A Comparative Analysis of Urban Drinking Water Management and Distribution Processes; a Case Study of Guma Valley Drinking Water Treatment Company in Freetown, Sierra Leone and Wuxi Drinking Waterworks Treatment from Tai Lake, Wuxi, P.R. China

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Abstract- As the issue of water crisis is becoming a major concern at global level, water resource management should be inculcated into government priorities, and this has to be done through sustainable development. In this paper, we focus on the comparative analysis of the surface water quality between Guma Valley dam in Sierra Leone and Tai Lake for Wuxi waterworks in P.R. China. The various drinking water treatment methods use at Wuxi waterworks, the company major challenges and the policy impact were also examined. The arising algae problem in Tai Lake is becoming a severe concern not only, to Wuxi waterworks but also to Wuxi local government. This is due to urbanisation and industrialisation of Wuxi municipality and the nearby cities along the Tia Lake, as they are the major source of pollution into the Lake.

With the current high rate of urbanisation, water supply in Freetown is a major challenge for the government through the ministry of water resources. The ancient pipe networks coupled with the seasonal behaviour and attitude of local residents in Freetown are the contributing factors for the water crisis in the city.

Index Terms- coagulation, Distribution, Guma Valley, Sedimentation, Microorganisms, Ozone, Pollution, Urbanisation, Waterworks

1. Introduction

Clean and safe drinking water is becoming a big challenge in the world as human activities are encroaching with every aspect of the environment; due to the reality that the aim of every government is to show a significant developmental growth (infrastructure)[1]. The idea of rapid development in the world has led many countries into safe drinking water crisis as most of the sources of drinking water are polluted. This is mainly due to the high level of industrialization in the developed countries in the early 1980s, when the world was at the revolutionary face to make life easy and comfortable[2].

Currently, one of the dreams of the United Nations (UN) is to provide safe drinking water to everyone in the world as it is inculcated in the United Nations sustainable development goals (SDGs) number six (6) ‘’clean water and sanitation’’ which is targeted to be achieved by 2030. To effectively and efficiently achieved this dream, United Nations added a paradigm as goals number seven (7) and eight (8), ‘’affordable and clean energy’’ ‘’decent work and economic growth’’ respectively as these are the key indicators that every government in a country may want to achieve for the its citizens. However, the process of achieving these objectives leads to the neglecting of the safety of the entire environment.

One of the recent issues of water crisis in the world is the Cape Town water shortage in South Africa which was reported by many social media, as one may wonder the lead course of the water shortage in the city, which could have led the city to be the first city in the world to go zero day without water[3]. Secondly, the city of Nairobi in Kenya was receiving drinking water from the Nairobi drinking water company on a rational basis, which is a clear indication of future water shortage for the city of Nairobi.

The rapid development of china from the evolution in 1930 to date is amazing and innovative; demonstrate that every country in Africa may wants to follow their developmental foot step. This rapid development one way of the other has course negative environmental impact, specifically in the aquatic ecosystem, as water bodies are heavily polluted[4]. As a result, intensive energy input is requires for the Chinese cities to provide clean and safe drinking water to the population.

Despite these countries located close the seas, and the earth covering approximately 70% of water, especially drinking water,

is not as abundant as one might think, only around 3% of it is fresh water that is available to the entire world. Water management is one sector that every government should in cooperate in the sustainable development plans as the water resource is scare and limited in the world.

The focus of this paper is to compare the quality of the sources of water for Guma Valley Water Company in Freetown, Sierra Leone and the Wuxi waterworks treatment plants, treatment methods and distribution systems to households.

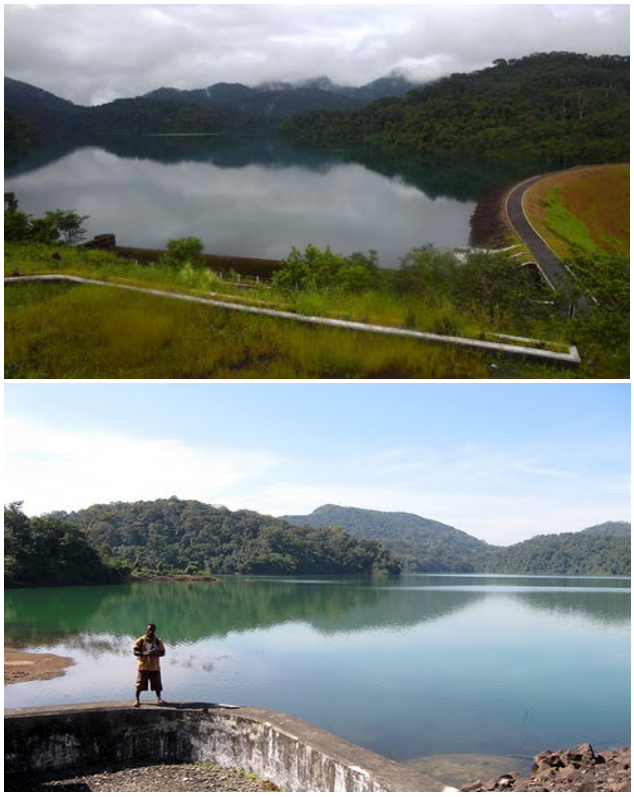
2. Guma Valley Drinking Water Treatment

Guma valley water company, been a government company is charged with the responsibility of treatment and providing safe drinking water to the 1.7 million population in Freetown (water regulatory act 2012). Despite the tropical climate and weather condition in Sierra Leone, which courses the two main seasons, dry and wet (raining season) seasons, the company is oblige to a continuous provision of drinking water to the city of Freetown.

Even though Freetown is considered as one of the wettest capital cities in the world, yet even in the midst of heavy downpours its taps are often dry (Sierra Leone Water point Report). The result is that many neighbourhoods have no piped water installed and women and children must roam the streets with buckets on their heads and in their hands looking for water[5]. Many residents dig water wells in swampy areas or collect water from polluted streams and rivers for domestic uses and drinking (Sierra Leone Water point Report). The water company's infrastructure is decrepit that it provides less than 60 percent of the city's water needs throughout the year. As it stands the city of 1.7 million people needs about 35 million gallons of water per day but the water company only has the capacity to pump around 23 million gallons to the city.

2.1. Guma Valley's Source of Raw Water for Treatment

Guma Valley Water Company gets it raw water between the peninsular mountains which are covered with tick forest at a location called mile thirteen (13), where human activities since colonial days have been denied. The volume of the guma dam is always full during the raining season and drastically reduces during the dry season, which paves way for the company's management to give excuses on the water shortage in the city[6]. However, the source is always expected to replenish itself due to the hydrological processes. Local communities around the source used the raw water for both drinking and domestic purposes, which they think is more purified than the company's purification process.



Source of water for Guma Valley located along the Peninsula Mountains

2.2 The Company's Treatment Process

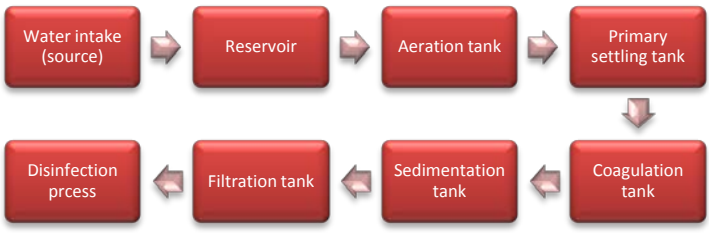
Guma valley Water Company, like any other drinking water treatment company follows the conventional procedures/steps for the treatment of the drinking water at it treatment facility regardless of the clear or turbidity free of the water but yet nanoparticles maybe present[7], even though the facility needs an upgrade to match up with recent technologies in drinking water treatment. The water treatment process start from the stream/rivers where the water is pump through the pipes to the reservoir, within the pipes are the masts screen that prevent the passage of larger particles like stones and sticks in the pipes.

From the reservoir, the water is pump to the aeration tank; the aeration tank is designed to allow air-water contact as much as possible, allowing all gas contaminants such as dissolved carbon dioxide (CO_2) to escape into the atmosphere. The water is then send to the primary settling tank allowing heavier organic solids to settle down, the clear water is then send to the coagulation tank to start the genuine conventional treatment process where the coagulants are mix with the water rapidly and send to the sedimentation tank for the settling of the flocks. Coagulants act like magnet by binding small contaminants particles into larger particles.

Sedimentation tanks allow the flocks to settle down at the bottom of the tanks for the period of one and half hours. The water goes to the next tank which is known as filtration tanks for the

filtration process. In the filtration tank, the water sips down the filter which is made up of two media; fine grain sand and gravel, the two media works together to remove small organic particles which were missed by the flocks.

The water goes to the disinfection stage to eliminate heavy microorganisms found in the water, chlorine gas is pump into the water to destroy dangerous bacteria and viruses present in the water. The chlorine is allows to stay in contact with the water to allow absolute disinfection for a period of two hours and then ready for supply to the city



Diagrammatic expression of guma valley drinking water treatment facility

2.2. Guma Valley Drinking Water distribution System

The company uses pipe lines system to distribute treated water from the treatment facility to the households of consumers. Due to the poor structures of the pipes system, the percentage of wasted treated water remains high in the city, contributing to the shortage of drinking water. There is a direct proportionality between increasing urbanization and industrialization and the rate of water scarcity in Freetown[6].

Households' piping connection systems in Freetown

The inadequate working investment within the company, the secondary distribution networks have not been extended to keep pace with the expanding city development. However, in the situation were the pipe line are not extended, the water company has to construct centralised water system for the communities (Sierra Leone - Rural Water Supply and Sanitation Project). This system makes the water availability more difficult in those communities as the effectiveness and efficiency is not guarantee.

Centralised water provision in Freetown

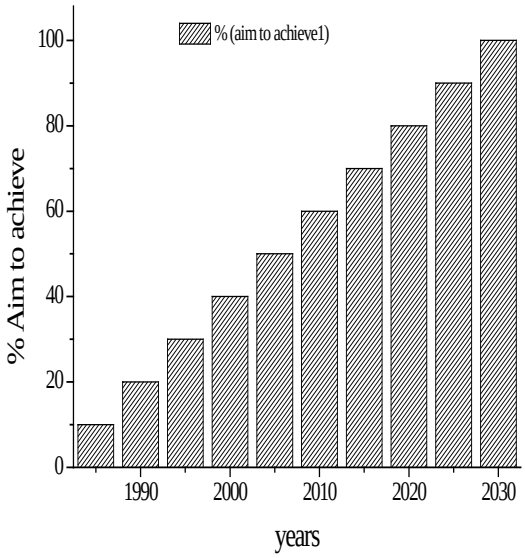
2.3. The Company's Management Strategies

Guma Valley Water Company has a sets of management strategies to improve the water services in Freetown, the capital city of Sierra Leone, among the numerous strategies are; the mapping Freetown's water pipes to improve the service delivery. Under this strategy, the company can easily detect leakages and the technicians can easily locate the point and fix the problem without delay of the supply process.

This in light enumerate the most important strategy leading to an assessment of the best approaches to addressing the current water problems with the existing distribution infrastructure and the upgrades that might be required to contain the new sources of water .

An assessment of all river catchments of significant size within the peninsular mountains to determine the options for direct river abstraction, which can add to existing sources with the aim to increase the volume of the reservoir and increase the treatment capacity for the sufficient supply of treated water to the city. This is follow with another relevant strategy, an assessment of the groundwater potential around the peninsular mountains and in the mainland neighboring to the peninsular mountains.

Water supply progress plans for every five years



80%
60%
40%
20%
1985
1990 1995 2000 2005 2010 2015 2020

Government estimates

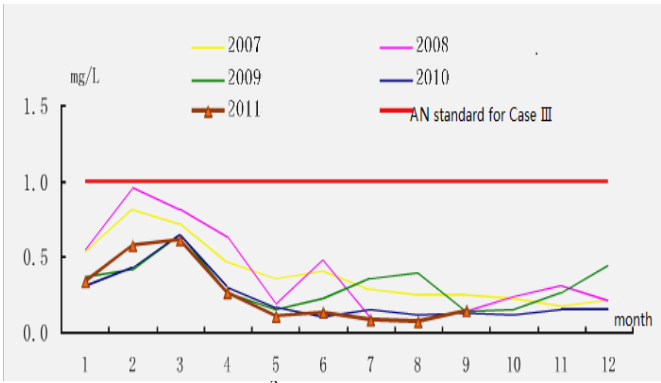
Government target

Actual water available supplies

Government target set to achieve in water supplies in the city between 2010 and 2015 was never achieved, rather there was a retrogressive movement in the water supply within the period in the city (water supply and sanitation in Sierra Leone, 2015).

3. Wuxi Drinking Waterworks Treatment

Wuxi waterworks is located in Jiangsu province, situated in the north of Lake Taihu, south of the Yangtze River with a treatment



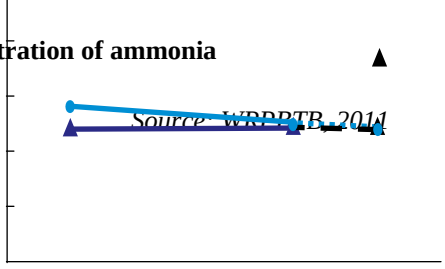
capacity of 600,000m^3 per day. Wuxi drinking water works in recent has introduced membrane treatment technology into operation to enhance safe and quality drinking water for the residents of the municipality.

3.1. Tai Lake surface water quality

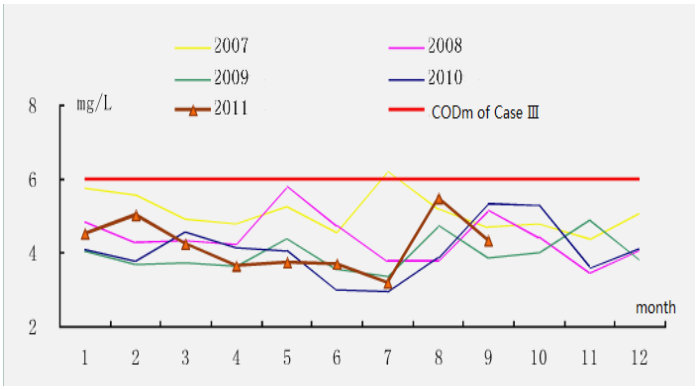
In recent years, the algae growth rate in Tai Lake has led the reduction of the raw water quality. To enhance to this problem in the water treatment process, Wuxi waterworks introduces the pre-treatment and advance treatment into the water treatment processes.

The quality of surface water is classified into five levels in Chinese national water standard[8]. Class Ⅰ and Ⅱ water can be used as drinking water source. The eutrophication level of the lake maybe evaluated as light in some distance and heavy at the edge, but yet still meets the Chinese water standards. According to a studied done by Tianjiao Qian 2012, the indices of TP, TN and CODm in more than 46 measured sections can reach the Chinese national water standard of class Ⅲ water[9].

Concentration of ammonia



The CODm Concentration

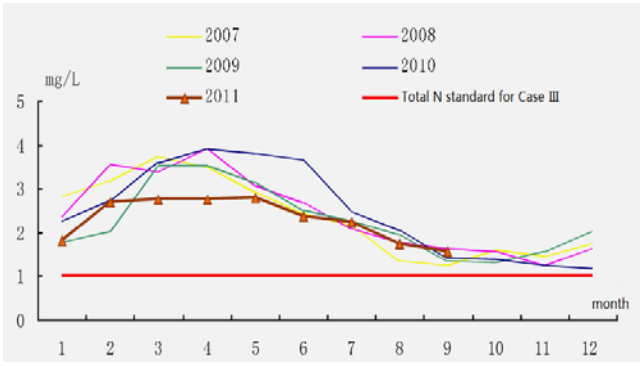


Source: WRPBTB, 2011

TP Concentrations

Source: WRPBTB, 2011

TN Concentrations



Source: WRPBTB, 2011

The red line in each figure stands for a critical concentration of water quality class 3, from the figures, the concentrations of ammonia nitrogen and CODm is always below the critical line while those of total N is higher than the standard[10]. The concentrations of total P are mostly above the critical line. Which means the water quality in Lake Taihu cannot satisfy the basic Chinese standard of class 3. The Environmental quality standards for surface water in P.R.China(GB 3838-2002), the class 3 water is the worst surface water that can be used for drinking water source, others worse than class 3 are not allowed to be used as drinking water source prior to treatment.

3.2. Pre-treatment

The pre-treatment of Wuxi drinking water is divided in two further methods, the ozone and the biological methods. In the aeration tank, biological membranes are placed in the water to aid the attraction of the micro-organisms inside the membrane fibers. Aeration brings water and air in close contact in order to remove dissolved gases (such as carbon dioxide) and oxidizes dissolved metals such as iron, hydrogen sulphide, and volatile organic chemicals (VOCs) that maybe in the raw water[11]. This is major process at the pre-treatment plant at Wuxi waterworks. Due to the algae problem in Tia Lake, pre-treatment of the raw water brings the necessity of have pure and safe drinking water at the end of the treatment processes.

Tai Lake, source of raw for Wuxi waterworks

After the water is pre-treated using both the mechanical and biological methods, it then send to another treatment facility for the normal conventional water treatment process. However, the mechanical pre-treatment aims at removing solid matter from Tai lake water that may be floating or dispersed; plastic bags, rags, leaves, pieces of wood or other substances.

3.3 Conventional treatments

The water from the pre-treatment plant send to the main treatment plant is then mix with coagulants in the coagulation tanks to start the actual conventional treatment process where the

coagulants are mix with the water rapidly using mixers with different velocity in descending order of the tanks and send to the sedimentation tank for the settling of the flocks. Coagulants act like magnet by binding small contaminants particles into larger particles.

Sedimentation tanks allow the flocks to settle down at the bottom of the tanks for the period of one and half or two hours. The water goes to the next tank which is known as filtration tanks for the filtration process. In the filtration tanks, the water sips down the filter which is made up of two media; fine grain sand and gravel, the two media works together to remove small organic particles which were missed by the flocks.

The water goes to the disinfection stage to eliminate heavy microorganisms found in the water, ozone and chlorine gas is pump into the water to destroy dangerous bacteria and viruses present in the water. The chlorine is allows to stay in contact with the water to allow absolute disinfection and then the water is ready for advance treatment.

3.3. Advance treatments

After the conventional treatment, the water is further treated using the member filtration, Membrane filtration is a streamlined process that helps create clean drinking water. This process is used to improve water quality, as it helps separate tiny particles from water. In general Wuxi waterworks uses ultra-filtration process for advance treatment.

Advance treatment centre of Wuxi waterworks

4. Management challenges

4.1. Pollution rate of discharge into Tia Lake

The pollution discharge amount different rivers flowing into Taihu Lake from Wuxi, Suzhou and Changzhou of Jiangsu Province is courses the high rate of increase of algae growth into Tai Lake. Pollution emission in the planning regions is large enough and contribute to the emission amount, domestic, industrial and agricultural pollutions take the first, second and third place respectively in polluting Tai Lake[12]. Regional water pollution and use of unfettered water sources can be an important mixed metals disclosure pathway for urban populations located in areas with limited water regulations and infrastructure and broad mining record[13].

Amount of domestic pollution in 2010

Region	Population	COD (ton/year)	NH_3-N (ton/year)	TN (ton/year)	TP (ton/year)
Urban area	3545.3	16891.84	1489.03	3695.02	185.04
Yixin	1265.5	14865.58	1148.78	1599.3	164.95
Jiangyin	1591.8	15341.62	1175.35	1469.9	194.68
Total	6402.6	47099.04	3813.16	6764.22	544.67

Source; Wuxi gov, 2011

The rapid urbanization of Wuxi city, the permanent resident population has been growing and their livelihood values keep improving which lead to a great growth in sewage release and waste production. The industries in Wuxi city are on a large scale of enterprises and are expanding every year. The new industries in biomedicine, new energy and new material are growing and the highly polluted industries such as chemical, textile are still occupying a considerable component in the entire industries. Mining also can lead to a heavy rate of ground water pollution as a result, during mining of mineral from underground[14], huge quantity of ground water is pumped out to make mining possible.

Amount of industrial pollution in 2010

Region	COD (ton/year)	NH_3-N (ton/year)	TN (ton/year)	TP (ton/year)
Urban area	3936.2	380	921	28
Yixin	2546.9	195.5	369.2	12.9
Jiangyin	8594.4	284.9	874.6	43.3
Total	15077.5	860.4	2164.8	84.2

Source; Wuxi gov, 2011

Agricultural pollution also contributes high percentage due to the nutrients like nitrogen and phosphorus that infiltrate into soil from the agricultural production activities. These includes farming, aquaculture and land cover and ecosystems removal for monetary valuation based on externality values[15].

Amount of Agricultural pollution in 2010

Region	COD (ton/year)	NH_3-N (ton/year)	TN (ton/year)	TP (ton/year)
Urban area	559.32	7.69	63.37	9.98
Yixin	1289.63	45.48	284.24	84.93
Jiangyin	369.09	2.64	61.03	6.95
Total	2218.04	55.81	408.64	101.86

Source; Wuxi gov, 2011

4.2. Climate impact

The unpredictable climate in Wuxi makes it sometimes difficult for the management to control the water treatment process as in the late spring or summer times, when the sunshine is copious and temperatures are appropriate, the algal flourish in Tai Lake. Despite the pollutant sources into the lake being controlled, the appearance of algae bloom keeps taking place. The blue-green algal blooms usually last for several weeks, sometimes months, depending mainly on the weather or flow conditions if no actions are engaged.

4.3. Policy enactment

There are a series of laws and policies aiming at water resources protection and algae control in China, the policies may be put into action and regulations, economic measures, information and educational measures as well as assigning obligation to different stakeholders in the enactment process. The 1984 China's National People's Congress Standing Committee Water Pollution and Prevention Law of the People's Republic of China remains the principal law in water pollution.

On the foundation of this law, provinces and municipalities should follow its principles to enact their own regulations appropriate for local state of affairs. If local governments already have their standards for water pollutant emissions, the local standards should be implemented[14]. If they don't, then the central government has the right to enact regulations that the local governments should obey.

5. Conclusion

Different technologies in drinking water treatment may sharply depend on the sources of raw for the treatment plant or company. Based on the two case studies between Guma Valley Drinking Water Treatment Company in Freetown, Sierra Leone and Wuxi Drinking Waterworks Treatment from Tai Lake, Wuxi, China, there is a vast range in technological utilization in the treatment and the distribution systems.

The poor and improper management of drinking water in Freetown led to the outbreak of cholera epidemic disease in 2011. The old piping systems for water distribution by Guma Velley water company in Freetown is questionable by most people of it water purity and safety for drinking without further treatment. One may argue that the level of pollution in Sierra Leone water bodies cannot be compares with Wuxi municipality water bodies, the that fact is Sierra Leone is considered as a mineral deposit country which attracts foreign mining companies to mines mineral.

This mining activity has negative impacts on the underground water quality as guma valley water source is between mountains. Groundwater of mining towns is very much affected due to mining activity. Despite studies may have not yet revealed that Sierra Leone water bodies are polluted, prevented measures and proper management of the source resource should be prioritized. Infrastructure systems provide products which are considered public good, users have an expectation that water, is available, affordable, safe and secure. Traditional environmental information coupled with climate data made known the temporal relationships between tremendous climatic events and the scarcity of water resource.

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