AN ASSESSMENT OF THE PERFORMANCE AND MAINTENANCE CULTURE OF THE AHMADU BELLO UNIVERSITY, SAMARU, ZARIA WATER TREATMENT PLANT

BY

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DECLARATION

I hereby declare that this dissertation titled "**An Assessment of the Performance and Maintenance Culture of Ahmadu Bello University Samaru Zaria Water Treatment Plant"** was done by myself in the Department of Mechanical Engineering, Ahmadu Bello University Zaria, under the supervision of Dr. M. Dauda and Dr F.O. Anafi. The information derived from literature has been duly acknowledged in the text and a list of references provided.

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CERTIFICATION

This dissertationtitled "**An Assessment of the Performance and Maintenance Culture of Ahmadu Bello University,Samaru, Zaria,Water Treatment Plant"** meets the regulations governing the award of degree of Masters of Science of the Ahmadu Bello University, Zaria, and was approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this work to God Almighty in appreciation for His love, care, protection and provision.

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ABSTRACT

The project "An Assessment of the Performance and Maintenance Culture of Ahmadu Bello University, Samaru, Zaria, Water Treatment Plant"aimed at assessing the performance and the maintenance culture of the Ahmadu Bello University Water Treatment Plant (ABU WTP).The technique of survey method, monitoring of treatment process and questionnaires were used to obtain and process the required data. Therefore, each treatment unit was visited and critically examined, treatment processes monitored, leakages along the distribution network monitored for five weeks; and base on this approach, some performance indicators (PIs) were selected and their values were computed and compared with known standards. It was observed that the pump efficiency was 76% which is acceptable. About 1150.2 liters (303.9 gallons) that is 0.024% of water loss as a result of leakage along the pipelinewithin five weeks. The workability of the plant units was 85%, the availability of power at the plant was 95.83% and the average daily time of power supply is found to be 22 hours.The plant uses chlorine as disinfectant and this is acceptable by World Health Organization (WHO).The materials used for the Tanks and Reservoir is of International Standard (Concrete and Block). The maintenance culture predominant in the plant is preventive maintenance. The automatic dosing machine at the plant was unserviceable, hence dosing is done manually, this is not acceptable by international standard. The overall performance of the treatment plant was found to be 50%; this performance is very low comparing to the assessment criteria.

TABLE OF CONTENTS

CHAPTER THREE: MATERIALS AND METHODS

CHAPTER FOUR: RESULTS AND DISCUSSIONS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

NOMENCLATURE

ABU	-	Ahmadu Bello University
AWWA	-	American Water Works Association
AAS	-	Atomic Absorption Spectrophotometer
BDM	-	Break Down Maintenance
BEP	-	Best Efficiency Point
bhp	-	Brake Horse Power
CBM	-	Condition Based Maintenance
CM	-	Corrective Maintenance
CPE	-	Comprehensive Performance Evaluation
CPVC or PVCc	-	Chlorinated polyvinyl chloride
DBPs	-	Disinfectants By-Products
EU	-	European Union
FMWR	-	Federal Ministry of Water Resources
g	-	Acceleration of gravity (m/s^2)
H	-	Head (m)
Kg/m^3	-	Kilogram per cubic meter
m	-	Meters
m/s^2	-	Meter per second square
m^3/s	-	Cubic meter per second
MAC	-	Mycobacterium Avium Complex

MC	-	Maintenance Concept
MCL	-	Maximum Contaminant Levels
MM	-	Maintenance Management
NTU	-	Nephelometric Turbidity Unit
NPSH	-	Net Positive Suction Head (m)
OJT	-	On the Job Training
O & M	-	Operation and Maintenance
P_{in}	-	Pump Input
P_{out}	-	Pump Output
PCL	-	Pump Centre Line
PMM	-	Performance Measurement Models
PLFs	-	Performance Limiting Factors
PM	-	Preventive maintenance
PP	-	Polypropylene
PVC-U or uPVC	-	Unplasticised polyvinylchloride
P_{hydr}	-	Hydraulic Power
Q	-	Flow rate (m^3/s)
SDWA	-	Safe Drinking Water Act
SON	-	Standard Organization of Nigeria
SWTR	-	Surface Water Treatment Rule

TDH	-	Total Dynamic Head
TCU	-	True Colour Unit
UNU	-	United Nations University
USEPA	-	United State Environmental Protection Agency
WHO	-	World Health Organization
WTP	-	Water Treatment Plant
ρ	-	Density (kg/m^3)
η	-	Efficiency (%)
%	-	Percentage

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Drinking water is a fundamental requirement of the human body. Good quality drinking water is primarily sourced from rainfall or from surface water sources such as streams, rivers, springs, and lakes (IWMI, 2000). Where these surface waters do not exist or where they exist in quantities that cannot adequately support the dependent populations, ground water resources are exploited in the form of wells and boreholes to provide this vital body requirement (Adakole and Abulodi, 2011).Water has and continues to be the center of ancient and present day civilizations for sustenance (Anon,2004).

Water occupies about 75% of the earth's surface. Freshwater (surface water) resources are limited to less than 30% of the earth's hydrosphere, making potable water still more limiting (Newcome *et al.*, 2005). Rainfall is the primary source of water. Before present day developments and in some rural areas in developing countries, rain water is still relatively very clean and it is directly abstracted for drinking and used for other domestic purposes without any significant consequence (Bellamy *et al.*, 2000). Rainwater flows into streams, rivulets, rivers and lakes which are referred to as surface water sources (Cornwell and Macphee, 2001).

Also, under heavy and sustained rainfall, rainwater ponds on the ground and slowly infiltrates and percolates through layers of porous strata until it reaches impervious stratum where it forms pools to become ground water (Young,2006). Globally, all sources of water are inter-related in a continuous circulation known as the hydrological cycle in which surface water, ground water, seas and oceans are influenced by meteorological interactions like evaporation, transpiration and edaphic movements (infiltration and percolation). The water environment – including the oceans, rivers, streams, groundwater, all seas and adjacent

coastal areas - forms an integrated whole that is an essential component of the global life-support system. Recent climatic changes have resulted in extreme conditions of floods, landslides and droughts, which have in some regions become disastrous in their consequences (WHO, 1994).

It is vital for human being to have cleandrinking water. This is why the Ahmadu Bello University community drinking water in Samaru-Zaria must meet many different quality standards and has to go through a sequence of maintenance to have an efficient performance. Surface water withouttreatment cannot be used as municipal drinking water because it has high concentration of natural organic matter (NOM) which can be harmful for human health and can form intolerable reactions or biological growth in distribution systems (Abolude*et al.*,2009). Hence, without adequate maintenance culture, the water treatment plant performance can never be of acceptable standard.

It is against this backdrop that the present work is concerned with the assessment of the performance and maintenance culture of the Ahmadu Bello University, Samaru-Zaria water treatment plant for efficient supply of drinking water. It is a work geared towards evaluating the operations of ABU water plant in terms of pump efficiency, quality of treated water, water pipelines, tanks and reservoir.

1.2 Problem Statement

The heavy burden of shortage of water treatment and distribution by the negligence in maintaining the plant systems gave birth to the idea of maintenance culture of water treatment plant. The development of expensive, complex and highly-developed equipment, and machinery which led to the need to achieve higher product quality, longer machine life, higher machinery effectiveness and operational safety, has motivated the effort to improve maintenance concepts(Al-Najjar*et al.*, 2001).

Also, one of the major challenges associated with water treatment plant is leakages along the distribution lines. While efforts are being made to improve the supply situation, poor maintenance culture is paid toward minimizing the losses, particularly leakages due to faulty fittings (Lambert, 2002). Iron corrosion is one the most complicated and costly problems facing the plant drinking water facilities.

Water treatment is one of the most challenging and complex systems that municipalities need to deal with considering limited resources. A study from mid-90s showed that the continuously deteriorating Nigerian water supply system would require ₦3.1 billion to bring the system at satisfactory level. Unfortunately, since the commissioning of ABU water works in 1981, the Ahmadu Bello University water supply plant is still at Phase-I state, while the entire campus population has increased tremendously **(**Tukura *et al.*, 2011). This means that the supply currently may be inadequate orthe plant maintenance has been neglected.

1.3 Significance of the Study

The result of this research issues is very expedient in view of the following:

Firstly, adequate understanding about the quality treated water distributes by of Ahmadu Bello University water treatment plant, the pump efficiency, the leakage rate, volume of water loss per weekand the predominant maintenance culture at the plant.

Secondly, the research will suggest way of reducing the volume of water leakage along the pipelines. Also, findings of the study will contribute much needed information on the effective maintenance culture at the ABU WTP.

1.4 Aim and Objectives

The aim of this research is to assess the performance and maintenance culture of Ahmadu Bello University water treatment plant for efficient delivery of portable drinking water.

The Specific objectives of this research therefore are as follows:

i. To access the Ahmadu Bello University Samaru Zaria water treatment plant processes and the predominant maintenance culture.

ii. To assess the pump efficiency and performance indicators of the Ahmadu Bello University, Samaru-Zaria water treatment plant.

iii. To determine the plant's operational efficiency in terms of staff, quality of treated water and rate of leakages and causes.

1.5 Scope of the Study

The scope of the present research was to study the performance and maintenance culture of the ABU water treatment plant by assessing the plant's components like tanks, pumps, treatment process, pipelines and quality of treated water. A questionnaire was used to assess the maintenance culture predominant in the plant. This study was not in any position to medically investigate and examine the type of diseases associated withdisinfectants by-products (DBPs)or the potential health effects associated with long term exposure already documented in literature (Adakole*et al.*, 2011).

1.6 Justification

Machines, buildings and other service facilities are subject to deterioration due to their use and exposure to environmental conditions. Process of deterioration, if unchecked culminates in rendering these facilities unserviceable and brings them to a standstill. The task

of maintenance is to keep the above in satisfactory condition, according to standard set by management, keeping in view the cost aspect also.

Water treatment is one of the most challenging and complex systems that municipalities need to deal with considering limited resources. Such will constitute a basis for advocacy for an appropriate agency of school to supervise water treatment. Proper maintenance culture will enhance efficient functioning of the plant components for adequate delivery of portable drinking water to the end users.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter is a review past works that are pertinent to the studies carried out in this research. It also specifically considers some relevant concepts such as water, water treatment plant, plant components, unit processes involved in water purification, maintenance and maintenance culture.

2.2 Purpose of Assessment

Assessment can be defined as the process of determining the performance altitude of a water supply system.

According to Cairncross *et al*(1985) in their book explained that the purpose of assessment or evaluation and major potential objective of a water supply are as follows:

i. To assess the degree of service of completed water supply.

ii. To find out how this might be increased by improvements.

iii. To provide feedback for planners on the validity of the original planning, assumption, particularly regarding benefits.

iv. To provide feedback on appropriateness of the current strategy for the treatment plant in terms of resources allocation, choice of technology, etc, in the light of its current objectives and observed benefits.

v. To indicate area where complementary input, such as health education and agricultural extension would improve the overall efficiency and effectiveness of rural water investment.

The success of any treatment plant can be ascertained through effectiveness and efficient mechanism of monitoring and evaluation. The present state of water supply in the light of what is happening on the ground requires that an assessment study be carried out. Demand for water resources is increasing with population, urbanization also is intensifying coupled with economic development, therefore, the need to develop and use water resources efficiently and sustainable is urgent for the benefit of both present and future generation (Michael, 1993). To achieve these objectives, the treatment plant must be well conceived, prepared and implemented together with necessary mechanism for feedback to be able to measure the success of the treatment plant.

2.3 General Concept of Treatment Plant Assessment

Treatment plant assessment is the process of evaluating the efficiency, capacity, performance, reliability and effectiveness in meeting the objectives of a treatment plant. Assessment takes place whenever people or group of people evaluate the quality or level of performance of a treatment plant, in fundamental nature, assessment attempts to determine whether specific objectives have been accomplished or not, therefore, qualitative and quantitative judgments are made about a project or treatment plant. The judgments are based on testing devices like oral interview, on site measurement of desire parameters. Assessment completes the overview of treatment cycle of forecasting, policy formulation, planning, implementation, control and monitoring.

2.4 Assessment Process

Assessment process can be grouped into many ways including functionality, capacity, reliability, performance, maintenance culture and coverage of the plant.

2.4.1 Treatment Plant Operation

Treatment plant operation focuses on the physical system and its engineering aspects, it is the immediate or direct consequences of treatment plant, it is an efficient level, and input and systems outcomes are under the control of the engineer. The immediate concern here is for the physical status and functioning of water supply projects and sanitation schemes, which can be assessed in terms of accessibility, quality, quantity and reliability. These factors can be assessed in straight forward physical unit (Gray, 1996).

2.4.2 Treatment Plant Performance

This level deals with the use of water supply facility systems by members of the community, where the treatment plant is located. The project planner is directly concerned with good performance, but if technical inputs in operation and actual usage of the facility by the community is not fully controlled, then the effective level desired and long term usage will not be attained, hence proper input operation and usage practices must be ordered (WWEM,1999).

2.5 Water

Water is a transparent fluid which forms the world's streams, lakes, oceans and rain, and is the major constituent of the fluids of living things (Ehlers and Kraft, 2001). Man can survive for many days without food but without water, it is very difficult to survive for long (Young, 2006). He needs water for domestic and industrial uses, irrigation, hydro-electric power generation and recreation to mention but a few. In most cases, he turns to rivers for water supply.The acceptable drinking water standard parameters for a WTP in Nigeria by the Nigerian National Water Supply and policy (FMWR, 2000) are shown in Tables 2.1.

Table 2.1: Acceptable Drinking Water Standard Parameters for a WTP by the Nigerian National Water Supply and Policy (FMWR, 2000)

Parameter	Unit	Maximum Permitted Levels
Colour	TCU	15
Odour (Od)	-	-
Taste (Ta)	-	-
Temperature (T)	^{o}C	Ambient
Turbidity (Tu)	NTU	5
Aluminum (Al)	Mg/L	0.2
Chlorine (Cl)	Mg/L	250
Conductivity (Cd)	µs/cm	1000
Iron (Fe)	Mg/L	0.3
Lead (Pb)	Mg/L)	0.01
Nitrate (N)	Mg/L	0.2
pH Value (pH)	-	6.5 -8.5
Sulphate ($S0_4$)	Mg/L	100
Total Dissolved solid (TDS)	Mg/L	500
Zinc (Zn)	Mg/L	3
Total Organic Carbon (TOC)	Mg/L	5
Free Residual Chlorine (TRC)	Mg/L	0.2-0.25

2.5.1 Sources of water

Water can be collected from surface or subsurface sources for the purpose of water supply. It can be rainfall, surface water, ground water, etc. The choice of source to be

considered depend on the natural phenomenal as the availability of the source in relation to the priority as the case with which it can be supplied to the consumers (Casey, 1992).

Fair *et al* (1971) in their finding concluded that the nature of the water source commonly determined the planning, design and operation of the collection, purification, transmission and distribution network.

2.6 Water Treatment

Water treatment is, collectively, the industrial-scale processes that make water more acceptable for an end-use, which may be drinking, industry, or medicine (WHO, 2004). Water treatment is unlike small-scale water sterilization that campers and other people in wilderness areas practice (Green, 2009). Water treatment should remove existing water contaminants or so reduce their concentration so that the water becomes fit for its desired end-use, which may be safely returning used water to the environment(WHO, 2004). Water treatment is andthe act or process of making water more potable or useful, through purifying, clarifying, softening, or deodorizing (AWWA,1999a). The processes involved in treating water for drinking purposes may be solid separation using physical processes such as settling and filtration, and chemical processes such as disinfection and coagulation (Owens, 2001).

2.6.1 Methods of treatment

There are three main methods of treatment process:

a. Physical Processes which depend essentially on physical properties of the impurities. Typical examples of this type of process are screening, sedimentation, filtration and gas transfer.

b. Chemical Processes which depend on the chemical properties of an impurity or which utilize the chemical properties of added reagents. Examples of Chemical process are: Coagulation and precipitation.

c. Biological Processes which utilize biochemical reactions to remove soluble or colloidal impurities, usually organics.

2.7 Water Treatment Plant

A water treatment plant is a hydraulic structurewhere various physical, biological or chemical processes are used to change the properties of the raw water (e.g. by removing harmful substances) in order to turn it into potable water safe for human consumption (WHO/UNICEF, 2000). Water treatment can range from a simple system of no treatment, simple chlorination, addition of corrosion control chemicals, to a more complex system that adds coagulation, flocculation, sedimentation, and filtration (USEPA, 1990a). Water used in backwashing filters or other sanitary operations is either released into wastewater-collection systems or returned to the hydrologic system. After treatment, water usually is sent to finished water storage or directly into the distribution system. The components of a water treatment plant are: Pump, Tanks, Pipelines and Unit process (USEPA 1990c). The process and equipment requirements and WTP equipment maintenance by American National Standard Institute EN 13306: 2001/ ASME/ANSI EA-2-2009 for a WTP are shown in Tables 2.2 and 2.3.

Table 2.2: Process and Equipment Requirements by American National Standard Institute EN 13306: 2001/ASME/ANSI EA-2-2009 for a WTP.

S/N	Parameter	Requirements
1.	Flocculation time (min)	≥ 40 mins
2.	Flocculation	Minimum two (2) tapered flocculators with variables speed
3.	Maximum Surface Loading rate in clarifiers (m/h)	≥ 7
4.	% of clear water recirculation (max)	7% - 15%

5.	Filtration rate (m/h)	10
6.	Type of filters	Open gravity filter
7.	Number of filters	2 (Materials concrete or stainless steel)
8.	Filter Sand Depth	800mm (min)
9.	Filter sand effective size (mm)	0.5 - 0.6 (max of 1.45)
10.	Depth of retaining media (Coarse sand and gravel)	600mm
11.	Back wash rate	Up to 45m/hr for water and air
12.	Type of back wash	Sequential Air/water
13.	Settled Water Pumps	2
14.	Clear water pumps (38-40 L/s, minimum)	2 (duty/standby)
15.	Back wash pump	1 pump
16.	Air blower	1 blower
17.	Clear Water tank	2 140 KL (min)
18.	Coagulant type	Alum
19.	Coagulant Pumps	2 (Duty/standby)
20.	Disinfection	Chlorine
21.	Pump Efficiency (%)	≤85
22.	Pump Discharge ,Q	≥ 2300m^3/hr
23.	Pump Power (KW)	≥ 42
24.	Reservoir Capacity (minimum)	1.5 ML
25.	Personnel (minimum)	39
26.	Method of Leakage detection	Alarm signals

Table 2.3: Standard Hazard Control Elements for Distribution System by American National Standard Institute ASME/ANSI EA-2-2009 for various types of Water Supply.

S/N	Potential Control Strategies	Control Measures
1.	Distribution System Maintenance	Flush and Clean tanks regularly

		Minimize Stagnation Maintain and replace infrastructure Monitor to detect areas of water quality degradation.
2.	Cross-connection and avoidance of transient pressure	Institute a cross-connection control programme. Maintain positive distribution water pressure. Avoid hydraulic surges that may create control leakages.
3.	Pump	Monitor change in pressure and power input On/off when not in use Replace worn parts

2.8 Design of Treatment Plant Units

The design of treatment plant unit involves the design of aeration tank, mixing chamber, settling tank, filter tank, cleared water tank and distribution tank (Ostfeld and Shamir, 1996).Hofkes (1981), concluded that the first step in designing a water supply is to select a suitable source or a combination of sources that is capable of supplying enough water for the community at any time of the year..

In the design of water treatment plant, the provision of safe water is the prime goal, anything less is unacceptable.

2.8.1 Aeration tank

Aeration tanks usually are constructed of reinforced concrete and left open to the atmosphere (Owens, 2001). Aeration is used to reduce the combination of taste and odour producing substance such as H_2S to a limited extent.

The limiting element in gravity aerators is the available head and to find the time of exposure in water falling through a distance (Fair *et al*, 1971).

$$T = n \sqrt{(2nh/g)} \qquad (2.1)$$

Where: T = time (s)

n = number of descents

h = height of fall (m)

g = gravitational force (m/s^2)

2.8.2 Rapid mixing flocculation

Rapid mixing fluctuation aims at the disposal of the entire dose of chemicals throughout the mass of the raw water (Hofkes, 1981). Flocculation is defined as a process whereby fine moving, destabilized particles come into contact with each other to form a large readily selectable floc (Casey, 1992). In the design of a flocculation tank, the velocity gradient and the detention time are very important.

$$G = p/uV \qquad (2.2)$$

Where; G = Velocity gradient (m/s)

p = Power (W)

V = Volume (cm^3)

u = dynamic velocity (m/s)

Twort *et al* (1985) concluded that the method used for mixing can be hydraulic or mechanical. The usual power input for mixing is based upon a typical mixing time of 2 to 3 seconds with a G value of about 800 to 1000/sec.

The design details for a gravitational flocculation are as follows:

i. Width of tank should be minimum of 45 m

ii. Depth of flow should not be less than 1.0m

iii. The usual detention time is 10 - 20 min.

iv. Loss of head is 15 - 60 cm (Casey, 1992).

2.8.3 Sedimentation tank

In water treatment plant, setting tank, especially design for sedimentary is widely used. Sedimentation may be defined as a process whereby suspended sedimentary particles settle at the bottom of the tank by gravitational force. Sedimentation tank may be rectangular, circular or square (Mcintosh, 2003).

According to Casey (1992), the coagulants commonly used are alum ($Al_2(SO_4)_3$) and the design procedures for sedimentation tank are as follows:

i. Detention time 3 - 4 hours

ii. Velocity of flow not greater than 30cm/min

iii. Tank dimension: L: B (4:1)

iv. Depth 2 - 5 m

v. Slopes rectangular 1% and circular 8%

2.8.4 Filtration

USEPA (2003) defined filtration as the process of separation of suspended matter from water by passing it through porous medium. He stated that the water from a rapid gravity filter is not bacteriologically pure and before the water passes into supply, it must be disinfected by the addition of chlorine (Cl_2) or other disinfecting agent.

The design details of rapid sand filter are as follows:

i. Rate of filtration = 6, 250L/h/m^2

ii. Size of bed L= 6m - 9m and B 1.5m - 6m.

iii. Depth of filtration = 2.5m - 4.0m

iv. Surface loading = 1,200 – 18,000 L/dm^2

2.9 Water Transmission

Depending on the topography of local condition, water may be conveyed through free flow conduct or pressure. The transmission main is normally designed for the carrying capacity that is required to supply the water demand on the maximum day at a constant rate basis. For a water supply with diesel engine or electric motor driven pump, the daily pumping often is limited to 16 or less hours. In such case, the design flow rate for the transmission main is to be adjusted accordingly (Hofkes, 1981).

2.10 Distribution System Design

The objective of distribution system is to supply water to the end users by means of a network of distribution pipes. USEPA (1995) defined distribution system as that part of water work which receives water from the pumping station or from conduit by the gravity flow and delivers it throughout the district to be served. He explained that the requirements of an ideal distribution system are as follows:

i. The quality should not get deteriorated in the distribution system.

ii. Every consumer should get sufficient head pressure.

iii. The design of layout should be economical.

iv. All pipe should be at good quality to leakage.

v. All distribution pipes should be preferably laid one meter away above the service line.

vi. It should be capable of being repaired and replace without causing distribution to traffic.

2.11 Design of Service Reservoir

Duggal (1980) stated that the service reservoir is used principally as distribution reservoirs where a tank on the ground will not supply the required pressure. He added that the

use of reservoirs makes design of pumps very economical, as there is a considerable reduction in the pump capacity cost, pumping head and the load on pumps.

USEPA (2011a), explained that the balancing reservoir is provided to meet the varying rate of demand against the uniform rate of flow into it and when the demand of water exceeds the rate of supply, the water flow into the distribution system both from the elevated balancing reservoir as well as through direct pumping by means of the bypass loop.

2.12 Pumps

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action (Fig 2.1) (Hydraulic Institute, 2000). Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps.Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid (Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes, from microscopic for use in medical applications to large industrial pumps. Mechanical pumps may be submerged in the fluid they are pumping or be placed external to the fluid.Pumps have two main purposes:

1. Transfer of liquid from one place to another place (e.g. water from an undergroundaquifer into a water storage tank)
2. Circulate liquid around a system (e.g. cooling water or lubricants through machines and equipment)

Pumps come in a variety of sizes for a wide range of applications. They can be classified according to their basic operating principle as dynamic or positive displacement pumps (ASME B73.2-2003). In principle, any liquid can be handled by any of the pump designs. Where different pump designs could be used, the centrifugal pump is generally the most economical followed by rotary and reciprocating pumps. Although, positive

displacement pumps are generally more efficient than centrifugal pumps, the benefit of higher efficiency tends to be offset byincreased maintenance costs.

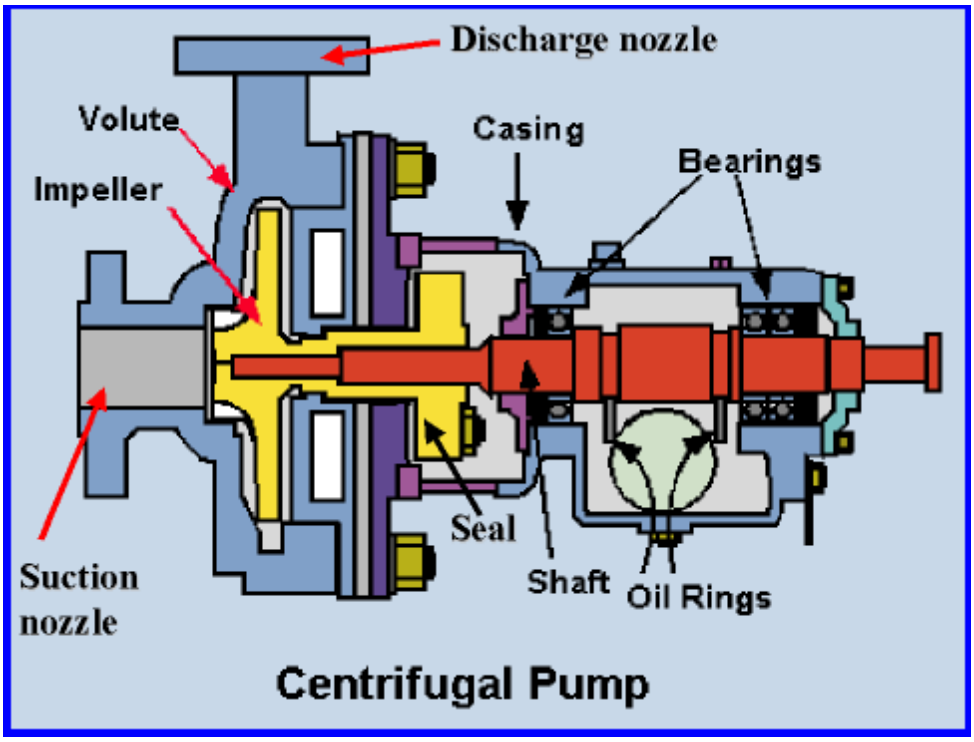

Figure 2.1: Main Components of a Centrifugal Pump (Sahdev, 2008)

2.12.1 Pump power and efficiency (P, η)

When pumps are not performing efficiently, it is either because the wrong pump had been chosen for the job, or because the pump was worn. If the pump is not doing its job, this can increase pumping costs and reduce productivity. To contain costs, you need to monitor your energy usage regularly and repair and maintain the pump to operate efficiently (Smith and Richards, 2003). Pump efficiency measures how well the pump converts electrical power to useful work moving the water. An acceptable efficiency for a single impeller centrifugal pump, for example, is above 65% (Hydraulic Institute standards, 2000).

The work performed by a pump is a function of TDH, flow rate and the specific gravity of the fluid. Pump input (HP_{in}) or brake horse power (bhp) is the actual power

delivered to the pump shaft. Pump output (HP_{out}) or hydraulic horse power (whp) is the energy delivered to the fluid per time unit (eqn. 2.1) (Warman, 2009). Due to mechanical and hydraulic losses in the pump, H P_{out} is always smaller thanHP_{in}. Therefore efficiency is defined as HP_{out} divided by HP_{in} (eqn. 2.2) (Warman, 2009). The impeller geometry is optimized to provide highest flow rate at a certain speed at a given diameter at its point of best efficiency (BEP). If operating a pump off its (BEP), losses due to increasing turbulences and recirculation will increase and reduce efficiency. These effects are caused by a mismatch of the pump's design flow rate and the actual flow rate. The difference between inlet vane angle and approaching flow angle is increasing as moving away from the BEP as well as losses between impeller vane exit and the diffuser. Result of this is an increased flow between the impellers shrouds and the casing (Christian Allerstorfer, 2006).

$$HPout = H \; x \; \rho \; x \; g \; x \; Capacity \qquad (2.3)$$

$$\text{Efficiency, } \eta = \frac{HPout}{HPin} \text{ x } 100\% \qquad (2.4)$$

where:

Capacity = Volume of water; H = required pump head, in meters;ρ = specific gravity = 1 at 68 ^{o}F; P = electrical power input.

2.12.2 Pump maintenance/repair

While the pumps systems in commercial buildings are typicallynot complex or physically demanding on the pump, following the best industry practices to maintain and repair the pumps and components can extend the life of the equipment and help to keep energy costs down (Christian, 2006). Continuous monitoring of key pump and motor

operating characteristics can provide information about the condition of the pump and the system. The flow rate and differential pressure should be monitored for the pump, aswell as the electric power orcurrent of the motor (Instream Flow Council, 2002).

A simple key performance indicator that could be used for monitoring pump system performance is the flow energy intensity.The current condition of the pump system can be determined if at any time a baseline flow energy intensity is captured for a new or optimized pump system. Any major changes from the baseline flow energy intensity can help to determine when the pump system or components should be analyzed or repaired (Andrews, 2005). Another key performance indicator for monitoring a pump system is the system efficiency (Casada, 2012).

2.13 Pipe

A pipe is a tubular section or hollow cylinder, but not necessarily of circular cross-section, used mainly to convey fluids, slurries and masses of small solids (Billmann and Rolf, 1987). To ensure safe operation of the system, the manufacture, storage, welding, testing, etc. of pressure piping must meet stringent standards (Ing, 2005). Water pipeline is a tubular cylinder used to convey water. (ASME, 2008).

2.14 Leakage

Water leakage is an important component of water losses. The more pressure in the main the more leakage, as shown by the continuous line (Zhang,1997) .Water leakage in drinking water distribution systems is a serious problem for many cities and a huge challenge for water utilities (Ryan, 2005). A water system includes *intakes*, water pipelines, storage reservoirs and pumps. Once the water enters the system at the *intakes* from the source, pumps provide *energy* to convey the water through the pipelines to storage reservoirs from which it

is distributed to consumers (Rahiman*et al.*, 2007). Pipelines are formed of multiple pipes with joints and leakage generally occurs where the pipe joints are faulty or where defects develop in the pipe body (Hauge, 2007).

The longer leakages remain unattended, the larger the economic and resource loss will be to the authorities, as electric power to run the pumps and chemicals to treat water are also wasted (Andrew and Bryan,2002).Types of leak openings include a puncture, gash, rust or other corrosion hole, very tiny pinhole leak (possibly in imperfect welds), crack or micro-crack, or inadequate sealing between components or parts joined together (ASME, 2008). Leaks can be caused by damage; for example, punctures or fracture. Often leaks are the result of deterioration of materials from wear or aging, such as rusting or other corrosion or decomposition of elastomersor similar polymer materials used as gaskets or otherseals (Farley and Trow, 2003).

2.14.1 Leakage Detection

Major leaks can be visible on the surface: these have to be fixed in priority. It is the first and most import *step* of leaks control in developing countries (ASME/ANSI EA, 2009). Purchasing leak detection instruments is an approach typical of developed countries, but not necessarily the most adapted one for developing countries (Farley, 2001; Mcintosh, 2003). Leakage assessment uses various techniques such as district and/or wastage metering, pressure control, sounding or passive leakage control for continuous supply.Billmann and Isermann (1984) classified main methods for leakage into threecategories:

1. **Hardware based methods:** Typical hardware based detection methods include acoustic sensors, gas detectors, negative pressure detectors, and/or infraredthermography.

2. **Software based methods:** Different software with varying complexity and reliability are used. Examples include flow/pressure change detection and mass/volumebalance, model based systems and pressure point analysis.

3. **Biological methods:** Maybe the most time consuming method. Experiencedpersonnel walk along the pipes and looks for obvious damage and sound.

2.14.2 Leakage control

Water leakage from pipes is caused by several reasons such as degradation, corrosion and breakage of water pipes due to traffic load (Espen, 2007). As water pipes maintain high water pressure, the amount of water leakage will increase rapidly if prevention measures are not taken (Liu *et al.*, 2011). Accordingly, water leakage prevention is a critical measure to be taken in the water supply business. Less leakage means less utilization of precious water resources and we can then offer a more stable water supply service (Turner, 1991). It also prevents excess amounts of water to be discharged into the water supply network, resulting in cost reductions. Furthermore, it also contributes to energy conservation and natural resource conservation thus the reduction of environmental load (Andrew and Bryan, 2002).

There are several key issues to be resolved in the controlof leakages from pipelines: (1) the effective and timelydetection of leaks; (2) the prediction and assessment of theprobability of leaks in different pipelines and areas, andthe development of appropriate techniques based on theprobability analysis; (3) the classification and managementof the sub-areas within the whole distribution system; (4)the management of the large-scale detection instrumentsand signals, and the processing and utilizing their data tooptimize the operation of the distribution system. Based onthese requirements, this study has successfully developeda system to detect, forecast, provide advance warning, andcontrol of pipeline leakage (Geiger, 2005).

In order for effective and efficient portable water delivery, there is need for maintenance.

2.15 Fundamentals of Maintenance

Through the last decades, there has been considerably development of techniques for assessing plant reliability or dependability and life circle costs, which more or less can influence the choice of plant. Nevertheless, there is another factor that affects life cycle profitability which is of growing importance; this is known as maintenance (King *et al.*, 2000).“Maintenance is the combination of all technical, administrative and managerial actions during the life cycle of an item in tended to retain it in, or restore it to a state in which it can perform the required function”(EN 13306: 2001)

The development of expensive, complex and highly-developed equipment, and machinery which led to the need to achieve higher product quality, longer machine life, higher machinery effectiveness and operational safety, has motivated the effort to improve maintenance concepts(Al-Najjar*et al*., 2001).Maintenance is thus vital support functions in business, particularly as increasingly large investment are being required in physical assets (Tsang *et al*., 2000). Maintenance in industries according to Komonen (2002)has two essential objectives, i.e. high availability of production equipment and Low maintenance costs. These above stated objectives and other indirect impact of maintenance on the economic performance of organizations have been clearly established (Mobley, 2004).

2.16 Maintenance concepts (MC)

There are different types of maintenance approach depending on the condition and application. Alsyouf (2004)describes maintenance concept as the general structure that governs the types maintenance actions (corrective, preventive, condition based etc.) to be performed. For example, as shown in Figure 2.2, maintenance operations are basically divided in two main groups; Corrective maintenance and Preventive maintenance (which includes condition-based and scheduled maintenance).

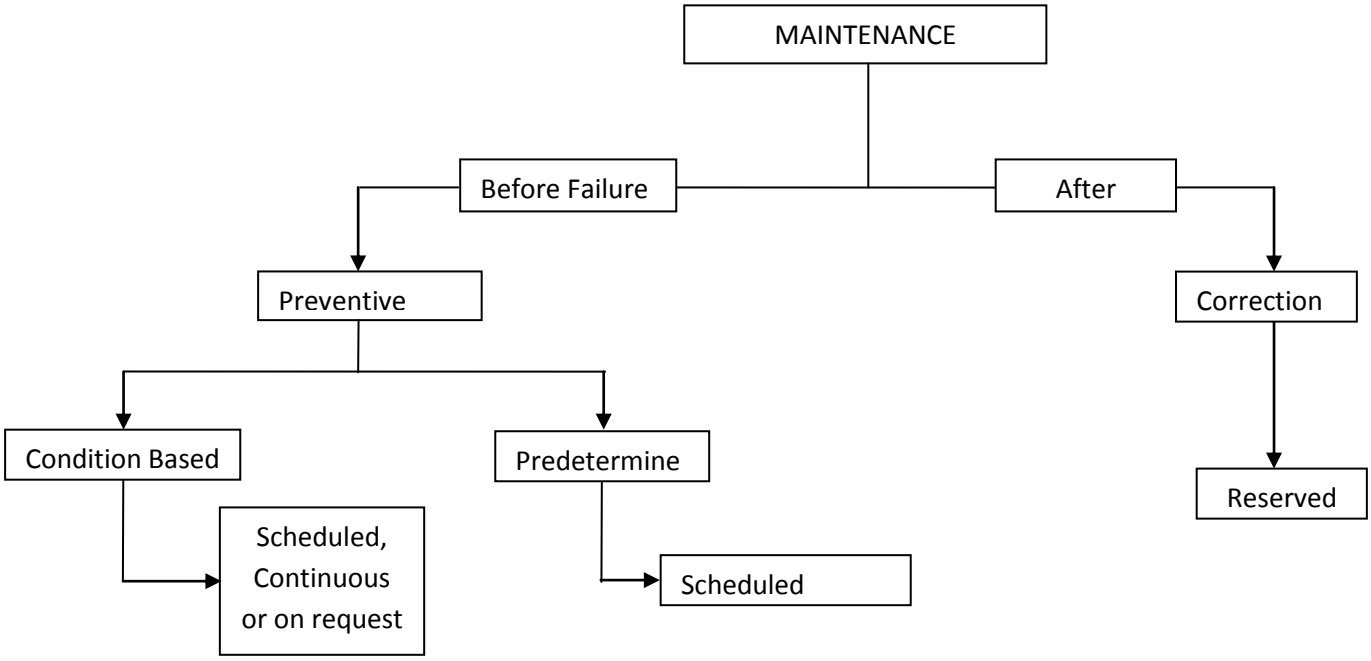

Fig 2.2: Maintenance Classification (ENS 13306: 2001)

2.16.1. Corrective maintenance (CM)/ Breakdown maintenance (BDM)

Corrective maintenance or breakdown maintenance is the kind of maintenance carried out after a failure has occurred, and it is intended to restore an item to a state in which it can perform its required function (EN 13306: 2001).According to Chiang *et al*(2001), corrective maintenance may consist of maintenance activity which includes repair, restoration or replacement of component that has undergone failure or that has totally broken down. The challenge as explained by Mobley (2002) is to detect problems thatare beginning to develop, before they lead to total failureand to correct the faults at the lowest possible cost. One of the advantages of adopting corrective maintenance isthat the machines are not over maintained and machine condition is not monitored (Al-Najjar, 1997). However,its disadvantages liesin the increase of production down time, overtime labor, high cost of spare parts as well as risk of secondary failures (Al-Najjar, 2007).

2.16.2. Preventive maintenance (PM)

The European Standard (EN 13306: 2001)defined preventive maintenance as the maintenance carried out at predetermined intervals or according to the prescribed criteria and intended to reduce the probability of failure ordegradation of the functioning of an item. According to Wireman (1990)preventive maintenance is any planned maintenance activity designed to improve equipment life and avoid any unplanned/ unscheduled maintenance activities. It is a systematic approach to a regular inspection carried out at a pre-determined interval or in accordance to prescribed criterion, intended to reduce of preferably eliminate probability of failure or performance of degradation of an item/equipment (Alsyouf, 2004). The aim of preventive maintenance is to reduce the number of failures and their financial expenditure by performing maintenance at a predetermined point of times without considering the component/ equipment condition (Sherwin, 2000). PM involves inspection, testing, repairing and replacement of equipment before failure occurs, and is in most cases applied to complex system in order to avoid operational failure especially when the failures consequences are critical, with regards to environment, economy or safety

(Alsyouf, 2004; Isermann, 1997).

Preventive maintenance consists of routine actions taken in a planned manner to prevent/minimize chances of breakdown and ensure operational accuracy economically. There are two aspect of preventive maintenance. The objective of the first, which can be termed as “Routine Maintenance”, is the preventive of wear and deterioration and involves such activities as lubrication, cheating and collecting scrap and other wastes. Lubrication ensures long life and safe working of the equipment, without mishaps. The second aspect of preventive maintenance is “Inspection”. Periodic inspection will permit early and timely detection of faults in equipment so that repairs and replacement may be undertaken before the faults assume the proportion and shape of a breakdown. The term preventive maintenance is very commonly used to include planned repairs/replacements and overhauls of plant carried out to eliminate/reduce breakdowns (Al-Najjar., 2007).

2.16.3. Condition-Based Maintenance (CBM)

Condition-based maintenance according to BS 3811:1993is the kind of maintenance that is carried out according to the need which is been indicated by the condition monitoring. CBM strategy is one which is based on deterministic and probabilistic models. It takes predictive maintenance one step further by performing the inspection in a "real-time" mode. Data about the failure behavior of the system are obtainable through suitable condition monitoring (CM) parameters which provides information concerning the real state of the systems. Vibration monitoring, shock pulse measurement (SPM), oil and debris monitoring and electrical current are few ofseveral existing condition monitoring techniques that may well be used in a user-friendly way to select the most cost-effective maintenance policy (Al-Najjar, 1997).

2.17 Performance Measurement

Performance measurementis the process of collecting, analyzing and/or reporting information regarding the performance of an individual, group, organization, system or component (Upadhaya*et al.*, 2014). It can involve studying processes/strategies within organizations, or studying engineering processes/parameters/phenomena, to see whether output are in line with what was intended or should have been achieved. Komonen (2002)stress the need for the measurement of maintenance performance in order to show the impact of maintenance as a function on company's overall goals. Performance measurement of machine/ equipment performance would enable top management to visualize maintenance function impact on company's business (Sherwin, 2000). Performance of machine/equipment is measured with regards to clearly defined company's objective. The generally classified maintenance indicator measures equipment performance, as

such it availability, reliability and overall equipment effectiveness (OEE) (Eti*et al.*, 2006). Overall Equipment Effectiveness is a benchmark used in world-class maintenance programs, and measures equipment performance which goes beyond just availability or machine uptime (Morbley, 2002). The models for performance measurement (Hansen, 2005)are shown in Fig 2.2.

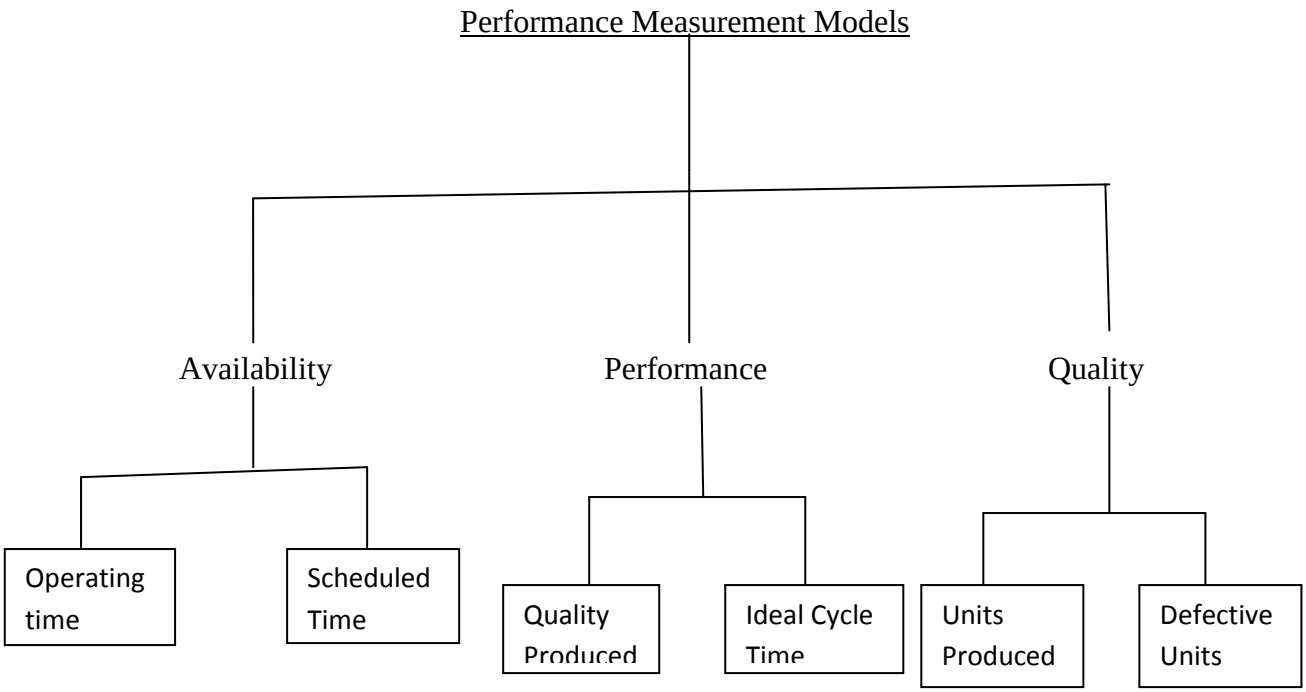

Fig 2.2: Models for Performance Measurement

2.18 Culture

Culture is said to be the way a group of people live their lives (Encarta Dictionaries, 2010). The dictionary defined culture as total inherited thoughts, values, knowledge and beliefs, which represent the communal foundation for social action. It is an integrated pattern of human deeds (thought, speech, action etc.) and communication (E.H, 1985). Thus a successful business, organization or developing environment should reflect the way people live. The models for culture includes: psychological job characteristics, individual perceptions and organizational core task (Krell, 2000).

2.18.1 Organizational Culture

Organizational cultureis a pattern of sharedbasic assumptions that the group learned as it solved its problems of external adaptation and internal integration that has worked well enough to be considered valid and therefore, to be taught to new members as a correct way to perceive, think and feel in relation to those problems (Coyle *et al.*, 2003). The significance of cultural approach to maintenance activities is that it allows a general view of the social dynamics in a complex setting. An organization can influence by positive or negative reward the behavioral actions and values of its members individually, while also the organization itself is constrained by those same individuals (Eti, 2004).

2.18.2 Maintenance culture

Maintenance work depends on the ability to solve problem, the core element of maintenance skills therefore is knowledge of the equipment and its mode of failure (Gasskov, 1992). According to Eti*et al.* (2006) culture tends to mature (occasionally in unwanted way) as the external environment evolves. Such desirable environmental changes have included the information technology revolution, rapid technological breakthrough,lowering cultural barrier or difficulty to communication as well as rising communal values. In addition, organization should be devoted to building a supportive cultural environment (in addition to growth, responsibility, and undeniably vision) also taking into account employees as individuals (rather thanjust general workers) are essential requirements for achieving optimistic organizational culture and of course high quality maintenance.From a maintenance perspective, the most significant influence on the culture of maintenance is the top management, and thus should be able to create and maintain an internal environment in which the employees can become completely involved in achieving organizational objectives. For a successfuland sustainable maintenance program, development and proficiency building

of top managers are decisive. It is coherent to provide an environment and a culture that add to employee's wellbeing, rather than exhausting their satisfaction, Eti*et al.*, (2006).

2.18.3 Maintenance organization

Maintenance organization according to Campbell and Jardine (2001) may take an immeasurable number of forms, the best for a particular situation being determined by systematic consideration of factors as maintenance work load and its pattern, cost of unavailability, location of plant, amount of emergency work, production organization and maintenance resources. Kelly (1984)further stated that in many cases the problem is one of achieving the optimum balance between plant availability and maintenance resource utilization. The dominant factor in the design of a maintenance organization is unavailability cost. Maintenance organization can be considered as being made up of three essential and interconnectedcomponents i.e.

- **Resources**- personnel, spare parts and tools, of a particular size, composition, location and movement.
- **Administration**- a hierarchy of authority and responsibility for deciding what, when and how work should be carried out.
- **Work planning and control system**- a mechanism for planning and scheduling the work and feeding back information which is needed if the maintenance effort is to be correctly directed towards its defined objective.

2.18.4 Maintenance organization goals

Maintenance/ production systemas a whole according to Kelly (1984)is a continuously evolving organism in which the maintenance organization will need continuous modification in response to changing requirement. Wireman (1990) further states that

properly determining the type of maintenance organization is influenced by the goals and objectives of the maintenance organization. The main task ofa maintenance organization is to match maintenance resources to the maintenance workload with the mission to achieve and sustain optimum availability.

2.18.5 Maintenance resources

Maintenance resources includes personnel (manpower), spare parts, technical data/ information, test equipment/ tools, funding etc. that are available or provided for the purpose of maintenance operations.

Manpower– according to Kelly (2006), thiscan possibly classified according to the technical area in which it is employed (mechanical, electrical, instrumentation, etc.), it can however be further divided according to craft (welder, electrician, etc.). Since maintenance work mostly tends to require more than one craft, the abovecategorization is done on the basis of the main craft content to each job.

Spare parts– achieving optimum balance between the cost of ordering and holding (depreciation, interest charges,rental etc.) and cost of stock out (loss of sales due to unavailability, temporary hire charges etc.) isthe objectives spare parts organization should address. The main difficulty according to Kelly (2006) arises from the variety and complexity of thousands of different items (of widely varying cost, lead times and usage rate) required sustaining a typical operation.

Testing equipment/ tools– though it is similar to the objective of spare parts organization, but the problem of control differs because tools are not in the same sense consumable. The main task however with returnable tools is the development of a system for monitoring their loan and maintaining or replacing themif necessary when returned.

Technical data/ information– this include all document, catalogs, manuals or drawing that might facilitate maintenance work or operation. This can be categorized into training, reference, instruction, scheduling and control

2.19 Ahmadu Bello University Water Treatment Plant

Dams are constructed across rivers to serve as water reservoirs (Anon, 2004).The Ahmadu Bello University water treatment plant obtains its raw water from the Kubanni reservoir created from a dam across the River Kubanni. The reservoir has a catchment area of 57 km^2 (22 square miles) and a width of 122 meters and a mean depth of 6 meters (Adakole, *et al.*, 2011). With the dam construction, an all year round raw water supply to the water treatment plant supplying the A.B.U. community with drinking water is guaranteed. According to the Ahmadu Bello University Water Resources and Supply Committee report, (Anon, 2004), the water treatment plant was established in 1970 when it was apparent that municipal water treatment plant in Zaria could not adequately meet the water demand of the Ahmadu Bello University community. This fact was further buttressed by the fact that existing water yield of the few bore holes could not meet the water demand of the fast expanding university community. This comprised the increasing students' populace, the university academic and support staff and their dependent family populace. The nearby Samaru Community was somehow dependenton the university water supply as it became evident after the water works commissioning when regular incidences of power outages resulted in disrupted water supply to the Samaru community from the Zaria municipal works. The water treatment works was designed to supply 13.64 million litres of potable water per day. Its source of raw water is the impounded reservoir called Kubanni manmade lake. The design of Ahmadu Bello University Water Supply Scheme was done in two phases, i.e., Phase-I and Phase-II. At commissioning in 1981, the Ahmadu BelloUniversity water treatment plant in its phase I stage of

development was to supply about 4.8 million litres (1.2 million gallons) of potable water per day, to a total population of 22,000 people (these include; students, residents and non-resident senior and junior staff including their families and other dependent relatives).

Apart from the dam, the water treatment plant include water intake structures, water treatment works, a booster station, main pressure pipelines and several small sized overhead tanks distributed over the ABU main campus. The construction of the impounded reservoir (dam), which is the main raw water source, the intake structures, the raw water pumps house, and the construction of the entire treatment plant including the installation of pumps were completed in 1981. Full operation however, started in January, 1982, initially with three pumps at intake, 1,500m^3 clear water well, three pumps at high lift, 3 numbers of Sand-gravity filters, 4 numbers of Bottom Hooper type sedimentation tanks (later in 1990, one number was added to make a total of five tanks). The booster station was commissioned in 1985, for the purpose of increasing pressure to convey treated water to high-pressure zones. It was established in between Dan-Fodio Hall and Area BZ Staff Quarters. The station started initially with two pumps of similar capacities and one underground reinforced concrete tank of about 110m^3 capacity. Presently, the station was expanded to house 2 additional pumps all of similar capacities and an additional steel surface tank of 117m3 capacity. The distribution mains include pressure pipelines ranging from 350mm diameter to 75mm diameter which distribute treated water from the treatment plant to all the low pressure zones, these are:

(a) Academic Areas including students' hostels

(b) Area 'A1' and 'AII' Staff Quarters

(c) Area III Staff Quarters

(d) Parts of Area BZ Staff Quarters

(e) A separate line to booster station tanks

On the other hand, the booster station pumps and distributes treated water to all the high pressure zones located in upper Area BZ, Areas, 'C', 'E', 'F' and 'G'. During the design stage, it was proposed that by 1995, the Ahmadu Bello University water supply plant would be in Phase-II to supply the full designed capacity of 13.6 million litres of treated water per day to an approximate population of about 72,000 people, by up-grading the facilities installed in Phase-I. Unfortunately, since its commissioning in 1981, the Ahmadu Bello University water supply plant is still in its Phase-I state, while the entire campus population has increased tremendously. This means that the supply currently is grossly inadequate and water supply is generally unreliable especially in students' hostel like Dan Fodio and residential areas on higher elevations such as Upper Area BZ, Areas C, E, F and G. The water treatment plant is very poorly served with electricity, which in most instances compounds its problem. It is however, worth noting that some rehabilitation and replacement of parts and stocking of vital components like the service laboratory has taken place in the last couple of years. There is also a replacement of the two aged stand by generators with one higher capacity generating set.

2.20 Typical Water Treatment Plant

This section compares some Water Treatment Plants (WTPs) around the world with the ABU Water Treatment Plant as follows:

Stickney Water Reclamation Plant, Chicago:

Capacity - 1.44 billion gallons per day. Owner - Metropolitan Water Reclamation District (MWRD). The Stickney WWTP, located on 570 acres in Cicero, Illinois, southwest of Chicago, serves 2.4 million people living in Chicago and 43 suburban communities. It consists of two plants — the western plant which began operating in 1930, and the southwestern plant which entered service in 1939. Treatment Processes:

Flocculation/Sedimentation, Oxidation, Filtration, Adsorption, Stabilization, Disinfection and Backwash water purification then distribution. Number of pumps installed - Sixteen. Predominant Maintenance - Preventive. Filtration method used at the plant - Slow sand filtration (Okun*et al.*, 1997)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter is a description of the details of materials and methods of assessing the performance and the maintenance culture of ABU Samaru-Zaria water treatment plant and the research procedure that was followed for the assessment. The purpose is to determine whether facilities and operating practices are sufficiently reliable to deliver water of acceptable quantity and quality to consumers. The evaluations will also provide written technical assistance for improving the plant's performance. To assess the ABU WTP performance and maintenance culture, the various sections of treatment plant were examined through the following methods:

i. Surveying methods, by visual inspection, in-depth interviews and structured questionnaires.

ii. Visitations.

3.2 Materials

The materials used for this research are:

1. Treated water sample obtained from ABU WTP for quality test.
2. A questionnaire was used to assess the plant maintenance culture

Some of the equipment used in this research include: Micrometer screw gauge, Stop Watch, Bucket, gallons and vehicle.

3.3 Methods

3.3.1 Water treatment section

*3.3.1.1 Surveying*The chemical house, coagulation, sedimentation (clarifiers), filters, clear well tank were surveyed by visual inspection, and questionnaires were also administered personally to some staff that are literate within this section. The questionnaires were complemented by personal talk with the water chemist and other staff of the section.

3.3.1.2 Visitation: This section was visited for a period of four months covering only day shifts. The information that was gathered in both survey and visitation exercise cover the number of treatment plant units that are in good working condition, performance/efficiency of the units, average volume of water treated daily, quality of water treated, total number of staff presently working in this section, operation and maintenance of the system.

3.3.1.3 Water Treatment Procedure: The procedure for water treatment at the ABU WTP was monitored for weeks and the procedure for water treatment at the ABU WTP is outlined in Plates 3.1 to 3.10.

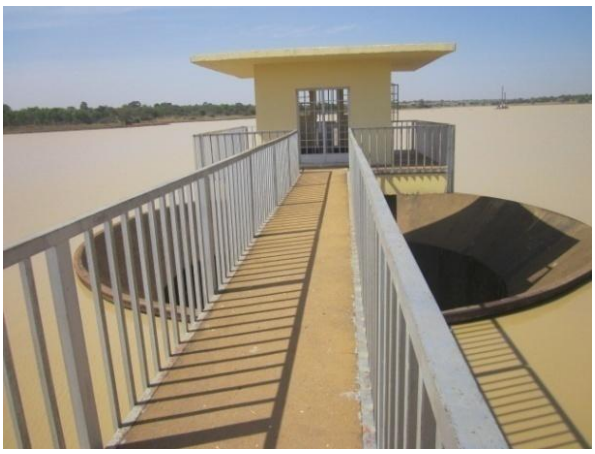

Plate 3.1: Raw water tank Plate 3.2: Ahmadu Bello University, Zaria, Dam

Plate3.3: From dam to lift pump station

At the treatment plant, the raw water from the dam (Plate 3.2) through steel pipes (Plate 3.3) first reaches the RAW WATER chamber (Plate 3.1). Alums and Polyelectrolyte are added (Plate 3.4) for coagulation and precipitation of dissolved particles. During coagulation, liquid aluminium sulfate (alum) and/or polymer is added to untreated (raw) water. When mixed with the water, this causes the tiny particles of dirt in the water to stick together or coagulate. Next, groups of dirt particles stick together to form larger, heavier particles called flocs which are easier to remove by settling or filtration.

The water is then made to pass to a series of Sedimentation tanks(Plate 3.5) where the precipitated particles settle below. As the water and the floc particles progress through the treatment process, they move into sedimentation basins where the water moves slowly, causing the heavy floc particles to settle to the bottom. Floc which collects on the bottom of the basin is called sludge, and is piped to drying lagoons.

Plate 3.4: Addition of Alums and Polyelectrolyte

Plate3.5: Sedimentation tank

The water is then moved to the FILTRATION TANK (Plate 3.6) for filtration. Water flows through a filter designed to remove particles in the water. The filters are made of layers of sand and gravel. Filtration collects the suspended impurities in water and enhances the effectiveness of disinfection. The filters are routinely cleaned by backwashing.

Plate3.6: Filtration chamber

After filtration, the water is moved to the RESERVOIR (Plate 3.8) where Chlorine is added to kill germs. Water is disinfected before it enters the distribution system to ensure that any disease-causing bacteria, viruses, and parasites are destroyed. Chlorine (Plate 3.7) is used because it is a very effective disinfectant, and residual concentrations can be maintained to guard against possible biological contamination in the water distribution system.

Plate 3.7: Addition of Chlorine at the Reservoir

Plate3.8: ABU WTP Reservoir

After chlorination, sample of the water was taken to the quality control lab (Plate 3.9) for analysis and results obtained and recorded. If the water conforms to WHO standard , the water is pumped by a series of lift pumps (Plate 3.10) to the ABU overhead tanks (distribution unit) for distribution to the ABU community.

Plate 3.9: Quality Control Laboratory

Plate 3.10: Series of Lift Pumps

3.3.2 Electrical Section

The same method in 3.3.1 above were applied here (that surveying and visitation). The information gathered from this section covered the sources of electric power to the plant, the total daily power demand of the plant, the average daily power supply to the plant, number of staff presently working in this section, number of stand by generators and their capacity, workability and efficiencies, amount of money spent on fuel, number of electrical units/facilities that are in working condition, illumination at the plant and the maintenance culture practice in this section.

3.3.3 Mechanical Section

The same method in 3.3.1 was applied in this section. The intake room (low lift pump station), high lift pumps station, sludge pumps, chemical dosing pumps, interconnection pumps, filtered water sampling pumps. Air blowers were visited and surveyed by visual inspection, in-depth interviews, structured questionnaires. This section was equally visited for a period of six weeks covering day shifts only. The information obtained from this section covered total number of pumps in the intake, their installed capacities and their present operating capacities, efficiency, total number of high lift pumps, total number of pumps presently working, total number of staff working in this section.

3.3.3.1Determination of pump performance

This section explains how the performance and efficiency of the pumps were assessed. The method used is the ANSI B73. 1 for WTP (ANSI, 2002).

Step 1—Preliminary Milestones

There was an agreement with the plant managerto ensure a timely and efficient assessment.

Step 2— First Assessment Meeting on -Site

The first assessment meeting reviewed the work to be done. The meeting reviewed the number of pumps and pumping systems adopted at the plant. One pump was selected for closer study, since all the pumps are of the same power.

Step 3— On-site Inspection

Following the initial meetingvisual inspection was carried out with focus on the systems identified as priorities. This inspection took place when systems were operational and operators and other personnel were available and explained operations and the demands on the systems. With the permission of the site lead, the pumps were snapped as shown in Plate 3.10, which assisted in the analysis.

Step 4 —.Pump Flow Rate

The pump flow rate (Q) was determined using the bucket method:

1. The Volume of the container was measured.
2. The container was placed at the discharge point.
3. The pump was switched on and water flowed into the container
4. With a stopwatch, the time it took water to fill the bucket with water was read and recorded.
5. The total volume of water discharged per seconds was recorded.
6. The flow rate was calculated using (eqn. 3.1).

Flow rate, Q = Liters Pumped ÷ Time (3.4)

Liters pumped = 110cm^3/h

Step 5—Obtaining the Pressure Head

Total head is the height in metres from source water level to the end of the discharge pipe. The value of the pressure head, H = 33m.

Step 6 - Pump Power Input, HP_{in}

The pump power input was read from Pump curve supplied by the Manufacturer. The Q was traced to the corresponding H to be 13KW.

Step 7 - Pump Power Output, HP_{out}

The Pump Power output is calculated as follows:

H= 33 m; Capacity = 110 cm^3/h or 110,000kg/h = 110,000kg/h÷3600 sec/h = 30.6kg/s and g = 9.8m/s^2

HP_{out} = 30.6 (kg/s) x 33 (m) x 9.8 (m/s^2) = 9896.04 Nm/s

1 Nm = 1 Joule and 1 Joule/sec = 1 Watt (Hydraulic Pump Institute, 2000).

HP_{out} = 9896 Watts = 9.9 KW

Step 6—Determine the Pump Efficiency

The pump efficiency was calculated using (eqn. 2.2).

Pump efficiency, η = 9.9/13 x 100% = 76%

3.3.3.2 Assessment of Pipe Lines

The water pipe lines used in water distribution within the ABU community was assessed on the following: structure, materials.

3.3.3.3 Leakages

Biological method was used to determine leakage rate. Awalk was taken along the pipes to observe obvious damage and sound(Management of Environmental Quality).A

bucket was used to collect the volume of water leaked per seconds. The leakage rate was only carried out on the distribution pipelines. This procedure was repeated for five weeks. The leakage rate (LR) was determined from the following formula (Goslan*et al.*, 2009):

$$LR = \frac{Volume\ of\ water\ leaked}{Time\ taken} \quad (3.3)$$

Where LR is the leakage rate (m^3/s), V is volume of water leaked (m^3/s) and t is time taken (s).

3.3.4 Maintenance Culture

The same methods in 3.3.3 above were employed in this section. A questionnaire was given to the plant Director and the plant Maintenance Engineer. The maintenance culture assessed for their effective performance on the all the Plant components as stated above. The following performance was assessed: sources of maintenance fund, total monthly operation cost, equipment/facilities available for maintenance, staff attitude towards maintenance, type of maintenance predominant. A sample of the questionnaires administered in this study is shown in Appendix A.

3.3.5 Data Analysis

3.3.5.1 Primary Data Obtained Through Survey Method and Observations: These data were analyzed and interpreted using assessment criteria.

*3.3.5.2 Operation and Maintenance Performance Indicators:*During the consultation and surveys, information gathered were used to calculate and analyze the performance indicators (PIs) (Sunday and Duro, 1984). Some of the PIs stressed include:

i. Functioning Treatment Plant Unit PIs

A simple count of the proportions of the treatment units which are not functioning is a direct indication of the operation and maintenance status. This is calculated as

Functioning treatment Unit = $\frac{Number\ in\ Working\ order}{Total\ number}\ x\ 100\%$ (3.4)

ii. Routing Monitoring of Water Quality PIs

This identifies whether or not utilities routinely monitor water quality. Clearly, utilities that routinely monitor water quality will be able to detect whether water is up to require quality to supply to its consumers. Over 80% of utilities indicated that they do routinely monitor water quality at various places in the distribution system.

iii. Percentage Sample Failing to Meet Quality Standard PIs

This is the measure of the quality of water delivered to consumers.

Percentage of Sample failing to quality standard =

$$\frac{No\ of\ sample\ tested\ that\ fail\ to\ meet\ quality\ standrd}{Total\ No\ of\ sample\ tested\ for\ a\ given\ time}\ x\ 100\% \quad (3.5)$$

iv. Percentage Treatment Capacity Utilized PIs

This measure is based on treatment capacity rather than network capacity which would be more difficult to measure. This is calculated as:

Percentage treatment plant capacity =

$$\frac{Average\ daily\ volume\ of\ water\ treated}{Total\ design\ capacity\ of\ the\ treatment}\ x\ 100\% \quad (3.6)$$

v. Percentage of Population Served PIs

This indicator measures the extent of service, but does not measure quality of service. This performance indicator is calculated as:

Performance population served = $\frac{Total\ No\ of\ person\ served}{Total\ No\ of\ person\ in\ the\ area}\ x\ 100\%$ (3.7)

vi. Maintenance Cost as a Percentage of Total Operating Cost PIs

It is a measure of the relative level of maintenance costs in comparison with total operating costs. A high percentage is likely to indicate a high level of maintenance but it is possible that the reason could also be relatively low denominator. It is calculated as:

Maintenance as a percentage of total operating cost =

$$\frac{Total\ maintenance\ cost}{Total\ operation\ and\ maintenance\ cost}\ x\ 100\% \qquad (3.8)$$

vii. StaffPer Million Cubic Water Distributed

This indicator calculates the number of staff per million cubic meters water distributed per year. It is a measure of overall staffing levels. This indicator is calculated as:

Staff per million cm^3 water distributed =

$$\frac{Total\ No\ of\ staff}{Volume\ of\ water\ distributed\ in\ a\ year}\ x\ 100\% \qquad (3.9)$$

viii. Recording of Interruption to Supply PIs

This indicator is simply a YES or NO indicator which identifies whether or not utilities routinely record plant as infrastructure failure that affects consumers.

ix. Availability of Power Supply

This is a measure of the availability of power supply. It is measured in terms of the average numbers of hours each day when a normal supply is provided. The benchmark for this measure is 24 hours a day on average. It is calculated as:

Availability of power supply = $\frac{Average\ hours\ of\ supply\ per\ day}{Total\ hours\ in\ a\ day}\ x\ 100\%$ (3.10)

3.3.6 Performance Measurement Models (PMM)

It is calculated with the formula:

PMM = (Availability)*(Performance)*(Quality) (3.11)

i. Availability

The Availability portion of the OEE Metric represents the percentage of scheduled time that the operation is available to operate.

Availability = operating time / scheduled time (3.12)

ii. Performance

The Performance portion of the OEE Metric (also known as process rate) represents the speed at which the Work Center runs as a percentage of its designed speed.

$$\text{Performance} = \frac{\text{Quantity of water treated} * \text{Ideal Cycle Time}}{Operating\ time} \quad (3.13)$$

iii. Quality

The Quality portion of the OEE Metric represents the Good Units produced as a percentage of the Total Units Started. The Quality Metric is a pure measurement of Process Yield that is designed to exclude the effects of Availability and Performance.

$$\text{Quality} = \frac{\text{Quantity of water treated} - \text{failed quantity}}{Quantity\ of\ water\ treated} \quad (3.14)$$

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Chemical House

The results obtained in this section through survey are shown inTable4.1.

Table 4.1: Chemical House results

Parameters	Results	Remarks
Chemical used	Alum	Standard
Disinfectant	Chlorine	Standard
Number of staff	3	Acceptable

4.1.2 Treatment Section

In this section, it was observed that the automatic dosing machine is not working, hence the dosing is done manually. Also the volume of water treated daily is found to be 5500m^3 while the total population target for water supply is 72000 which is for phase I. The results are shown in tables4.2 -4.4.

Table 4.2 Tanks Parameters

Parameters	Aeration Tank	Sedimentation Tank	Filtration Tank
Design (Shape)	Rectangular	Rectangular	Rectangular
Materials	Concrete and Block	Concrete and Block	Concrete and Block
Design Capacity (m^3)	-	64,000	-
Number of Tank	One	Four	Three
Type	Bottom Hooper	Bottom Hooper	Sand-gravity
Breakdown	0	0	0

Table 4.3: Treatment Section Result

Parameters	**Results**	
Volume of water treated daily (m^3)	5,500	
Volume of water treated per year (m^3)	2,007,500	
Hours of Operation per day (hr)	24	
Number of days of operation per week	7	
Hours of Operation	142	
Illumination	Well illuminated	Only day monitored
Staff	5	

Workability is calculated as follows:

Workability = $\frac{No\ of\ Operation\ per\ week}{Total\ No\ of\ hours\ in\ a\ week}$ x 100%

= $\frac{142}{(24x7}$ x 100% = 85%

Table 4.4: Reservoir Parameters

Parameters	Results	Remarks
Materials	Concrete and Block	Acceptable
Design	Cylindrical	Acceptable
Capacity	2.5 Million Liters	Acceptable
Maintenance Culture	Preventive Maintenance.	Acceptable
Maintenance Process	Cleaning and painting (once a month)	Acceptable

4.1. 3 Mechanical Section

The results obtained in this section are shown in Table 4.5.

Table 4.5: Mechanical Section Results

Parameters	Results
Pressure Head, H (m)	33
Discharge Q (L/s)	110cm^3/h
Efficiency, η (%)	76
Power required , HP_{out} (kW)	9.9
Power input, HP_{in} (kW)	13
Number of pumps	Five
Number of Serviceable Pumps	Three
Operating Time (hr)	Four hours per pump
Breakdown	2
Types	Weirs and KSB
Staff	3

4.1.3.1 Pipe Lines

The results for the Pipelines parameters are shown in Table 4.6.

Table 4.6: Assessment Result for the ABU WTP Pipes Parameters

Parameters	Treated Water Pipe	Filtration	Raw water	Distribution	Tap
Materials	Steel	Steel	Steel	Asbestos	Steel
Size (inch)	30	24	12	24	¾
Shape	Circular	Circular	Circular	Circular	Circular
Remarks	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

4.1.3.2 Leakages

Results for leakages on the distribution pipeline are shown in Figure 4.1 - 4.2 and Table B1 in Appendix B respectively.

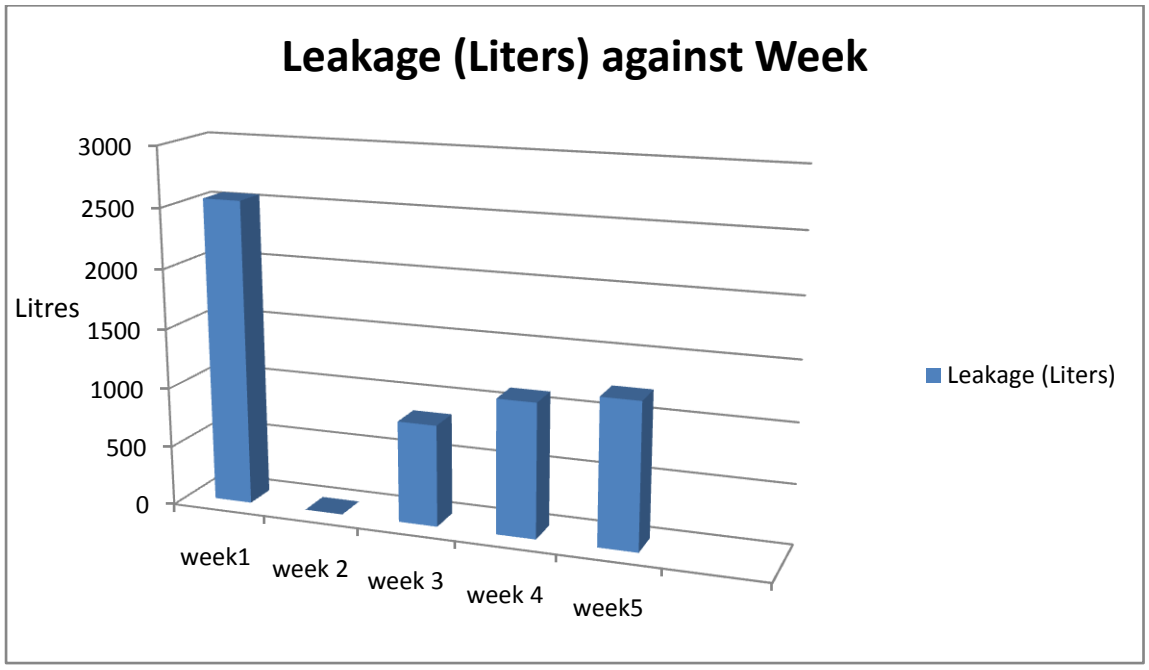

Figure 4.1: Leakage per Week

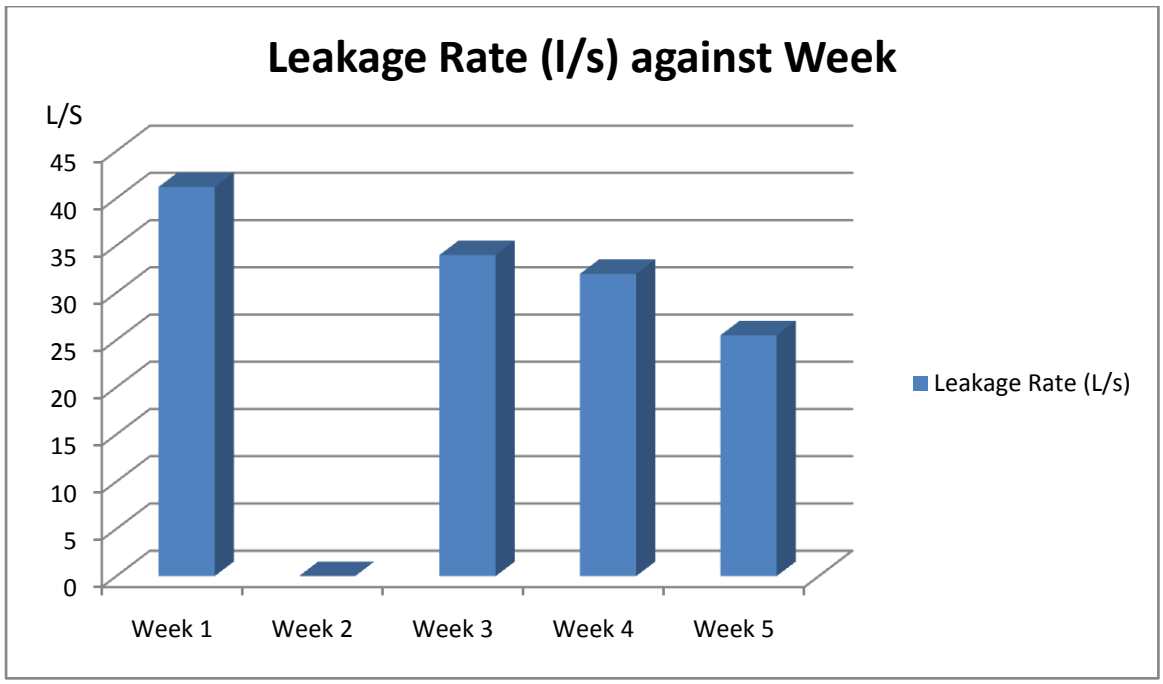

Figure 4.2: Leakage Rate Per Week

4.1.4 Electrical Section

In this section, it was found that the main source of electric power supply to the plant were both P.H.C.N and electric generators which are two in number as shown in Appendix C. The hours of supply were appreciative. Whenever there was power failure, the generator becomes the power source. The results are further presented in Table 4. 7.

Table 4.7: Generators parameters

Parameters	Results	Remarks
Generator type	Parkins	Good
Capacity(KVA)	500	Acceptable
Number in working order	1	
Breakdown	1	
Total Power demand for the plant (V)	415	
Diesel used per day in case of power outage (liter)	155	Not always
Engine type	Diesel	Good
Amount spent for diesel daily when there is power outage (₦)	25,575	Not economical

Maintenance culture	Preventive (Change oil & filters)	Once a month
Number of staff	2	

4.1.5 Maintenance Section

From the information obtained, the system is maintained by the school management. The amount spent on pipelines is more compare to other components of the ABU WTP. The number of staff is 8.

4.1.6 Questionnaire Analysis

4.1.6.1 Plant Water Treatment Assessment and Performance

Table 4.8: Questionnaire Analysis on Treatment Processes

Question	Answer	Remarks
How many departments make up the plant?	Five; Namely: Treatment Unit; Plumbing Unit; Laboratory Unit; Mechanical Unit; Electrical Unit.	WHO,1990 acceptable standard.
How many staff do you have in the plant?	Thirty	
State the preliminary treatment processes used within your treatment plant.	- Screening to remove floating matter - Chemical treatment to remove algae and aquatic nuisance - Micro-straining to remove algae, aquatic plants and small debris	Acceptable (USEPA, 1995)
State the Main Treatment Processes used within your treatment plant	- Chemical feed and Rapid mix - Coagulation/flocculation to	WHO/UINCEF,2000

	convert non settleable to settleable particles - Sedimentation to remove settleable particles - Filtration to remove bio-contaminants and solid matter - Softening to remove hardness causing chemicals - Neutralization with lime to increase pH of the water - Corrosion control to prevent scaling and corrosion	
What is the present disinfecting agent used in the treatment processes?	Chlorine	Acceptable Standard USEPA, 2011a; Borst, *et al*, 2001
Purity of treated Water within the ABU communities varies in some of the water points. What do you think that is responsible for this? (Please give detail explanation)	The pipes are about 46 years now.	The pipes should be changed.

Table 4.8 shows some of the facilities in the treatment plant. Regarding the preliminary water treatment processes, the ABU treatment plant (100%) has screening devices to remove floating objects before the water is passed into the plant for treatment. It is likely that a plant without screening devices are fed by raw water that is free of floating matter hence do not require screens to separate these materials from the water abstracted. The

survey also showed that the treatment plant surveyed have preliminary chemical treatment (such as alum, lime, chlorine, and polyelectrolyte) to remove algae and other aquatic plants that could disturb their treatment processes. The polyelectrolyte is recently introduced due to high turbidity experience by the present dredging ongoing. They do not have to chemically treat for aquatic plants as they do not constitute a problem in their water treatment.

On the availability of pre-sedimentation facilities to remove large settleable solids like coarse sand and gravelly particles, the water treatment plants responded in the affirmative process as screening, Aeration, coagulation, sedimentation, filtration, reservoir to consumer .This is not surprising because the raw water raw water is abstracted from manmade reservoirs, which allow the gritty fraction to settle.

The ABU water treatment plant reported having coagulation and flocculation as the main method of treating water after the coagulating agent; usually ferrous aluminiumsulphate (alum) has been thoroughly mixed with the water. After using the alum, the water treatment plant use sedimentation to remove or separate settleable particles from the water being treated. The separation also acts as a preliminary stage for removing bio contaminants which support microbial growth. The water treatment plants use softening process in their water treatment process. But direct physical inspection of their facilities showed that the plant had no separate facilities for softening other than the combined liming and coagulation. This is responsible for the response. All the water treatment plants disinfect water to get rid of micro-organisms which could be disease vectors. In addition, the disinfection process also sterilizes other bio contaminants and other solid matter which may breed disease vectors.

The ABU treatment plant (100%) is capable of carrying out turbidity tests on the water undergoing treatment, the plants could measure PH, residual chlorine,etc. Heavy metal determination is one notable area where the plants facilities or expertise could not lay claim to. Each department of the WTP plays different roles, to ensure day-to-day smooth running of the WTP. In line with this, the number of staff in ABU WTP is not sufficient for efficient operation of the plant. But the plant maintenance engineer claims that the number is sufficient for them. The purity of the treated water varies due to age of the pump. Hence, there is need

to replace the pipes with PVC-U pipes and the Ahmadu Bello University sets up a multidisciplinary team of researchers from the Water Resources and Environmental Engineering, the Microbiology and Chemistry Departments to investigate the occurrence of these products in its treated drinking water and undertake investigations into the balance between optimum microbial control and disinfectant use in the control of disinfection by-products in conventionally treated drinking water.

4.1.6.2 Plant Maintenance Culture and Performance

Table 4.9: Questionnaire Analysis on Maintenance Culture of the plant

Question	Answers	Remarks
What is the Maintenance culture Predominant in your Plant?	Preventive Maintenance	EN 13306: 2001
State the maintenance procedure and materials you apply on the following components of your plant and how often do you carry out the maintenance: a. Pump. b. Pipelines. c. Tanks. d. Reservoir.	Pumps: Greasing of shaft, bearings and impellers, Monitoring of Pressure control and changing of worn parts. Pipelines: Blockage removal, Replacement and New laying. Tanks: Cleaning and painting Reservoir: Cleaning and painting	

Is there any supervisory control and data acquisition (SCADA) systems in the plant for monitoring your WTP Operations?	No
Please, intimate on the following in your maintenance culture: a. Maintenance Planning b. Maintenance Organization c. Materials Procurement. d. Performance limiting Factors (PLFs).	Maintenance Planning: The maintenance planning is scheduled by the plant management and carried out as scheduled if materials are available. Maintenance Organization: Plant Director - Plant Engineer (Assistant Director) - Chief Lab Tech - the technicians. Materials Procurement: The materials are procured by the ABU Management and kept in the WT. When needed, request is made by the department. Performance Limiting Factors: Manual and technical report, Age of equipment, finance and support from School administrative body.

Table 4.9 shows some maintenance culture and administrative activities practiced at the ABU WTP. The predominant maintenance culture in the plant is PreventiveMaintenance. It consists of routine actions taken in a planned manner to prevent/minimize chances of breakdown and ensure operational accuracy economically. The research showed that this culture is not strictly practiced on the water pipeline and pumps. The rate of pipeline leakages and variation in purity of treated are obvious evidence to this. The plant claimed that they do carry out laying of new pipes, but the asbestos pipes are about forty-six years now and this is the main reason behind the variation in purity of treated water as complained by the Plant maintenance engineer. Also, out of seven, two has been dormant for over two years. The pipe that conveys water from the aeration pump to the aeration tank is covered with a

sack (Plate D1). This pipe supposed to have been welded back to reduce losses. The maintenance culture practiced on the tanks and reservoir are acceptable Table 2.2 (ASME/ANSI EA-2-2009).

The plant's maintenance organization includes: the plant director, plant Engineer (Assistant Director), Chief Lab Tech, and the technicians. Each plays very important role at the plant to ensure smooth running of the plant to meet the water demand. The plant's maintenance organization has the responsibility ofensuring adequate water supply within the ABU community with the available resources.

The maintenance planning is scheduled by the plant management and carried out as scheduled if the materials are available. For example, the generator maintenance is after every 100 hours and sand filter is back-wash once in two days. The problem facing ABU water treatment plant maintenance planning process is that maintenance supervisors and planners lack the desired privilege required to perform the necessary maintenance work, as well as maintenance scheduling execution (with respect to maintenance activities) which includes provision of resources. The reason is because materials used in the plant is procured by the authority and kept at the central store consume by the water treatment plant on request. On request, before approval, the emergency may accumulate, thereby reducing the plant's performance. With this, the plant efficiency can never be 100%.

Through a comprehensive performance evaluation (CPE), non-technicalor management and human resources related limitations are identified as performance limiting factors. Some of PLFs include: Manual and technical report, Age of equipment, finance, absence of Supervisory control and data acquisition (SCADA) and support from School administrative body. For instance, when pipeline breakage occurs, before approval of another pipe for replacement, the rate of water leakage increases thereby causing water shortage within the area. Absence of accurate Manual and technical report on job done, limits the routine activities of the plant.

4.1.7 Calculation of Performance Indicators

The performance indicators (PIs) were calculated in this chapter based on the formulae presented in chapter three. The results compared with a known standard values.

4.1.7.1 Functioning Treatment plant Units PIs

From the results obtained, the total number of treatment plant unit is 31 and 4 of these broke down, which means that the total number of units working order is 27.

Functioning treatment plant PIs, equation (3.4)

$$= \frac{27}{31}\ x\ 100\% = 87.1\%$$

4.1.7.2 Routine Monitoring of Water Quality PIs

From the results obtained, this PIs is not acceptable in the dosing department. The automatic dosing machine which measures the appropriate quantity of alum needed is not working. Manual loading cannot give accurate result due to human error.

4.1.7.3 Percentage Sample Fail to Meet Quality Standard

From results obtained, all the units were tested within four months in which two failed to meet quality standard. This PIs also identified the level of water quality, which normally should be close to 0%.

Percentage Sample failed equation (3.5) = $\frac{2}{31}\ x\ 100\% = 6.5\%$

4.1.7.4 Percentage Treatment Capacity Utilized PIs

The average daily volume of treated water is 1300m^{3}per day and the design capacity of the treatment plant is 5500m^3.

Percentage treatment capacity from equation (3.6) = $\frac{1300}{5500}\ x\ 100\% = 23.6\%$

4.1.7.5 Percentage Population Served PIs

The average daily volume of treated water taking per capita consumption, the total number of people served is 28000. The total number of is 72000.

Percentage treatment capacity from equation (3.6) = $\frac{28000}{72000}\ x\ 100\% = 39\%$

4.1.7.6 Availability of Power Supply PIs

The average daily time of power supply is found to be 22 hours. The total hours in a day are 24 hours.

PIs equation (3.10) = $\frac{23}{24}\ x\ 100\% = 95.83\%$

4.1.7.7 Treatment Plant Performance

The performance of the treatment plant is the ratio of the raw water flow to the plant capacity. The raw water flow is 200m^3 per hour which is

4.1.8 Performance Measurement Models Calculation

4.1.8.1 Availability

Availability from equation (3.12) =$\frac{Operating\ time}{Scheduled\ time}\ x\ 100\%$

Scheduled time = 10 hours; Shift = 1 hour and Breakdown = 1 hour

Availability = $\frac{8\ hours}{10\ hours}\ x\ 100\% = 80\%$

4.1.8.2 Treatment Plant Performance

The performance of the treatment plant is the ratio of the treated water flow to the plant capacity. The water flow is 230m^{3}per hour which is 5500m^3 and 38500m^3 per day and week respectively. The plant capacity is 81600m^3.

The plant performance = $\frac{38500}{81600}\ x\ 100\% = 50\%$

4.2 Discussion

4.2.1 Chemical House

The survey showed that the treatment plant have preliminary chemical treatment (such as alum, lime, chlorine, and polyelectrolyte) to remove algae and other aquatic plants that could disturb their treatment processes. The polyelectrolyte is recently introduced due to high turbidity experience by the present dredging ongoing. They do not have to chemically treat for aquatic plants as they do not constitute a problem in their water treatment. Chlorine is used as the disinfectant.

4.2.2 Treatment Section

The treatment processes consists of screening, Aeration, coagulation, sedimentation, filtration, reservoir to consumer. The facilities in the treatment plant are shown in tables 4.2 - 4.4.It was observed that the automatic dosing machine is not working, hence the dosing is done manually. Also the volume of water treated daily is found to be 5500m^3 while the total population target for water supply is 72000 which is for phase I. Therefore there is need for expansion work at the plant. Regarding the preliminary water treatment processes, the ABU treatment plant (100%) has screening devices to remove floating objects before the water is passed into the plant for treatment.

The reservoir material and capacity (Table 4.4) revealed that the ABU WTP reservoir is of international standard (ASME/ANSI EA-2-2009). The material does not corrode. Its capacity is as given in the result obtained. Chlorine is added at the reservoir before analysis on the water is finalized before distribution. The type of maintenance for the reservoir is by cleaning and painting and it is always carried out as scheduled.

The tanks material and design (Table 4.3) revealed that the ABU WTP aeratio, sedimentation and filtration tanks are of international standard (ASME/ANSI EA-2-2009). The sedimentation tank has surface area of 400 m^2 and maximum flow rate of 9.0 m^2/s. When discharge rates exceed the capacity of a sedimentation tank, one or more additional sedimentation tanks will be needed to accommodate the higher flow rates. For these circumstances, additional tanks must be added in parallel(i.e., side by side) to split the flow

(KCIW, 2001). To achieve this, the ABU WTP sedimentation tanks are in this order.

The sedimentation process can be completed by a number of specific processes, the main aim is to use gravity to separate solid particles from the liquids that will pass on to later stages of treatment. As particles settle in the sedimentation tank, large pieces of solid waste fall to the bottom of the sedimentation tank into what is called the sludge zone. The area above the sludge zone is deeper than the sludge zone and contains recently introduced liquids still to be settled at one end and liquids that have completed the settling process at the other.The working volume of the sedimentation tank must have sufficient volume to allow for a minimum hydraulic retention time of 90 minutes under peak instantaneous flow conditions. The peak instantaneous flow rate must be the lower value of the maximum capable pumping rate to the sedimentation tank or the maximum discharge rate allowed by the local sewer utility. This standard shows that the ABU WTP tanks material, capacities and process performance are acceptable. This section has workability of 85%

4.2.3 Mechanical Section

The pumps parameters and efficiencies by calculation (Table 4.5) revealed that the pumps performance are of acceptable limit. Each of pumps operates for minimum of four hours for efficient performance and increases the distribution uniformity. A typical

centrifugal pump is designed to operate above 65% efficiency(Hydraulic Institute, 2000).The ABU WTP pump operates at an efficiency of 76%, hence the ABU WTP Pump performance is highly acceptable .Continuous monitoring of key pump and motor operating characteristics can provide information about the condition of the pump and the system. The flow rate and differential pressure should be monitored for the pump, aswell as the electric power orcurrent of the motor in order to extend the pumps life span and continuous efficient performance.

The pipelines material and design (Table 4.6) revealed that the ABU WTP pipe are of international standard (ASME/ANSI B16-2009). The major problem with the distribution pipe is the age. Due to the age of the pipes, there leakage do occur along the distribution lines as the pressure builds up. But the plumbers are up and doing in tackling this to ensure there is no shortage of water within the ABU communities. Water leakage from pipes is caused by several reasons such as degradation, corrosion and breakage of water pipes due to traffic load. As water pipes maintain high water pressure, the amount of water leakage will increase rapidly if prevention measures are not taken (Rolf Isermann, 1984).

The leakage results (Figures 4.1 -4.2 and Table B1), shows that the leakage rate in week one was high. It is evidence that the absence of leakage detection devices causes loss of water along the pipeline when it occurs. The average leakage within the five weeks was 26.54 liters, while the Average leakage within the five weeks was 1150.2 liters. The ABU WTP is expected to distribute 4.8m (1.3m gallons) per day. The result showed that about 1150.2 liters (303.9 gallons) that is 0.024% of water loss as a result of leakage along the pipeline per week. If 0.024% out of 100% of treated water loss as a result of leakages, the ABU WTP distribution performance is at acceptable limit. But it is advisable to install a digital leakage detecting device at plant. The percentage leakage here was during the day operation, due to the time schedule of the research. Night operation was not accounted for.

The leakage monitoring meters may survey the nearby pipe segments over a limited distance. Thus, it isdifficult to determine the precise leakage location fromthe leakage alarm signals surveyed by nearby monitoringmeters (NC Turner, 1991).Therefore, biological method is applicable to identify the exact location of pipe leakage. Water leakage not only resultsin the waste of good quality water resources, but alsoleads to a higher risk of drinking water pollution (whichmeans a health threat to water consumers). Furthermore,bursts in main pipelines severely disturb the public order.Therefore, the development of technologies and strategiesfor detecting, providing, advance warning, and controllingwater pipeline leakage is of crucial for both the watersupply companies and the public (Kishawy and Gabbar,2010). Therefore, the ABU WTP should liaise with the Computer Engineering, Electrical and Water Resources Engineering to develop a software for detecting, providing, advance warning and controlling the water pipeline leakage.

Less leakage means less utilization of precious water resources and the plant can then offer a more stable water supply service. It also prevents excess amounts of water to be discharged into the water supply network, resulting in cost reductions. Furthermore, it also contributes to energy conservation and natural resource conservation thus the reduction of environmental load. When leakage occurs, it takes the maintenance team up to three hours to carry out the necessary replacement, thereby causing more loss of volume of water required by the ABU community.

4.2.4 Electrical Section

In this section, it was found that the main source of electric power supply to the plant were both P.H.C.N and electric generators which are two in number as shown in Appendix C. The hours of supply were appreciative. Whenever there was power failure, the generator becomes the power source. The results presented in table 4.7 showed that the ABU WTP has

two standby generators which one is not serviceable at the time of the survey. The generators are diesel engine and has capacity of 500KVA which is capable of powering the pumps at the plant. The generator is serviced once in a month. The illumination at the ABU WTP during day operation was found to be of standard.

4.2.5 Treatment Performance

The treatment plant performance which was calculated to be 50%. This percentage indicates that the performance level of the treatment plant is low. It is less than the minimum percentage required (AWWA, 1999b). This percentage may be due to technical problems or low raw water flow. However, in order to improve the performance of the treatment plant, raw water flow should be increased to at least 40% of the actual flow. The PIs calculated did not meet the standard.

Table 4.10: Comparison of the Result Finding with Existing Ones

Parameters	WHO	EU	Kayes WTP	ABU WTP
Pump Type	NA	NA	Centrifugal	Centrifugal
Sedimentation Tank design	Rectangular (≥L:W) = (≥4:1)	Rectangular (≥L:W) = (≥4:1)	Rectangular (≥L:W) = (≥4:2)	Rectangular (≥L:W) = (≥4:1)
Aeration Tank Design	Rectangular (≥L:W) = (≥4:1)	Rectangular (≥L:W) = (≥4:1)	Rectangular NA	Rectangular (≥L:W) = (≥4:1)
Tanks Material	NA	NA	Concrete and Block	Concrete and Block
Treatment Process	NA	NA	Screening, coagulation, sedimentation, filtration, reservoir to consumer	screening, Aeration, coagulation, sedimentation, filtration, reservoir to consumer
Leakage detection	NA	NA	Digital alarm	NIL
Disinfectant	Chlorine	Chlorine	Chlorine	Chlorine
Maintenance Culture	Preventive	Preventive	NA	Preventive

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The assessment of the performance and maintenance culture of Ahmadu Bello University Water Treatment Plantwas carried by assessing the plant components. A typical WTP must have the following components (Table 2.1). The ABU WTP assessment results are in close agreement with the components. The leakage results showed that about 1150.2 liters (303.9 gallons) that is 0.024% of treated water loss as a result of leakage along the pipeline. The maintenance culture predominant in the plant is Routine check i.e. is preventive maintenance and it is the best type of maintenance if strictly followed to avoid equipment breakdown or system failure. The ABU WTP unit's workability is within the range. Through a comprehensive performance evaluation (CPE), non-technicalor management and human resources related limitations are identified as performance limiting factors. Some of PLFs include: Manual and technical report, Age of equipment, financial and support from School administrative body.

5.2 Conclusion

The present research centered on the assessment of the performance and maintenance culture of Ahmadu Bello University Water Treatment Plant by assessing the plant components and water treatment process. From the results obtained and discussions, the following conclusions are made:

(1) The result showed that about 1150.2 liters (303.9 gallons) that is 0.024% of water loss as a result of leakage along the pipeline. If 0.024% out of 100% of treated water is loss as a result of leakages, the ABU WTP distribution performance is at acceptable limit. The major problem with the distribution pipe is the age.

(2) Most of the treatment plant units are functioning and their workability is within the range of acceptance. The automatic dosing machine at the plant is not functional, thereby making the dosing method unacceptable. The treatment processes consists of screening, Aeration, coagulation, sedimentation, filtration, reservoir to consumer.

(3) Most of the PIs calculated did not meet the standard.

(4) The treatment plant performance which was calculated is 50%. This percentage indicates that the performance level of the treatment plant is low. It is less than the minimum percentage required (AWWA, 1999a). This percentage may be due to technical problems or low raw water flow. However, in order to improve the performance of the treatment plant, raw water flow should be increased to at least 40% of the actual flow.

(5) The predominant maintenance culture in the plant is PreventiveMaintenance. It consists of routine actions taken in a planned manner to prevent/minimize chances of breakdown and ensure operational accuracy economically. The research showed that this culture is not strictly practiced on the water pipeline and pumps. The rate of pipeline leakages and variation in purity of treated are obvious evidence to this. The plant claimed that they do carry out laying of new pipes, but the asbestos pipes are about forty-six years now and this is the main reason behind the variation in purity of treated water as complained by the Plant maintenance engineer. Proper education and training can facilitate or increase the perception of maintenance in the plant.Some of PLFs include: Manual and technical report, Age of equipment, financial and support from School administrative body.

(6) The ABU WTP pump efficiency is 76%. Considering the distribution pipes age, the leakages along the pipeline network can be attributed to the pump efficiency.

5.3 Recommendations

In the course of the investigation, some recommendations has been made, for efficient and quality supply of portable water within the ABU communities:

i. Supervisory control and data acquisition (SCADA) systems should be installed to monitor and control the operation of the system.

ii. Pumps should start up slowly to reduce the scouring effect of a sudden increase in water velocity that may lead to dirty water.

iii. The quantity of raw water coming to the plant should be increase so that the volume of treated water will also increase.

iv. Research should be carry out on corrosion rate of ABU WTP water pipelines.

v. Expansion work should be done at the plant to increase the PIs to the standard limits.

vi. Research should be carried out to ascertain the actual population figures for the ABU community with the actual population growth rate.

vii. The asbestos pipes should be replace to reduce the rate of leakages along the distribution network.

5.4 Contributions to knowledge

(1) The treatment plant performance which was calculated is 50%. This percentage indicates that the performance level of the treatment plant is low. It is less than the minimum percentage required (AWWA, 1999a). This percentage may be due to technical problems or low raw water flow. However, in order to improve the performance of the treatment plant, raw water flow should be increased to at least 40% of the actual flow.

(2) The ABU WTP pump efficiency is 76%. Considering the distribution pipes age, the leakages along the pipeline network can be attributed to the pump efficiency.

(3) The result showed that about 1150.2 liters (303.9 gallons) that is 0.024% of water loss as a result of leakage along the pipeline. If 0.024% out of 100% of treated water loss as a result of leakages, the ABU WTP distribution performance is at acceptable limit.

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APPENDIX A

QUESTIONNAIRE FOR WATER TREATMENT PLANT PROCESSES, PERFORMANCE AND MAINTENANCE CULTURE OF THE AHMADU BELLO UNIVERSITY WATER TREATMENT PLANT

Dear Sir,

QUESTIONNAIRE FOR WATER TREATMENT PLANT PROCESSES, PERFORMANCE AND MAINTENANCE CULTURE OF THE AHMADU BELLO UNIVERSITY WATER TREATMENT PLANT

I am a postgraduate student of the Ahmadu Bello University, Zaria from the department of Mechanical Engineering Department. I am undertaking a research on the ' Assessment of the Performance and Maintenance Culture of Ahmadu Bello University Water Treatment Plant'. In this study, focus is on the available Administration, plant treatment processes, the capacity of the plant, distribution of treated water and maintenance culture of the treatment plant. The information being requested is for academic research purposes only. Please, your cooperation is highly solicited, thank you.

SECTION A

Please, this section is to be filled by the Plant Manager.

1. How many departments make up the plant (with names)? ----------
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2. How many staff do you have in the plant? ----------

3. State the preliminary treatment processes used within your treatment plant. ----------
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4. State the Main Treatment Processes used within your treatment plant
5. What is the present disinfecting agent used in the treatment processes? ----------

SECTION B

Please, this section should be filled by the Plant Maintenance Engineer.

6. Purity of treated Water within the ABU communities varies in some of the water points. What do you think that is responsible for this? (Please give detail explanation) ---------
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7. What is the Maintenance culture predominant in your Plant? ----------

8. State the maintenance procedure and materials you apply on the following components of your plant and how often do you carry out the maintenance?

a. Pumps----------

b. Pipelines----------

c. Tanks ----------

d. Reservoir ----------

9. Is there any supervisory control and data acquisition (SCADA) systems in the plant for monitoring your WTP Operations?

10. Please, intimate on the following in your maintenance culture: Maintenance Planning, Maintenance Organization, Materials Procurement and Performance limiting Factors.

APPENDIX B

LEAKAGE RESULTS OF ABU WTP PIPELINES

TABLE B1: Leakage Results of ABU WTP Pipelines for Five Weeks

Weeks	Volume Leaked (l)	Time Taken (s)	Leakage Rate (l/s)
Week 1	2552	62	41.2
Week 2	0	0	0.0
Week 3	850	25	34.0
Week 4	1125	35	32.0
Week 5	1224	48	25.5
Average	1150.2	34	26.54

APPENDIX C

ASSESSING THE KSB PUMP PARAMETERS

Plate C1: Assessing for the Pump Parameters during the Research

Plate C2: Assessing for the Pipe Leakages during the Research

APPENDIX D

ASSESSING THE STANDBY GENERATORS

Plate D1: The Unserviceable Generator

Plate D2: The Serviceable Generator