KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HUMANITIES AND SOCIAL SCIENCES
DEPARTMENT OF ECONOMICS

PRODUCTION INEFFICIENCY IN WATER TREATMENT AT THE BAREKESE HEADWORKS IN GHANA

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THESIS SUBMITTED TO THE DEPARTMENT OF ECONOMICS OF THE COLLEGE OF HUMANITIES AND SOCIAL SCIENCES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR AWARD OF MASTER OF SCIENCE IN ENERGY AND RESOURCE ECONOMICS

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JUNE, 2016.

DECLARATION

I hereby declare that this submission is my own work towards the Master of Science and that, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in text.

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ABSTRACTS

The primary objective of this study was to investigate the volume of water loss in the process of water processing at the Barekese Water Treatment plant, to estimate the water loss due to operational downtime and overused water for water treatment. The study also perform a trend analysis to understand the pattern in water loss over the years. To achieve these objectives, monthly time series data was obtained about the Barekese Plant from January 2000 to December 2014. The study used both descriptive and inferential statistical tools to analyze and answer the research questions. The study used t-test to compare the volume of water loss due to operational downtime and overuse of water for treatment. The study estimated that the plant or the nation at large loses about 12.3 and 54.1 Million Ghana cedis over the past 15 years due to overused water for treatment and operational downtime respectively. The study also found that, statistically, there was no significant difference between the volume of water loss due to operational downtime and overused water for treatment.

DEDICATION

This work is dedicated to the Almighty God, who through his providence gave me the opportunity to pursue this program and saw me through to the end, His name be glorified. Also to my wife Charity Darko and children; Nana Kwabena Darko, Nana Yaa Pinamang Darko and Nana Opoku Ware Darko for their love and support.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Water is one of the most important resources to humans. It is no surprise that it covers about two thirds of the world surface area. Water is an infinite resource available in many parts of the world. However availability to safe drinking water the world over is a big problem. Only 20% of the global population has access to running water and over 1 billion people do not have access to clean water (WWO, 2010). Therefore the need for provision of safe drinking water to avert any health problem. Water is a medium by which food nutrients are carried to all parts of the plant, animal and human organism. About 65% of the human body, 70% of the elephant, 80% of the potato and 95% of the tomato is water (Adombire, 2007). Water is the most prominent natural resource among other resources created by God for mankind. The reason is that, water is extremely for human livelihood and sustenance. No matter ones orientation, level of development and growth, social and economic conditions, access to water is extremely for human survival.

In Ghana, Ghana Water Company Limited is responsible for providing potable water for urban dwellers. This water is supplied at a cost which is calculated by the company. Since water is considered a very need for human survival and should therefore be available for all, it is supposed to be supplied at a cost which can be affordable to all consumers. The provision of portable water is done through lots of activities like planning, development and operation of water system in large towns and cities and some small towns that are not under community management. Statistics indicates that, approximately 10.3 million people have access to improved water supplies in Ghana.

Sixty one percent of the 8.4 million residents in the country urban area have improved water supply service provided by Ghana Water Company Limited network while 3.3 million urban residents in Ghana depend on alternative water serves (Ghana Water Sector Assessment, 2015).

It is in view of the above that this research is design to look at the cost of production losses in the process of water treatment using Barekese water treatment plant as a case study. It is believed that the outcome of the study will help in reducing inefficiencies in water treatment plants across Ghana, particularly at Barekese and ensure that potable and drinkable water are available for domestic and industrial consumption in the country.

1.2 Problem Statement

There is a widespread perception among water professionals today of a crisis in water resources management. Water resources are poorly managed in many parts of the world. Many people especially the poor and those living in rural areas lack access to adequate water supply and sanitation. Moreover, this is not a new problem for it has been recognized for a long time, yet the efforts to solve it over the past three or four decades have been disappointing, accomplishing far less than had been expected. According to (Gleick, 1993) freshwater forms about 2.5% (1.4 billion km^3) of the estimated total volume of water on earth. It is intriguing to note that of this amount, less than 1% of all freshwater resources is available for human consumption and for ecosystems. The number of people who rely on the earth's limited freshwater reserves is increasing every day. Though total runoff of global freshwater supply as compared with the current consumption, we will discover that the supply is currently about 10 times larger than consumption. However that statistics is also misleading since it mask the impact of growing demand and the rather severe scarcity situation that already exists in certain parts of the world including parts of Africa, China and several parts of the United States. In fact, a scarcity of clean, fresh water is one of the world's most pressing environmental problems (Arms, 2008).

Unfortunately, high volume of this highly important substance is wasted during the process of treatment.

It is a fact that water treatment in most of Ghana Water Company Headworks or systems are saddled with production losses and since the various production systems have not yet been expanded to their maximum allowable yield, much attention has not been paid to production losses

1.3 Objectives

The main objective of the study is to investigate production inefficiencies and analysis the trend of the various water losses in relation to time they occur.

1.3.1 Specific Objectives

i. To ascertain the quantitative value of operational inefficiencies in the water treatment process.

ii. To estimate the revenue loss due to operational inefficiencies in water treatment at Barekese water plant.

iii. To perform trend analysis of the various water losses due to inefficiency in water treatment at Barekese water treatment plant.

1.4 Research Questions

i. What is the annual revenue loss due to abnormal water loss and operational downtime at the Barekese Headworks?

ii. What is the trend, seasonality and randomness of water loss due to inefficiency in water treatment at Barekese water treatment plant?

1.5 Significance of the Study

This study will add to the body of knowledge about the subject matter by bringing into the fore, those factors that causes loss of production during water treatment at Barekese water treatment plant, ascertain the revenue loss due to production inefficiencies in water treatment process, and establish the trend, seasonality and randomness of water loss. Lots of work has been done by authors like Doe (2007),

Brooks (2007), Nyame (2011), Attimah (2012), Djida, Chabani1, Idir1, And Bounazef (2012), Gram (2012) on water production, treatment, and distribution vis-a-vis production losses worldwide particularly in Ghana but no attention has been placed on the quantum of waste or losses recorded in the process of treating water for human and industrial consumption as well as its attendant lost revenue. The concentration of available research work on water process inefficiencies had been more on the demand side, however this research deals with the supply side and is therefore important, as it intend to fill this missing gap. The research work will be a reference material for academic and policy work in the area of water treatment and efficiency in production and will contribute to the stock of literature.

1.6 Scope and Limitations of the Study

This study to be undertaken will focus on 15years duration (2000-2014). The choice of this period is due to the fact that the period fall within the time that there were various expansions and rehabilitation on the plant i.e. huge investment for the increase in production output.

As a matter of necessity, the study will be delimited to some socio-economic, political and environmental issues which pose challenges to operations of the water treatment plant in recent years.

The main limitation of the proposed study is in the area of data, since the data for the study is secondary. Another problem is the unavailability of data on the causative factors of both abnormal water loss and operational downtime. Time, finance and some structural problems are the other drawback envisage in the study. Nonetheless efforts will be made to see that this limitation are ameliorated.

1.7 Methodology

The study will employ Descriptive statistics (mean) as well as inferential statistical tool (independent t-test) to analyze and answer the research objectives. To perform trend analysis of the various water losses due to operational inefficiencies, a times series plots of the losses will be done on each loss to understand their trend over time. The time series data will be decomposed into constituent parts of trend, seasonality and randomness. Also a simple estimation method will be used to estimate the revenue loss due to inefficiency in operations.

1.8 Organization of the Work

This thesis is presented in five chapters. Chapter one describes the background, research question and the objective of this research. Scope and limitations of the study is also discussed in this chapter. Chapter two covers the literature review where works on the topic is analysed, i.e. the relevant theoretical and empirical literature on water production inefficiency and cost of production loss. Chapter three explains the methods employed in carrying out the study and the limitations of the research methods and tools used to attain the results. Chapter four discusses the results of this work. The data collected is organized and analyzed in this chapter using various statistical tools and methods. Finally, Chapter five provides plausible recommendations toward making water treatment efficient and the conclusion to the topic.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews the theoretical framework such as the economic value of water, water treatment and concept of process loss. Furthermore it also contains the empirical analysis which reviews studies on production losses and economic impact.

2.1 Theoretical Framework

2.1.1 Economic Value of Water

"In a market system, economic values of water, defined by its price, serve as a guide to allocate water among alternative uses, potentially directing water and its complementary resources into uses in which they yield the greatest total economic return" (Ward & Michelsen, 2002).

The word value to be observed, has two different meanings and sometimes expresses the utility of some particular object and sometimes the power of purchasing other goods which the possession of that object conveys. One may be called value in use; the other, value in exchange. The things which have the greatest value in use have frequently little or no value in exchange and on the contrary, those which have the greatest value in exchange have frequently little or no value in use. Nothing is more useful than water; but it will purchase scarce anything; scarce anything can be acquired in exchange for it. A diamond, on the contrary, has scarce any value in use; but a very great quantity of other goods may frequently be acquired in exchange for it" (Adam *Smith*, Wealth of Nations - book I, chapter IV).

2.1.2 The Cost of Water

The cost of water in comparison with other commodities and utility services has unique features which complicate its supply. Water is costly to transport relative to electricity but relatively cheap to store. However its transmission infrastructure is relatively less expensive than that of more valuable liquids such as petroleum. (Hanemann, 2005). Capital intensiveness is another distinctive economic feature of water supply as compared to other public utilities and the manufacturing industry in general. Also its asset specificity makes it less deployable to be moved to another location and do not have alternative use other than its purpose. Furthermore, its physical capital in storage and conveyance infrastructure has long life, i.e. its pipe network can have an economic life of fifty to hundred years or even more, far longer than that employed in most manufacturing industry and public utility sectors. (Hanemann, 2005). Many components of water supply exhibits economies of scale, especially surface water storage. Given a specific dam site with a very good yield, by increasing the capacity of the treatment plant and the transmission mains can significantly reduce the unit cost of producing and conveying a cubic meter of water respectively. With the economic features explained, it implies that water supply costs are heavily dominated by fixed cost. For example, a simple surface water system with minimal treatment of drinking water and heavy reliance on gravity flow, the short-run marginal cost of water supply may be approximately zero except for the cost incurred in pumping to move the water through the system. Even in systems of full drinking water treatment, the short-run marginal cost is low as compared to the long-run marginal cost in water supply. (Hanemann, 2005).

2.1.3 The Price of Water

In many countries water supply users are not charged for the water per se, rather they pay for the water supply infrastructure capital and operating cost. This implies that the price most users pay for water does not reflects its scarcity value but rather its physical supply cost. The state owns the water source and the right to use it is given away for free. However the Ghana government requires payment of a royalty to extract the resource. The government of Ghana do levy an abstraction charge for water through the Water Resources Commission and these charges are meant to cover administrative fees and not based on an assessment of the economic value of the water being withdrawn. There is a tendency to underprice water , because most water agencies set price to cover the historic (past) cost of the system rather than the future replacement cost. Due to the extreme lumpiness and longevity of surface water supply infrastructure, there is a large gap between these two costs. When current demand is far below the supply capacity, there is a strong economic incentive to set price to cover just the short-run marginal cost, which is extremely small. When capacity becomes more fully utilized as demand grows, it is economically optimal to switch to pricing based on long run (i.e. replacement) marginal cost. However the water supply agencies are often politically locked into a regime of low water prices focused narrowly on the recovery of the historical cost of construction. (Hanemann, 2005)

2.1.4 Water Pricing Method

There are various pricing methods that are used in the water industry worldwide. Water utilities are normally regulated because of the monopoly they have in a local area and the requirement to ensure that they earn only a fair rate of return. Water utilities when charging its consumers have different price structures to choose from. The price structure is volume-based. One of the price structure is the flat rate of which the marginal cost of additional water consumption is zero. With this type of system, water used by individual customers is not metered and thus the amount billed is unrelated to actual volume used. Hence this does not solve the incentive-toconserve problem. Another pricing structure is the declining block pricing of which the cost per unit of consumption decreases with additional unit of consumption. With this system consumers are charged higher price for less consumption of water and a lower price for higher consumptions. This pricing system is inefficient and thus stimulate high-income consumers not to practice conservation, whiles place an undue financial burden on low-income consumers. This system is popular in cities with excess capacities and that use this method to attract business or more consumers. Finally water utilities trying to promote water conservation and maximizing their rate of returns, applies the increasing pricing structure. Under this system the cost per unit of consumption increases with additional units of consumption. The disadvantage with this system is that, revenues obtained for the first units consumed are lower. However the advantage is that those low-income consumers who need some water but cannot afford the marginal price paid by extravagant users can have access to water without jeopardizing their budget, unlike the uniform pricing structure. Furthermore there is a seasonal rate structure that is applied by utilities where the cost per unit of consumption changes with time periods, i.e. prices during peak demand periods exceeds prices during off-peak periods.

2.1.5 PURC Tariff Setting

Ghana Water Company Limited which has monopoly in providing pipe borne water to the urban population in Ghana is regulated by the Public Utilities Regulatory Commission (PURC). In pursuant to its statutory responsibility, the PURC has a tariff setting guideline which guides the Commission, utility companies and other stakeholders as a transparent basis for setting rates for both water and electricity. The commission is enjoined by statute to take the consumer interest; investor interest; the cost of production of the service and the assurance of the financial integrity of the public utility into account in preparing the guidelines. During tariff review, proposals are submitted by the utility service provider sixty days before the effective date of the new tariffs. The public also make an input through nationwide public hearings by the utilities and the PURC by law makes the tariff decision within thirty days of receiving all necessary information. To ensure reasonable rates which assures the financial integrity of the Public utilities, the PURC's policy is to institute an efficient tariff regime such as the Automatic Adjustment Formula (AAF) which is implemented quarterly. The main objective of the AAF is to sustain the real value of the tariffs by adjusting it based on variations in factors such as fuel price, foreign exchange, inflation and generation mix. (PURC, 2015)

2.1.6 The Concept of Water

Water, according to Symons *et al* (2000) is a transparent, odorless, tasteless compound of hydrogen and oxygen, H_2O. Water, in a more or less impure state, constitutes rain, oceans, lakes, rivers and other such surface water bodies as well as groundwater. Water, an abundant natural resources, is critical for the sustenance of human life. Water occupies a central position in the basic needs of humans to the extent that it is next to oxygen in order of importance (Ogunnowo, 2004). Literally then, water means life and prosperity. Water is a key determinant of sustainable development that should be carefully managed to make for suitable and sustainable human health cum well-being (Ogunnowo, 2004).

The basic purpose for which water is domestically required includes drinking, bathing, cooking and general sanitation such as laundry, flushing of closets and other household chores. Other important uses of water are for economic activities, livestock and irrigation.

Thus, an assured supply of water both qualitatively and quantitatively for these purposes greatly improves the social and economic activities of people (Fanira, 1977; Oyebande, 1986, cited in Ogunnowo, 2004). The fact that water is a major constituent of all living matter, explains that water therefore is a basic necessity for life. It is very much needed in all aspects of life. This implies that water gives life. Both plants and animals need it for survival and growth. Any shortage or pollution of such a vital resource hinders growth and development. Therefore there is the need to harness sources to explore and develop existing water sources and manage them to ensure adequate quantity and quality supply at all times for survival and growth.

2.1.7 Water Treatment

Water treatment is any unit process that changes or alters the chemical, physical, and bacteriological quality of water with the purpose of making it safe for human consumption and appealing to the customer. The broader objective of water treatment operations is to provide potable water for consumption, however the basic goal is to protect public health.

2.1.7.1 Stages of Water Treatment

Water treatment is made up of various stages or unit processes combined to form one treatment system. A water treatment system may apply one or a combination of some of the unit processes or even all of the below discussed processes to treat a source water. However it should be noted that these processes do not necessarily apply to very small water systems. In some small systems, water treatment may consist of nothing more than withdrawal of water via pumping from a groundwater source to storage to distribution.

Screening

The treatment process that is employed preliminary to remove suspended sediments and debris from surface water before it is channel to the intake pumps is referred to screening. This process is essential since surface water contain fish and debris which can clog or damage pumps, clog pipes and cause problems in water treatment.

Aeration

Aeration is the process whereby water is brought into contact with air for the purpose of oxidation of iron and manganese and the removal of volatile organic compounds such as carbon dioxide, hydrogen sulfide, methane and such as responsible for odor and taste.

Coagulation and Flocculation

With the Coagulation process, the forces that tends to hold apart suspended particles are reduced thus enhancing the coming together of smaller particles to heavier settleable and filterable particles of which process is known as flocculation. Thus, coagulation and flocculation must be considered conjunctively and that coagulation precedes flocculation.

Clarification

This is the stage that the flocs formed at the coagulation and flocculation stage are removed from the water by either sedimentation (settling) or flotation. In Ghana we clarify the water through sedimentation in either sedimentation tanks or clarifiers. The flocs settle to form a thick colloidal substance called sludge, which is then removed from the clarifier.

Filtration

Water Filtration process is the separation of larger and unsettle particles from water by passage through a porous filtration media usually sand, granular coal, or granular activated carbon. This is normally done by rapid gravity and horizontal sand filters, however it can be done through pressure or slow sand filters which is essentially a biological process, whereas the others former are physical treatment processes.

Disinfection

The process whereby organisms in water are destroyed or made inactive is known as Disinfection. This can be achieved by the application of different chemicals such as; chlorine, ozone, bromine, u.v. light etc. This stage is the most important stage in the treatment process since the health of water consumers is very paramount.

PH Correction

Alum is an acid salt and this causes a reduction in the pH of the water when it is added. A reduced pH results in acidic or aggressive water. This water has the potential of attacking the distribution system to cause corrosion in the pipelines. At this stage hydrated lime is added to raise the pH of the water. The lime does an additional work of **softening** the water.

2.1.8 Concept of Efficient Production

As a matter of fact, it is pertinent to define the term production. The literature describes the term production as the transformation process of material and nonmaterial input goods to higher output goods (Günther and Tempelmeier, 2004). Due to the complex structures of modern production facilities, these can be considered as systems. Günter and Ropohl define a system as a model of integrity with a relationship between attributes (inputs, outputs, states, etc.). A milieu or a super system surrounds this structure (Günter, 1978). The production system interacts with its natural, technological, political, legal, economic, and social-cultural environment. The smallest part of a production system is the independently working operating system. REFA defines an operating system as a system that fulfills work tasks as a cooperation of people and resources (machinery, materials). Seven additional design objects are relevant for this interaction. These include people, resources, work assignment, workflow, input and output as well as environmental factors (Nebl, 2007). The interaction of these factors has to be as efficient as possible. Efficiency can be divided into technical efficiency and cost efficiency. Technical efficiency is the condition when no production factors are wasted. Economic efficiency in terms of microeconomics can be seen as the realization of the minimum cost combination. While economic efficiency in this sense presupposes technical efficiency, technical efficiency does not require economic efficiency (Beck, 1994). The difference between the input and output of a working system is considered as a loss. Losses can be incurred by the use of all factors of production.

It is necessary to define the input factors in more detail. In the existing literature, the interacting design objects are stated as factors of production.

Literature gives several definitions of the term ‘factors of production’ (FOP). International economists see the conceptual factors of production as the economic factors (for example labor, capital, ground, and entrepreneurship) defined by Adam smith and David Ricardo. German business research suggests other FOP. Gutenberg, (1972) as one of the first authors, has defined these factors. His work is fundamental for the description of dependencies and processes within a production system. A basic view of production is the smallest element of the production system. The operating system just works with the existence of the design objects. These design objects can be classified into groups, such as elementary factors. Elementary factors include people or manpower, machinery, and the work objects (material, supplies). This group is only one part of the majority factors of production.

Gutenberg, (1972) divides these factors into two primary groups and structures input factors according to availability and independence. The first group includes the elementary fop. These are divided into potential factors and consumable resources. While the potential factors like manpower and machinery affect the technical production capacity, they are not physically part of the product. They are present in the production in order to create value. Consumable resources are mainly materials and supplies which are used physically to produce output goods. Another possible classification is the categorization into primary and derivative factors. The primary factors are similar to elementary factors and the factor leadership, which, however, is not an elementary factor. Derivative factors include planning, organization, and control activities of the production system and the work system. They are responsible for the composition of the elementary factors in the production process. Additional factors, namely by intangible rights, services, and information. Another definition of the fop is given by Ishikawa, who developed the cause effect diagram. He defines four main factors describing the general conditions of an operational system. These are manpower, machines, material, and method (4m). Over time, other main factors have been added, namely management, environment, and measure. Energy as an additional factor belongs to the elementary factors and is classified as supplies.

2.1.9 Concept of Process Loss

Process loss is the loss that results from the conversion of an input raw material into finished products. Alternatively it can also be said to be the difference between the input quantity and the output quantity resulting from production operation.

$$\text{Process Loss} = \text{Normal process loss} + \text{Abnormal process loss}$$

Where normal loss is the loss which is inevitable or anticipated before production. Whereas abnormal loss is that loss that exceeds the normal loss. Abnormal loss occurs as a result of inefficiencies due to rough handling, machine breakdown, accidents, carelessness, low quality raw material, etc. Since normal loss is uncontrollable, it is catered for prior to production. However abnormal loss can be avoided if the right precautionary measures are followed. Therefore, abnormal loss is also called an avoidable loss. The value of an abnormal loss is assessed on the basis of the production cost with which the profit and loss account is charged. (BlogSpot, 2010).

2.2 Empirical Analysis of Related Work

Djida Bounazef et al, (2014) presented an approach to management analysis of industrial production losses by method of experimental design, a mathematical modelling which relies on statistical surveys that allows the observance of the action of each factor on the loss of production and the interactions of these factors together in pairs on the production process. His work is a case study done on a company that manufactures polyethylene pipes with eight production lines which stop frequently due to rapture of raw materials, accidental stops and maintenance and human resources management stops. These causes of production stops was analyzed using the design of experimental method while the waste generated by frequency of production stops is analyzed by statistical process control.

The annual status report on water loss reduction plan for Miami Dade Water Sewer Department MDWASD prepared by (Black & Veatch, 2012) recommends real and apparent water loss mitigation approaches over a twenty year period with corresponding monetary savings. The MDWASD water system consists of three regional water treatment plants, treated water storage and pumping facilities. The analysis of the report was structured in a format of a standard water balance, focusing on water supplied, authorized consumption, water losses, system data and cost data. The water balance was created using the AWWA software and analysis of existing data provided by MDWASD. The International Water Association (IWA) and the American Water Works Association (AWWA) developed the standard methods and terminology to perform water audits and to assist water utilities in tracking their distribution system losses. The AWWA free Water Audit Software (version 4.2) was used to calculate all the required indicators, which is used to develop the overall water balance and relevant performance indicators. In the report, water loss reduction strategies were built upon calibrated and standardized models. The report suggest two kinds of audits that can be performed: a top-down water audit and a bottom-up water audit. The top-down water audit, discusses the modelling/audit tools and methods that are used to properly quantify losses and design the strategy. The bottom-up water audit, discusses intervention tools commonly used to reduce losses.

(Madelene Malmsten et al 2008) in her dissertation estimates cost structure of a water and wastewater system by a multivariate regression approach using transcendental logarithmic cost function. This was an econometric cost analysis of urban water supply and sewerage treatment with an application to a section of Swedish community. After the determination of cost structure, the system was analyzed in terms of efficiency, technology, growth, capacity, expenses, etc. Conclusions drawn from the study established the existence of economies of scope between water and wastewater in the utility industry. In carrying-out the system analysis, a sample size of 25 of 200 systems was used to represent the overall descriptive statistics for the water and sewerage organizations in the study. The horizontal product analysis of the economies of production output density and economies of customer density applies a mathematical measurement. The estimation shows that the larger utilities exhibits diseconomies of production output density and diseconomies of customer density. Whiles the economies of production output density and economies of customer density are exhibited by the smaller utilities.

In measuring production losses, Gram (2013) introduces the Balanced Scorecard methodology which is a metric system to control the performance of companies. This method was developed by KAPLAN and NORTON in cooperation with twelve companies and management consultants. With the application of the Balanced Scorecard to measure production losses, he indicates the necessity to set indicators to see which losses influence others and therefore recommends to draw up a strategy map. The strategy map helps to identify losses and to choose the right indicators or main losses. It also shows the relationships between the losses and the occurrence in the defined perspective which are given as machine, manpower, energy and material.
The first step of the scorecard procedure is to identify the losses in the system, secondly assign the identified losses to the defined losses i.e. main losses and then thirdly measure and evaluate the losses.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

The purpose of this study is to estimate the annual revenue loss due to excessive use of water for treatment and due to operational downtime, and to perform a trend analysis of the amount of water loss from the year 2000 to the year 2014. This chapter provides information on the data needs of the study, the type of data and the source of all data used in this study. The chapter also outlines the methods used to analyze the data so as to answer the research questions.

3.1 Study Area

The Barekese Water Treatment Plant is located 26km North of Kumasi which is the capital town of the Ashanti Region of Ghana. It has an impounded Dam situated on the Offin River with an estimated volume of 27.4Mm^3. The construction of the Dam started in October 5, 1965 and was completed in June 26, 1969. The Barekese Water Treatment Plant started production in September 1971 with a plant capacity of 12MGD (54,545m^3/d). However through the years, the plant has gone through phases of expansion to the current capacity of 136,000m^3 equivalent to 30MGD. The Barekese water system draws its raw water from the Offin River which has a designed yield of 220,000m^3/d and treats it at the Barekese treatment works. The raw water is withdrawn through an intake tower with three level gates and directed to an intake pump house via a 1200mmØ metal pipe line. Raw water is pumped from three Lowlift pumps to five cascading aerators. Aluminum Sulphate is injected into the aerated water for coagulation and then transported to a dividing chamber. The water from the distribution chamber is equally divided into five Clariflocculators for sedimentation after which the

settled water is transferred into thirty cells of rapid gravity filters for filtration. Chlorine gas and hydrated lime are utilized for disinfection and pH correction respectively and the final water is transferred via high lift pumps to a booster station at Achiase for onward transmission to the Suame Reservoirs, before gravitating to the transmission and distribution network. The Kumasi city is supplied by the Barekese and Owabi water systems, with about 90% of the total water produced from the Barekese Headworks. A limited amount from Barekese System
also goes to the Offinso District.

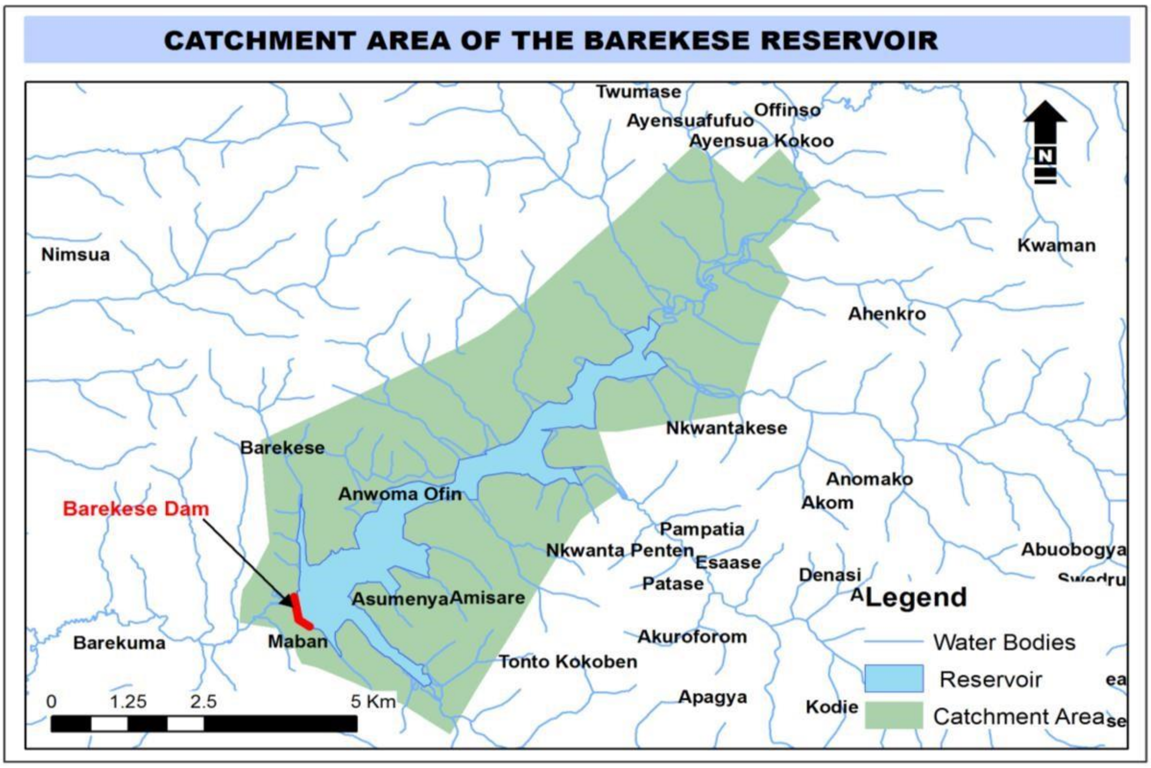

Figure 3.1: Catchment area of Barekese Reservoir

3.2 Data Source

All the data used by the study were obtained from secondary sources. The study relied on monthly time series data from the year 2000 to the year 2014. All the data used in this study were obtained from the Barekese Headworks, except the data on the prices of water, which was obtained from the Head office of the Ghana Water Company Limited.

3.3 Research Design

The first objective considered in the study was to perform a trend analysis of the various water losses due to inefficiency. To achieve this objective, time series plots of the losses were made. The time series loss data were further decomposed into constituent parts of trend, seasonality and randomness. This is to reveal the true trend in the data over time.

To estimate the revenue loss due to inefficiency in the operations of Barekese Dam data on operational downtime, the number of hours of operational downtime, the volume of water treated and the hours it took to produce were collected. Monthly time series of these variables were obtained and used to estimate the amount of water loss due to operational downtime.

To estimate the loss due to excessive water used for treatment, the study estimated the excess amount of water used for water treatment above the amount the plant was designed to use (operational normal loss). According to Royal Haskoning, the Consultant for the Barekese Expansion project (Final Version 2009), The Barekese Dam was designed to use 3 percent of its raw water for treatment. Any amounts beyond this amount constitute an excess and might be due to inefficiency in operation. The monetary value of this loss was estimated by multiply the amount loss and the average price per period. Detail descriptive of the estimation method is discussed in the coming sections.

3.4 Data Analysis

This section outlines the method and models used to analyzed the data. In summary the study used descriptive statistics (mean) as well as inferential statistical tools (independent t-test and simple regression) to analyze and answer the research objectives.

3.4.1 Estimation of Annual Revenue Loss

One of the study's primary objectives was to estimate the revenue lost due to operational inefficiencies. The study identified two major sources of loss, which are the loss due to excessive water use in water treatment and the loss due to operational down time.

Equations (1) to (2) presents the formula for estimating the annual revenue loss due to excessive water use for treatment and the water loss due to operational downtime respectively. The terms inside the brackets in both equations (1) and (2), [$\frac{SL_t-3}{100} \times RW_t$ and $\frac{ODT_t}{HO_t} \times TW_t$], computes the volume of water loss due to excessive use and operational downtime respectively. The total revenue lost in a year is computed with equation 3.

$$R_1 = \sum_{t=1}^{12} \left(\frac{SL_t - 3}{100} \times RW_t \right) \times P_t \tag{1}$$

$$R_2 = \sum_{t=1}^{12} \left(\frac{ODT_t}{HO_t} \times TW_t \right) \times P_t \tag{2}$$

$$\text{Total Revenue Lost}_y = R_1 + R_2 \tag{3}$$

Where

SL_t = System loss (i.e. % of water used for water treatment) at time t.

RW_t = Total amount of raw water extracted to be treated at time t.

TW_t = Total amount of treated water produced at time t.

R_1 = Revenue loss in a given year due to over use of water during water treatment.

R_2 = Revenue loss in a given year due to operational downtime.

ODT_t = Operational downtime hours

HO_t = Operational hours

P_t = Average tariff per 1000litres of water consumed at time t.

3.4.2 Comparing R_1 *and* R_2

As part of the study objectives, the researcher sought to statistically compare the revenue loss due to excessive water use and revenue loss due to operational downtime. This was accomplished using the two sample independent t-test. The test, null hypothesis that there was no statistical difference between R_1 and R_2 against the alternative hypothesis that R_1 and R_2 are different from each other, with a 95 percent level of significance.

3.4.3 Time Series Trend Analysis

After the various loss has been computed using the formula derived above, a detailed time series trend analysis was done on each loss to understand their trend over time. The analysis was further extended to understand any seasonality within the data and attempt at explaining them.

3.5 Definition of Variables

This section defines the various variables used in the study. It also provides the unit of measures as well as their use in the study.

Raw Water Withdrawn

Raw water withdrawn refers to the volume of water withdrawn from the Barekese Dam to be treated. It has been measured in cubic meters and on monthly basis. It has been represented by the variable RW_t in equation 3.2 and was used to compute the total water loss due to excessive amount of water use for treatment.

Treated Water Produced

Treated water produced refers to the net volume of water after treatment process. It is measured in cubic meters and it represents the volume of water sent to the Ghana Water Company distribution network and to the final consumers. It has been represented as TW_t in equation 3.5 and used to compute the volume of water loss each month due to operational downtime.

Water Used for Treatment

During the water treatment process some amount of the raw abstracted water is used for the treatment. Originally, the plant is designed to use only 3 percent of its raw abstracted water for treatment. However, the actual amount of water used for treatment most of the time is higher than the 3 percent. The extra amount is what this study refers to as abnormal loss represented as AL_t in equation 3.2.

System Loss

System Loss refers to the amount of water used for treatment expressed as a percentage of the total raw water withdrawn in each period. By subtracting 3 from the system loss figure, the result refers to the percentage of excess water used for the treatment.

Hours of Operations

Hours of operations as the name suggest refers to the number of hours plant operated in a given month. This has been represented as HO_t in equation 3.5 that was used to compute the amount of water loss due to operational downtime.

Operational downtime

Operational downtime refers to the number of hours in a month that the plant was shut down for whatever reason. Some of the reasons are power outages, power fluctuations, equipment failure/operational challenges, deliberate machine stops for maintenance activities, etc.

This variable was represented by ODT_t in equation (2) and used to estimate the volume of water loss due to operational downtime and the revenue loss due to operational downtime.

Tariff

Tariff refers to the average of the water tariffs approved by PURC that the Ghana Water Company charges the various types of consumers. Various consumer groups are charged with different tariff structure and the tariff used in this study is the average of all these tariffs. On the consumer groups, we have metered domestic consumers, commercial/industrial consumers, public institutions/Government departments, unmetered premises, premises without connections and special commercial consumers. Periodically, the PURC reviews the tariff at which water should be sold to these final consumers.

For example, effective from 1 July 2014, the tariffs were, 153.44 GHp for metered domestic consumers, 328.02 GHp for commercial/industrial consumers, 295.08 GHp for public institutions and government departments, and 998.72 GHp for unmetered premises, 151.69 for premises without connections and 929.81 for special commercial consumers. Note that the tariffs are charged per 1000 litres of water.

CHAPTER FOUR

ANALYSIS AND DISCUSSION OF FINDINGS

4.0 Introduction

This chapter analyzes and discuss the findings of the study. The chapter is organized into sections, where the first section presents a summary of the variables used in the study. The remaining section answer the research objectives. This study is mainly an exploratory exercise as it seeks to understand the behavior of certain variables over time. The primary objective of this study was to estimate the revenue loss due to overuse of water for treatment and the revenue loss due to operational downtime and examine the trend of water loss over time.

4.1 Data Summary

To achieve the research objectives, monthly time series data was collected from the Head office of Ghana Water Company as well as from the Barekese plant management on variables such as raw water withdrawal (RW), treated water produced, water used for treatment, all measured in cubic meters. Data on the system loss (the percentage of raw water used for treatment), and the hours of operation for each month as well as the hours of operational downtime due to a number of reasons.

Table 4.1 presents the descriptive summary of these variables.

4.1.1 Operational Inefficiencies

The results indicates that, the Barekese Water Treatment Plant withdraws between 1.4 million cubic meters to 3.2 million cubic meters of water each month. On average, it withdraws about 2.2 million cubic meters of water each month. The results also indicates that, the Plant on average treats about 2 million cubic meters of water each month. The plants uses on average 164,500 cubic meters of water each month for water treatment which result in average system loss of about 7.5 percent of raw water abstracted each month.

Table 4.1 also indicates the number of hours the plant is operated in a month. The result showed that, the plant is operated from about 480 hours to 742 hours each month and an average of 656hours each month. In each months, the plant is shut down (operational downtime) for a number of reason (such as during power outages). The hours of operational downtime varies from about an hour to about 236hours a month and on average 72 hours each month.

Finally, Table 4.1 also presents the average tariff at which water is sold by the Ghana Water Company. The average tariff over the 15 year period varies from about 14 GHp to 3 Ghana cedis 48 GHp with an average of 1 Ghana cedis 9 GHp per 1000 liters of water.

Table 4.1 Descriptive Summary of Variables

VARIABLES	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Raw Water Abstracted (m^3)	1447368	3263994	2256491.10	371284.03
Treated Water Produced (m^3)	1343112	3092000	2091904.96	381157.83
Water used for Treatment (m^3)	77033	361417	164586.14	59832.68
System Loss (%)	3.58	15.65	7.49	2.85
Hours of Operations (hrs)	479.00	742.75	656.98	50.41
Operational Downtime (hrs)	1.25	236.00	72.32	43.87
Average Tariff	0.1397	3.4828	1.09	0.86

4.2 Estimation of Total Revenue Lost

The study sought to estimate in monetary terms the total amount of revenue lost due to the use of water above and beyond the recommended plant requirement of 3 percent and also due to operational downtime. Using equations (1) and (2) from chapter 3, the volume of water loss due to excessive water use and operational downtime have been estimated for each month and the results summed over the twelve months to obtain the yearly amount as indicated in Table 4.2.

The first column in Table 4.2 presents the years, the second column, presents the volume of water loss due to excess water use for treatment over the years, column 3 presents the volume of water loss due to operational downtime, column 4 presents the yearly average tariff, the last two columns computes the revenue losses due to excessive use of water for treatment and operational downtime respectively.

Table 4.2 Computation of Revenue Losses

Years	AWL	WLDOD	Tariff/ 1000 Liters	R1	R2
2000	1847165.70	5043761.62	0.14	258049.05	704613.50
2001	1753949.20	3168657.97	0.24	427218.18	771805.87
2002	2311303.70	2421620.16	0.34	776386.10	813442.31
2003	1598246.40	1875448.00	0.46	736978.11	864800.39
2004	2053643.40	1082618.22	0.52	1069948.21	564044.09
2005	1253025.10	1581936.08	0.54	674127.50	851081.61
2006	1203339.60	1655121.35	0.54	647396.70	890455.29
2007	1461526.20	1561300.63	0.78	1136994.31	1214613.83
2008	848155.28	1957406.28	1.08	914565.84	2110671.19

2009	656099.72	2297858.37	1.08	707472.33	2477780.68
2010	590722.62	3269333.55	1.51	893143.07	4943068.85
2011	477723.57	2415949.95	1.84	878390.33	4442207.18
2012	471820.80	5216664.35	1.93	911888.06	10082247.19
2013	656451.27	5397978.91	2.18	1433673.16	11789051.00
2014	247989.14	3619802.40	3.21	795995.54	11618841.73
Total	**17431161.70**	**42565457.85**		**12262226.48**	**54138724.71**
Average	**1162077.45**	**2837697.19**	**1.09**	**817481.77**	**3609248.31**

Source: Author's construct

The total column figures showed that, from the year 2000 to 2014, the Barekese Water Treatment Plant has overuse 17,431,161.70 m^3 of water for treatment above and beyond the 3 percent plant specification. On average, the plants overuse about 1,162,077 m^3 of water each year in water treatment. On the other hand, from the year 2000 to 2014, 42,565,457.85 m^3 of water has been lost due to operational downtimes resulting in a yearly average of 2,837,697.19 m^3.

The total revenue loss due to excessive use of water for treatment in each year from 2000 to 2014 has been computed in column 5. The result showed that, over the 15 year period, the plant has lost 12,262,226.48 Ghana cedis which translate into a yearly average revenue loss of 817,481.77 Ghana cedis. Total revenue loss due to operational downtime over the 15 year period was 54,138,724.71 Ghana cedis translating into a yearly average revenue loss of 3,609,248.31 Ghana cedis due to operational downtime. Comparatively, the figures indicates that, revenue loss due to operation downtime outweigh revenue loss due to excessive water by 41,876,498.23 Ghana cedis.

4.3 Comparing Water Loss from Operational Downtime and Excessive Use for Treatment

This study also sought to relatively compare water loss from operational downtime and excessive water use for treatment. In other words, operational downtime and excessive water use, which contribute more to water loss. To answer this research objectives, the two sample t-test was deployed. The results of which are presented in Table 4.3.

Average amount of water loss each month due to excessive water use in treatment (W_1) was 115011.31 m^3 and that from operational downtime (W_2) was 483935.30 m^3.

The average mean difference suggest that, operational downtime results in about 368924 m^3 more than excessive water used for treatment.

Table 4.3 Two sample independence t-test results

Mean			t	Std. Error Mean	df.	P-value
W_1	W_2	$W_1 - W_2$				
115011.31	483935.30	-368923.99	-1.88	195895.78	179	0.061

However, the results from the t-test indicates that this difference might not be significantly different from zero at the 5 percent level of significance. The test statistic was -1.88 with a p-value of 0.061, which was higher than 0.05. This therefore implies the failure to reject the null hypothesis that there was no significant difference between the volumes of water loss from these two sources. This result implies that, on the average, these two sources contribute equally to total revenue loss and should therefore receive equal attention in the design of measures to combat and reduce the losses.

4.4 Trend Analysis of Water Loss

In this section, the researcher perform trend analysis of the amount of water loss from excessive use and operational downtime. The purpose of this section was to identify any discernible pattern in the behavior of the losses in relation to the time they occur so that appropriate measures can be taken to minimize them if possible.

4.4.1 Trend Analysis of Water Loss due to Excessive Water Use in Treatment

The purpose of this section was to ascertain and understand the trend in the abnormal water loss over the period under review and also examine the variation in abnormal water loss over each month of the year. The reason behind this objectives was to help identify the times in each year that most of the water loss occurs.

Figure 4.1 presents a time series plot of the abnormal water loss in the first panel. The plot in panel I indicates a plot of the observed monthly data from January 2000, to December 2014. The line graph indicates a downward trend but in the presence of random and seasonal components, the trend was not very clear. A time series decomposition was performed where the observed abnormal loss data was decomposed into its random component, seasonal component and the trend component.

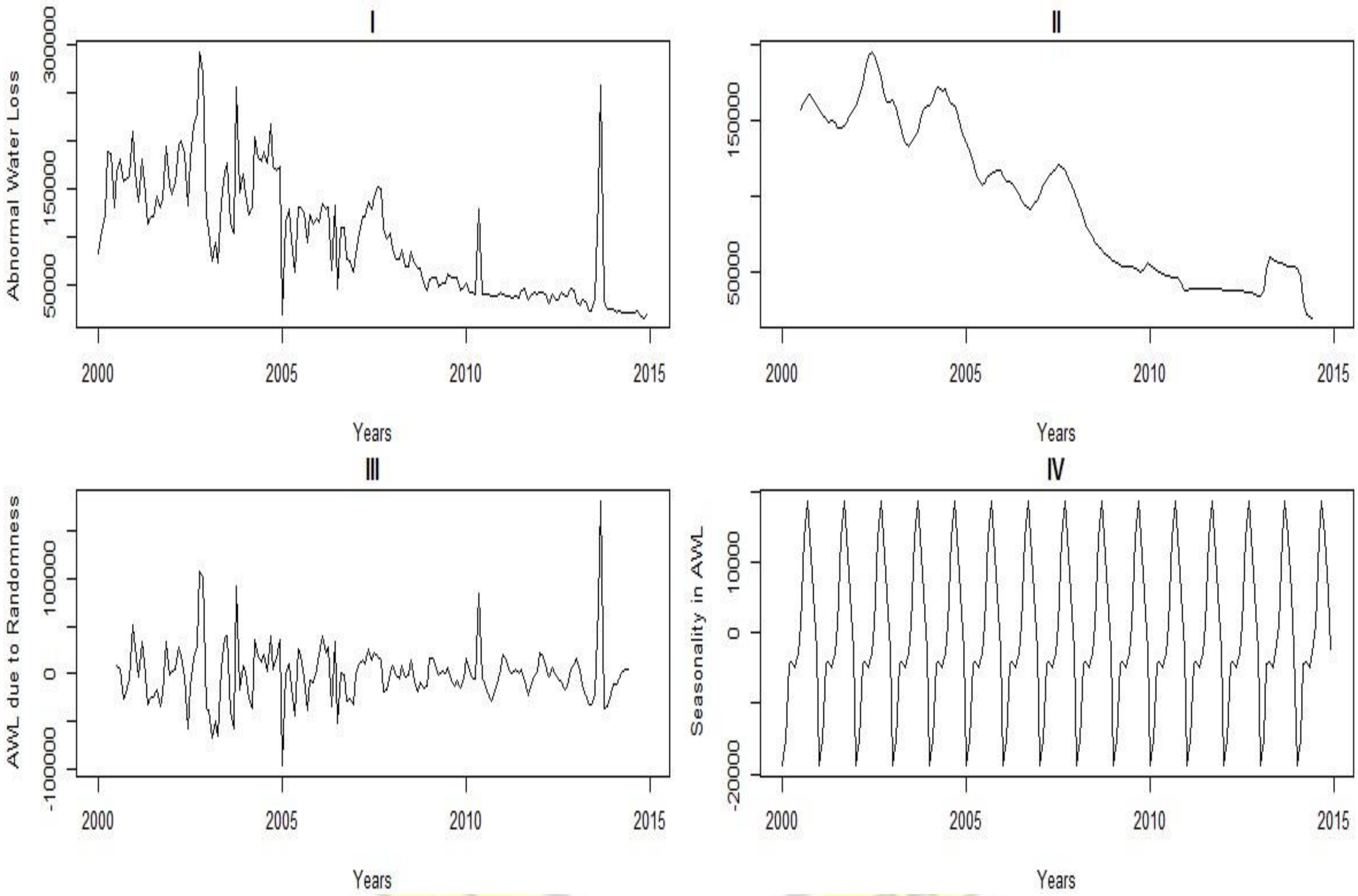
I
Abnormal Water Loss
300000
150000
50000
2000
2005
2010
2015
Years
II
150000
50000
2000
2005
2010
2015
Years
III
AWL due to Randomness
100000
0
-100000
2000
2005
2010
2015
Years
IV
Seasonality in AWL
10000
0
-20000
2000
2005
2010
2015
Years

Figure 4.1 Time Series Decomposition of Abnormal Water Loss

Panel II in Figure 4.1 shows the true trend after the decomposition of the random and seasonal components, which were also plotted in panels III and IV. Panel II clearly indicates that, from 2000 to 2014, the volume of water overused for treatment has been declining.

Panel III plots the randomness in the abnormal loss and it fluctuates around zero even though the absolute amount in terms of volume are in the hundred thousand. The randomness implies the amount of abnormal water loss that could not be accounted for by seasonality and the trend components.

Panel IV presents the plot for the seasonal component of the abnormal water loss. The figure indicates a repeated pattern each year.

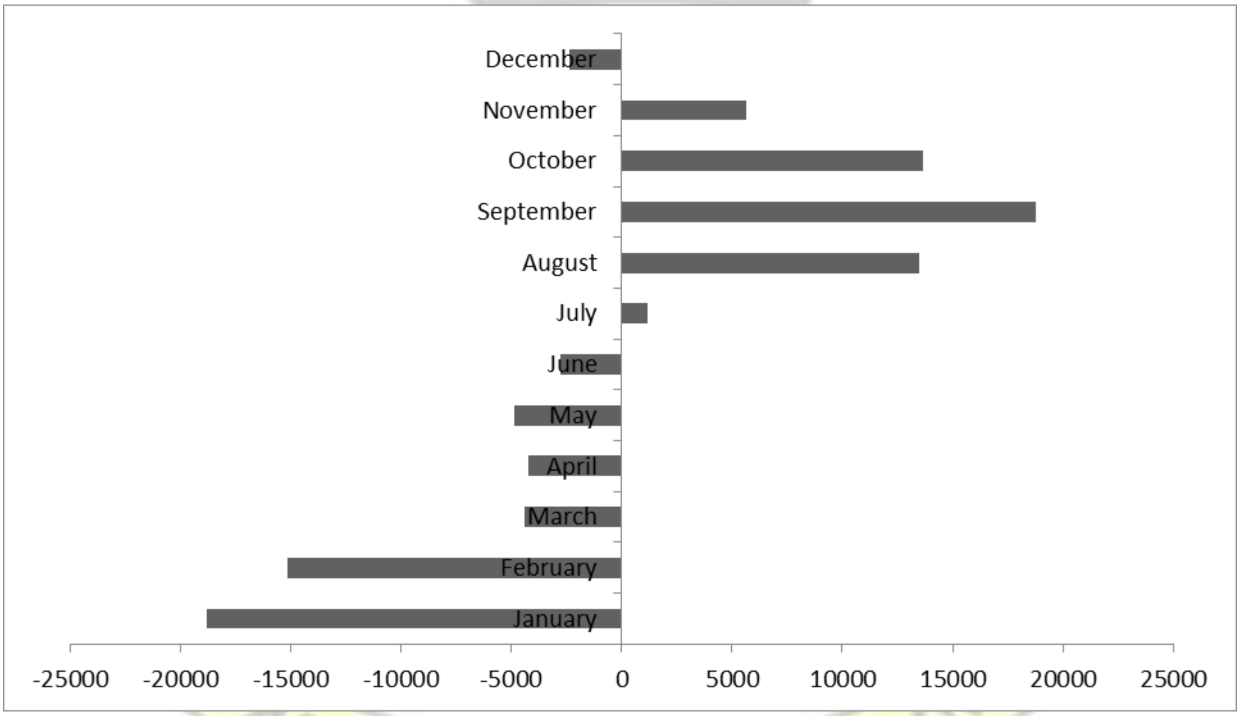

Figure 4.2 Average Seasonal Abnormal Water Loss

To enhance the understanding of the seasonal components, the average seasonal abnormal water loss for each month over the period 2000 to 2014 were computed and the result plotted in Figure 4.2. The figure indicates that, the average volume of abnormal water loss from December the previous year to June is negative. What this implies is that, there is a reduction in abnormal water loss in each year from December to June the next year. In other words, from December to June, the Plant experience reduction in abnormal water loss of about 7,520 cubic meters each year. It is therefore important to pursue this and attempt to understand the courses of these seasonal reduction so as to improve and reduce abnormal water loss further. It is also of note that, the highest reduction in abnormal loss occurs in January and February each year.

Conversely, Figure 4.2 indicates positive seasonal abnormal water loss from July to November. The result indicates that on average the volume of abnormal water loss increase each year from July to November by about 10,529 cubic meters. It is also important to look out for the reasons for the increase in abnormal loss from July to November each year so that appropriate measure are adopted correct the causes.

4.4.2 Trend Analysis of Water Loss due to Operational Downtime

The formula used to compute the water loss due to operational downtime in column 5 in Table 4.3, was also used to compute water loss due to operational downtime for each month from January 2000 to December 2014. The results was then used for the trend analysis carried out in this section.

Panels I to IV in Figure 4.3 presents the monthly time series plot of the computed water loss due to operational downtime (WLDOD) and the decomposition of WLDOD into the trend, random and seasonal components to enable a clearer understanding of its trend over the years. Panel I plots the computed WLDOD but in the presence of randomness and seasonality, the trend is not that apparent. Decomposition of the WLDOD and plotting of the constituent components are presented in panels II to IV. It should be noted that, the plots in Figure 4.3 were scaled in thousands.

Similar to the behavior of revenue loss over the time period, the trend component have declined from 2000 to 2003 then remained mostly lower until 2009 where it has increased significantly. As said earlier, the recent upsurge could be attributed to the power crisis. However due to the lack of relevant information on power outages, the loss due to power outages could not be decoupled from the total loss due to operational downtime. It however plays an instrumental role in the pattern of the loss due to operational downtime. Panel III presents the monthly random components of the water loss due to operational downtime. The value fluctuates around zero and it indicates that, the randomness in the water loss will in the end balance out. The more interesting plot is the seasonal component plotted in panel IV. The seasonal plot shows the repeated pattern in the water loss in each month over the years. Understanding of the causes of the seasonality can help in design of policies that can reduce water loss.

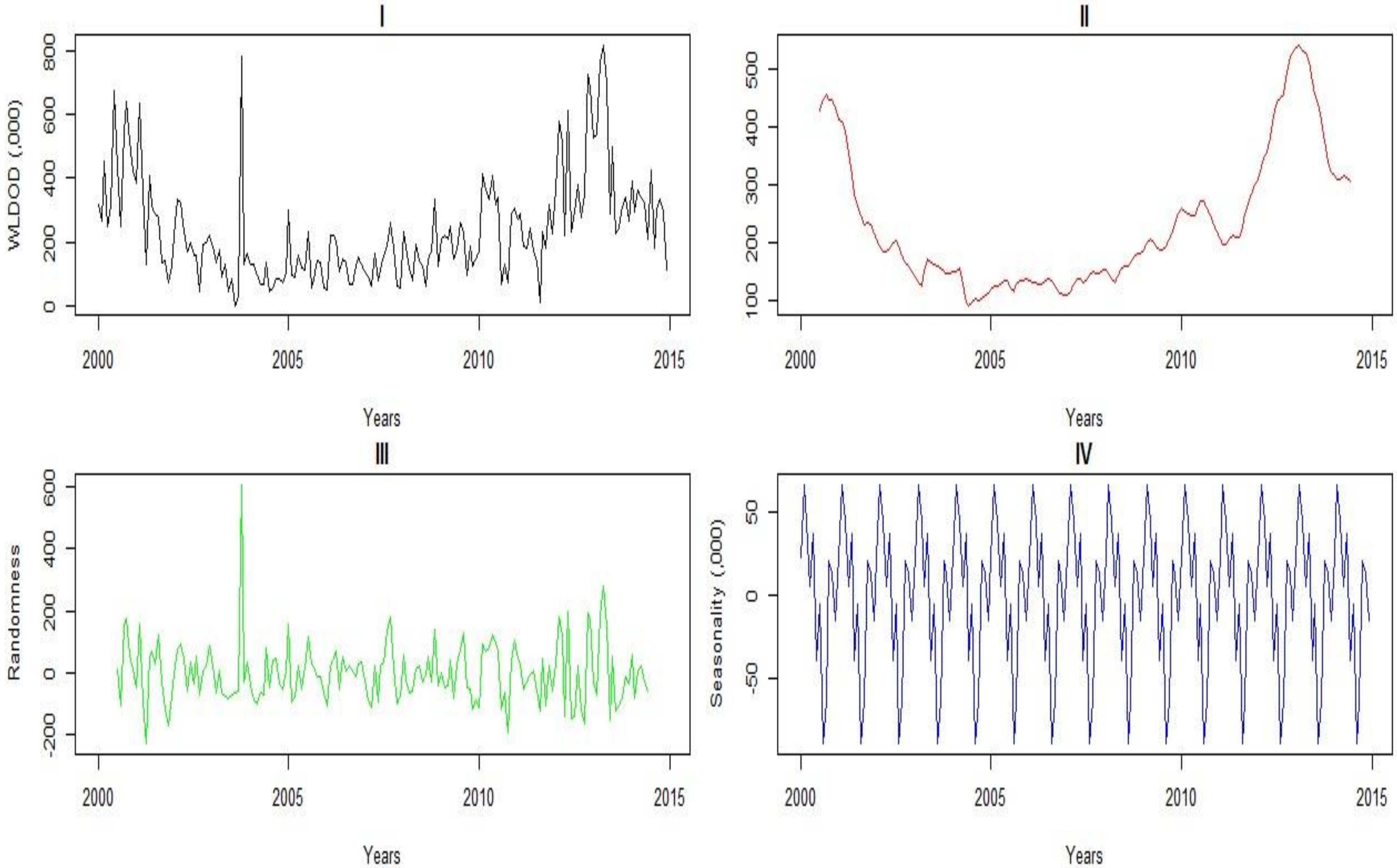
I
WLDOD (,000)
0
200
400
600
800
2000
2005
2010
2015
Years
II
100
200
300
400
500
2000
2005
2010
2015
Years
III
Randomness
-200
0
200
400
600
2000
2005
2010
2015
Years
IV
Seasonality (,000)
-50
0
50
2000
2005
2010
2015
Years

Figure 4.3 Time Series Decomposition of Water Loss due to Operational Downtime

To facilitate an understanding of the seasonal components, the average of the seasonal component was computed for each month of the year in the results plotted in Figure 4.4.

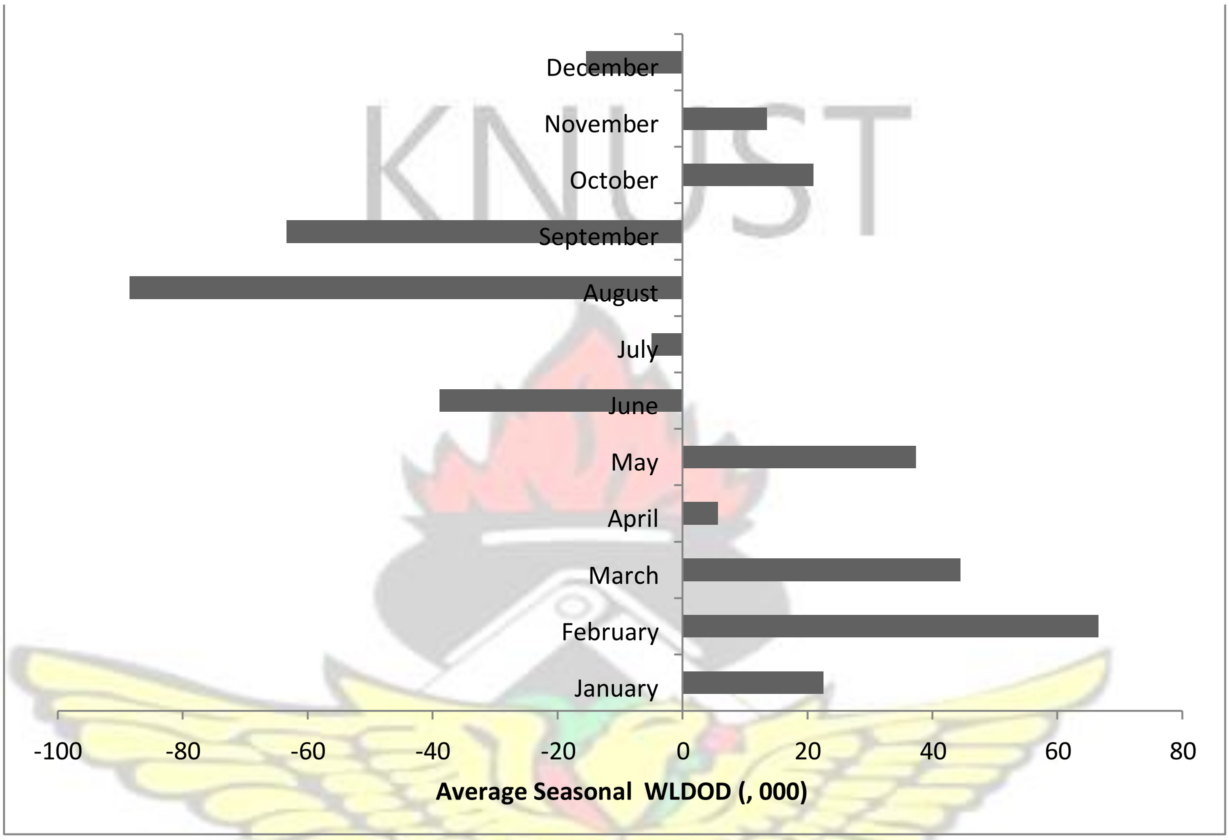

Figure 4.4 Average Seasonal Water Loss due to Operational Downtime

The result of the plots indicates that, each year in December, September, August, July and June water loss due to operational downtime is reduced on average of about 42,000 cubic meters. The months with the highest reduction are August and September. Efforts should therefore be made to understand the reasons behind this behavior especially in August and September.

On the other hand, the months of January to May, October and November all have experience increase in water loss due to operational downtime. In these months, the average seasonal water loss due to operational downtime is around 30,000 cubic meters.

The month of February witnesses the highest increase in water loss due to operational downtime. Efforts should be directed at understanding the factors that water loss due to operational downtime in February to be around 70,000 cubic meters each year.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This is the last and final chapter of the study. It consists of a summary of the research findings, conclusion in relation to the research objectives and recommendations based on the research findings. The study sought to compute the revenue loss due to abnormal loss and operational downtime in the operations of the Barekese Water Treatment Plant and to examine the trend in water loss.

5.2 Summary of Findings

To achieve the above mentioned objectives, the study collected monthly time series data from January 2000 to December 2014. Data was on the volume of raw water withdrawal, the volume of treated water, amount of water used for treatment, the system loss, which is just water used for treatment expressed as percentage of the total raw water withdrawn for each period. The study also obtained data on the hours of operation of the plant, the hours of operational downtime in each month and the average price at which water is sold to the public over the same period.

Descriptive summary of the data revealed that, the Plant withdraws on average, about 2.2 million cubic meters of water each month, treats about 2 million cubic meters each month using about 164,000 cubic meters of water for water treatment resulting in a system loss of about 7.5 percent each month. The summary results also showed that, the plant is operated about 657hours each month and about 72hours of operation time is lost each month due to a number of reasons such as power outages, power fluctuations, deliberate stops, equipment failure etc. The summary data also revealed that average price per 1000 liters of water was 1.09 Ghana cedis.

The study estimated that the Barekese Water Treatment Plant has overuse 17,431,161.70 m^3 of water for treatment above and beyond the 3 percent plant specification. On average, the plants overuse about 1162077 m^3 of water each year in water treatment. It was also estimated that operational downtime caused a loss by an average of 2837697.19 m^3. The total revenue loss from 2000 to 2014 has been computed be 12,262,226.48 and 54,138,724.71Ghana cedis due to excessive water use and operational downtime respectively. On average, the estimated yearly revenue loss were 817,481.77 and 3,609,248.31 Ghana cedis.

Trend analysis of the abnormal water loss revealed that, abnormal water loss has been falling. It showed that, the operations of the plant have been improving toward the efficient level over the years. Note that, an efficiency level in the case of abnormal loss is where only 3 percent of raw water is used for treatment. Time series decomposition of the abnormal water data revealed the presence of a seasonal component which indicates that, from December to June, the plant experience an average reduction in abnormal water loss by 7, 520 cubic meters while from July to November each year, the plant experience an average increase in abnormal water loss by 10,529 cubic meters of water. The study also revealed that, the highest seasonal reduction in abnormal water loss occurs every January and February while the highest increase in abnormal loss occurs in September each year.

The study also compare the average contribution of excessive water use and operational downtime to total water loss in each month using the two sample t-test. Even though the average mean difference was positive in favor of operational downtime, the statistical result showed no significance difference at the 5 percent level. There was however a significance difference at the 10 percent level of alpha.

This results suggest that both sources of water loss should receive equal attention in the design of remedies.

5.3 Conclusion

Based on the research findings, the research arrived at the following conclusions. That the inefficiencies in the operation of the Barekese Water Treatment Plant have cause the nation to lose a lot in revenue. The overuse of water for treatment alone have caused revenue loss of about 12.3 Million Ghana cedis while operational downtime alone cause the nation to loss about 54.1 Million Ghana cedis over the past 15 years. The study also conclude that while revenue loss from abnormal water loss has been falling, revenue loss from operational downtime has been increasing in recent years. Finally the overall inefficiencies in the operation of the plant have resulted in loss of about 66.4 Million Ghana cedis over the past 15 years.

5.4 Recommendation

Based on the research findings, the following recommendation was made. It is recommended that, management of the Barekese Water Treatment Plant put measures in place to reduce the operational downtime and abnormal water loss. For example, the study revealed that, in the months of January and February the plant experiences a reduction in abnormal water loss significantly and in August and September the plant experience reduction in water loss due to operational downtime. Management can commission an investigation into the occurrences in these mean to identify what causes the reductions in these months so they can be replicated in each other month of the year.

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APPENDIX : DATA

YEAR	MONTH	AVERAGE	Tariff	AL_Amount	WLDOD	TWL	R1	R2	TRL
2000	JAN	13.97	0.139667	81654.44	317200.62	398855.1	11404.4	44302.35	55706.76
2000	FEB	13.97	0.139667	104877.06	268346.57	373223.6	14647.83	37479.07	52126.9
2000	MAR	13.97	0.139667	123031.21	453454.12	576485.3	17183.36	63332.43	80515.78
2000	APR	13.97	0.139667	188379.3	250560.65	438940	26310.31	34994.97	61305.28
2000	MAY	13.97	0.139667	185947.11	313752.08	499699.2	25970.61	43820.71	69791.32
2000	JUN	13.97	0.139667	130395.41	672444.3	802839.7	18211.89	93918.05	112129.9
2000	JUL	13.97	0.139667	166882.5	434669.16	601551.7	23307.92	60708.79	84016.72
2000	AUG	13.97	0.139667	180303.14	252226.27	432529.4	25182.34	35227.6	60409.94
2000	SEP	13.97	0.139667	157913.25	541922.28	699835.5	22055.22	75688.48	97743.7
2000	OCT	13.97	0.139667	159601.9	640095.55	799697.4	22291.07	89400.01	111691.1
2000	NOV	13.97	0.139667	163740.35	514671.5	678411.9	22869.07	71882.45	94751.52
2000	DEC	13.97	0.139667	208706.46	427039.19	635745.7	29149.34	59643.14	88792.48
2001	JAN	13.97	0.139667	166418.83	386504.45	552923.3	23243.16	53981.79	77224.95
2001	FEB	13.97	0.139667	135707.66	631735.34	767443	18953.84	88232.37	107186.2
2001	MAR	13.97	0.139667	179915.05	349732.57	529647.6	25128.14	48845.98	73974.12
2001	APR	27.82	0.278167	157087.18	132182.84	289270	43696.42	36768.86	80465.28
2001	MAY	27.82	0.278167	113054.64	405101.43	518156.1	31448.03	112685.7	144133.7
2001	JUN	27.82	0.278167	121379.99	311630.66	433010.6	33763.87	86685.26	120449.1
2001	JUL	27.82	0.278167	120635.44	290381.84	411017.3	33556.76	80774.55	114331.3
2001	AUG	27.82	0.278167	141813.32	276146.17	417959.5	39447.74	76814.66	116262.4
2001	SEP	27.82	0.278167	131221.03	137806.27	269027.3	36501.32	38333.11	74834.43
2001	OCT	27.82	0.278167	141034.05	137806.27	141034.1	39230.97	38333.11	39230.97
2001	NOV	27.82	0.278167	193218.63	72655.767	265874.4	53746.98	20210.41	73957.39
2001	DEC	27.82	0.278167	153513.97	124288.29	277802.3	42702.47	34572.86	77275.33
2002	JAN	27.82	0.278167	144156.84	223223.68	367380.5	40099.63	62093.39	102193

2002	FEB	27.82	0.278167	155616.71	335448.92	491065.6	43287.38	93310.71	136598.1
2002	MAR	27.82	0.278167	195579.26	323199.2	518778.5	54403.63	89903.24	144306.9
2002	APR	27.82	0.278167	200001.23	233668.76	433670	55633.68	64998.86	120632.5
2002	MAY	27.82	0.278167	185571.39	170165.67	355737.1	51619.77	47334.42	98954.19
2002	JUN	27.82	0.278167	133307.09	198773.88	332081	37081.59	55292.27	92373.86
2002	JUL	27.82	0.278167	179723.41	159665.24	339388.6	49993.06	44413.55	94406.61
2002	AUG	41.67	0.416667	216568	156924.42	373492.4	90236.67	65385.17	155621.8
2002	SEP	41.67	0.416667	227280.53	46482.546	273763.1	94700.22	19367.73	114067.9
2002	OCT	41.67	0.416667	292150.75	191152.7	483303.5	121729.5	79646.96	201376.4
2002	NOV	41.67	0.416667	20739952	196350.74	20936303	8641647	81812.81	8723459
2002	DEC	41.67	0.416667	123278.19	220617.98	343896.2	51365.91	91924.16	143290.1
2003	JAN	41.67	0.416667	106293.18	186797.8	293091	44288.83	77832.42	122121.2
2003	FEB	41.67	0.416667	75197.82	136391.06	211588.9	31332.43	56829.61	88162.03
2003	MAR	47.00	0.47	94019.8	177820.11	271839.9	44189.31	83575.45	127764.8
2003	APR	47.00	0.47	73386.15	92697.674	166083.8	34491.49	43567.91	78059.4
2003	MAY	47.00	0.47	136660.05	131716.74	268376.8	64230.22	61906.87	126137.1
2003	JUN	47.00	0.47	167207.11	47386.364	214593.5	78587.34	22271.59	100858.9
2003	JUL	47.00	0.47	176469.71	83090.147	259559.9	82940.76	39052.37	121993.1
2003	AUG	47.00	0.47	112843.58	3465.1632	116308.7	53036.48	1628.627	54665.11
2003	SEP	47.00	0.47	102738.11	31618.913	134357	48286.91	14860.89	63147.8
2003	OCT	47.00	0.47	255762.03	778535.75	1034298	120208.2	365911.8	486120
2003	NOV	47.00	0.47	146190.42	129094.94	275285.4	68709.5	60674.62	129384.1
2003	DEC	47.00	0.47	165053.09	164382.02	329435.1	77574.95	77259.55	154834.5
2004	JAN	47.00	0.47	143517.83	133129.18	276647	67453.38	62570.72	130024.1
2004	FEB	47.00	0.47	122057.88	128001.1	250059	57367.2	60160.51	117527.7
2004	MAR	47.00	0.47	129688.05	97879.365	227567.4	60953.38	46003.3	106956.7

2004	APR	53.80	0.538	202894.82	70475.746	273370.6	109157.4	37915.95	147073.4
2004	MAY	53.80	0.538	182766.94	66091.413	248858.4	98328.61	35557.18	133885.8
2004	JUN	53.80	0.538	179531.88	135804.88	315336.8	96588.15	73063.02	169651.2
2004	JUL	53.80	0.538	187780.45	46857.732	234638.2	101025.9	25209.46	126235.3
2004	AUG	53.80	0.538	176198.52	56646.653	232845.2	94794.8	30475.9	125270.7
2004	SEP	53.80	0.538	218125.29	84594.771	302720.1	117351.4	45511.99	162863.4
2004	OCT	53.80	0.538	173037.86	87062.544	260100.4	93094.37	46839.65	139934
2004	NOV	53.80	0.538	168201.83	72156.509	240358.3	90492.58	38820.2	129312.8
2004	DEC	53.80	0.538	172762.49	100542.21	273304.7	92946.22	54091.71	147037.9
2005	JAN	53.80	0.538	19252.01	298784.54	318036.6	10357.58	160746.1	171103.7
2005	FEB	53.80	0.538	115254.7	99707.317	214962	62007.03	53642.54	115649.6
2005	MAR	53.80	0.538	128751.95	93695.346	222447.3	69268.55	50408.1	119676.6
2005	APR	53.80	0.538	97077.95	158602.74	255680.7	52227.94	85328.27	137556.2
2005	MAY	53.80	0.538	63088.89	117668.57	180757.5	33941.82	63305.69	97247.51
2005	JUN	53.80	0.538	130999.78	113819.79	244819.6	70477.88	61235.05	131712.9
2005	JUL	53.80	0.538	130407.83	231626.16	362034	70159.41	124614.9	194774.3
2005	AUG	53.80	0.538	124154.56	54889.503	179044.1	66795.15	29530.55	96325.71
2005	SEP	53.80	0.538	94488.17	83088.937	177577.1	50834.64	44701.85	95536.48
2005	OCT	53.80	0.538	122712.81	144812.68	267525.5	66019.49	77909.22	143928.7
2005	NOV	53.80	0.538	113591.84	134505.2	248097	61112.41	72363.8	133476.2
2005	DEC	53.80	0.538	118817.09	55699.277	174516.4	63923.59	29966.21	93889.81
2006	JAN	53.80	0.538	114907.06	50071.502	164978.6	61820	26938.47	88758.47
2006	FEB	53.80	0.538	134653.14	222197.05	356850.2	72443.39	119542	191985.4
2006	MAR	53.80	0.538	127949.65	218705.26	346654.9	68836.91	117663.4	186500.3
2006	APR	53.80	0.538	131461.06	205303.94	336765	70726.05	110453.5	181179.6
2006	MAY	53.80	0.538	65638.59	110738.64	176377.2	35313.56	59577.39	94890.95

2006	JUN	53.80	0.538	132923.09	147368.54	280291.6	71512.62	79284.27	150796.9
2006	JUL	53.80	0.538	46254.89	137407.5	183662.4	24885.13	73925.24	98810.37
2006	AUG	53.80	0.538	108475.61	68323.499	176799.1	58359.88	36758.04	95117.92
2006	SEP	53.80	0.538	109673.73	65876.3	175550	59004.47	35441.45	94445.92
2006	OCT	53.80	0.538	76539.95	126009.63	202549.6	41178.49	67793.18	108971.7
2006	NOV	53.80	0.538	74319.82	153432.84	227752.7	39984.06	82546.87	122530.9
2006	DEC	53.80	0.538	63331.33	131831.79	195163.1	34072.26	70925.5	104997.8
2007	JAN	53.80	0.538	81582.73	110333.1	191915.8	43891.51	59359.21	103250.7
2007	FEB	53.80	0.538	103205.47	91231.907	194437.4	55524.54	49082.77	104607.3
2007	MAR	53.80	0.538	120966.4	64248.963	185215.4	65079.92	34565.94	99645.87
2007	APR	53.80	0.538	120589.74	165064.31	285654	64877.28	88804.6	153681.9
2007	MAY	83.78	0.83775	136935.01	79611.441	216546.5	114717.3	66694.48	181411.8
2007	JUN	83.78	0.83775	129322.86	112035.84	241358.7	108340.2	93858.02	202198.2
2007	JUL	83.78	0.83775	142906.07	159745.47	302651.5	119719.6	133826.8	253546.3
2007	AUG	83.78	0.83775	151756.5	185390.53	337147	127134	155310.9	282444.9
2007	SEP	83.78	0.83775	149489.48	263247.79	412737.3	125234.8	220535.8	345770.6
2007	OCT	83.78	0.83775	108622.1	184496.51	293118.6	90998.16	154562	245560.1
2007	NOV	107.83	1.078333	98084.13	61888.412	159972.5	105767.4	66736.34	172503.7
2007	DEC	107.83	1.078333	102728.91	60008.299	162737.2	110776	64708.95	175485
2008	JAN	107.83	1.078333	88183.45	234038.25	322221.7	95091.15	252371.2	347462.4
2008	FEB	107.83	1.078333	76886.78	190140.13	267026.9	82909.58	205034.4	287944
2008	MAR	107.83	1.078333	76309.41	117840.64	194150.1	82286.98	127071.5	209358.5
2008	APR	107.83	1.078333	85648.42	79222.663	164871.1	92357.55	85428.44	177786
2008	MAY	107.83	1.078333	69498.23	191904.33	261402.6	74942.26	206936.8	281879.1
2008	JUN	107.83	1.078333	68550.5	141385.53	209936	73920.29	152460.7	226381
2008	JUL	107.83	1.078333	83973.31	122391.82	206365.1	90551.22	131979.2	222530.4

2008	AUG	107.83	1.078333	72881.42	65320.571	138202	78590.46	70437.35	149027.8
2008	SEP	107.83	1.078333	66370.52	150425.08	216795.6	71569.54	162208.4	233777.9
2008	OCT	107.83	1.078333	67054.08	167644.9	234699	72306.65	180777.1	253083.7
2008	NOV	107.83	1.078333	51113.12	335343.99	386457.1	55116.98	361612.6	416729.6
2008	DEC	107.83	1.078333	44349.7	125656	170005.7	47823.76	135499.1	183322.8
2009	JAN	107.83	1.078333	55119.66	209969.36	265089	59437.37	226417	285854.3
2009	FEB	107.83	1.078333	56795.58	221176.47	277972.1	61244.57	238502	299746.5
2009	MAR	107.83	1.078333	57290.54	207230.06	264520.6	61778.3	223463.1	285241.4
2009	APR	107.83	1.078333	48073.5	247970.54	296044	51839.26	267394.9	319234.2
2009	MAY	107.83	1.078333	50930.28	148973.36	199903.6	54919.82	160642.9	215562.8
2009	JUN	107.83	1.078333	52031.61	176600.79	228632.4	56107.42	190434.5	246541.9
2009	JUL	107.83	1.078333	60834.96	258290.77	319125.7	65600.37	278523.5	344123.9
2009	AUG	107.83	1.078333	58058.4	234145.24	292203.6	62606.31	252486.6	315092.9
2009	SEP	107.83	1.078333	57211.68	97555.55	154767.2	61693.26	105197.4	166890.7
2009	OCT	107.83	1.078333	56754.59	185708.65	242463.2	61200.37	200255.8	261456.2
2009	NOV	107.83	1.078333	44487.84	126280.94	170768.8	47972.72	136172.9	184145.7
2009	DEC	107.83	1.078333	47943.98	146307.55	194251.5	51699.59	157768.3	209467.9
2010	JAN	107.83	1.078333	51365.8	168383.35	219749.2	55389.45	181573.4	236962.8
2010	FEB	107.83	1.078333	41509.66	413538.9	455048.6	44761.25	445932.8	490694
2010	MAR	107.83	1.078333	42729.87	365333.59	408063.5	46077.04	393951.4	440028.4
2010	APR	107.83	1.078333	40220.4	334499.4	374719.8	43371	360701.9	404072.9
2010	MAY	107.83	1.078333	128206.04	406346.53	534552.6	138248.8	438177	576425.9
2010	JUN	182.17	1.821667	40406.9	319751.19	360158.1	73607.9	582480.1	656088
2010	JUL	182.17	1.821667	40707.3	338059.96	378767.3	74155.13	615832.6	689987.7
2010	AUG	182.17	1.821667	40457.98	66726.991	107185	73700.95	121554.3	195255.3
2010	SEP	182.17	1.821667	37921.84	133176.73	171098.6	69080.95	242603.6	311684.6

2010	OCT	182.17	1.821667	37618.01	75171.389	112789.4	68527.47	136937.2	205464.7
2010	NOV	182.17	1.821667	37692.2	288772.82	326465	68662.62	526047.8	594710.4
2010	DEC	182.17	1.821667	41566.9	308057.4	349624.3	75721.04	561177.9	636898.9
2011	JAN	182.17	1.821667	40601.5	271576.11	312177.6	73962.4	494721.1	568683.5
2011	FEB	182.17	1.821667	38872.34	291879.73	330752.1	70812.45	531707.6	602520
2011	MAR	179.19	1.791917	37302.6	18999027	19036330	66843.15	34044673	34111516
2011	APR	179.19	1.791917	35907.18	183877.79	219785	64342.67	329493.7	393836.4
2011	MAY	179.19	1.791917	38962.26	241361.23	280323.5	69817.12	432499.2	502316.3
2011	JUN	179.19	1.791917	36592.58	178362.56	214955.1	65570.85	319610.8	385181.7
2011	JUL	179.19	1.791917	44678.44	144664.17	189342.6	80060.04	259226.1	339286.2
2011	AUG	179.19	1.791917	46350.14	12450.304	58800.44	83055.59	22309.91	105365.5
2011	SEP	191.23	1.912283	34894.86	233494.85	268389.7	66728.86	446508.3	513237.2
2011	OCT	191.23	1.912283	38354.22	181156.64	219510.9	73344.14	346422.8	419767
2011	NOV	191.23	1.912283	41835.22	318664.17	360499.4	80000.79	609376.2	689377
2011	DEC	193.27	1.932733	39485.62	227926.12	267411.7	76315.17	440520.4	516835.6
2012	JAN	193.27	1.932733	41349.74	361326.01	402675.8	79918.02	698346.8	778264.8
2012	FEB	193.27	1.932733	42000.76	575263.16	617263.9	81176.27	1111830	1193007
2012	MAR	193.27	1.932733	38027.02	514524.14	552551.2	73496.09	994438	1067934
2012	APR	193.27	1.932733	29923.86	220538.69	250462.6	57834.84	426242.5	484077.3
2012	MAY	193.27	1.932733	40629.54	612552.6	653182.1	78526.07	1183901	1262427
2012	JUN	193.27	1.932733	33752.14	233927.22	267679.4	65233.89	452118.9	517352.8
2012	JUL	193.27	1.932733	33610.12	295891.38	329501.5	64959.4	571879.1	636838.5
2012	AUG	193.27	1.932733	42364	378934.43	421298.4	81878.31	732379.2	814257.5
2012	SEP	193.27	1.932733	37571.18	275813.95	313385.1	72615.07	533074.8	605689.9
2012	OCT	193.27	1.932733	37995.04	351736.6	389731.6	73434.28	679813.1	753247.3
2012	NOV	193.27	1.932733	45189.2	724748.01	769937.2	87338.67	1400745	1488083

2012	DEC	193.27	1.932733	43436.06	682202.95	725639	83950.32	1318516	1402467
2013	JAN	193.27	1.932733	32364	527340.54	559704.5	62550.98	1019209	1081760
2013	FEB	193.27	1.932733	28282.98	536324.91	564607.9	54663.46	1036573	1091236
2013	MAR	193.27	1.932733	33997.56	763720.89	797718.4	65708.22	1476069	1541777
2013	APR	193.27	1.932733	32707.18	814279.18	846986.4	63214.26	1573785	1636999
2013	MAY	193.27	1.932733	22003.86	699111.11	721115	42527.59	1351195	1393723
2013	JUN	193.27	1.932733	22650.86	288611.43	311262.3	43778.07	557808.9	601587
2013	JUL	193.27	1.932733	34172.94	501215.31	535388.3	66047.18	968715.5	1034763
2013	AUG	193.27	1.932733	143074.18	226069.73	369143.9	276524.2	436932.5	713456.7
2013	SEP	193.27	1.932733	256808.3	242968.23	499776.5	496342	469592.8	965934.8
2013	OCT	293.78	2.937755	31691.52	313292.26	344983.8	93101.91	920375.8	1013478
2013	NOV	293.78	2.937755	25056.98	339446.49	364503.5	73611.26	997210.5	1070822
2013	DEC	293.78	2.937755	24455.92	269187.59	293643.5	71845.49	790807.1	862652.6
2014	JAN	293.78	2.937755	23747.02	393644.53	417391.5	69762.92	1156431	1226194
2014	FEB	293.78	2.937755	20967.74	295554.82	316522.6	61598.08	868267.6	929865.6
2014	MAR	293.78	2.937755	23049.88	362410.18	385460.1	67714.89	1064672	1132387
2014	APR	293.78	2.937755	21214.18	342392.49	363606.7	62322.06	1005865	1068187
2014	MAY	293.78	2.937755	21602.86	320784.27	342387.1	63463.9	942385.5	1005849
2014	JUN	293.78	2.937755	21525.36	208156.52	229681.9	63236.23	611512.8	674749
2014	JUL	348.18	3.481812	20272.92	423150	443422.9	70586.5	1473329	1543915
2014	AUG	348.18	3.481812	19995.24	184075.12	204070.4	69619.67	640915	710534.7
2014	SEP	348.18	3.481812	22230.44	304439.12	326669.6	77402.22	1060000	1137402
2014	OCT	348.18	3.481812	17452.3	333809.7	351262	60765.63	1162263	1223028
2014	NOV	348.18	3.481812	15891.8	293000	308891.8	55332.26	1020171	1075503
2014	DEC	348.18	3.481812	19437.96	115316.84	134754.8	67679.33	401511.6	469190.9