desirable: 6.5 – 8.5
Desirable: 15 mg/l Pt – Co
Desirable: Less than 75% of the saturation concentration
Desirable: 150 – 500 mg/l
Desirable: 0.3 mg/l
Source: Lenntech WHO/EU drinking water standards comparative table

TABLE 2, 3 and 4. The low values indicate that the water is potable and safe for drinking and other domestic applications. Cr, Cd, Ni, Mn, Zn and Pd were not detected. These metals represent a variety of health concerns. Lead and cadmium are suspected carcinogens while chromium, zinc, manganese and nickel are essential to human nutrition at low doses, yet demonstrate adverse health effects at higher doses[12]. The levels of Fe detected at the borehole were 0.15 mg/l and ranged between 0.07 – 0.21 mg/l at the other sampling points. These levels are below the WHO desirable standards of 0.3 mg/l. Excess levels of iron in water promotes the growth of “iron bacteria”, which derived their energy from the oxidation of ferrous iron to ferric iron. Levels of iron above 0.3 mg/l stain laundry and cause taste[1].

Nitrate is one of the four essential priority chemicals to be monitored in drinking water. Compared with EU standards, the concentrations of nitrate detected at the various sampling points including the borehole are below the permissible standard as can be seen in TABLE 3 and 4. There were significant decrease in levels of nitrate from the borehole to various quarters and hostels. This decrease in nitrate levels may be due to reduction reactions or bacteria action[13] occurring during storage or distribution. Nitrates occur widely in ground water, and reduction of which produces nitrite. Nitrite is the actual etiologic agent of methemoglobinemia[8]. The level of nitrite observed at the borehole, (7.40 μg/l) is far below the EU and WHO standards as shown in TABLE 4. Significant increase and decrease occur at several places at the water flows from the borehole. Nitrification is a microbial process by which ammonia is sequentially oxidized to nitrite and nitrate. This microbial action can continually affect the concentration of nitrite depending on various operational practices such as residence time of water in storage tanks and circulation within the distribution system[14]. Nitrification must have played a key role in the significant change in concentration at the various points depending on the operational practice at play.

The levels of calcium, magnesium, sulphate, chloride, bicarbonate and phosphate as shown in the TABLE 2 and 3 are below the WHO and EU standards. This depicts the water to be low mineralized, soft and free of sewage contamination[13]. There were also significant increases and decreases observed as the water flows from the borehole to the residential quarters. Interaction of water with cement linings of A/C pipes can increase ion concentration in drinking water[3] while operational practices such as residence time and circulation could decrease ion concentration[14].

The BOD_5, COD and Total N-nitroso compounds are shown in TABLE 3. While N-nitroso compounds were not detected, BOD_5 and COD observed at the borehole were 0.03 mg/l and 0.04 mg/l respectively. Some N-nitroso compounds are extremely potent carcinogens. There occurrence in drinking water results from reactions occurring during chlorination[15]. The absence of N-nitroso compounds suggests that the water is safe for drinking. BOD_5 and COD determine the oxygen equivalent of the organic matter in a sample that is susceptible to oxidation by microorganism and strong chemical oxidant respectively[8]. The values of BOD_5 and COD observed at the borehole are very low compared with that obtained for other sources of drinking water in Edo State by Akhionbare[16]. These low values suggest that biodegradable and non-biodegradable organic contamination of the aquifer and the water during distribution is low. This is a not-so-surprising finding as groundwater is noted for its low organic contamination[17]. Significant changes in BOD_5 and COD was also observed as the water was piped to homes for use. Increase in biodegradable and non-biodegradable organic in water results in increase in BOD_5 and COD. The low BOD_5 and COD are within WHO permissible limits[18] and make the water potable.

Total Coliform Count

Total coliforms are a group of closely related bacteria (family Enterobacteriaceae) that have been used for many decades as the indicator of choice for drinking water. Total coliforms are used to assess water treatment effectiveness and the integrity of distribution system. Though total coliforms were not mentioned in the WHO’s 1993 guidelines but the EU’s 1998 guidelines stipulates absence of coliform in drinking water. The EU guidelines stated that drinking water should undergo treatments that eliminate coliform bacteria before being distributed to homes. High-quality groundwater can be characterized as containing <1 colifrom per 100 ml [5]. TABLE 3 shows that the total coliform observed at the borehole is 1 per 100 ml and increase in some sampling points. Presences of nutrients, protective habital and favorable water temperatures are conditions that favour proliferation of coliforms. The detection of 1 coliform per 100 ml of water suggests that the water treatment was not effective. The increases at some point indicate poor integrity of the distribution pipes.

CONCLUSION AND RECOMMENDATIONS

Based on the physico-chemical and microbial characterization of the drinking water at the borehole and the ten residential quarters, it was found that the low levels of nitrate, nitrite, phosphate, BOD_5, COD sulphate make the water fit for consumption. The results for calcium, TDS, conductivity indicates that the water is soft and low mineralized. The absence of Pd, Cd, Cr, Ni, Mn and N-nitrosamine further improved the safety of the water. The total coliforms count suggests that the water treatment was ineffective. Significant changes observe in the course of distribution may be attributed to poor management of the distribution system and ineffective treatment of the water before distribution.

It can be concluded that the water is safe for consumption at any of the ten quarter, but there is need to improve the management of distribution network, and treatment before distribution. The pH needs to be raised by liming and the mineral content has to be increased by remineralisation. Remineralisa tion will improve the organoleptic qualities of the water and provide adequate supply of physiological minerals.

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