

AMERICAN UNIVERSITY OF NIGERIA

DEPARTMENT OF NATURAL AND ENVIRONMENTAL SCIENCES

Senior Research Project

**AN ASSESSMENT OF COLIFORMS IN THE AMERICAN UNIVERSITY OF
NIGERIA WATER DISTRIBUTION SYSTEM**

By

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INTRODUCTION

WATER DISTRIBUTION

Generally, water has numerous purposes: drinking; bathing; washing clothes and dishes; cooking; flushing toilet, irrigation, just to name a few. Its significance cannot be over stressed. This is on the grounds that every day each individual uses water for one thing or the other.

As water flows throughout the distribution system, microorganisms can contaminate the flow of water through the pipes, air valves, pump boosters, network of piping system and sometimes through the plumbing system.

Inability to attain a water quality as high as feasible can open individuals to the risk of getting diseases that can easily be avoided through percussive methods.

Drinking and domestic use

Household or domestic water is mainly the water used for drinking, washing and cleaning purposes. Water quality hence is dependent on its micro-constituents and whether or not it has adverse effects on consumption. Therefore, water containing harmful or toxic microorganisms and elements is regarded as unfit for household consumption. Basic examples of toxins found in household water incorporate microorganisms, for example, protozoa viruses, and bacteria; inorganic contaminants, for example, salts, metals, radioactive contaminants and small amounts of organic contaminants.

However, industrial water includes water sources used mainly for industrial purposes. The quality of water in this scenario is therefore slightly different than the water meant for consumption purposes. For instance, hard water, which constitutes

high concentrations of minerals, hampers the effectiveness of soaps or detergents whereas drinking water should most preferably be hard water because of the presence of ions such as calcium and magnesium.

On the other hand, environmental water describes water available to the biosphere and which in some way affects the balance of the ecosystem. Lethal constituents and high masses of specific microorganisms pose risks for non-drinking purposes, for example, swimming and irrigation which inhibits the use of domestic water. The measured quality of water bodies is called *Ambient Water Quality*.

Importance of good water supply

The quality of water is noted as important not only because it affects health, but also because it has the tendency to improve it as well. The body is made up of 70% water and the amounts of magnesium and calcium present in any body of consumable water has the ability to improve bone mass and density.

The elements present in water, depending on their quantities, have the ability to hamper the effectiveness of industrial machines by causing rust, brittleness, clogging, bursting, etc. Hence, to ensure the a good standard water quality, there needs to be an understanding of what pollutants and contaminants upset the balance of water constituents is necessary to ensure that balance is not tempered with.

Trace levels of ammonia, barium, lead, copper, nitrites, radium, selenium, etc. have negative effects on humans if present in large amounts and can only be curtailed via treatment. There is the point-of-use treatment which involves the treatment of water at the point of consumption using methods such as reverse osmosis, ultraviolet technologies and distillation. On the other hand, point-of-entry

involves the treatment of water needed for household chores using methods such as ion replacement and filtration. On the line of water distribution or supply, filtration comes as it is a key process in ensuring good water quality.

Description of the purification methods

Physical Form of Water Purification: It is thus named because it is concerned with filtration techniques. Filtration is used while purifying water because it effectively rids the said portion of water of particles, silts or debris. Sometimes, for special purposes, specific filters capable of filtering out bacterial form can be engaged. A few examples of physical purification include:

1. Screen: Usually used to remove large contaminants like leaves and twigs.
2. Sand Filtration: It is a vigorous process used to remove suspended solids from water. It consists mainly of a filter medium containing multiple sand layers of different sizes and densities. These solids are precipitated as residue when water is made to flow through the filter. Because smaller solids have the ability to pass through sand filters, they are subjected to a secondary filtration.
3. Cross Flow Filtration: This is a filtration concerned with using a permeable membrane to remove both salts and dissolved organic matter that only permeates the contaminants. The filtrate is removed as the process goes on. The following are types of cross flow filtration: micro-filtration, ultra-filtration and reversed osmosis.
4. Cartridge Filtration: It generally operates effectively and economically on applications having excessively high contamination levels. They consist of fibers and are normally used as final processes as polishing filters.

Chemical Form of Water Purification

1. **Chemical Addition:** This process mainly consists of agents such as chelating, oxidizing and reducing agents. They are necessary to add to the water to prevent the negative effects of hardness, caused by the deposition of elements
2. **Clarification:** It consists of a series of processes that involves the addition of coagulants to remove large. Suspended solids. Coagulants help to reduce the charges of ions causing the particles to gather and form larger particles called Floccs. These particles are removed as water flows. Further treatment may be needed because the water may still contain some suspended solids.
3. **Deionization and Softening:** This is commonly processed through a system called Ion Exchange. It consists of a tank of synthetic resin which is treated to selectively absorb certain cations or anions and replace them with desirable counter-ions until all the available spaces are filled up with ions.
4. **Disinfection:** Disinfection is one of the most important and widely known steps in the purification of water for household use. Often referred to as biocides, they serve the purpose of killing undesired microorganisms in the water; ozone, chlorine and controlled UV-radiation disinfections are good examples.
5. **Distillation:** Distillation is the collection of water vapor, after boiling. Because most contaminants do not vaporize, with a properly designed system, the remaining organic and inorganic contaminants and biological impurities can be obtained.
6. **Electro dialysis:** Electro dialysis is a complex technique which employs the use of electrical currents and special membranes – membranes which are semi permeable to ions based on their charge. Those membranes that

permeate cations and anions are placed alternately with electrodes on each side and flow channels between them. The electrodes draw their counter ions through the membranes, so that these are removed from the water.

Sometimes, the water in cities are pH adjusted to prevent corrosion from pipes and to prevent the dissolution of lead into the water supplies.

Biological Water Purification

Biological water purification is a process undertaken to lower the load [The Biological Oxygen Demand (BOD)] of dissolved organic compounds using Microorganisms such as bacteria to decompose these compounds. There are two main categories of biological treatment: aerobic treatment where the water is aerated with oxygen and anaerobic treatment which runs under oxygen free conditions.

Water safety and quality

Water is one of the key fundamental supplements required by the body in sufficient amount in other for authentic human functioning. It is not produced by the body. It constitutes some amount of the body fluid, for example: sweat, urine, blood, saliva, just to name a few. Then again, it can be acquired from the ingestion of food and fruits.

The nature of water ought to be free from high concentrations of any pathogenic microorganism that can result in an ailment on intake. Pathogenic microorganisms can be evident but should not be present in concentrations that can result in disruption of the body on intake. Throughout the years, there has been much discussion over the satisfactory concentration of pathogenic microorganisms in

water. Be that as it may, the United States Environmental Policy Agency (USEPA) worked up an adequate concentration level that is renowned around the world.

Around the world, diverse health organizations have set principles for water quality. Out of the different sorts of water sources, water taken into the body ought not to contain microorganisms like bacteria, and should have a low concentration of dangerous chemicals (that is, chemicals toxic to humans). The presence of these microbes in water are evident in nature and testing for specific bacteria can be time consuming. This is why it is better to use indicator organisms to check if coliforms exist in water distribution systems.

Water quality is a term most adequately used to insinuate the substance, physical, organic, and radiological characteristics of water. It should measure the condition of water bodies in respect to the requirements of one or more life structures and to any human need. Regularly, the most broadly perceived benchmarks used to assess water quality relate to wellbeing and the security of human contact and drinking water. Therefore, the nature of desired water quality fluctuates with intended usage.

Faults in the system

The following is a list of reasons for water pollution:

- Untreated water from motorways and cleared surfaces when it rains runs-off conveying sediments, lethal chemicals from the engine of vehicles, pesticides and composts from gardens, pathogens and microscopic organisms like bacteria from pet waste and broken septic tanks into nearby water bodies.

- The increase of nutrients leads to large algal blooms which eventually leads to reduced amounts of dissolved oxygen in the water after the death and decomposition of these algae creating hypoxic or “dead zones,” in which organisms cannot survive.
- Also wastes that are not appropriately discarded wash into drains or get blown into waterways and turn into debris.

WATER-BORNE RELATED DISEASES

Classification

Contamination of water by disease causing and non-causing organisms happens mainly from the source where water is obtained, although it can also arise during water treatment or within the distribution system. Contamination may also arise due to some environmental factors.

One of the significant water pollution issues seen to be prevalent is the exposure to transmittable diseases through water that is contaminated with mammal waste. Water-borne related diseases usually arise from the use of water that has both been treated but there is a problem with the efficacy of the process and generally water that has not gone through any treatment processes. Flushing out the water distribution system really helps in reducing the risk of getting water borne related diseases.

Furthermore, the inclusion of filters at different points in the water distribution system helps in the reduction and finally elimination. As a result if this, the probability of water-borne related diseases occurring is reduced because the

filters filtrate both pathogenic and non-pathogenic organisms and ensure the cleanness of water quality.

Water pathogens such as *Giardia* and *Salmonella* can be introduced in as a result of periodic habitation of domestic animals. These animals that live near water areas are known reserves for these intestinal pathogens and are causative agents of water uncleanness.

Indicator organisms

Water comprises fundamentally of microorganisms that are unsafe to mammals in general.

Simply put, indicator organisms are organisms used as an intermediary to screen conditions in a particular environment. Indicator organisms include mainly of three types: indicator bacteria, which are used to show the existence of coliforms in water bodies; indicator fungi, used for microbial testing as a part of pharmaceutical organizations routine when making drugs and indicator helminths, which are used to check the safety of recycled waste water.

However, indicator bacteria organisms like coliforms are good indicators in checking for the presence or absence of pathogenic organisms. This is solely because indicator organisms help show fecal contamination in water. In cases of fecal contamination, indicator organisms ought to show up in concentrations that can be corresponded with a degree of contamination and also, should have a life expectancy rate that is not higher than that of pathogenic organisms. This is so that indicator bacteria can show their presence. Since most pathogens are not easily found,

indicator organisms are used as a monitoring tool in changes or conditions in the environment, in relation to water.

One of the most widely used group of indicator organisms is the coliform bacteria. These organism are defined by their unique characteristics: organisms that ferment lactose and produce gas under high temperature. Coliforms do not normally occur in surface water, but are always found in human and animal faeces. Therefore, the presence of coliforms in water indicates the presence of recent fecal contamination.

In cases of fecal contamination, indicator organisms ought to appear in concentrations that correspond with the degree of contamination and also, should have a life expectancy that is not longer than that of pathogenic organisms. Since many pathogens are not easily cultured in the lab, indicator organisms are used as a monitoring tool in changes or conditions in the environment, in relation to water.

In relation to epidemiological studies, it is not generally important for indicator organisms to show fecal contamination in water. It might be sufficient to get a sign of the existence of individual pathogen by different techniques. The most imperative system is to discover, specify and give an estimate of seen coliforms.

Most Probable Number (MPN) Test

The most probable number test is a useful tool when trying to undergo an assessment of the quality of water. The test is used to assess the concentration of viable microorganisms in water by means of using liquid broth growth as a means to monitor in series of dilutions. It is also helpful in undermining the particulate material that interferes with plate count enumeration methods.

This is one of the various tests that can be utilized to test the quality of water. It takes into consideration the discovery of the vicinity of coliforms in specimens also, estimation of their numbers. It comprises of three stages.

The first stage is the presumptive test. Here, lauryl tryptose broth (LTB), which is used, is comprises of tryptose, lactose, sodium chloride, dipotassium phosphate, monopotassium phosphate, and sodium lauryl sulphate. Fermentation by the coliforms produces gas which is a positive result showing coliform presence.

The media is made in different strengths. The double-strength media is made using double the amassing of single-strength.

Series of dilutions are produced using the water tests by including 10ml of water sample to five tubes of double strength, 1ml to five tubes of single strength and 0.1ml to five tubes of single strength. Durham tubes are put inside every tube that contains the water containing the broth (Gerba & Pepper, 2004). These Durham tubes identify the presence of gas. The gas is delivered by the aging of lactose by the coliforms. A table is then used to enumerate the amount of coliforms found of each sample per 100ml.

The last test is the completed test. Here the presence of pathogenic organisms like E.coli, are tested for in the positive indicated tubes. Levine's Eosin Methylene Blue (EMB) and Endo agar are used. (Gerba & Pepper, 2004, p. 118). Levine's EMB agar contains methylene blue which hinders gram-positive microscopic organisms (Gerba & Pepper, 2004, p. 117). In EMB medium, lactose fermenters show up nucleated or with a green sheen while non-coliforms don't have nucleated settlements (Maier, Pepper, & Gerba, 2009, p. 488). E.coli and

Enterobacter aerogenes can be separated in light of size with E.coli being littler and having a metallic sheen (Gerba & Pepper, 2004, p. 118).

Endo agar contains a fuschsin sulfite marker which helps in identifying lactose fermenters (Gerba & Pepper, 2004, p. 118). For the Endo agar, other colonies could be seemly red while non-forming ones have no color (Maier, Pepper, & Gerba, 2009, p. 488)

Interview

Basic Historical Context:

This is an interview conducted on the basis of getting to know how the AUN water distribution system works. Also, it was conducted to give the student a firsthand exposure with water resource engineers in the field. The interview was structured in such a way to get information concerning mainly the weaknesses and strengths of the system and how the distribution system here works. It was conducted on the 7th of April, 2015 while the informant, Mr. Dahiru was taking the student and Dr. Boyd on a tour of the distribution system and lasted for about 45minutes.

Interview Summary:

In AUN, there are two different kinds of lines or pipes that supply water. They are: the Fire Hydrant line and the Potable Water line.

The fire hydrant line is hardly used. It is used in fire emergencies or when there is low supply of water to some part of the school. It has a booster pump that allows for the attainment of a lot of pressure to quench fire during outbreaks.

The first place to experience water in times of crises or when water is pumped is the lowest point on campus which is the Roseria Volpi dorm. This is after water has been pumped. If there is no water on campus, it is the last place to experience water outage and the first place to regain water after pumping.

The Potable water line has a booster but is not used because topographically, the storage and distribution tanks are situated at the highest point on campus. Also, because minus the advantage of the distribution tank being the highest point on campus, the tank is also 12 meters tall which allows for gravitational free flow of

water, hence, it works mainly with gravity. When being distributed, gets to the top of each building before distributing round the building.

Water on campus is continually pumped. This is done in order to avoid water crisis. However, what keeps the water resource people in check is the graduated rule located on the tank and the meter inside the control room which shows a precise reading of the level of water currently inside the tank.

In the distribution system, steels pipes are used from the pump site to the storage tank and plastic pipes throughout the distribution system on campus. All the buildings on campus are interlinked to the distribution tank. On campus, these pipes have junctions that break off to supply other buildings. However, no building has its own storage tank. Water moves with the right amount of pressure and satisfies each building requirement.

Initially at the onset of AUN, the school drilled 13 boreholes. After a few years, these boreholes could not deliver as much water as it was intended to distribute. Normally, AUN requires 120 cubic meters of water per hour but those initially drilled boreholes could not deliver as much.

After assessing the situation, Mr. Dahiru got permission from Mr. Alex Cobo to drill two boreholes which are the ones the currently being used by the university. The AUN borehole does not just supply water to the campus but also supplies to the AUN hotel, AUN club, AUN printing press and to the Faculty housing at North Campus. These boreholes work in such a way that they are dependent on backflow. Backflow means that when the storage tank on campus is filled up, a designated pumping machine on campus automatically pumps the water back to the pump site causing the

people at the control room to switch off the pumping machine. This allows for constant water supply to the faculty housing, the club, printing press and hotel.

At the site, fumigation was stopped two years ago because fumigation contaminates the water system. Occasionally, the boreholes are serviced.

The septic tanks on campus are interconnected and the network of these tanks are being sent to a general septic tank which is emptied twice a year.

Water tests are conducted quarterly every months. It comprises of two main tests: Biological and Chemical analysis.

The United States Environmental Protection Agency, USEPA, put together a chart that shows a tolerable level of acceptance of water quality and that is what the campus uses.

OBJECTIVES AND HYPOTHESIS

Objectives:

- To check for the negative health effects of drinking water containing coliform bacteria.
- To find out how much coliforms are in the cafeteria (the dispenser and water used for cooking).
- To compare the amount and type of colonies found in each collection point with the nearby sewer.

Hypothesis:

The number of coliform bacteria currently present in AUN distribution system is enough to cause water-borne related diseases.

MATERIALS AND METHODS

Materials:

1. Ten sterile bottles.
2. Ten sterile pipettes.
3. Micro-pipettes (100 and 1,000 micro-liters).
4. An autoclave.
5. Incubator.
6. 15 test tubes per sample (15ml and 10ml).
7. Durham tubes.
8. Test tube rack.
9. Weighing balance.
10. Magnetic stirrer.
11. Stirring rods.
12. Inoculating loop.
13. Bunsen burner.
14. Petri dishes.
15. 70% ethanol.
16. Foil.
17. Beakers.
- 18.** Two conical flasks (1,000ml).

Reagents:

1. Distilled water,
2. lauryl tryptose broth,
3. Eosin Methylene Blue (EMB) agar

4. Endo agar media.

Methods:

The procedure followed was as in Bacteriological Examination of Water: The Coliform MPN Test and Standard Coliform Most Probable Number (MPN) Test.

This experiment entails three major test. However, due to unavailability of materials, only two of the three tests were conducted: Presumptive and Completed Test.

Collection of Water Samples:

Water samples were obtained from the pump site located close to the AUN hotel, the storage tank at the back of the faculty offices, the new library, Peter Okocha Hall, Arts and Sciences. Cafeteria dispenser, cafeteria cooking water and faro water bottle.

The samples were obtained by first putting on the taps and allowing them to flow for some seconds and obtaining the sample carefully so that there was no spill.

Procedure:

Presumptive Test:

This is the first part of the experiment. Here the indication of gas in the Durham tube shows the presence of coliforms. It also entails using two different concentrations of the media Lauryl Tryptose Broth (single and double). Here, 15 test tubes are used for each sample: 5 for the Double-Strength Lauryl Tryptose Broth with 10ml of sample; 5 for the Single-Strength Lauryl Tryptose with 1ml of sample and 5 for the Single-Strength Lauryl Tryptose Broth with 0.1ml of sample.

- 1.) Single-Strength Lauryl Tryptose Broth (SSLTB) was prepared following the manufacturer's (Oxo, UK) directions. Briefly 20 g tryptose, 5 g lactose, 5g sodium chloride, 2.75 g dipotassium phosphate, 2.75 g monopotassium

phosphate and 0.1 g sodium lauryl sulphate were mixed with 1 L of water.

Double strength lauryl tryptose broth (DSLTB) was prepared with the double the reagents in 1 L of water.

- 2.) In this experiment, two sizes of test tube were used: a 10ml and 15ml tubes. The 10ml tubes are for the SSLTB tests and 15ml tubes for the DSLTB tests. Durham tubes were introduced into all tubes, upside down in order to capture the gases released by the bacteria during fermentation. 10ml of DSLTB were added to the 15 ml test tubes, 10 ml of SSLTB were added to the 10 ml test tubes. All tubes were autoclaved at 121°C and 15 lbs for 15 minutes
- 3.) 10 ml of the water sample were added to each of the 5 DSLTB tubes. The water and the broth were mixed gently making sure not to introduce bubbles into the Durham tubes.
- 4.) 1ml of water sample was added to each of the 5 SSLTB tubes as above.
- 5.) A further 0.1 ml of water sample was added to 5 more SSLTB tubes as above.
- 6.) After inoculation, the test tubes were capped and incubated at 35°C for 24 ± 2 hours.
- 7.) After incubation for the required time, tubes with gas were recorded as positive and those without gas were recorded as negative (see Table 2.1)
- 8.) The most probable number (MPN) of coliform in the water samples were calculated using Table 1.1.
- 9.) Tubes with gas production were stored at 4°C for the next test. Refrigerating preserves the tube and slows down the growth of bacteria.

Table 1.1 showing the Most Probable Number (MPN) table for various combinations of positive and negative results

5 of 10 ml each	5 of 1ml each	5 of 0.1ml each	MPN Index 100ml	5 of 10ml each	5 of 1ml each	5 of 0.1ml each	MPN Index 100ml
0	0	0	<2	4	2	1	26
0	0	1	2	4	3	0	27
0	1	0	2	4	3	1	33
0	2	0	4	4	4	0	34
1	0	0	2	5	0	0	23
1	0	1	4	5	0	1	31
1	1	0	4	5	0	2	43
1	1	1	6	5	1	0	33
1	2	0	6	5	1	1	46
2	0	0	5	5	1	2	63
2	0	1	7	5	2	0	49
2	1	0	7	5	2	1	70
2	1	1	9	5	2	2	94
2	2	0	9	5	3	0	79
2	3	0	12	5	3	1	110
3	0	0	8	5	3	2	140
3	0	1	11	5	3	3	180
3	1	0	11	5	4	0	130
3	1	1	14	5	4	1	170
3	2	0	14	5	4	2	220
3	2	1	17	5	4	3	280

3	3	0	17	5	4	4	350
4	0	0	13	5	5	0	240
4	0	1	17	5	5	1	350
4	1	0	17	5	5	2	540
4	1	1	21	5	5	3	920
4	1	2	26	5	5	4	1,600
4	2	0	22	5	5	5	≥ 2,400

Source:

Completed Test:

The presence of growth and gas production in the presumptive test indicates the presence of coliform bacteria but does not identify the actual bacterial species.

Further growth in selective and differential media was used to determine the types of bacteria present in the water source.

Here, using an inoculating loop, the selected positive tubes are streaked on the endo agar and EMB plates

- 1.) Examine and record the results. For the endo agar plates, if reddish colonies are formed, the test is positive and vice versa. For the EMB plates, if dark centers are formed, the test is positive.
- 2.) Eosin Methylene Blue (EMB) media is partially selective, in that gram positive are inhibited by methylene blue. It is also differential in that different species of coliforms have different colony morphologies when grown on the media. Bacteria that can ferment lactose, the only carbon source in the media, will lower the pH of the media around the colony causing the eosine and

methylene blue to turn the colony dark blue. Bacteria that cannot ferment lactose produce colonies that are colorless or pink.

- 3.) No lactose fermentation, neutral or alkali pH: colonies are colorless or amber (Proteus, Shigella and Salmonella)
- 4.) Low lactose fermentation produces mucoid pink-brown colonies (Enterobacter)
- 5.) Medium level fermentation create colonies with a dark blue center (Klebsiella) or colonies that are uniformly light blue.
- 6.) High level fermentation by *E. coli* produces a high level of acid on this media and therefore creates colonies that are dark blue with a metallic sheen.

Precautions:

- I ensured my hands were washed before and after the experiment.
- I ensured that there were no spills when putting the media (lauryl tryptose broth) into the tubes.
- I closed the tubes with caps and ensured they were not too tight (loosely tightened).
- I labelled all the tubes according to what they stood for, that is, their concentration and sample. This was done so there would not be no mix-ups.
- I refrigerated the media (lauryl tryptose broth) to ensure it stayed fresh for the each use.
- I ensured the Durham tubes were placed upside down in the test tubes and were not broken before putting in the media (lauryl tryptose broth).

RESULTS

Table 2.1 showing the results of the Presumptive Test carried on a section of AUN Distribution System.

Sample	DSLTB (10ml)	SSLTB (1ml)	SSLTB (0.1ml)	MPN Index per 100ml
Arts and Science	4	0	0	13
Cafeteria (Cooking Water)	5	0	0	23
Cafeteria (Dispenser Water)	0	0	0	<2
Faro water	0	0	0	<2
Library	5	0	0	23
Peter Okocha Hall	1	0	0	2
Pump site	4	1	0	17
Storage tank	5	0	0	23

Above is a table showing the results of the presumptive test carried on some strategic points on AUN campus. Table 2.1 shows the number of positive tubes out of 5 for each of the three dilutions. The MPN index is a statistical calculation based the number of test tubes able to produce gas (ferment) or show indication of the presence of coliform (see Table 1.1).

Also according to table 2.1, the cafeteria dispenser and Faro Water have low (or no) numbers of coliforms. An explanation for this result will be that in the cafeteria, the dispenser water goes through a lot of filtration and hence, it turns out that filtration helps in reducing the number of coliforms. However, it may or may not be the same for faro water. If it is not the same, then, the company either adds chemicals to aid purification or the borehole that is drilled has equally low numbers of coliforms.

DISCUSSION

Challenges Faced in Generating Data

During my project, there were a few issues faced in generating the data I needed. For instance, when I initially started this experiment, I intended to use a water bath. On usage, there was a power outage and this affected my experiment because the samples were supposed to stay under a temperature condition of 35°C for 24hours and the objective was bridged due to the outage. My initial results were as follows:

Table 2.2 showing the Presumptive Test of the positive tubes during the outage period

Name of Sample	DSLTB (10ml)	SSLTB (1ml)	SSLTB (0.1ml)	MPN Index per 100ml
Peter Okocha Hall	5	3	1	110
Art and Science	3	3	0	17

Here, the results obtained was at 1:40 pm on the 19th of March. My inference to this is, during the outage, the coliform bacteria had a conducive environment (temperature) to grow, hence, the outcome.

Table 2.3 showing the Presumptive Test after subtracting the number of hours lost and putting in an incubator.

Name of Sample	DSLTB (10ml)	SSLTB (1ml)	SSLTB (0.1ml)	MPN Index per 100ml
Art and Science	5	4	-	130
Peter Okocha Hall	5	4	2	220

There is a change because they were not inoculated completely for 24hours (the power outage). However, the tubes were transferred to the incubator at 8:01am the following day. Changes or growth was still checked at 1:35pm but due to the disruption in room temperature, I allowed the test tube to stay until 8:05pm later that day to complete the tubes stay to 24hours. The result I obtained is seen in table 2.3.

There was also an issue in the making of the Endo Agar media. There was an assumption that Endo Agar had the necessary supplements and there was not any need to out any additives. This was found out after the first two completed tests did not show any indication of bacteria. We then re-made the media.

I was also unable to do carry out the second aspect of the test (confirmed test) due to unavailability of materials.

Results Compared with Other Water Systems

Weaknesses and Strengths of AUN Distribution System:

Initially, there was an issue concerning recovery during an outage. About three years, this was the case as there was no air valve in the piping system. In water distribution systems as big as the one we have on campus, it is advised to have air valves in the

system. This allows air to move out when water is pumped. The solution was to incorporate air valves into the system.

Plans to Increase or Decrease Water Supply:

The campus currently has plans to decrease the water supply to the campus. The campus is currently looking for a way to recycle waste water and use it for mainly for irrigation. This plan removes irrigation from the distribution system and leaves it solely dependent on the recycled water. This is currently still in the design stage.

Also, besides irrigation, the numerous car wash sites found on campus also contributes to water loss. It is also intended to be included in the recycled water distribution system and over time, the numerous car was sites reduced to just one.

In general, the water resources department is looking for ways to reduce water supply and wastage.

Which of the Collection Points Had the Most Coliform Colonies and Why?

For this research, according to Table 1.1, the storage tank, cafeteria cooking water and the library had the highest number of coliforms.

My inference to this result is either the piping system connecting the pump site to the campus is contaminated by pathogenic microorganisms or the storage tank is not well kept. There is a chance that microorganisms are contained inside the storage tank and have not been properly eradicated.

Unfortunately, since the map of water distribution was unable to obtain, from my point of view, it is safe to say the same coliforms contained in the water are transported to these other locations (Cafeteria cooking water and the library). This is because of the visible distance seen – they are close to the storage tank.

RECOMMENDATION AND CONCLUSION

From past research and now, I conclude that there is a significant reduction in the number of coliform bacteria in AUN's water distribution system. However, with the inclusion of filters throughout the distribution system, I feel AUN can reduce the number of coliforms to an acceptable level (<1 per 1000 ml).