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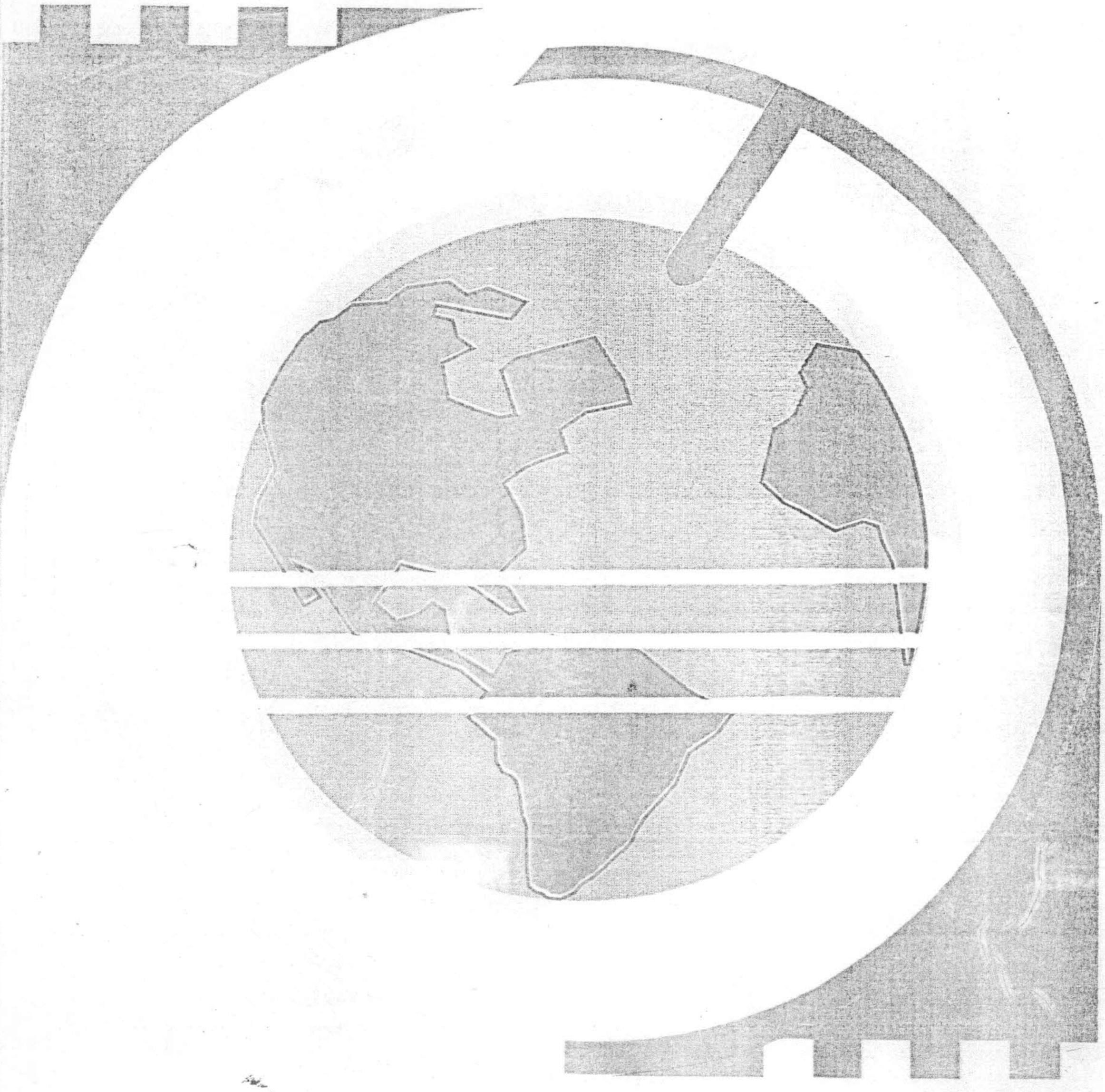

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CONTENTS

RELATIONSHIP BETWEEN CHLORINE RESIDUE AND BACTERIOLOGICAL QUALITY OF PUBLIC TAP WATER SUPPLY IN ILORIN, NIGERIA

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Abstract

The study examined the relationship between chlorine residue and bacteriological quality of tap water in Ilorin. Twenty six water samples were collected from public taps at equidistance position of 500m along three road axis away from treatment plants using sterilized 50cl capacity plastic bottles. The samples were subsequently analyzed at both Chemistry and Microbiology Laboratories of University of Ilorin following the standard procedure on drinking water. Of all the five water quality parameters examined in the study, only chloride level conforms to WHO (2008) standard on drinking water. Correlation analysis carried out revealed a strong negative relationship (r = -0.86) between free chlorine residue and fecal coliform count. The poor quality of pipe born water supply in the study area can be linked to inadequate chlorination, ageing infrastructure, unwholesome workmanship by plumbers and poor maintenance culture on the part of consumers authority concerned. The study thus put forward a number of recommendations towards improving the quality of water being piped to the people.

Introduction

One of the factors contributing to inaccessibility of portable water is the issue of quality. This is because; utility of water is limited by its quality which may make it unsuitable for particular uses. There is wide difference in quality of water in the environment of man. This is because pollutants are often introduced in water from a number of sources (Wright et al., 2004). Polluted water usually encourages concentration of coliform of different types, the ingestion of which may expose the consumer of such water to bacterial infection.

According to World Health Organization (2008), more than one billion people in low income countries lack access to safe water. The reports further observed that 88% of the 4 billion annual cases of diarrheal and cholera diseases can be attributed to unsafe water. Diseases contacted through drinking water kill about 5 million children annually and make almost 20% of the world population sick (WHO, 2004).

Raw water contains microbes which need to be treated before such water can be considered safe for drinking. The most widely accepted means of purifying water is by chlorination, a process of adding the element chlorine. This procedure which has been in practice since early 90s is necessary to control microbial contaminants and restrain bacterial growth. Chlorine is best applied to water which contains resistant micro-organism such as cardiac and cryptosporidium.

However, in the course of applying chlorine to water intended for distribution within an area, such chlorine is consumed in the process of killing the bacteria present in the water. This action thus causes the chlorine level in the treated water to drop, thereby posing great danger to the healthy living of consumers of such water. Not only that, during the distribution of the treated water, bacterial regrowth may lead to deterioration of water quality, amplification of corrosion, generation of bad tastes and odour and proliferation of macro-invertebrates. Bacterial regrowth and coliform occurrence depend upon a complex interaction of drinking water characteristics, engineering and operational parameters (Camper, 1995).

Since quality of water is vital to public health (Shittu et., al 2013) efficient surveillance and checks are of vital importance in executing a high profile management of the resource hence the examination in this study, of the relationship between chlorine residue and bacteriological quality of pipe borne water in Ilorin metropolis. According to Gunnarsdottir and Gissurars (2008), investigation of microbial risk in drinking water from source to consumers can be an excellent management tool in the development of water safety plans for all service providers, especially the public water utilities.

The Study Area

Ilorin, the capital city of Kwara State Nigeria is the study area in this investigation. (Fig. 1). The city which lies between latitude $8^0 24^1$ and $8^0 36^1$ north of the equator and between longitude $4^0 10^1$ and $4^0 36$ east of Greenwich meridian in the Guinea savannah belt of Nigeria. Ilorin with a population of 847,582 (NPC, 2007) covers an area of about 150km square. The city is one of the fastest growing urban centres in Nigeria.

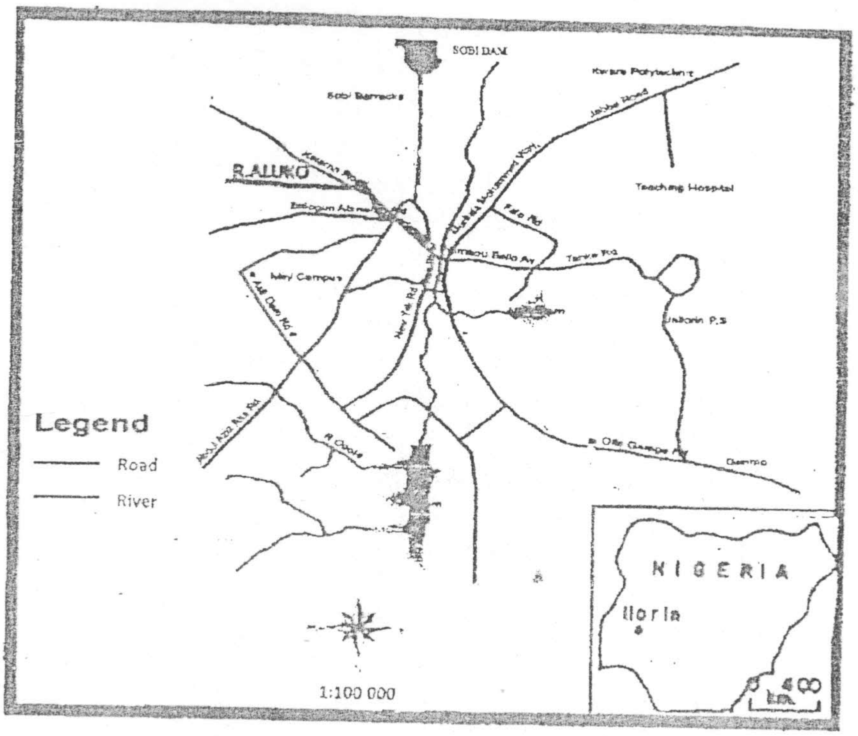

Fig 1: Ilorin: The Study Area.
Source: Author's Fieldwork, 2013.

Ilorin with mean annual rainfall of 1200mm (Olaniran, 2002) is characterized by eight months of wetness and four months of dryness. Temperature in the town is uniformly high and evaporation values range between 3.1 and 7.8mm (Oyegun, 1983). Public water supply in Ilorin is from Asa, Agba and Sobi dams which utilize the six major reservoirs in the town to service the increasing population of the city through over 150Km length water pipelines.

Methodology

Water samples were collected from 26 sampling points located along the streets at equidistance points of 500m away from the treatment plants in the city (Fig.2).

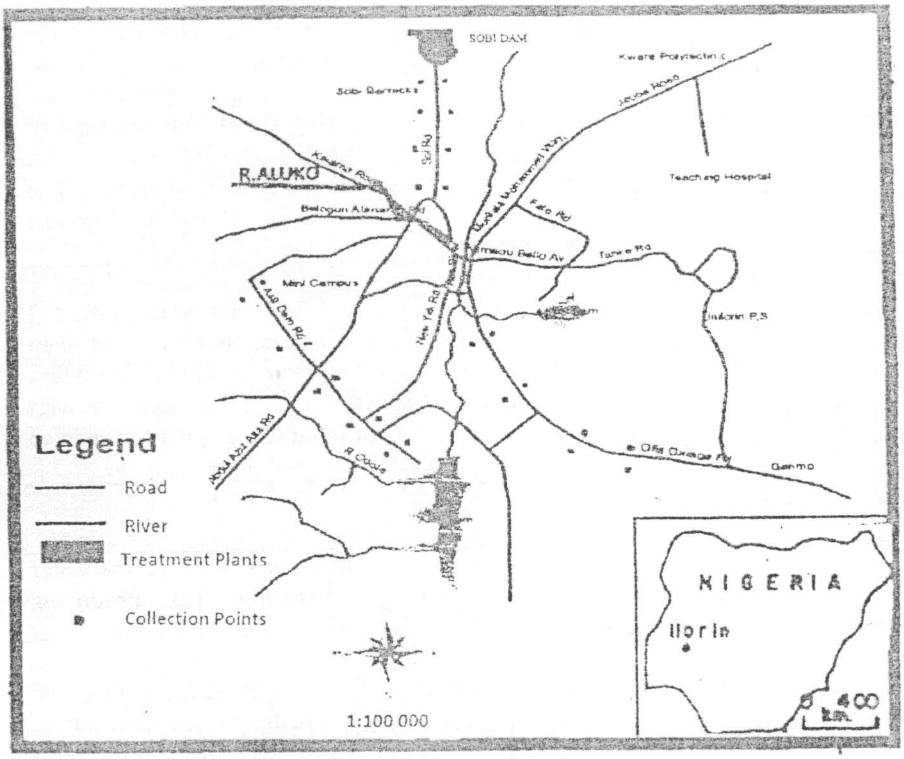

Figure 2: Map of Ilorin showing sampling points
Source: Author's Fieldwork 2013.

The water samples were collected in sterilized 50cl capacity plastic bottles and were immediately analyzed at both Microbiology and Chemistry Laboratories of University of Ilorin in accordance with standard methods of American Public Health Association (2000). In all, five tests were conducted on each water sample collected. Two of the tests were on chemical composition i.e. Free Chlorine residue and Chloride while the remaining three (biological) were on Total Bacteria count, Total coliform count and Fecal coliform count. The analytical procedures adopted in carrying out the tests are as presented on the Table1.

Table 1: Analytical Procedures Adopted in Investigation

Chemical

Free Residual Chlorine	DPD Test	Diethyl Paraphenylene Diamine indicator test is carried out using a comparator. This test is the quickest and simplest method for testing chlorine residual. With this test, a reagent is added to a simple of water colouring it red. The strength of colour is measured against standard colours on a chart to determine the chlorine concentration. The stronger the colour, the higher the concentration of chlorine in water.
Chlorine	Mohr method	100 moles of water sample was measured into a clean conial flask and placed on a white surface. I mole of potassium chromate solution was then added to reveal a yellow solution. This solution was then titrated against silver nitrate solution with constant stirring until lightest precipitate or reddish colouration persists at the end point.

Biological

Coli Form Count	Most Probable Number	This was done to confirm whether or not the water contained lactose fermenting, gas producing bacteria. It was used to determine the most probably number of coliforms in the water samples besides their properties of fermenting lactose and producing gas. After inoculation and incubation, the production of gas was presumption that coliforms were present in the samples. Nine McCartney bottles containing sterile MacConkey broth and inverted Durham tubes in a 3-3-3 tube regimen were set for each sample according to the water sample. After inoculation, the bottles were corked and incubated at 35^0C for 24hours for gas production and lactose fermentation. Production of gas in the Durham tubes and colour change from red to yellow (acid production) confirmed the presence of coliforms in the samples. The results were read using the practical Microbiology of Dubey and Maheshwari, 2004.
Fecal Coliform/Streptococci Count	Membrane Filtration	Samples to tested were passed through a membrane filter of particular pore size (0.45 micron). The microorganisms present in the water remain on the filter surface. When the filter is placed in a sterile petri dish and saturated with an appropriate medium, growth of the desired organism is encouraged, while that of the organism is

		suppressed. Each cell develops into a separate colony, which can be counted directly, and the results calculated as a microbial density. Sample volumes of 1ml and 10ml were used for the water testing, with the goal of achieving a final desirable colony density range of 20-60 colonies/filter. A 10ml volume of water sample is drawn through a membrane filter (45m pore size) through the use of a vacuum pump. The filter is placed on a petri dish containing M-FC agar and incubated for 24hours at 44.50^{0}C. this elevated temperature heat shocks non-fecal bacteria and suppressed their growth. As the fecal coliform colonies grow they produce an acid that reacts with the aniline dye in the agar thus giving the colonies their blue colour.
Total Bacterial Count	Pour-Plate Method	About 1ml of each sample was serially diluted to 10^{-2} near the Bunsen burner to keep the environment free of contaminants. 1ml of the 10^{-2} dilution was used to seed the properly labeled plates in duplicates, and cooled sterile melted nutrient agar was poured into the corresponding plate and swirled to ensure homogeneity. The media were allowed to set and incubated at 37^{0}C for 24hours with plates turned upside down, and the plates were observed for growth and subculture as soon as colonies were (Fawole and Oso, 2004)

Source: Compiled from Standard Analytical Procedure for Water Analysis (1999) and University of Ilorin Microbiology Laboratory Manual.

Results and Discussion

Biological laboratory results on Free Chlorine residue, Chloride, Total Bacterial count, Total Coliform count and Fecal coliform count are as presented on Table 2

Table 2: Laboratory Results of the Biological Analysis

Parameters tested / Sample Location	Free Chlorine Residual (mg/l)	Chloride (mg/l)	Total Bacteria count (cfu/ml)	Total Coliform count (cfu/ml)	Fecal Coliform count (cfu/100ml)
ASA 1	0.41	19.42	120	320	0
ASA 2	0.36	21.48	130	280	0
ASA 3	0.32	14.56	120	320	0
ASA 4	0.28	23.21	140	260	0
ASA 5	0.28	25.27	160	800	0
ASA 6	0.22	35.84	130	320	0
ASA 7	0.20	35.21	130	0	0
ASA 8	0.14	31.62	160	460	0
ASA 9	016	40.46	170	360	0
ASA 10	0.10	44.74	180	360	0
SOBI 1	0.40	20.20	140	0	0
SOBI 2	0.38	21.38	150	400	0
SOBI 3	0.39	19.56	170	320	0
SOBI 6	0.29	42.80	180	220	0
SOBI 7	0.17	44.21	180	400	0
SOBI 8	0.13	44.36	160	420	0
AGBA 1	0.37	23.40	140	0	0
AGBA 2	0.33	44.30	160	340	0
AGBA 5	0.22	60.11	190	400	200
AGBA 6	0.18	59.67	180	240	500
AGBA 7	0.15	54.41	240	420	500
AGBA 8	0.11	54.81	250	400	480
TOTAL	6.88	909.22	43.30	8060	1680
MEAN	0.26	34.97	166.54	310	64.62
STANDARD DEVIATION	0.09	14.15	49.68	170.76	172.71
COVARIANCE (%)	38.31	40.47	29.83	55.08	251.80

Source: Author's Fieldwork (2013)

The result shows that the values of free chlorine residue generally range between 0.10 and 0.37mg/l in the study area. However, for each of the three road axis examined in the study, values of free chlorine residue range between 0.11 and 0.41 mg/l along Asa Dam road axis, between 0.13 and 0.40 mg/l along Sobi road axis and between 0.11 and 0.37 mg/l along Agba road axis. This parameter has a mean value of 0.26mmmg/l, standard deviation of 0.09mgll and covariance of 38.31% in the study area.

The chloride contents of the sampled water ranged between 20.2 and 44.36 mg/l along Sobi road axis and between 21.4 and 54. 81 mg/l along Agba road axis. Chloride in the study area has a mean value of 34.97 mg/l, standard deviation of 14.15mg/l and covariance of 40.47%.

The value of Total Bacteria count varies between 120 and 180cfu/ml; 140 and 180 cfu/ml and between 140 and 250 cfu/ml along Asa, Sobi and Agba road axis respectively with a mean and standard deviation of 166.54cfu/ml and 49.68 cfu/ml and covariance of 29.83%.

The mean value of Total coliform count was 310cfu/ml and this value oscillates between 280 and 800cfu/ml along Asa road axis; between 220 and 420 cfu/ml along Sobi road axis and between 240 and 420cfu/ml along Agba road axis. Total coliform count has a standard deviation of 170.7cfu/ml and covariance of 55.08%. Fecal coliform was observed to be absent along Asa and Sobi road axis but present towards the rear end of Agba road axis with values ranging between 200 and 500 cfu/100ml. The mean value of this parameter was 64.62cfu/100ml. Presence of fecal coliform indicates high degree of water contamination. However, the covariance value of this parameter shows a very high variability (251.80%).

For the five studied parameters (Table 2), fecal coliform count exhibits highest degree of variability while Total Bacterial count exhibits the least. Values of all the parameters progressively increased with distance from treatment plants except that of free chlorine residue whose values decrease with increasing distance from the three treatment plants examined in the study.

The laboratory result from the three road axis presented on Table 2 was further summarized to have a general idea on level of chemical and biological contamination of pipe borne water in the study area (Table 3).

Table 3: Mean Values of Parameters in Samples Collected within Ilorin City

Sample/points Parameters tested	1	2	3	4	5	6	7	8	9	10
Free Chlorine Residual (mg/l)	0.39	0.36	0.35	0.29	0.28	0.23	0.17	0.13	0.16	0.10
Chloride (mg/l)	20.34	22.21	26.14	31.38	43.31	46.08	41.61	43.59	40.46	44.74
Total Bacteria Count (cfu/ml)	130	210	150	160	170	160	180	190	70	180
Total Coliform count (cfu/ml)	106.67	340.00	333.33	306.67	400.00	260.00	273.3	426.6	360	360
Fecal Coliform Count (cfu/100ml)	0	0	0	0	0	0	66.67	166.6	166.67	169

——→ Increasing distance from Treatment Plant

Source Author's Fieldwork (2013).

The result shows that free chlorine residue progressively decreased from 0.39 to 0.10mg/l over a mean distance of 5km in the city. Chloride, Total Bacterial count and Total coliform count however progressively rise with increasing distance from the three treatment plants. Fecal coliform count was only noticed at a distance of 3.km away from treatment plants and this progressively increase in concentration from 66.67cfu/ml observed at 3.5km distance away from treatment plant to 169cfu/ml observed at 5km distance away from treatment plant. This rate of increase in concentration of fecal coliform count represents more than 250% over a distance of just 1.5km in the study area. This result portrays serious danger to quality water supply in the city. Ilorin, the study area is rapidly going through process of urbanization (Aderamo, 1990). The implication of this rapid urban growth on quality water supply in the city is that, as the settlements expand, more residential houses will be built at the urban fringes thus increasing the physical distance of residents of the city to treatment plants with its consequence effects on pollution.

The effectiveness of chlorination in public water supply system in the study area can be explained by analyzing the relationship between free chlorine residue and fecal coliform count present in water along the sampling points. This relationship is as demonstrated on figure 3.

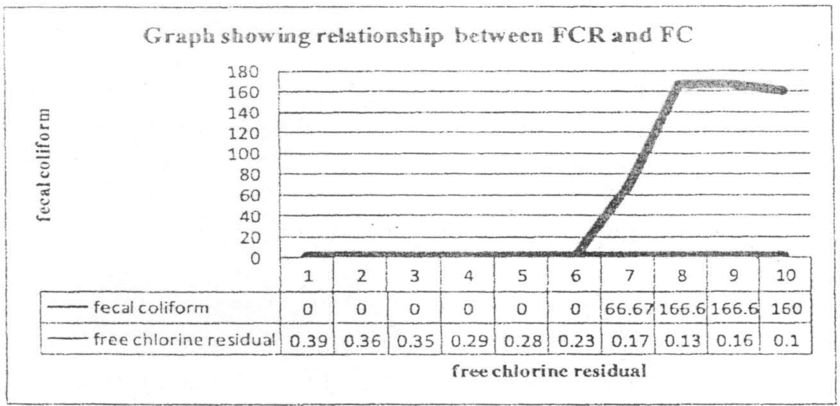

Figure 3: Free Chlorine Residue against Fecal Coliform
Source: Author's Fieldwork 2013.

As showed on the figure, fecal coliform count only becomes noticeable in the study area from the 7th sampling point (3.5k away own treatment plant) when the value of free chlorine residue dropped from its initial value of 0.39mg/l at the first sampling point to 0.17mg/l. The fecal coliform count however rises sharply from 66.67cfu/ml observed at the 7th sampling point to almost a constant value of 166.6cfu/ml at the 8th, 9th and 10th sampling points.

Readings of the two water quality parameters (free chlorine residue and fecal coliform count) presented on Table 2 was further subjected to correlation analysis and a value of r=-0.86 was obtained. This result implies a strong negative relationship between the two parameters. Thus, as the concentration of free chlorine residue in water drops, the amount of fecal coliform increases.

The above result cannot be considered good as only water samples examined at distance less than 3.5km away from the treatment plants (i.e. sampling points 1 to 6) conforms with WHO (2008) standard guideline on chlorine residue of between 0.5 and 0.2mg/l in drinking water. Not only that, WHO (2008) expect the value of fecal coliform count to be zero in any drinking water. Studies such as Shittu et al. (2013), Chan et al (2007) and WHO (2008) have attributed the presence of coliforms in drinking water supply of surface origin to treatment system's inadequacies and poor public hygiene practices. Chloride level in all the sampled water however conforms to WHO (2008) standard on drinking water. Fecal streptococcus in water is an indication of fecal contamination. This thus means that such water has come in contact with human or animal fasces (Gleeson and Gray, 1997). Such water when injected poses great danger to human health.

The presence of fecal conliform in pipe-borne water in the study area could be due to several factors. Amongst such factors include pipeline breakages, regrowth phenomenon if coliform bacteria or inadequate chlorination at the treatment plants. Rossie (1975) suggested that water for distribution should contain at least 1.0mg/l chlorine when leaving the treatment plant and that a minimum of 0.2mg/l residual chlorine should be maintained in the water during distribution. According to him, higher concentrations may become necessary if bacteriological analysis so indicates.

Inadequate disinfectant put in water being piped to people from treatment plants may encourage regrowth phenomenon of coliform bacteria. This is because as distance increases from treatment plants, the concentration level of such disinfectant which is expected to combat fecal coliform bacteria is reduced, hence the regrowth of such bacteria. Other factors which might have caused water contamination in the study area include pipe breakages improperly tightened joints and bad workmanship practices among the plumbers. Pipe leakage is a common feature in the study area. Apart from accidental breakages, activities of sulphur bacterial accounts for some rust formations in iron pipes. In some instances, plumbers do not dig enough to burry service pipes hence their frequent breakages. Incidentally, there is this general laxity in the replacements of damaged pipes in Ilorin, both by the authority concerned and the consumers themselves.

Conclusion and Recommendations

Adequate provision of potable water is of great importance in any human society. This is because of its role in healthy living, ecological integrity and sustainable economic growth. The health of a nation is the state of well being of its people. According to Sule (2003), healthy people and good environment flourish where water is available in adequate quantity and acceptable quality.

Based on the findings from this study, the following recommendations are thus put forward towards improving the living standard of residents of Ilorin and achievement of Millennium Development Goals on water.

i. Regular monitoring of water quality in the town by authority concerned
ii. Increase in effectiveness of chlorination process by the water management board
iii. Regular monitoring of distribution networks to effect immediate repair when damage occurs and replacement of iron which can easily get corroded with plastic pipes.
iv. Enforcement of appropriate workmanship methods by the plumbers responsible for laying and repair of water pipes.

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