The Analysis of Physio-chemical Properties of Surface Water Treatment

A Case Study on the White Water Treatment Plant in Monrovia, Liberia

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Abstract Water is a valuable commodity that is essential for human survival and the environment, yet is also spreads a variety of infectious diseases. According to WHO estimates, inadequate sanitation and dirty water cause up to 80% of all illnesses and disorders worldwide. The best and most successful treatment technique is a problem in the world's drinking water treatment, which is strongly reliant on accessible water sources. The raw water (influent) is treated through coagulation, flocculation, sedimentation, filtration, and disinfection before being sent to the reservoir for consumption. Water treatment should be at its best, with some steps made to increase the quality of treated water for human consumption. This study explains the water treatment process in traditional treatment plants and ensures that best practices are followed in order to meet the World Health Organization's requirements (WHO). All of the important physiochemical factors are taken into account in water quality analysis so that the treatment procedure can be optimized.

Physio-chemical parameters like pH, Turbidity, Electrical Conductivity, Total Dissolved Solids (TDS), Temperature, Residual Chloride, Faecal Coliforms, and Total Faecal Coliforms were taken into account during the water quality analysis in the laboratory at the White Plains Treatment Plant, which is the study area.

The average water quality metrics evaluated at the White Plains Water Treatment Plant are all in compliance with WHO requirements. The White Plains Water Treatment Plant situated outside of Monrovia, is the primary supply of drinking water to the inhabitants of Monrovia and its environs, and it employs Aluminum Sulfate as a coagulant. The Liberia Water and Sewer Corporation, a government owned company, is in charge of its operation.

Keywords: Physio-chemical properties, drinking water quality, Surface water treatment, White Plains Water Treatment Plant.

1. INTRODUCTION

Water is still a valuable item in the lives of humans and other organisms, and it is considered life by some people. If there is no excellent quality water for plants and animals to drink, lives on this planet are pointless. Water consumption has increased over the previous 100 years as a result of improved lifestyles, massive population development in urban areas, and industrial activities. According to reports, more than one-sixth of the world's population lacks access to safe drinking water sources, and climate change has impacted surface water quality and availability (floods and droughts).

In 2010, over 28% of the world's population (1.8 billion people) using dangerous water, with another 18% (1.2 billion people) collecting water from large sources. About two-fifths of Africans lack improved water supply, 60.2% have access to clean drinking water sources, and 36% lack improved sanitation facilities.

Waterborne infections such as diarrhea, life-threatening illness and disabling illnesses are caused by a lack of adequate drinking water for people largely in impoverished nations around the world. The demand for fresh water is expanding on a daily basis as a result of global urbanization (more population, developing economies, changing lifesystles, etc.) putting pressure on finite natural resources and ecosystems.

Major drinking water sources are at risks of pollution due to extensive agricultural activities resulting from the usage of fertilizers, insecticides, pesticides, landfills, industrial activities resulting from the usage of heavy metals, domestic wastes, leakages from septic tanks and pit latrine can contaminate both surface and groundwater sources thereby affecting aquifers. Base on the availability of these contaminants in water sources, water should be treated in order to meet the standards of the World Health Organization and other guideline bodies in the world in order to be consumed by humans and other usage. In 1973, the act to amend the Public Utilities Law established the Liberia Water and Sewer Corporation with the mandate to construct, install, establish, operate, manage and supply to safe drinking water, sewerage services to every area in Liberia and also maintain both water and sewer facilities. The White Plains Water Treatment Plant and the entire water supply system in Monrovia, including the distribution network, were built in 1960 by the

Chicago-based Corporation (AB & H), a Donohue Group affiliate, with a capacity of around 8 million gallons per day on a 24-hour operation schedule. Because the older intake was being damaged by salty water due to low water levels in the Saint Paul River during the dry season, they were driven to return to the use of onsite River (St. Paul) intake, which allowed for the use of low lift pumps for raw water supply. The treatment plant was designed to handle increase demand of the population of Monrovia and its environs after the infiltration galleries on Bushrod Island which was the main source of water supply could no longer withstand the growing population of Monrovia and its surroundings. Before the Liberian Civil War which started in 1990, the White Plains Water treatment Plant produced 16 million gallons per day on a total population of 500, 000 people which was adequate to meet their needs to of increasing population using two major transmission mains (16" & 36") for water delivery. During this time, the White Plains Water Treatment Plant was operated on a 24-hour basis with an intake from a 42-inch pipe from the Mount Coffee Hydro-Plant as a raw water source which flowed by the means of gravity through 5km downstream toward the treatment Plant. Currently, the total population of Monrovia and its environs is about 1, 500,000 people which triple the number of people before the war thereby creating huge demand for water supply in the study area.. This huge increase in population was created after the Liberian Civil War in 1990 which caused many people to migrate to urban areas most especially the capital city of Liberia. During this civil war, the White Plains Water Treatment Plant was vandalized by rebels and some community dwellers which caused filter, sedimentation basins, pumps and some other equipment to be non-functional and thus creating obstacles in the daily operation of the plant. Due to the growth in population, the plant's capacity was drastically decreased to fewer than 5 million gallons per day, versus a daily demand of 32 million gallons. The African Development Bank provided funding for partial rehabilitation work to return the plant to its pre-war state. EleQtra, a business that manages both public and private finances, was given the contract for the renovation of the White Plains Water Treatment Plant. The contract took into consideration to restore the main transmission network (36" concrete pipe) and also conduct 10 bars pressure testing on the transmission line in order to identify leakages and total pressure the network withstand as well as capital improvement works which took into account the intake facility, storage and some main parts of the transmission and also the distribution networks.

The treatment plant still uses the conventional treatment process which was used before the Liberian Civil War in 1990 even after some rehabilitation works were carried out. Because of its ease of operation, relatively simple design, and low energy consumption, this treatment method eliminates colloidal and suspended particles from raw water and is one of the most popular physicochemical processes used in surface water treatment. Aluminum sulfate, often known as alum ($Al2\ (SO4)3\text{-}18H2O$), is the most widely used coagulant for surface water treatment and the production of safe drinking water in the world. Charge neutralization assists in the removal of colloidal and suspended contaminants from water. The White Plains Water Treatment Plant, which is the primary supply of drinking water for Monrovia and its environs, is operated and managed by the Liberia Water and Sewer Corporation, a state-owned enterprise in Liberia. Coagulation is a crucial step in the surface water treatment process that removes colloidal and suspended contaminants from the raw water. This treatment method is one of the most commonly utilized physio-chemical processes in surface water treatment because of its ease of operation, relatively simple design, and low energy consumption. Aluminum sulfate is use most frequently as the world for surface water treatment in order to provide safe drinking water. Charge neutralization assists in the removal of colloidal and suspended contaminants from water. This study focuses on the St. Paul River, which delivers raw water to the White Plains Water Treatment Plant.

Due to increasing turbidity, water quality is poor throughout the rainy season, especially during the peak months (July & August). For removing colloidal and suspended particles from raw water, coagulation is one of the most critical processes in the surface water treatment process. Because of its ease of operation, relatively simple design, and low energy consumption, this treatment process is regarded one of the most common physicochemical processes used in surface water treatment.

1.1 Major Sources of Water Contamination

The principal sources of pathogenic contaminants in water use for drinking and other purposes come from human excreta and animal which cause water-borne diseases, but bacteria is another source that enter through surface runoff or by inundation or the penetration of floodwaters. During flooding, there are high levels of bacteria and other pathogenic organisms that are transmitted by the floodwaters. Some other sources of water contamination come from agricultural activities which carry residual herbicides, insecticides, fertilizers and domestic (septic tanks). Leakage from pit latrine and septic tank can cause water contamination which causes the water to be unsafe for consumption by humans. Therefore, it is important to distance boreholes or wells far away from the septic and pit latrine. The World Health Organization established a guideline for the construction of pit latrines and septic tanks from underground water sources, stating that the distance between a borehole or well and a pit latrine should be no less than 30 meters and at least 2 meters above the water table, and the distance between a septic tank and the water table should be 15-17 meters. Water from pit latrines, human excreta, animal waste, insecticides, pesticides, fertilizers, septic tanks, industrial wastewaters, and other sources should be thoroughly treated or boiled before being used for domestic purposes, as this helps to prevent water-borne diseases, improve social and economic growth, and reduce poverty.

1.2 Water Quality

Despite the significance of water to humans and their environment, numerous infectious diseases are transmitted by it thereby creating some effects to life of humans and plants. As a result, before humans and other creatures use water, it must be of sufficient quality. Microbiological, chemical, and physical characteristics of safe drinking water meet WHO criteria for national drinking water quality standards (WHO, 2007).

According to the Asian Development Bank/International Center for Integrated Mountain Development, water quality is expressed by a variety of physical, chemical, and biological variables that are influenced by both natural and anthropogenic factors. The aesthetic value of water is enhanced by alkalinity, hardness, dissolved oxygen (DO), chloride, Total Dissolved Solid (TDS), and other water quality parameters, whereas ammonia, lead, arsenic, and nitrate may have detrimental health effects. Water with a high or low pH, or a high level of turbidity, is harmful to drink, but water with the proper amount of chloride and hardness is desired, but water with a higher level of the same is unattractive. Phosphate, nitrate, ammonia, and iron levels are all measured in the same way. Some chemical components, such as arsenic and lead, are toxic or dangerous.

From a microbiological standpoint, water used for drinking should be devoid of pathogens as well as opportunistic microorganisms. E. coli bacteria have long been recognized as an excellent microbiological indicator of drinking water quality due to their ease of separation and counting in water quality studies. Humans and other warm-blooded animals have these microbes in their intestines. They suggest the presence of excrement and the likelihood of pathogenic organisms of human origin existed samples of water collected. The presence of these microorganisms in drinking water can cause diseases such as typhoid, cholera, diarrhea, dysentery, and hepatitis, among others. According to the World Health Organization (WHO), a lack of appropriate water supply is a serious issue, and fecal pollution of water sources and treated water is a continuous problem around the world (2002). Approximately 1.1 billion people around the world rely on contaminated drinking water from rivers, creeks, lakes, and open wells. The bulk of the 1.1 billion people on the planet live in Asia (20%) and Sub-Saharan Africa (42%) (WHO/UNICEF, 2000; WHO/UNICEF-JMP, 2004). Water-borne diseases account for 90 percent of human infections in developing nations, owing to the use of filthy water sources (Pimentel et al., 2004). According to the World Health Organization (WHO), up to 80% of all sickness and disease worldwide is caused by poor sanitation, pollution, or a lack of water; thus, water is essential.

1.3 Water Associated Problems in Liberia

Liberia is a nation in West Africa with tropical, hot and humid climate. It has six major rivers, creeks, lakes, etc and rich in groundwater sources. The average annual rainfall in Liberia exceeds 2500mm. It ranges from over 4500mm along the coast and sharply decreases at 2000 toward the interior. Liberia's capital city, Monrovia is one of the wettest cities in the world with annual precipitation exceeding 5000mm thus causing flooding in some areas. As of 2005, Total Actual Renewable Water Resources (TARWR) by volume was 232 billion m3/year and per capita of 66, 530 m3/year. Surface water amounted to 86%, 26% is groundwater and 26% represents both surface water and groundwater systems shared value, but the total actual renewable water resources use is 0.05 %. On the other hand, the management of this resource is very poor that the capital city of Liberia faces severe shortages most especially during the dry season. Bulk of the water supplied in urban cities comes from groundwater. The Liberia Water and Sewer Corporation is sole function is to supply all urban cities of safe and affordable drinking water followed the standards for the required drinking water requirements in the world. Despite abundant water sources in the African nation, Liberia, there is still a huge challenge coupled with the Millennium Development Goals (MDGs) which states that the Millennium Development Goals (MDGs) through the

WHO and United Nations International Children's Emergency Fund (UNICEF) Joint Monitoring Program (JMP) defined basic access to water as water that comes from an improved source such as piped borne water supply system, protected well, borehole, or harvesting of rainwater system within a close proximity of walking distance of 1 km (15 minutes) of the residence (UN, 2003). Although water from improved sources is not always microbiologically safe (UNICEF/WHO, 2011), these sources have been demonstrated to have lower levels of microbiological contamination than unimproved sources such as untreated surface water in general (Bain et al., 2014, Shields et al., 2015). Many wide ranges of micropollutants, including pesticides, industrial compounds and pharmaceuticals from agricultural run-off and wastewater come from the aquatic environment (Heeb et al., 2012; Eggen et at., 2014). Ecological and human health are affected by the availability of micropollutants, including endocrine disrupting chemicals (Bergman et al., 2013).

2. Methodology

In this chapter, significant data were collected which can be applied to the treatment process in producing good water quality for drinking.

In removing turbidity different levels (75, 150, 300 NTU) to yield a desire result, Pollen Sheath and Date Seeds are used as coagulants, Mukheled (2012).

Treatment plant with low turbidity levels like Malaysia, the seeds of Moringa Oleifera served as coagulant in the stage of coagulation, Eman et al. (2010)

Natural coagulant such as what was used in Malaysia in the domestic turbid in the process of treating water and was highly recommended to be used in Nigeria by Aho et al. (2012)

In most developing countries, waste materials from domestics and even industrial effluent are discharge directly into water bodies thereby gradually depleting water quality(Onojake et al., 2011; Varol and Sen, 2009; Boyacioglu, 2007). Most of our surface water sources are vulnerable to pollution due to their role in accepting industrial, municipal waste and run off from farmlands within their drainage basins (Singh et al., 2004)

There are other coagulants from plant origin that are essential in the treatment process. They are Cassia Angustifolia Seed, Chestnut and acorn, Nirmali Seed and maize, Cocciniaindica Fruit Mucilage, Mesquite bean and Cactus Latifaria can also be used as an alternative in the treatment process. In case of removing turbidity (100 to 1200 NTU) up to 93%, Methi, Beheda, Drum Stick, Bhindi and Guar Seeds are used in the treatment process. All these natural products are used as coagulant or coagulant aid in the treatment of surface water which will help in the reduction of Aluminum Sulfate.

C. Smith, A. Peters, R. Conti, and P. Smets, discussed water supply sources for Monrovia (Liberia) during and after the Civil War.

In 39 Kathmandu valley locales, E. coli bacteria ranging from 4 to 460 cfu per 100 mL were detected in home drinking water. S. Sharma (1978) DISVI collected 472 samples from 58 sampling stations, 44 water taps, seven storage facilities, and seven water treatment plants in the Kathmandu valley for a study on the quality of drinking water in the Kathmandu valley, which revealed bacterial contamination in the majority of the test points (1989).

According to studies (JICA, 1990), ground water, an important drinking water sources in the Kathmandu valley, contains significant quantities of iron, magnesium, and ammonia (JICA, 1990). The water quality of 21 stone spouts was examined by ENPHO/DIVSI in 1990. In 81 percent of the total samples, the results revealed high bacterial contamination and the presence of fecal contamination.

A one-year investigation into the microbiological quality of Kathmandu's drinking water. Water samples were collected from 39 taps and 6 treatment plants. According to ENPHO/DIVSI, there was significant contamination in 18% of treatment facilities and 50% of public taps (1992).

A study of bottled water was conducted in the Kathmandu valley. Twenty different types of mineral water were tested for hygienic properties and chemical levels. Coliforms were discovered in three samples, fecal coliforms in one, and Salmonella spin in two, according to the microbiological analysis. The researchers came to the conclusion that bottled water is polluted. Furthermore, several epidemiology studies have found no link between human health outcomes with FIB levels, especially when pollution is not from a known source like a wastewater treatment facility (WWTP) (Dwight et al. 2004; Colford et al. 2007). Furthermore, the FIBs' determination excludes information on the source of emissions.

S.R. Pokhrel (2000) examined 42 samples of bottled water from seven different businesses for physiochemical and microbiological characteristics. He discovered that the physio-chemical parameters were within permissible limits, but that the Total Plate Count revealed a bacterial count of up to 162. In addition, yeast and coliform bacteria were discovered. (Sharma, S., 1993) investigated the quality of drinking water in Kathmandu and Pokhara and reported widespread pollution. The coliform levels were 2400/100 mL and 4800/100 mL, respectively, in the studied locations. In Kathmandu, the water delivery system is outdated, and a lack of maintenance has resulted in regular failures (ADB, 1995). In July 1997, Masaaki N. and Hiroaki N. tested bottled water in the Kathmandu valley.

2.1 Overview of Drinking Water Treatment

In surface water treatment process, the removal of Turbidity and some other contaminants from the raw water require settling, aeration/flocculation, coagulation, sedimentation, filtration and disinfection which are essential in water treatment process most especially in conventional treatment process. For effective and efficient treatment to be carried out at a water treatment plant, the below aspects are taken into serious consideration in order to meet the aims and objectives of the plant:

1. Make sure to achieve high cost performance of chemical
2. Efficient and effective energy control
3. Decrease non-revenue water

Many studies and research are carried out in order to improve the performance of water treatment plants. The coagulant consumption is one component of optimization that is addressed in this section.

2.2 Water Treatment Process

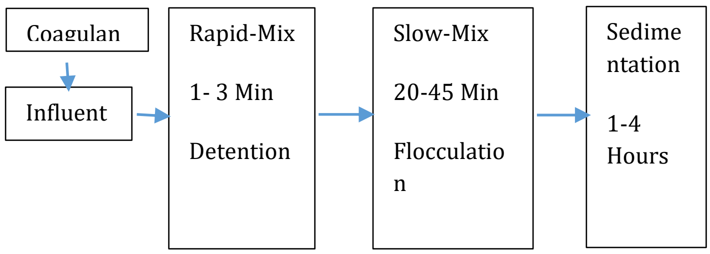
The treatment plant is located on the St. Paul River's bank in White Plains. This facility employs a traditional treatment method that involves separating the coagulation (rapid-mix) and flocculation (slow-mix) phases, followed by sedimentation and filtering. Depending on the high quality of the raw water from the catchment region, some plants are intended to go straight from flocculation to filtration. The equipment used for both rapid-mix and slow-mix speeds can be changed to allow for the addition of coagulants with multiple feed points, flocculants, polymers, and other chemicals, as long as there is enough space between the feed points and the income partible substances. This type of plant has conservative retention times and rise rates and usually contains large sedimentation basins. The White Plains Water Treatment Plant uses conventional treatment process which includes: 1) Screening- at the raw water in-take point (catchment point/St. Paul River), where four low-lift pumps are used to send water into the plant from the river.

2) Flocculation/Coagulation- Aluminum Sulphate is being used as coagulant at which point the raw water get in contact with this coagulant. Both surface water and groundwater comprise of suspended and dissolved particles that are require to be separated within the treatment process. The suspended particles differ in size, shape, density, charge which is negative and source and require the rightful application in order to have good test analysis. Coagulation-These particles resist each other when they came in close proximity with each other and those solid particles that are suspended will remain in their position and will not cluster and settle together, only when the right coagulation and flocculation is applied. Once this process is not completed correctly, there will be no proper sedimentation taking place. Chemicals are added to the water to neutralize the negative charges on the non-settable solid particles which include organic substances (color-producing) and clay thereby allowing the suspended particles to clump together. If these charge particles are not properly neutralized through mixing (rapid) 1 to 3 minutes, then more chemicals will be require in order to complete the neutralization.

3) Sedimentation Basins- There are four rectangular sedimentation tanks with capacity of 500,000 gallons each where the water moves after being coagulated.

4) Aeration takes place immediately after the sedimentation tanks by exposure of sediment to the sunlight, 5) Rapid sand filtration accomplished in 8 filtration tanks which are backwashed three times a day during the time of operation. The backwashed is carried on by using cleaned/treated water, 6) The filtered water is transferred into 2.5 million gallons capacity ground reservoir, 7) While in the storage tank, hydrated lime for neutralization is added, followed by the addition of chlorine solution (HTH-High Tech Hypochlorite) as disinfectant.

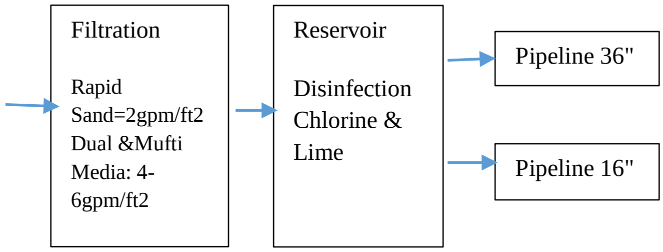
Figure 1. The Conventional Treatment Process Diagram



The raw water (influent) before going through the coagulation (rapid-mx) stage to properly disperse coagulant and promote collisions, coagulants are added and flocs are formed and take place in the slow-mix stage, thereafter the water then settle in the sedimentation basins allowing particles to settle down at the end of the tank and the water moves in the filtration stage for it to be filtered and the clean water moves to moves to the reservoir where chlorine and Hydrated Lime are added to complete the treatment process. The water is then pumped through the transmission mains by High Lift Pumps to Monrovia and its surroundings.

2.3 Sample Collection

Water samples are collected from the catchment area, sedimentation basins and clear well/final reservoir by lab technicians and chemists to conduct tests. The below parameters: pH, Total Dissolved Oxygen (TDS), Turbidity, Conductivity, Fecal Coliform, Total Coliform and Residual Chlorine are analyzed and compare with the World Health Organization standards in the treatment plant's laboratory. In conducting the test for water quality, standard methods for the examination of water are followed.



This table shows the apparatus/equipment used to measure Temperature, pH, Turbidity, Conductivity, Dissolved Oxygen, Chlorine, Total Coliform, Faecal Coliform which are used in the laboratory to analyze the water quality. These measuring apparatuses /equipment should be under an ideal temperature in order to have desired results.

Table 1. Physico-chemical parameters and microbial analysis equipment

Parameter	**Measuring Equipment**
Temperature	Wegtech Conductivity Meter
pH	pH meter
Turbidity	Turbid-meter
Conductivity	Conductivity meter
Dissolved Oxygen	Winkler's iodimetric titration
Chloride	Titration method
Total Coliform	MPN method
Faecal coliform	MPN method

2.4 Sampling Frequency

Water samples are collected every three (3) hours at the catchment area (Raw water), 1 hour at the sedimentation basins, filtration and water storage reservoir and are analyzed by technicians and chemists in the laboratory. The one (1) hour time interval allow the Alum which get in contact with the water before entering the four sedimentation basins to dissolve thereby forming flocs and other particles to settle before collecting a sample to be analyzed in the laboratory. When the water moves into filtration and later into the reservoir, disinfection takes place after one (1) hour the sample is also collected to be analyzed in the laboratory. Once the quality of the water in the clear well meets the requirement of World Health Organization (WHO) standards, the treated water is then pumped through the two transmission mains (16" & 36") pipeline to Monrovia and its environs for consumption by the inhabitants. At some locations in the Monrovia and the surroundings areas, samples are taken every week to analyze the pH, Turbidity and chlorine levels at the consumers-end to know whether the World Health organization Standards are met.

3.0 Results and Discussion

Water quality, both surface and ground, is an important consideration in the treatment of drinking water. Temperature, Total Faecal Coliforms, Nitrate, Iron, Arsenic, Total hardness, Ammonia, Chloride, and Phosphate are all important physio-chemical parameters in the treatment process. All treatment plants, including the White Plains Water Treatment Plant, must meet drinking water quality guidelines set out by the World Health Organization (WHO) and the Environmental Protection Agency (EPA). When it comes to water quality, the metrics examined at the White Plains Water Treatment Plant meet WHO guidelines, however reagents prevent the inclusion of a few more critical characteristics. Water production is insufficient to meet the existing demands of the inhabitants of Monrovia and its environs.

Table 2. Requirements for Drinking Water Quality (Source: WHO (1994) and EPA (2006)

Parameters	**WHO Standards**	**EPA**
pH	6.5-8.5	6.5-8.5
Total Dissolved Solids (mg/L)	600	500
Alkalinity(mg/L)	-	-
Chloride (mg/L)	250	250
Total hardness mg/L(as CaCO3)	200	-
Dissolved Oxygen (mg/L)	>5	-
Ammonia(mg/L)	1.5	-

Nitrate-N(mg/L)	10	10
Iron(mg/L)	0.3	0.3
Phosphate(mg/L)	-	-
Arsenic(mg/L)	0.01	0.01
Total coliform(MPN/100mL)	0	0
E.coli(MPN/100mL)	Nil	Nil

The Liberia Water and Sewer Corporation conduct tests on few physio-chemical parameters at the White Plains Water Treatment Plant which include pH, Total Dissolved Solids (TDS), Chloride, Total Coliforms, E.coli, Conductivity and Turbidity, but Nitrate, Iron, Ammonia, Phosphate, Arsenic are not tested at the treatment plant due to re-agents and some testing apparatus which are very important parameters in the treatment process. These few tests that are done meet the World Health Organization (WHO) Standards.

Table 3. Water Quality Parameters and average test results at WTP

Parameters	**Raw Water**	**Settled Water**	**Finished Water**	**WHO Standards**
pH	7.23	6.85	7.2	6.5 - 8.5
Turbidity (NTU)	15.2	7.01	1.08	<5 NTU
Temperature (° C)				
Conductivity (µS/L)	36.1	60.5	78.2	< 500 S/l
TDS(mg/L)	18	30.2	39.1	< 500 mg/l
Chloride(mg/L)	-	-	1.75	0.2 – 2 mg/l
Fecal Coliform	-	-	0	0 count/ 100 ml
Total coliform (MPN/100mL)	present	-	Absent	0 count/ 100 ml

Source: White Plains Water Treatment Plant, LWSC

This table shows the few parameters that are tested at the White Plains Water Treatment Plant and present an average values (analyses) for the physio-chemical parameters which are in accordance with the World Health Organization (WHO) standards.

Table 4: The average end user test analysis on 16" transmission main

Parameters	Caldwell Booster	Salt Town	Fofee Town	WHO standards
pH	7.2	7.36	7.35	6.5 - 8.5
Turbidity (NTU)	1.39	1.41	1.5	<5 NTU
Chloride(mg/L)	1	0.99	1.2	0.2 – 2 mg/l

Source: White Plains Water Treatment Plant, LWSC

Table 5. The average end user test analysis on 36" transmission main

Parameters	**12th Street**	**Jacob Town**	**Fiamah**	**WHO Standards**
pH	**7.2**	**7.36**	**7.35**	**6.5 - 8.5**
Turbidity (NTU)	**1.39**	**1.41**	**1.5**	**<5 NTU**
Chloride(mg/L)	**1**	**0.99**	**1.2**	**0.2 – 2 mg/l**

Source: White Plains Water Treatment Plant, LWSC

After testing at the water treatment plant, additional tests are also conducted at the end-user end (households) at specific locations/areas to know the level of chlorine content, Turbidity and the pH. These test are carried out three times a week on the 16" transmission main which passes through Caldwell and reaches Central Monrovia

4.0 Conclusion

According to the findings, while water's few physio-chemical parameters such as pH, Turbidity, Conductivity, Total Dissolved Solids, Coliforms, Total Coliforms, and Chlorine meet WHO's standard requirements for safe drinking water, other important parameters such as hardness, total iron, phosphate, nitrate, ammonia, and alkalinity are not analyzed using APHA (1998) standard methods due to a lack of apparatus. The laboratory at the White Plains Water Treatment Plant lacks an effective air condition for analyzing water samples that are collected from the raw water intake, sedimentation basins and restored reservoir. There is also a shortage of re-agents to conduct these tests.

The study also discovered that in removing turbidity at different levels (75, 150, 300 NTU) to yield a desire result, Pollen Sheath and Date Seeds are used as coagulants, Mukheled (2012), and also treatment plant with low turbidity levels like Malaysia, Moringa Oleifera are used as coagulant in the stage of coagulation, Eman et al. (2010)

Natural coagulant such as what was used in Malaysia in the domestic turbid water treatment, it was highly recommended to be used in Nigeria by Aho et al. (2012)

There are other discoveries from the study that coagulants can be generated from plant origin which are essential in water treatment process. They are Cassia Angustifolia Seed, Chestnut and acorn, Nirmali Seed and maize, Cocciniaindica Fruit Mucilage, Mesquite bean and Cactus Latifaria can also be used as an alternative in the treatment process. In case of removing turbidity (100 to 1200 NTU) up to 93%, Methi, Beheda, Drum Stick, Bhindi and Guar Seeds are used in the treatment process. All these natural products are used as coagulant or coagulant aid in the treatment of surface water which will help in the reduction of Aluminum Sulfate.

There are huge challenges which range from constant power supply to chemical supply and also maintenance of the plant which is impeding the plant not to operate on a 24-hour basis. More is require by the government of Liberia through its developing partners and the Liberia Water and Sewer Corporation to deliver safe and affordable drinking water.

5.0 Recommendation

1. Despite the few physio-chemical properties listed below: pH, Turbidity, Conductivity, Total Dissolved Solids, Coliforms, Total Coliforms and Chlorine meet the standard requirement for WHO in relating to safe drinking water, considering some other analysis like hardness, total iron, phosphate, nitrate, ammonia, alkalinity, etc on a daily basis that are also important in water quality.
2. The St. Paul River, source of Monrovia's water supply should be tested four times a year at both upper and lower strains evident by salt intrusion in 2019. The salt content was not observed at the treatment process at the plant, but rather by the consumers. This occurred in the dry season when the level of the river dropped below sea level.
3. Based on the inadequacy of Aluminum Sulfate which cause the operational hours at the treatment plant to be reduce, there is a need to plant/use Moringa Oleifera Seeds as coagulant in the stage of coagulation, Eman et al. (2010)
4. The need for the usage of renewable energy such as solar for efficient and effective operation at the White Plains Water Treatment Plant cannot be over-emphasized.
5. The end users test should be conducted every day at said locations mentioned in this paper.
6. Laboratory should be fully air condition at all time according to standard operating procedure for conducting water quality analysis. All other personnel working at the treatment plant and even guest should follow-suit the same.
7. All laboratory technicians/chemist should adhere standard at all times when conducted water quality analysis
8. Reagents for other water quality parameters should be made available at all times in order to conduct all of the tests according to WHO standards for surface water treatment.

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