Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Environmental Engineering Chair

Efficiency Evaluation of a Conventional Drinking Water Treatment plant Units: A Case of Jimma Town

BY: Ephrem Getahun

A thesis Submitted to the School of Graduate Studies of Jimma University, Jimma Institute of Technology in Partial Fulfilments of the Requirements for the Degree of Masters of Science in Environmental Engineering

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Main advisor: Prof. Dr.-Ing Esayas Alemayehu

Co-advisor: Mr. Wendesen Mekonin

July 2021

Jimma, Ethiopia

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Ephrem Getahun

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Signature Date

This thesis has been submitted for examination with my approval as university supervisor.

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ABSTRACT

Drinking water supplied to the community passes through a series of treatment processes (depending on their sources) before they reach to the end users. For surface water sources, conventional drinking water treatment technology is widely applied. Jimma city is one of the cities in Ethiopia which require well treated and enough amount of water. This city has conventional treatment plant which was constructed and starts function in 2015 with a design capacity of 12,196m³/d. Therefore, the objective of this study was to assess the efficiency of the treatment plant in each treatment unit to provide good quality and enough amount of well treated water to the town. But due to urbanization and population growth there was a limitation in providing good quality and enough amount of drinking water. Different methods were used during the study period: laboratory used to measure and evaluate physical, chemical and biological parameter of the water; providing questions and visual observation to determine the management and control practice The design capacity of the unit processes was evaluated by considering current peak water demand and selecting appropriate loading rates as basic criteria and the quantity of water provided to the institutions was investigated by conducting data from the institution and Jimma city water supply office and analysed by arithmetic method and evaluated with the forecasted demand from the design document. The analyses of the findings indicate that the plant has no capacity to treat adequate water demanded with current peak daily demand of 19912.76m³*/d. Water parameter (physical, chemical and biological) result: biological result show that the raw water have contaminated by bacteria both fecal and total coliform bacteria measured after disinfection was (FC=18mg/L and TC=61mg/L.)the rest physical and chemical result measured after disinfection was:* p^H *(7.13), turbidity(0.4NTU), temperature (21.9°C), E.cond (119µs/cm), TDS (60mg/L), total hardness(32mg/L),* Mg^{2+} *(18mg/L),* Ca^{2+} *(14mg/L), alkalinity (500mg/L),* Fe^{2+}*(0.01mg/L),* Mn^{2+}*(0mg/L),* SO_4^{2-}*(10mg/L),* NH_4^+*(0mg/L),* Cl^- *(4.99),* NO_3^-*(5.978mg/l). All chemical and physical parameters were under the permissible limit of WHO standard except alkalinity with a result equal to the maximum standard kept by WHO and the biological parameter was totally fell the standard. The analysed management and control practise was poor. Water was not adequately available in all schools in the city. Design, operational and control factors were identified as major causes for the weak performance of the plant*

Key words*:By product; Design efficiency; Drinking water; Jimma city; Treatment unit*

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CCP	Composite Correction Program
CFU	Colony Forming Units
DBP	Disinfection By-Product
DWTP	Drinking Water Treatment Plant
EC	Electrical Conductivity
EPA	Environmental Protection Agency
HAA	Haloacetic Acids
JCWSO	Jimma City Water Supply Office
JCWTP	Jimma City Water Treatment Plant
NOM	Natural Organic Matter
NTU	Nephelometric Turbidity Units
TDS	Total Dissolved Solid
TTHM	Trihalomethane
WHO	World Health Organization
WTP	Water Treatment Plant

CHAPTER ONE
INTRODUCTION

1.1 Background

Water is the essence of life. Water is the vital source of existing for the world living feature in general. No water No life so, to have a better life situation everyone should protect water source carefully. Water is one of the main important components of the environment. Approximately, 97% of the total water is found in oceans, which is not appropriate for drinking, and only 3% is considered as fresh water, out of this 2.97% is found as glaciers and ice caps. Only the remaining little portion, 0.03%, is obtainable as surface and ground water for human use (Muhammad *et al*., 2013).

Water quality is the measure of how good the water is, in terms of supporting beneficial uses or meeting its environmental standards. Potable water is the water which is suitable for drinking and cooking purposes. Portability considers both the safety of water in terms of health, and its acceptability to the consumer, usually in terms of taste, odour, colour, and other sensible qualities (Benignos, 2012).

Various health problems may occur due to inadequacy and poor drinking quality of water supply. Infant mortality rate is high due to unsafe water supply. Therefore, drinking water quality should be completely free from pathogenic microorganisms, physic-chemical element in concentration that causes health impact. It should be clear and aesthetically attractive, low turbidity and colour recommended by WHO guide lines and should not be saline, contain any compounds that cause offensive and taste, should not cause corrosion scale formation, discolouring or staining and should not have a temperature unsuitable for consumption.

The production and supply of safe drinking water to consumers at all times constitutes a major challenge to water authorities. This task is more challenging in tropical countries like Ethiopia, where strong seasonal variations prevail. This variation can affect the efficiency of water treatment, water supply pattern and the quality of water in the water distribution system too (Sisay*et al*.,2017).

Potable or drinking water is defined as having acceptable quality in terms of its physical, chemical, and bacteriological parameters so that it can be safely used for drinking and cooking. A daily per capita consumption of 2 litters is the generally accepted value for a person weighing 60 kg. This is the value used in estimating ingestion exposure to potentially hazardous chemicals in drinking water. The actual water intake, however, varies considerably from individual to individual, and also according to climate, physical activity, and culture (Ashok Gadgil, 1998).

Water treatment plants are expected to provide safe and aesthetically acceptable water to consumers at a reasonable cost. Conventionally, management and operation of a water treatment plant (WTP) is based on monitoring finished water quality parameters and then comparing them to the regulatory requirements. Nonetheless, the performance of each treatment unit in a WTP is important and needs to be evaluated to ensure the unit's performance is successful. Multiple factors such as variability in source water quality and component (unit) specific factors such as velocity gradients in coagulation and flocculation, surface overflow rate for the sedimentation basin, and contact time for disinfection, all can impact the quality of finished water(Zhang*et al*., 2012)

The conventional water treatment systems widely used in urban drinking water include coagulation, sedimentation, sand filtration, and disinfection processes (Alemayehu, 2019).

Jimma cityhas moderate access to supply of water. The community is directly related and dependent on the accessibility of water there.

Jimma city conventional water treatment plant is constructed five years ago to solve the problem of drinking water consumption of the people of the city (Jimma city water supply office). But now because of urbanization and population growth many limitations have been seen. In the last five years of JCWTP functions no study were done on the efficiency of the plant through each treatment unit in relation with the control and management practice as a research level. So this study focused mainly in the quality and quantity aspect of each treatment unit to assess well treated drinking water to the community based on WHO standard.

1.2 Statement of the problem

This treatment plant provide treated water for a five years to the people lives in the city but, now a days due to increase in urbanization the plant does not give the expected well treated amount of water to the community in town and also population growth as a result of urbanization is commonly observed in the flat regions of many countries; hence, the flat beds of river basins are more susceptible to being affected (Chamara*et al*., 2017).

Increase in population and urbanization the water source used for drinking water in JWTP is become more contaminated through time to time. So, in this water different impurities were introduced which were not considered during the design due to construction of villages around the source of the raw water used. Contamination of surface and ground waters is the most serious problems affecting the health of the population. Therefore each treatment unit should be evaluated weather they are functioned within this growth of the city or fail to provide well treated and enough water for the people of the city. So, the study was done to determine the limitation WTP units which affect the performance of the TP in providing the expected quality and quantity of water to the city

1.3 Objective

1.3.1 General objective

To assess the efficiency of drinking water treatment plant in each treatment unit to provide good quality and enough amount of well treated water to the town

1.3.2 Specific objective

I. To investigate the capacity of each treatment unit (intake, aeration, coagulation, flocculation, sedimentation, filtration and disinfection) pertain to quality and quantity aspect.

II. To determine the by product at different treatment unit and evaluate the control and management practice.

III. To investigate drinking water demand and supply of the town for the various institutions

1.4 Research question (hypothesis)

I. Does the design capacity of major unit processes have an impact on the performance of treatment plant pertain to quality and quantity aspect?

II. Does the by product produced and control and management practice at different treatment unit limit the provided water quality?

III. Does the treatment plant provide drinking water of the town for the various institutions?

1.5 Significance of the study

Based on the result of different study scarcity of drinking water is a big problem especially in developing country. Therefore, the significant of the study focused on solving the shortage of healthy, clean and enough amount of water to the public. And also prevent the community from water born disease. Prevent the dawn stream from being more polluted from the by product produced by the plant.

1.6 Scope of the study

The study was try to concentrate on improving the efficiency of JCWTP in providing good quality of water to the community by focusing mainly on the investigation of the factor that affect the different characteristic of water quality parameters such as physical, chemical, bacteriological and also the management and control area. The study will bounded only to assess the efficiency of the treatment plant and specific objective in investigating the supply and demand of drinking water to the institute and also in determining different impurities in each step of the treatment unit.

1.7 Limitation of the Study

The study was mainly focused on the treatment plant did not include the distribution. The study is also a cross-sectional study type in which samples were collected only in a single rainy season because of limitation of time and resources. The parameters assessed in this study are also specific and selected i.e. there was no complete assessment of all water quality parameters rather than we focused on major components. The researcher also faced difficulties in obtaining the design document of a treatment plant. But the research focused to obtain the necessary data and information during the entire study period with maximum effort.

CHAPTER TWO
LITERATURE REVIEW

2.1 Water as a resource and drinking water

Water is one of the components on environment which is the most essential for life to exist on the planet. The health of any community fully depends on the accessibility of adequate and safe water.

Water is an important natural resource in the world, and it is the most essential element on the earth to maintain human life (Issa, 2017). It is availability with appropriate quality and sufficient quantity is essential for human life and other purposes (Khwakaram*et al*., 2012).

“To reduce the incidence of water related and water borne health problems both adequacy and safety of drinking water are equally important” (Bharti*et al*., 2011).

“Contamination of drinking water quality are mainly from open field defecation, animal wastes, flooding, plants, economic activities, agricultural, industrial and businesses and wastes from residential thus the source of the water is near to this waste and also the plant is located around this area the waste easily enter to the plant by over flooding and infiltration” (Haylamichael*et al*., 2012).

2.2 Conventional drinking water treatment plants

“Water treatment plant (WTP) is a process of water to achieve a water quality to meet a specified goals or standards set by regulatory agencies” (Crittenden *et al*., 2012).

Water treatment plant is very important role in contemporary society. However, the pollution of the majority of the water source has become a subject of significant concern. Conventional methods for water treatment that involve removing the colloidal and suspended solid from raw water have a good level of efficiency (kiashemshaki*et al*., 2017).

Most current drinking WTPs use conventional treatment methods like coagulation-flocculation, sedimentation, filtration, and disinfection to produce fresh portable water (Aziz and Mustafa, 2019).

The major unit processes that make up the conventional water treatment plant are intake (screening), coagulation/flocculation, sedimentation, filtration, disinfection, and distribution.
Once water from the source has entered to the plant as influent, water treatment processes break down into two parts, clarification and disinfection. The first part, clarification, consists

of screening, coagulation/flocculation, sedimentation, and filtration. Clarification processes go far in potable water production, but while they do remove many microorganisms from the raw water, they cannot produce water free of microbial pathogens. The second part and the final step, disinfection, destroy or inactivate disease-causing infection agents (G/tsadik, 2013).

Water treatment plants are expected to provide safe and aesthetically acceptable water to consumers at a reasonable cost. Conventionally, management and operation of a water treatment plant (WTP) is based on monitoring finished water quality parameters and then comparing them to the regulatory requirements. Nonetheless, the performance of each treatment unit in a WTP is important and needs to be evaluated to ensure the unit's performance is successful. Multiple factors such as variability in source water quality and component (unit) specific factors such as velocity gradients in coagulation and flocculation, surface overflow rate for the sedimentation basin, and contact time for disinfection, all can impact the quality of finished water(Zhang *et al*., 2012)

"The degree of removal of pollutants such as turbidity, colourand suspended impurities are a performance indicators used for WTP performance evaluation" (Vieira *et al*., 2008).Many attempts have been made to reduce the timescale for making decisions on the quality of drinking water and to have more general assessment processes which involve all concerned parameters (Issa and Alrawi, 2018).

2.2.1 Collection from Source and Storage (Intake)

Water is pumped from different sources as surface water and groundwater and directed into pipes or holding tanks. Screening is the first step of purification of surface water treatment which removes large fragments such as sticks, leaves, trash and other large particles which may create a problem in later purification steps (Bartaula, 2016). Most deep groundwater does not need screening before other purification processes. Storage means to improve quality of water through sedimentation of silt and other suspended matter by the action of gravity (Bartaula, 2016). Colour and turbidity are subjected to reduce for considerable percentage and bacteria also disappear to as much as 90 to 95 % (Bartaula, 2016).

2.2.2 Aeration

Water is mixed with air to increase dissolved oxygen through aeration which removes dissolved gases such as carbon dioxide and oxidizes dissolved metals such as iron, hydrogen sulphide, manganese and volatile organic chemicals (VOCs) (Rabah, 2012). Higher oxygen level in water helps the formation of coagulation mass, further, it also enhances taste and removes odour (Belbase, 2011). In general, aeration is done with the treatment of groundwater supplies in conjunction with lime softening and for the removal of some VOCs (USACE, 1985).

2.2.3 Coagulation and rapid mixing process

Coagulation technology is an economical and simple water treatment technology widely employed at domestic and mass scale and has been one of the primary purification treatments of water supply. Coagulation is a general term for the two processes of coagulation and flocculation (Huang *et al*., 2018).

The uses of coagulant chemical promote aggregation of small and colloidal particles into larger particles. The coagulant chemical neutralizes the electrical charge on the surface of the small particles, resulting in destabilization of the colloidal suspension (Pa. DEP, 2014).

"Coagulation is a process where colloids is reduced in way to form micro- particles can be produced then this micro particle in flocculation process form large structure (floc) and also coagulation is used to reduce turbidity and colour by chemical dose and P^H minimize natural organic matter (NOM) and total organic carbon (TOC)" (Matilainen*et al*., 2010).
Chemical coagulation is achieved by addition of inorganic coagulants such as aluminium and iron salts (Duan and Gregory . 2003).

2.2.3.1 Limitation of coagulation process and factor affecting coagulation

Coagulation is aimed at the removal of suspended colloidal particles when the stabilized colloids are aided to overcome their repulsive forces leading to the aggregation of the particles into flocs. The factors that affect the process are type coagulant used, its dose and mass, p^H and initial turbidity, alkalinity and temperature of the water that being treated and properties of the pollutant present (Alemayehu, 2019).
Factor affecting the effectiveness of coagulation process are P^H: Extremes can interfere with the coagulation/flocculation process and the optimum pH depends on the specific coagulant, Alkalinity : Low alkalinity causes poor coagulation ,May be necessary to add lime, soda ash or caustic soda to add/replace alkalinity and pH during the coagulation process and waters alkalinity must be considered when using Alum since every 1 mg/L of alum added will consume 0.5 mg/L alkalinity (as CaCO3) for coagulation. Therefore supplemental addition of alkalinity to the raw water is often required to achieve the optimum coagulation P^H thus a waters alkalinity must be considered when using Ferric since every 1 mg/L of Ferric added

will consume 0.92 mg/L alkalinity (as $CaCO_3$) for coagulation. Therefore supplemental addition of alkalinity to the raw water is often required to achieve the optimum coagulation P^H (Pa. DEP, 2014).

Temperature: Low water temperatures slow chemical reactions, causing decreased efficiency and slow floc formation. And also Polymers, Bentonite Clay and coagulant aids can be added to assist floc formation in cold water thus higher coagulant doses may be required to maintain acceptable results (Pa. DEP, 2014).Turbidity: Difficult to form floc with low turbidity water, may need to add weighting agents (Pa. DEP, 2014).

Limitation

Coagulation itself results in the formation of floc but flocculation is required to help the floc further aggregate and settle. The coagulation-flocculation process itself removes only about 60%-70% of Natural Organic Matter (NOM) and thus, other processes like oxidation, filtration and sedimentation are necessary for complete raw water or wastewater treatment.

Coagulant aids (polymers that bridge the colloids together) are also often used to increase the efficiency of the process (Oladoja and Abiola, 2016).

The conventional coagulation process is generally effective in removing high molecular weight organics, but less in removing smaller molecular weight fractions (Nissinen*et al.*, 2001).

2.2.3.2 Chemical used in coagulation process

Coagulation occurs in successive steps intended to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc. If step one is incomplete, the following step will be unsuccessful. Therefore, a coagulant chemical is mixed into the water. All chemicals used in the water treatment process must be approved by both the Environmental Protection Agency (EPA) and the Department of Environmental Protection (DEP) for potable water use (Pa. DEP, 2014).Suspended particles in water normally have a negative (-) charge. Since these particles all have the same charge, they repel each other, keeping each other from settling. Coagulation neutralizes the forces; once the repulsive forces have been neutralized these particles can stick together (agglomerate) when they collide. The force which holds the floc together is called the Van der Waals force (Pa. DEP, 2014).

"Chemical coagulant mainly used in water treatment are Aluminium Sulphate (Alum) – $Al_2(SO_4)_3 \cdot 14\ H_2O$, Ferric Sulphate - $Fe_2(SO_4)_3 \cdot 9\ H_2O$ and Ferric Chloride - $FeCl_3 \cdot 6\ H_2O$" (Pa. DEP, 2014).

2.2.3.3 Evaluation of chemicals used in coagulation

China's inorganic coagulant and organic flocculants products have established a standardized system. The system mainly includes standard evaluation of coagulant technical indicators, coagulant performance and performance evaluation, and economic evaluation of coagulant. Among them, the standard evaluation of coagulant technical indicators consists of effective indicators, identification indicators, toxicological indicators and insoluble materials, which is an important evaluation standard for evaluating the efficiency, classification and safety performance of coagulants. The coagulation sedimentation experiment (jar test) is used to evaluate coagulation-flocculation performance, and the method is recognized and adopted by countries around the world. Its performance is evaluated from the aspects of transportation and storage, product and dilution, stability, use environment and so on (Harford *et al*., 2011).

Regarding the performance evaluation of inorganic coagulants, the chemical indicators cannot be comprehensively evaluated due to the uncertainty of the treated water samples. A better method is to evaluate it by the Jar Test method, which was first proposed by the United States in 1921 and is now recognized and adopted by countries around the world (Sun*et al*., 2019).

2.2.3.4 Jar test in determination of coagulation efficiency

"Jar test is useful laboratory experiment for the evaluation of coagulation/flocculation of untreated water in providing information on the effects of the concentrations of the coagulants on raw water and the water quality parameters and also used for the design of treatment facilities" (Susan*et al*., 2019).

The dose of the coagulant to be used can be determined via the jar test. The jar test involves exposing same volume samples of the water to be treated to different doses of the coagulant and then simultaneously mixing the samples at a constant rapid mixing time (Jiang and Jia-Qian 2015).

The micro floc formed after coagulation further undergoes flocculation and is allowed to settle. Then the turbidity of the samples is measured and the dose with the lowest turbidity can be said to be optimum (Aragonés et al., 2009).

2.2.3.5 By products of coagulation process

In coagulation, a positively charged coagulant (usually an aluminium or iron salt) is added to raw water and mixed in rapid mix chamber. The coagulant alters or destabilizes negatively charged particulate, dissolved, and colloidal contaminants. Coagulant aid polymers and acid may also be added to enhance the coagulation process. Turbidity and total organic carbon TOC are measures of particulates and dissolved organics impacting coagulation but if excess or not limited coagulant is added to the raw water charge neutralization results in the formation of metal coagulant precipitation which decrease the disinfection capacity of treating water and also excess sludge will be produced and corrosion (EPA, 2017).

2.2.4 Flocculation

Flocculation is a processes used in conjunction with, and preceded by coagulation. It is process of bringing suspended and destabilized particles (in coagulation) into contact with one another to form larger (floc) particles

These larger particles are more readily removed from the water in subsequent processes. Flocculation is generally accomplished by mixing the destabilized suspension to provide the opportunity for the particles to come into contact with one another and stick together (G/tsadik,2013).

“The process of flocculation effective by using chemical flocculent which are synthetic water soluble polymers based on acryl amide and its derivatives which are anionic or cationic group and also organic or in organic in nature” (Kim*etal.*, 2013).

“The selection of a flocculent for particular application is good, based up on their performance parameter where used to characterize the quality or extent of flocculation achieved with a given flocculent” (Kim *et al*., 2013).

There is a wide range of flocculants available varying in chemistry, ionic charge, molecular weight, branching, and physical form. Therefore, the selection of a flocculent for particular application is not based upon their chemical and physical composition. Instead, performance parameters (e.g., settling rate, residual turbidity, sediment volume of flocculent consumption) are used to characterize the quality or extent of flocculation achieved with a given flocculent (Kim *et al*., 2013).

2.2.4.1 Factor affecting flocculation and common problem

"In flocculation process detention time is crucial(very important) factor in floc formation and also the time required for flocculation when directly connected with filtration is 5-20 minute and for conventional filtration about 30 minute is required" (EPA, 2002).

Flocculation is affected by several parameters, including the mixing time, mixing intensity (G) and mixing speed. The product of mixing intensity and mixing time (Gt) is frequently used to describe the flocculation process (EPA, 2017).

Flocculation also affected by, primarily polymer type, ionic strength, water pH, slurry solids, flocculent dilution, shear, molecular weight, and process conditions. These factors, individually and collectively, have a great influence on the type of flocculent that will provide optimum performance, its optimum dose, and addition points (Pillai,1997).

2.2.4.2 Evaluation of flocculation performance

In the designing of Klapanunggal water treatment plant, the type of flocculation that will be used is hydraulic flocculation with a number of six compartments. Flocculation is a water treatment unit using slow stirring that considers the speed to prevent floc rupture due to excessive pressure, so it must consider the difference in water levels that exist in each compartment. This slow stirring aims to produce large floc particles that easily settle quickly (Jannah*et al.*, 2020).

the analysis of the flocculation unit, the detention time (td) parameters in the flocculation unit may not have values that are too large or too small, because if the value of td on the flocculation unit is too large there will be precipitation of the formed floc, and if the td value is too small causing floc to not form optimally (Jannah*et al.*, 2020).

2.2.5 Sedimentation

"Sedimentation is a physical water treatment process using gravity to remove suspended solids from water. Solid particles entrained by the turbulence of moving water may be removed naturally by sedimentation in the still water of lake sand oceans. Settling basins are ponds constructed for the purpose of removing entrained solids by sedimentation" (Alemayehu, 2019).

In this process, the majority of the solid are removed by gravitational settling; particles that do not settle and are still suspended are removed during filtration process (EPA, 2017).

2.2.5.1 Factor affecting sedimentation and limitation

Many factors clearly affect the capacity and performance of a sedimentation tank: surface and solids loading rates, tank type, solids removal mechanism, inlet design, weir placement and loading rate. Sedimentation (settling) is the separation of suspended particles that are heavier than water. Experimental and numerical investigations show that the performance of the sedimentation basins is influenced by velocity field variations and the geometry of the tank, especially, the location of the inlet, medium and outlet baffles (Razmi*et al*., 2009).

2.2.6 Filtration

Filtration is the process of passing water through material to remove particulate and other impurities, including floc, from the water being treated. These impurities consist of suspended particles (fine silts and clays), biological matter (bacteria, plankton, spores, cysts or other matter) and floc. The material used in filters for public water supply is normally a bed of sand, coal, or other granular substance. Filtration processes can generally be classified as being either slow or rapid (Alemayehu, 2019).

Rapid sand filtration is a purely physical drinking water purification method. Rapid sand filters (RFS) provide rapid and efficient removal of relatively large suspended particles. For the provision of safe drinking water rapid sand filtration require adequate pre treatment (usually coagulation and flocculation) and post treatment usually disinfection with chlorine (sustainable sanitation and water management book, 2019).

2.2.6.1 Factor affecting filtration

There different factor which affect the efficiency of rapid sand filtration those factor which affect filtration rate and cake moistures in plants or laboratory de watering system and processes:- Particle size of solid, filter aid, feed solid concentration, filter thickening, slurry P^H, flocculation(dispersion of fine solids), slurry age, viscosity of liquor and temperature, agitation speed, type of filter medium, filter cloth condition, applied vacuum, cycle time, surface tension and cake compression (Michaud, 2015).

2.2.6.2 Performance evaluation filtration

The performance of sedimentation stage and filtration stage in Khanqin City Water Treatment Plant are evaluated a removal efficiency between the turbidity of the raw water and treated water turbidity’s in the treatment plant (Issa, 2017).

“Sand flirtation is effective in removing suspended and colloidal matter and reduce a number of bacterial substantial and also change the chemical characteristic of the water by using different layer of sand so it is appropriate technique to use sand for water treatment”(Yousaf*et al*., 2013).

Samples were collected from both clarified and filtered water. Tests conducted were on fecal coliform, iron, manganese, sulphate, turbidity, colour, pH, and temperature. The mean estimated fecal coliform bacteria in samples collected from clarified water were 230/ 100 ml. After the clarified water pass through the filter media coliform bacteria and colour was removed by 100% and turbidity by 98.1 per cent. All parameters measured show positive agreement with WHO guideline values (Deboch and Faris,1999)

2.2.6.3 By product of sand filtration

In rapid sand filtration there is a big amount of sludge where produced in this sludge there will be metals which used in coagulation step and also ammonium. So these chemicals are toxic to aquatic life when we discharged to the river or stream (from reading notes).

2.2.6.4 Back washing in rapid sand filtration

For a filter to operate efficiently, it must be cleaned before the next filter run. If the water applied to a filter is of very good quality, the filter runs can be very long. Some filters can operate longer than one week before needing to be backwashed. However, this is not recommended as long filter runs can cause the filter media to pack down so that it is difficult to expand the bed during the backwash. Treated water from storage is used for the backwash cycle. This treated water is generally taken from elevated storage tanks or pumped in from the clear well. The filter backwash rate has to be great enough to expand and agitate the filter media and suspend the floc in the water for removal. However, if the filter backwash rate is too high, media will be washed from the filter into the troughs and out of the filter (Davis, 2019).

When Backwashing is needed the filter should be backwashed when the following conditions have been met. The head loss is so high that the filter no longer produces water at the desired rate Floc starts to break through the filter and the turbidity in the filter effluent increases; and/or filter run reaches a given hour of operation, Operational Troubles in Rapid Gravity Filters: - Air Binding, Formation of Mud Balls and Cracking of Filters. To avoid air binding problem, the filters are cleaned as soon as the head loss exceeds the optimum allowable value. Remedial measures to prevent cracking of filters and formation of mud balls breaking top fine mud layer with rakes and wash off the particles. Wash the filter with a solution of caustic soda. Removing, cleaning and replacing the damaged filter sand (Davis, 2019).

2.2.7 Disinfection process

"Disinfection is the most widely used treatment process in drinking water treatment it remove water related disease like typhoid and cholera in this process chlorine is used mainly as chemical oxidant and also the residual chlorine helps the water not been polluted through distribution system" (Ghernaout and Elboughdiri, 2020).

2.2.7.1 Factor affecting disinfection process

Disinfection technology is affected by factors like residence period, P^H and temperature (Ghernaout and Elboughdiri, 2020).

The principal factors that influence disinfection efficiency are disinfectant concentration, contact time, temperature and P^H. Disinfectant concentration and contact time are integral to disinfection kinetics and the practical application of the CT concept (CT being the disinfectant concentration multiplied by the contact time).Temperature, over the range appropriate for drinking-water, affects the rate of disinfection reactions according to the Arrhenius equation, although this may not hold for certain disinfectants at low temperatures. The pH of the disinfectant solution affects their action kinetics. For example, the disinfection efficiency of free chlorine is increased at lower pH values, whereas that of chlorine dioxide is greater at alkaline pH levels. Mono-chloramines are formed within seconds in the pH range7–9. (LeChevallier and Au, 2004).

2.2.7.2 Chlorination

"Disinfection is the most widely used technology for water treatment process to remove pathogen which cause disease like typhoid and cholera by using chemical oxidant like chlorine which is effective in removing (killing) pathogens" (Ghernaout and Elboughdiri, 2020).

Chlorine, added to water in the form of either as hypochlorous acid/hypochlorite ion or as chlorine gas, is still the most widely applied and most cost effective disinfectant worldwide, despite the well known problems of disinfection by product (DBP) formation. Before treated water leaves the water treatment plant, there's chlorination unit to maintain certain chlorine residual in the distribution system (Rahmani *et al*., 2013).

"Free residual chlorine is the amount of chlorine present in the water after disinfection process to indicate that the water is steel free of pathogen and it a safety for the water to be clean and potable to drink" (Rahmani *et al*., 2013).

Chlorine is added to the water to kill and/or inactivate any remaining pathogens. Water is often the different parameters on the two studied responses disinfected before it enters the distribution system to turbidity and aluminium sulphate so it is impossible to ensure that potentially dangerous microbes are killed. Simultaneously optimize both of them. We also could Chlorine, chloramines, or chlorine dioxide are most often conclude that after perused because they are very effective disinfectants, not ozonation, alum coagulation was applied and it was only at the treatment plant (Angreni, 2009).

2.2.7.3 Disinfection by product

Disinfectants, usually chlorine, can react with natural organic matter (NOM) in aqueous environments to form disinfection by-products (DBPs) in drinking water treatment processes (Zhou*et al*., 2019).

Disinfection is a critical step in drinking water treatment usually performed to safeguard the public health from pathogenic microbes and waterborne diseases. Harmful pathogens in water are destroyed by the use of disinfectants such as chlorine, chlorine dioxide, chloramines, ozone, and ultraviolet light. However, some naturally occurring organic matter, anthropogenic contaminants, bromide, and iodide are also present in water, and when a chemical disinfectant such as chlorine is added to water, it tends to react with organic matter to form disinfection by products (DBPs), which are known to have adverse health effects on humans. Disinfection by products (DBPs) are known for their carcinogenic, mutagenic, cytotoxic, genotoxic, orteratogenic effects. However, the formation of DBPs is a function of several factors such as the pH, temperature, source water characteristics, type of disinfectant, and residence time (Nsikak*et al*., 2017).

Disinfection by chlorination is the most important step in water treatment for public supply as chlorine remains in the water as long as it is not consumed. However, chlorine also reacts with the natural organic matter present in the water and produces a number of by-products with harmful long-term effects. During the disinfection process using chlorine, this disinfectant used in the drinking water treatment may convert soluble organic substances to harmful disinfection by-products including trihalomethanes(Issa, 2017).

The residual concentrations of disinfectant for the control of microbes, it may greatly elevate the generation of disinfection by-products (DBPs) (Ghernaout and Elboughdiri, 2020).

The residual chlorine ranged between 1.0 – 4.0 mg/l from various sampling points of treated water supply. It decreased to 1.0 mg/l in the some times and places in the water supply network and increased in other time and places that reached 4.0 mg/l. This increase may indicate contamination of the river and the incidence of a disease-producing organism in the raw water (Issa, 2017).

In disinfection processes the residual chlorine is the by product always for the treatment of the water after the distribution but in some cases excess chlorine is harmful due to its accumulation in human or animals body so it must be treated.
"Chemical disinfection in drinking water reduce infectious water born disease but disinfectant like chlorine react with natural organic matter to produce DBP, among them trihalomethanes(TTHMs) and haloacetic acids (HAAs) are found at the highest concentrations in treated drinking water from reaction of chlorine" (Domínguez*et al*., 2017).

2.2.7.4 Evaluation of disinfection process

In Khanqin City Water Treatment Plant the disinfection efficiency in removing bacteria was measured or evaluated by using E. Coli test , from the standard where E. Coli for water is zero but the result they found was negative (-ve) so they recommended that the KCWTP disinfection stage is effective in removal of bacteria(Issa, 2017).

The amount of disinfectant added to the water is referred to as the dose, and is usually measured as the number of milligrams added to each litre of water (mg/l). The amount of disinfectant destroyed in the reaction with the substances in the water is called the demand.

The amount of chlorine (either free or combined) that remains after a certain contact time is known as the residual chlorine. The residual is also important as a check on the effectiveness of the dosing. When chlorine is added to water, a certain period of time is required for the chlorine to react with the micro-organisms and compounds in the water. This time is called the contact time, and a minimum of 30 minutes is usually recommended. The presence of the residual chlorine should be determined only after the specified retention time. If a 30 minutes retention time was set, then the monitoring should be done after that time has elapsed. This is what is called the CT concept (concentration after a certain contact time). The concept uses the combination of a disinfectant residual concentration (in mg/L) and the effective disinfectant contact time (in minutes), to quantify the capability of a chemical disinfection system to provide effective pathogen inactivation to the required level. The use of this concept involves determining the CT values required at the actual, often variable, operating conditions (flow, temperature, and pH) and ensuring that the employed disinfection process achieves these values at all times (G/Tsadik.T, 2013).

Filter performance can be evaluated by various methods, such as on-line measurement of effluent turbidity (from individual and combined filters) and counting of particles or other surrogates for microbes. To provide comprehensive process control for filtration, it may be useful to measure other operational parameters related to filter performance (e.g. rate of head loss) (LeChevallier and Au, 2004).

2.3 Management and control practice in conventional water treatment plants

In developed countries, a wide implementation of water treating technologies and a proper management has led to a remarkable reduction of the risks associated to water ingestion (López-Roladen *et al*., 2016).

Urban water resources should be managed sustainably to achieve an appropriate balance between water demand and supply. This balance is increasingly difficult to sustain as urban areas increase in size, and precipitation decreases due to climate change. Traditionally, water shortages are managed through supply management, which is based on the assumption that economic growth generates new demands. Supply management does not control demand, but increases the supply to meet demands (Ali *et al*., 2017)

As a common practice, aluminium sulphate is applied according to the jars test results. The problem is to determine the optimal dose of aluminium sulphate related to raw water characteristics. Manual method is consisting to determine the quantity of the coagulant to apply experimentally and based on the jar test results. Jar test involves taking a raw water samples and applying different quantities of coagulant to each sample. After a short period of time, each sample is assessed for water quality and the dosage that produces the optimal result used a set point. This operation should be repeated by the operators each time when the quality of raw water changes. The aluminium sulphate is the compound likely to be mathematically modelled and therefore its value can be estimated according to the data available in the treatment plant. The optimization of using the coagulant is very interesting approach because under dosing of coagulant can lead to poor quality drinking water while too much coagulant leads to many operating problems (less efficient filtration and sedimentation, PH), healthy problems and can increase the cost of treated water (Farhaoui and Derraz, 2016).

Management plans describing actions to be taken during normal operation and documenting the system assessment (including upgrade and improvement), monitoring and communication plans and supporting programmes (LeChevallier and Au, 2004).

Chemical coagulation pre-treatment is the most important factor in ensuring efficient removal of microbes by coagulation, flocculation and clarification and by granular media filtration. It also indirectly affects the efficiency of the disinfection process. Although the coagulation process itself is unlikely to cause any microbial hazard or risk to finished water, a failure or inefficiency in the coagulation process could result in a high microbial risk to drinking-water consumers. Hazard control strategies for the coagulation process the first step is to choose an appropriate coagulant (and coagulant aid if necessary) and dose. Next, it is important to ensure that the chemical feed rate is appropriate for the plant flow, because changes in flow rate could result in an over or under-dose of coagulant, impairing performance. Water chemistry and temperature can affect the performance of many coagulants, and adjustment of pH may be necessary for optimal performance (LeChevallier and Au, 2004).

Critical to the performance of effective flocculation is gentle mixing to promote particle aggregation. The calculation of the velocity gradient necessary for proper flocculation can be estimated by the G value (LeChevallier and Au, 2004).

Most of conventional treatment processes, an adequate level of disinfection is critical for reducing microbial risk to acceptable levels. Microbial pathogens include highly diverse groups and it is impossible to monitor the survival of all pathogens. Estimating the level of inactivation of more resistant microbial pathogens, by applying the CT concept (disinfectant concentration and contact time) for a particular pH and temperature, ensures that more sensitive microbes are also effectively controlled (LeChevallier and Au, 2004)..

2.4 Water supply from treatment plant and institutional demand of water

The sustainability of water resources depends on the dynamic interactions among the environmental, technological, and social characteristics of the water system and local population. These interactions can cause supply-demand imbalances at diverse temporal scales, and the response of consumers to water use regulations impacts future water availability. This balance is increasingly difficult to sustain as urban areas increase in size, and precipitation decreases due to climate change. Traditionally, water shortages are managed through supply management, which is based on the assumption that economic growth generates new demands. Supply management does not control demand, but increases the supply to meet demands (Ali*et al*.,2017).

The diversity of water use within urban areas is worth attention due to the substantial number of ongoing activities. The main uses for water in urban areas are residential, commercial, industrial and institutional (Das Gracas Batista, 2018).

Demand forecasting models based on water supply and demand assessment are an asset to enhance actions of water managers and urban planners (House-Peters and Chang, 2011).

"To promote demand reduction understanding the factors that affecting water use helps to improve water management strategies especially in vulnerable regions due to extreme climatic change or growing population" (Das Gracas Batista, 2018).

"Since urban area is continuously grow the authority must provide safe water to the public so the authority work on developing suitable model for control and management practice of the water in accordance with need of community which live around the urban area use the water from the water supply" (Das Gracas Batista, 2018).

2.5 Research gap

There are different researches made in Jimma city water treatment plant and water supply capacity of the town. But those researches mainly focused on the source, type and causes of pollution at the source of the water (river) and also other researches made on the supply and demand of the drinking water of the plant to the town. But this study was focused on evaluating each treatment unit of the treatment plant capacity (efficiency) in providing treated water and the by product at each treatment unit was evaluated and also the control practice at each treatment unit was evaluated. So, these points are the main difference between other researches made before.

CHAPTER THREE
METHODOLOGY

3.1 Study area

Jimma city water treatment plant is located in Jimma 350 km southwest of Addis Ababa at an average altitude of 1780 m above sea level and is characterized by a temperate rainy climate with a warm summer. The city has a population density of about 3521 person perkmin 2015 and an average population growth rate of 4.9% per year. East African cities like Addis Ababa, Nairobi, and Mombasa have higher population levels and lower population growth rates. Jimma is therefore considered as a fast growing mid-sized East African city, similar to the Ethiopian cities Nekemte and Shashemene (N De Troyr*et al*., 2016).

There are two major rivers flowing through the city: Awetu, which bisects the centre of the city and Kito, which flows at the western end. At the eastern part of Jimma, some smaller rivers (Dipo, Seto, Kochi, University Stream, Aramaic, and Dololo) are present. South of Jimma, these rivers merge together and flow into Boye wetland, a large water body covered by vegetation. This was initially a pond but became overgrown by vegetation due to eutrophication. Eventually, the water from Boye ends up in the Gilgel Gibe River below the intake point of the water treatment plant of Jimma. The rivers are bordered by wetlands, which harbour a high diversity of foraging and breeding birds. The discharge of untreated domestic, industrial, and institutional wastewater, the disposal of solid waste, drainage, farming, clay mining, removal of riparian vegetation, and intensive livestock grazing threaten these valuable freshwater ecosystems (N De Troyr*et al*., 2016).

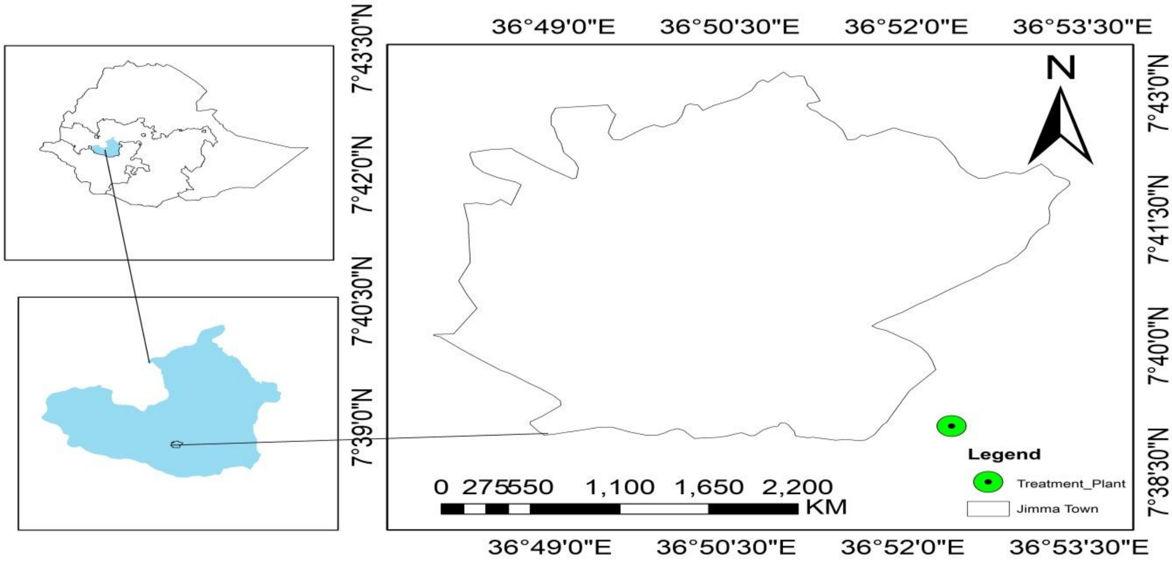

Figure 3.1 map of study area of Jimma city

3.2 Materials

Table 3.1 materials used for the study

Material (equipment)	Function
Sampling bottle	To collect the sampled raw water from each treatment unit
Taste tubes	Used to take equal quantity of sampled water to measure chemical, physical and biological parameters
Icebox	Used to protect the sample from being contaminated and keep them safe
Knife/spoon	Used to take chemical samples
Filter paper	For filtering the raw water to measure the chemical parameter and mainly for biological measurement
Distilled water	To wash the equipment to (clean the equipments)
Incubation machine	Used to measure bacteria
Sterilization machine	To kill the contaminant (impurities) from the instruments
Refrigerator	To keep the sample safe
Chemical reagents	Tu measure chemical parameters
Digital multi parameter (HI9829 model)	To measure the physical parameters
Spectrophotometer (model 6405UV),	Used to determine Ammonia and nitrate
Photometer (modeHQ40Dl)	Sulphate, manganese and iron
Jar	Jar test used to calculate chemical dosing in coagulation
Pipet	Used to add and decrease distilled water sampled water and chemical reagents

3.3 Study period

The study takes around seven months to accomplished (December – July)

3.4 Study design

Experimental and observation research design were used to evaluate the drinking water treatment plant capacity and water production quality. An experimental design was used for measuring the physicochemical and bacteriological quality of water at the source, treatment plant. The observational design was conducted by using the cross-sectional technique to inspect the design capacity of the major unit process, unit operation and to evaluate the quantity of water produced by the treatment plant.

3.5 Population

Population is the most determinant factor in water treatment plant. Now a day's Jimma city was growing fast due to this migration to the town was increasing from time to time. This increased the demand of potable water of the city. So, the study focused to improve the capacity of treatment plant and investigating the population density of the institution.

3.6 Sample size and sampling procedures

3.6.1 Sample size

One of the objectives of sampling was to assess the quality of the water supplied from JCWTP and at the point of the use. So, the samples at the site were taken carefully. Samples taken from the location was represents both the source of the water and the treatment plant. Also samples taken from all stage of the treatment plant starting from intake part then at each treatment unit and at the distribution step was measured. To determine the by product at each treatment unit the in and out water was taken as a sample and also the sample was taken for determination of alum dose by using jar test. For the demand of the institution the sample was taken from record material of a various institutions in the town and collected from Jimma city water supply and sanitation sector and other related sectors

Table 3.2 sample size

Sample location	Unit	days	Sample size
Raw water at the intake	Litter	3	2
Aeration	Litter	3	8
Flocculation	Litter	3	2
Sedimentation	Litter	3	2
Filtration	Litter	3	2
Disinfection	Litter	3	2

3.6.2 Sampling procedure

The sampling procedure was performed in the correct way by considering different factors that may affect the sample. Water was taken from different place at different time in order to obtain an accurate result. The bottles were cleaned by using distilled water. At the time of sampling, the bottles were labelled based on the sample station codes and again carefully rinsed three times by using the water which was taken as a sample and the sampling done by Collecting the samples that are representative of the water tested; use septic techniques to avoid sample contamination; The sample water was taken before and after each treatment unit of the treatment plant; The sample were taken with different material for each treatment unit; Determine number of institutions in town; investigate intake capacity of each institutions

3.7 Sample Analysis

All the water samples were analyzed in Jimma water supply laboratory and Jimma university environmental health science laboratory.

The physical parameters like turbidity, pH, Electrical Conductivity (EC), Temperature and Total Dissolved Solids (TDS) were measured, using digital multi parameter instruments (HI9829 model) immediately on the spot just as soon as sampling was performed. The rest both chemical and biological parameter were transported to the laboratory in the ice box and stored under the suitable temperature at $40^{o}C$ until analysis and transported to the laboratory.

The chemical analysis was carried out for Ammonia was determined by direct nesslerization method by using spectrometer. Chloride and alkalinity determined volumetric titration method. Total Hardness and calcium was determined by EDTA titration method. Nitrate was determined by spectrometer methods. Sulphate, iron and manganese determined by photometer (7500) and residual Chlorine was determined by using reagent DPD measured by photometer methods. All the results were compared with standard limits recommended by (WHO, 2004).

The microbiological analysis was conducted by using membrane filtration methods. Finally, in order to evaluate the treatment plant in terms of water production quality, the treated water was compared to water quality standard (WHO and national) guideline. Also, Jar test would be done on the raw water sample to obtain the optimum pH and alum dose for optimum coagulation and the results compared with the situation in the field.

3.8 Study variable

3.8.1 Dependent variable

- design efficiency of water treatment plant

3.8.2 Independent variable

- Treatment units (aeration, coagulation, flocculation, sedimentation, filtration and disinfection)
- By product (chemical parameter, physical parameter and biological parameter)
- Drinking water (demand of institution)

3.9 Data collection

3.9.1 Qualitative data

Data were collected from the source were the treatment plant was located by questions presented in annex1; interview the operator and observation method was applied to recognized the actual practice of the treatment plant. To assess performance and operation flexibility of the existing processes, chemical feed systems, process control, maintenance and safety of the treatment plant. Also data gathered from different sources such as internet, national mapping agency, ministry of water and energy, Jimma water supply office, from different researches, in our institute of Jimma university and from the community of the city etc.

3.9.2 Quantitative Data Collection

I. Investigating design parameter

The performances of plant operations were assessed based on the recommended design parameter of major process unit and standard operation criteria to meet their performance goals. “These include; raw water intake, rapid mix, flocculation, sedimentation, filtration, and disinfection operation (G/Tsadik, 2013)

A. **Coagulation and Flocculation** were purification methods which work by using “chemicals that effectively “adhere” small suspended particles together so that they settle out of the water or stick to sand or other granules in granular media filter. “The design parameter of coagulation and flocculation are based on addition of coagulant, rapid mixing, Flocculation and removal of flocks. For designing rapid mixing and flocculation processes was measure by (G) value. Therefore; the efficiency of the flocculation process was largely determined by the number of collisions between the minute coagulated particles per unit of time (GT value). The mean velocity shear gradient (G) was given by (G/Tsadik, 2013).

$G = \sqrt{P/\mu v} = \sqrt{Q\varrho gh/\mu v}$ --Eq. (3.1)

Detention time (T) was calculated by the following formulas

$T = V/Q$ --Eq. (3.2)

In the hydraulic rectangular weir rapid mix unit, the dimensions and the head loss (hl) were measured by using meter tape. The rate of energy dissipation (P) is given by the mass flowrate and head loss: Power transmitted to the water (watt).

$P = (QP) \times (gh)$ --Eq. (3. 3)

Where; G is velocity gradient (s^{-1}), T is detention time (minutes), P is density of water = 1000 kg/m^3, g is gravitational acceleration = 9.81 m/s^2, hl is head loss of the water (m), Q is volumetric flow rate in m^3/s, V is volume of the unit (m^3), μ is dynamic viscosity of water (poises, kg/m.sec), = 1.01x10-3 at temperature 20°C

The Headloss (hl) was determined by measuring the height differences of initially entering water level and the level of water at the out let chamber.

Alum was used as a chemical coagulant in the treatment plant. To calculate the dosage of alum the following procedures would be following:

Alum solution concentration was determined by the following for

$\text{Alum slution} = \frac{\text{mass of alum(Kg)}}{\text{volume of tank (L)}}$--Eq. (3.4)

Alum feed rate would be measured by collecting samples in a graduated cylinder for a specified time. For raw data collected during field evaluation.

Then the result in ml/min will be converting to mg/L of the Alum solution.

$\text{Alum feed} = \frac{\text{Alum solution(mg/L)}*\text{volume of pumped(L)}}{\text{time pumped(min)}}$--------------------------------------Eq. (3.5)

Alum dose was determined using the following formula

$alum\ dose\left(\frac{mg}{L}\right) = \frac{raw\ water\ flow\left(\frac{m^3}{day}\right)}{alum\ feed\ (\frac{mg}{L}}$---Eq. (3.6)

The results of the discussion with the operators, field observations and evaluations were intended to answer the following operational procedures and methods so as the factors limiting performance of the unit were identified.

B. Sedimentation

Sedimentation is the tendency for particles in suspension to settle out of the fluid which they were entrained and come to rest against a barrier. The unit sedimentation basin may also be referred to as sedimentation tank, clarifier, settling basin, or settling tank. The length, width, and depths of the sedimentation basin were measured by using meter tape and rope. The design of sedimentation basin was governed by three basic parameters like the quantity of water to be treated (Q), the selected detention period (T) and the selected surface loading rate settling velocity (So). Were calculated by the following formula

$$So = \frac{H}{T} \text{ --Eq. (3.7)}$$

$$T= \frac{BHL}{Q} \text{---Eq. (3.8)}$$

Where: So is Settling velocity (m/h),T is detention time (hour), H is depth of tank (m), B is width of tank (m), Lis length (m) andQ is flow rate (m^3/hr).

C. **Filtration rate**

The filtration rate was calculated by using the following formula.

$$\text{Filteration rate}(m^3/\,hr) = \text{filter surface area} * \text{filter loading rate} \text{-------------------Eq. (3.9)}$$

D. **Disinfection** The effectiveness of disinfection with chlorine was depending on the bases of design parameter of disinfection like the pH of the water, Turbidity of the water, the concentration of chlorine, contact time, water temperature and Presence substances (ammonia) affecting the effectiveness of disinfectant for this reason the effectiveness of disinfection was evaluated by using design parameter. The type of chemicals used for disinfection, the concentration, dosage, and how it is calculated was discussed with the operators. The operating reliability system of disinfection was confirmed by comparing the results with the recommended standards. Calcium hypochlorite (bleaching agent) 65 % available chlorine is used in the treatment plant (G/Tsadike, 2013). The feed rate and concentration of chlorine are determined as below. The percent solution was determining by using the following formula.

Percent solution $= \frac{\text{mass of calcium hypochlorite(Kg)}}{\text{volume of water(L)}}$------------------------------------Eq. (3.10)

The chemical feed rate was determined by filling volume of chemical in a graduated cylinder in specific time. Then ml/min will be converted to mg/l.

$Chlor(\frac{mg}{L}) = \frac{\text{feed rate}(\frac{\text{mg}}{\text{min}})}{\text{raw water flow}(\frac{\text{m}^3}{\text{hr}})}$---Eq. (3.11)

II. Assessing the quantity of water produce

In this part another thing was to examine the quantity of water that produce by the treatment plant, it was evaluated by comparing the capacity of treatment plant design to produces and current population and for the future 20 years because of the standard of treatment plant design for 25-35 year. This would be done by using an arithmetic method to estimate the future population which enables to estimate total demand of water by computing into the formula. The formula was given below

$Pf = P2 + Po\left(\frac{P2-Po}{t2-to}\right)tf - t2$---Eq. (3.12)

Where; Pf is future population,P_2 is present population, P_o is initial population, t_f is future year, t_2 is present year, t_o is initial year

III. Determination of rated capacities of major unit processes

The need to determine the rated capacities of individual unit processes was to compare with recommended design loading rates and evaluate the design capacity. After selecting appropriate loading rates for individual unit processes; the capacities of major unit processes were determined by using the following formulas

Clarifier (sedimentation and flocculation) basin capacity $= \frac{basin\ volume\ (m^3)}{detention\ time(\text{min})}$--------Eq. (3.13)

Filtration basin capacity= filter bed area (m^2) * filter loading rate($L/min/m^2$) ------Eq. (3.14)

Disinfection (Clearwater − well) capacity $= \frac{effective\ volume(m^3)}{required\ contact\ time(\text{min})}$ ------------------Eq. (3.15)the results of the calculations were used to develop a performance potential graph and the capacities of unit processes would be compared with the peak daily water demand.

IV. Assessment of unit processes performance

Assessment of unit processes performance was conducted by reviewing existing recorded data and conducting field evaluations. The quality of finished water and turbidity were used as indicators of performance. Results were compared with WHO drinking water standard requirements and reveal the performance status of the units (G/Tsadik, 2013 by referring USEPA, 1991).

i. Performance assessment based on turbidity goals

The performances of sedimentation and filtration units were evaluated by measuring their effluent turbidity.A digital multi parameter instrument (HI9829 model) was used for turbidity measurements.

a) Sedimentation performance

The performance of sedimentation process was assessed in accordance to the WHO turbidity goals of settled water consistently less than 10.0 NTU throughout the year, and no greater than 10.0 NTU, despite raw water turbidity fluctuations.

The performance assessment procedures are presented as follows:

Settled water samples were collected from the effluent of the basins. Samples were collected from the basins for 10 days. Then settled water turbidity was measured and the turbidity results versus time were plotted in a graph.

b) Filtration performance

To assess the performance of the filtration units; continuous measurement of effluent turbidity though out the filter run time was possible, because the treatment plant was operated for 24 hours a day. The performance filtration is measured in accordance with WHO standard of 5NTU.

ii. Identification of Performance Limiting Factors

After design, operation and maintenance data has been gathered and the performance of the treatment operations was assessed; an in-depth analysis was conducted to identify the specific factors that limit performance.

The 50-checklist performance limiting factors of USEPA handbook (G/Tsadik, 2013)was adopted in this study, to define each factor according to its specific cause of poor plant performance. Lists of defined factors for Assessing Performance Limiting Factors to identifying performance limitations associated with protection against microbial contaminants in the water treatment systems are presented in Annex 2.

In this study, major Performance limiting factors were categorized into design, operational and maintenance. The administrative factors were not identified because the current utility's administrator was new to the position and appropriate information cannot be found.

The performance limiting factors were identified according to the factors definitions presented in Annex 2. They were rated based on their adverse impacts on the performance as per the CEP rating system as A, B or C.

"A" rating for major effect on a long term repetitive basis; "B" rating for moderate effect on routine basis or major effect on a periodic basis and "C" rating for minor effect.

The identification of factors limiting performance categories under which factor name is listed in Table 3.3.

Table 3.3Performance limiting factors

Performance limiting factors category		
Design	**Operation**	**Maintenance**
Unit process adequacy	**1. Testing**	**1. Maintenance program**
A. Intake structure	a. Process Control Testing	a. Preventive
C. Aeration	b. Representative Sampling	b. Corrective
D chemical storage and feed facility	**2. Process Control**	**2. Maintenance resources**
E. Rapid Mix	a. Water treatment understanding	a. Materials and Equipment
F. Flocculation	b. Application of Concepts and testing to Process Control	b. Skills or Contract Services
G. Sedimentation	**3. Operational Resources**	
H. Filtration	a. Training Program	
I. Disinfection	b. Technical Guidance	
	c. Operational guidelines	

V. Assessing the quantity of water used by institutions

In this part another thing was to identify the quantity of water that used by institutions from the treatment plant, it was evaluated by comparing the capacity of treatment plant design for 25-35 year. This would be done by using the initial demand of institution and the current demand of the institutions in the town from the supply capacity of the treatment plant. This computed by gathering data from each institutions number of water mater and their billing in month.

3.10 Data processing and analysis

The study data processed and analysed done at JU environment biology laboratory for the major physical, chemical and biological parameter collaborated with Jimma city water supply office. And also the data processed for demand analysed by collecting record material from the Jimma city water supply office, institutions in the town and the design paper from a person who works at the treatment plant during construction period determine the supply amount of water to the institute from the plant.

The management and control practice evaluated by visual observation and from the interview with the persons which are responsible.

3.11 Ethical consideration

Ethical approval or clearance to carry out the study was obtained from Jimma University Environmental Engineering chair. Data and sample collection were conducted after obtaining informed consent from the concerned offices such as Zonal, and town water supply offices and Different administration offices. Study objectives were clearly explained to administration offices and water supply offices.

3.12 Dissemination plan

The result of this study will be presented to Jimma Institute of Technology Faculty of Civil and Environmental Engineering, Environmental Engineering chair and will be disseminated to Jimma city water supply office and other governmental and non-governmental organizations, which are concerned with the study findings. Publication in national and international journals will also be considered.

CHAPTER FOUR
RESULT AND DISCUSSION

4.1 Treatment unit capacity evaluation

4.1.1 Raw water intake capacity

Jimma city water treatment plant is located in Jimma 350 km southwest of Addis Ababa at an average altitude of 1780 m above sea level. Boye River located at X, Y coordinates 265415, 846258 and at an average elevation of 1708m. The normal raw water pumping level at the Intake is taken as 1703 m and the top water level at the inlet chamber at Treatment Works is 1727 m.

There are 4 raw water pumps of design capacity 450m^3/hr each. Two pumps were operated at the same time while the other two left as standby. The pumping capacity at optimum operation practice has the potential to produce 21600 cubic meters of water per day, in 24 hours operation. While the designed demand of water for the public was 21,048.7m^3/day.

During the field visit; the raw water flow from the two operating pumps are 900m^3/hr so the pumps were operated well as their design capacity. This mean the current peak operating flow rate satisfy the required peak daily demand of population served.

4.1.2 Coagulation/ rapid mix

The treatment plant has a Hydraulic rapid mix of raw water and coagulant with a mixing head of 0.5 m. The Alum concentration was 1%. The feed rate of alum varies depending on the raw water characteristics, but during the evaluation period the calculated alum feed from (equation 3.5) was found to be 38 kg/m^3/hr and from (equation 3.6), the Alum dosage was 40 mg/L this was in the range of the recommended optimum dose of 5-85 mg/l and also the flow rate (feed in L/hr) was 380 L/hr.

The pH of the coagulated water was found to be 6.97. pH between 6 to 7 is an effective range for Alum flocculation (IRC, 1991) the raw water pH was within the suggested range hence no need of pH adjustment. From the interview of operator and field observation once the jar test was done the floc formed used to check optimal dosage and making appropriate adjustment to chemical feed was checked by using observation. Without measure the physical parameter and take a scientific measurement, the pH of coagulated water never checked even while conducting jar test, the operator does not decide the dose of alum based on the minimum value of pH which highly reduces turbidity or higher amount of flock formed by measuring pH and turbidity after jar test. Therefore, when the jar test was conducted on the basis of to achieve optimal coagulant dose, optimum pH and proper alkalinity control at the chemical pre-treatment stage was basic for this reason jar test must be done when the situation of floc formation will be changed and consider another factor.

4.1.3 Flocculation

Basically flocculation shall be carried in the Up flow Sludge Blanket Clarifiers at large. It is worth mentioning that, flocculation process will start in the pipes conveying the coagulant dosed water from the hydraulic rapid mixer to the clarifiers and in the bottom section of the clarifiers. The result of gradient velocity for the flocculation take place in the channel from (equation 3.4) is $69.2s^{-1}$. Channel length of 20m and a volume $3.7m^3$with a flow velocity measured is 0.57m/s and head loss calculated by using a formula ($h_l=v^2/2g$) is 0.01166m and in the clarifier the flocculation take place in a detention time of 21minute and it is difficult to calculate the gradient velocity. In addition to this the piping system and appurtenance work have been designed to fit the flocculation requirement. The flocculation stage of the plant in the first section of the channel the gradient velocity is result is good which mean in the range as designed($10\text{-}100s^{-1}$) and the detention time given for the floc formation is 21 minute in the clarifier is also fit the design criteria given which is (15-30 s). But in this type of flocculation the floc forms in the clarifier of settling basin so it is difficult to know whether the floc is forming effectively or not.

This shows that the flocculation stage of the plant is not suitable for the operator to check the removal capacity of impurities from the raw water. Also from the oral interview the operator had a limitation of knowledge in this stage that means it did not know where the flocculation stage takes place.

Table 4.1Comparisons of actual plant flocculation and design criteria

Topic	Description	Information	
Genera flocculation information		Actual	Design criteria JCWTP design, 2008
	Type	Up flow sludge blanket clarifier	
	Maximum Velocity at Inlet(m/s)	0.57	0.6
	Velocity gradient(s^{-1})	69.2	10-100
	Detention time for the channel(s)	36	30-48
	Detention time in clarifier(min)	20	15-30

4.1.4 Sedimentation

The plant has six (6) trapezoidal sedimentation clarifier of 8m length and 8m width each side with two(2) row. This clarifier type is up flow sludge blanket clarifier which used for both sedimentation and flocculation. Each settling basin has a surface area of 38.05m^2 and a total of 228m^2 and total volume of 1826.4m^3 The detention time calculated from equation (3.8)2.03hr. But detention time of the design was (1-2) hour so this is not out of range. This indicated that the time taken for settling somewhat greater than the required design but the plant was operated well as design flow to the sedimentation basins. Surface loading rate settling velocity calculated by using (equation 3.7) was 3.05 m/hr the design settling velocity range (2.5-5m/hr) design range. The depth of water measured at the time of visiting the treatment plant was 6.2 which was less than the design value 6.4 this show that the clarifier somewhat field by sludge this decrease the required amount of treated water. The field evaluation results of the actual sedimentation basin and the design criteria are summarized in the table

Table 4.2 Comparisons of actual plant sedimentation performance and design criteria

Topic	Description	Information	
General sedimentation information		Actual	Design criteria JCWTP design, 2008
	Type	Upflow sludge blanket clarifier	Upflow sludge blanket clarifier
	Settling velocity(m/hr)	3.05	2.5-5
	Detention time(hr)	2.03	1-2
	Depth of water(m)	6.2	6.4

From the interview with the chemist routine removal of sludge from the sedimentation is not practiced since the treatment plant was giving function. This indicated that too much floc was being accumulated at the bottom of the basin for a long-time and become septic causing the sludge to bulk. So this decrease the efficiency of the clarifier in removing impurities with required capacity.

4.1.5 Filtration

The filtration basin type of Conventional - Rapid Gravity Sand Filters used in this JCDWTP has a discharge of (equation 3.9) 897.6m^3/hr and the loading capacity selected is 4.98m^3/hr/m^2. The filter loading rate is somewhat less than the desired value for quantity of water. This indicate that the flower filter rate decrease the capacity of the filter which affect the quantity of water produced Operators replied during the interview that the effluent turbidity of filter units was not monitored routinely. Proper influent flow and effluent turbidity monitoring are essential to maintain the desired filter performance. During the interview, the operator said that the sand media is not changed until know for six (6) years and they did not have the plan to change it. During this a long period, the effectiveness of the sand exhaustively depreciated and resulted in shorter filter run times, frequently washing of the filters.

Back wash of filters will be done by a combination of water and air to ensure economy in the usage of treated water. The interview with the operator in the site told me that the back wash done in three faces: the first face is washing the sand only by air then by water and air finally the washing was done by water only each face take 10 min a total of 30min is used for washing the filter media. But the time used to wash by air is higher than the recommended range of (3-4min). So, this had cause limitation on the performance of the filter media in providing the expected quantity of water. The design criteria used in this section was (G/Tsadik, 2013 referring Sujit*et al.*, 2002).

Table 4.3 Comparisons of actual plant filter performance and design criteria

Topic	Description	Information	
General Filtration Information		Actual	Design criteria of (G/Tsadik 2013,)
	Type	Conventional - Rapid Gravity Sand Filters	Conventional - Rapid Gravity Sand Filters
	Number of filter	6	
	Dimension		
	Length per stage(m)	6.8	
	Width per stage(m)	4.4	
	Total surface area(m^2)	179.5	
	Media condition		
	Sand depth	750	500-1000
	Supported gravel(mm)	450	450-600
	Filtration rate(m/h)	4.98	5-15
	Backwash Sequence	1) air scour 2) flow ramping 3) delayed start	1) air scour 2) flow ramping 3) filter-to-waste and/or delayed start
	Duration of each operation (min)	1) 10 2) 10 3) 30	1) 3-4 2) 10
	major unit process capacity(Selected Process Parameter)(s):		
	Surface loading rate($m^3/m^2/hr$)	4.98	

4.1.6 Disinfection

The filtered water was disinfected with Calcium Hypochlorite prior to store in the clear well. Chlorine concentration (equation 3.10) was 0.1% which is less than the design value of 0.5%

(G/Tsadik, 2013). During the visit time the chemist use dosing rate of 6mg/l which was above the design range kept (2.5-5mg/l) and calcium hypochlorite added was 114.42kg/day. And the percent solution used for 24 hour is 35 kilogram of calcium hypochlorite to 4m^3 of water. The chlorine dosing was out of the range but the residual chlorine determined was 0.6mg/L .The clear water well have a multiple baffled well was operated on a fill and draw basis.

Table 4.4 Comparison of actual plant disinfection performance and design criteria

Topic	Description	Information	
Disinfection		Actual	Design criteria fromJCWTP design,2008
	1. type	Contact type	Clear well
	T_{10}/T	0.5	1
	2.Dimension of disinfection water tank		
	Diameter (m)	15	25
	Minimum depth (m)	4	
	Total volume($m^{3)}$	900	
	Volume adjusted for T10/T($m^{3)}$	90	
	3. major unit process evaluation		
	Disinfectant	Calcium Hypochlorite	
	Max.disinfectant residual (mg/L)	0.6	1.5
	Maximum pH	7.13	8.5
	Minimum temperature (^{o}C)	23.9	5
	Required Guardia inactivation	0.5	0.5
	Assigned process capacity	19069.54m^3/day	

4.2 Major Unit process capability

Major unit processes (flocculation, sedimentation filtration and disinfection) were evaluated based on their capability, if basin size is adequate; to handle current peak daily water demand of the population served (T.G/Tsadik 2013).From the interview with the operator the daily demand of the treatment plant current capacity is in between 19000- 21000m^3/day this mean the mean value is around 20,000m^3/day. But from the design paper the population density in 2007 was 167,359 with average daily water demand of 7,022m^3/day and the prediction amount in 2025 was population density of 405,993 and average daily demand of 25,642m^3/day.From (equation 3.12) the present population calculated was 352,964. Depending on the future and the initial demand of water the current demand calculated by using interpolation was 19912.76m^3/day. This was in the range of the operator told (19000-20000m^3/day).The capabilities of major unit processes (from equations 3.13, 3.14, and 3.15) found clarifier (flocculation and sedimentation), filtration and disinfection units to be 21179.5, 21542 and 19069.54m^3/day respectively. Details of calculations are presented in Annex 3.

Comparison of major unit processes rated capabilities and the required daily demand of the population served is presented in the performance potential graph (Figure 4.1)

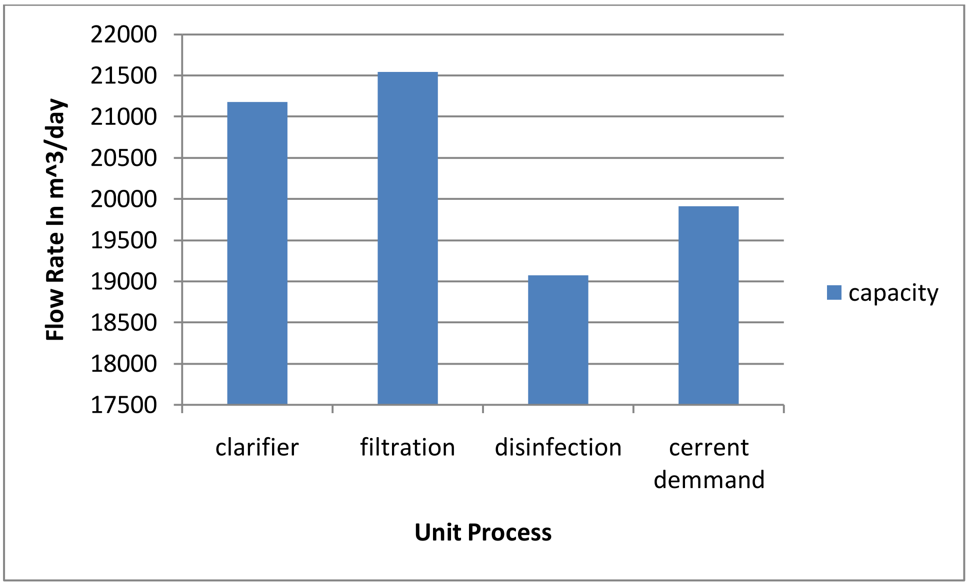

Figure 4.1 performance potential graph of JWTP

The figure 4.1 shows that the performance disinfection was not adequate in fulfilling the required current demand of population. But, the other two units are well sized in providing the require amount of water. Therefore the plant had a limitation in providing the required amount of treated water to the public

4.2.1 Unit Processes Turbidity Performance

The results of turbidity measurements from the sedimentation basins in the clarifier are presented in figure 4.2. Raw data is presented in **Annex 5.**

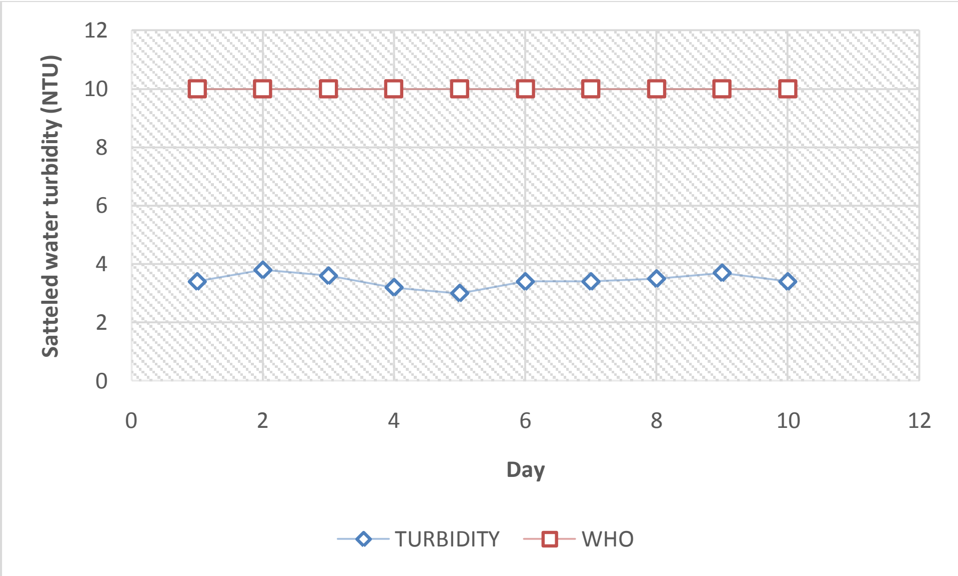

Figure 4.2 Sedimentation turbidity performances

From figure 4.2 the result of settled water turbidity is not the same in all days as evaluated this was happed depending on the raw water variation in each day. The turbidity in the clarifier was under the standard WHO guideline for turbidity in the sedimentation basin 10NTU. So, the clarifier performance in removing turbidity was excellent. But, the results found in each day was different this shows there is lack of control in alum dosage depending on the raw water and also the high amount of sludge accumulation at the bottom of the clarifier was excepted.

The overall performance of the treatment unit in removing the turbidity are presented in the figure 4.3 raw data was presented in the table 4.5

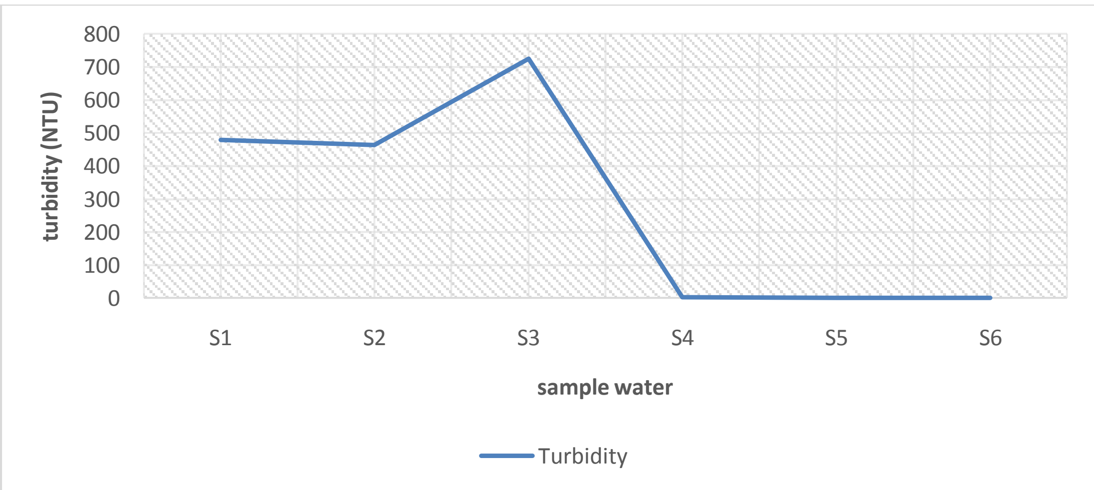

Figure 4.3 performance of treatment unit in removing turbidity

4.3 Performance evaluation of major unit process on the by product produced

In this section the major unit process evaluated based on the by product amount they reduced or increases. This study classifies the by-products on the basis of the water parameter; physical, chemical and biological parameter and the results of the onsite and laboratory tests are presented in table correspondingly.

4.3.1 Physical water quality parameter

under physical water quality parameter different measurement which are more important are measured and kept to evaluation for the treatment unit performance this are pH, temperature, electrical conductivity(E.Con), total dissolved solid(TDS) and total suspended solid (TSS). The raw data measurement for the physical water quality parameter are kept in the table 4.5

Table 4.5 Result of physical parameters measuring analysis result

Sample code	Location	Turbidity (NTU)	E.C (µs/cm)	pH	Temp(^{O}C)	TDS(mg/l)
S_1	Raw water	479	76	6.98	21.8	38
S_2	Aeration	463	75	6.97	21.8	38
S_3	Flocculation	726	78	6.61	21.3	57
S_4	Sedimentation	3.4	115	6.61	21.8	58
S_5	Filtration	0.4	117	6.87	21.7	59
S_6	Disinfection	0.4	119	7.13	21.9	60

4.3.1.1 pH

According to conducted measurement, pH of water varied from 6.61 to 7.13 with an average value of (6.86). The highest pH reading (7.13) was observed in Sump well (disinfection). The lowest pH (6.61) was recorded in the clarifier (sedimentation and flocculation). According to (WHO, 2004) guideline, the permissible limit of pH is from 6.5 to 8.5. Therefore; both the upper and lower limit pH of sampled water is not out of this range. For this reason, no need of adjusting optimum pH at coagulation. This indicates that performance of treatment plant of all units was efficient.

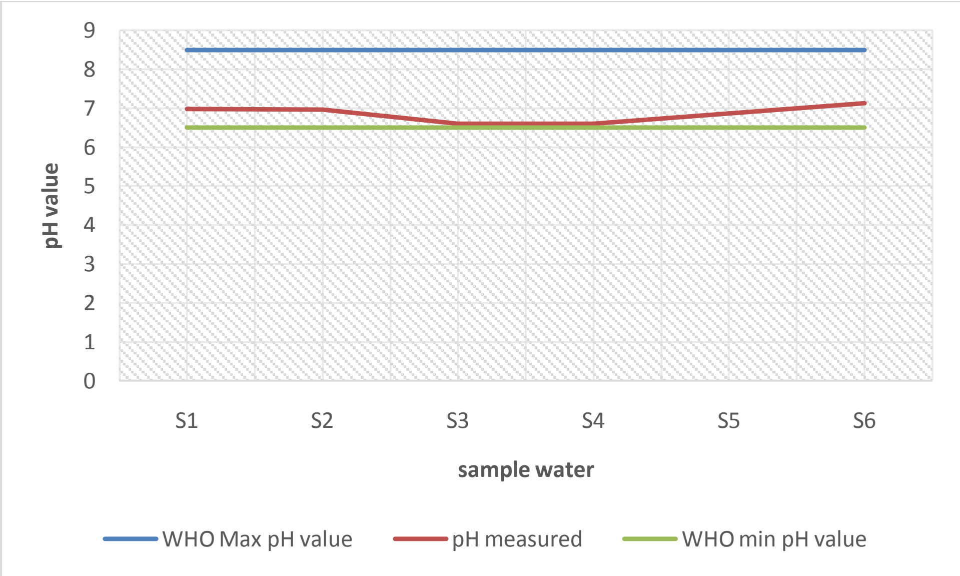

Figure 4.4 pH values for collected water sample

4.3.1.2 Temperature

The temperature of collected water samples ranges from 21.3°C to 21.9°C. The average temperature of a water sample is 21.71°C. The least (21,3°C) was recorded in flocculation water source while maximum temperature (21.9°C) was recorded in densification site. (G/Tsadik, 2013 by referring Temitope et al., 2012) drinking water with a temperature above 25°Cis undesirable for a human being and cause bone disease (pain and tenderness of bone) which children will get it more. Therefore, according to the result obtained from sample water, all water sources were recorded temperature below 25°C. But as measured value indicate that all water samples was also exhibited high temperature which is above WHO guideline value (15°C) therefore the plantwas not efficient in adjusting he raw water temperature.

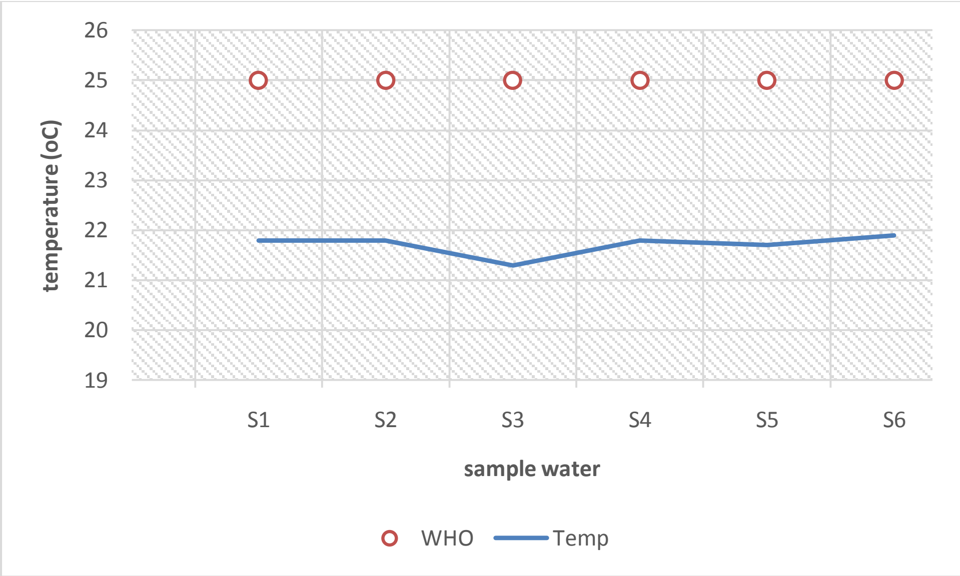

Figure 4.5 temperature of the collected sample water

4.3.1.3 Electrical conductivity (E.Con)

Dissolved ions increase the EC of water, so EC is often used as a surrogate for TDS. The lowest conductivity value recorded was 76µS/cm, this value was recorded in raw water (S1) of jimma gibe river. But maximum conductivity value recorded was 119µS/cm which is in Disinfection (S_6). The maximum value recorded did not exceed the permissible WHO guideline value (250µS/cm). The mean value recorded was 76µS/cm as it is indicated on (Figure 4.6). The lowered EC value is preferable for the health of consuming community because the higher value of conductivity above 250µS/cm can cause Anaemia, liver, kidney or spleen damage, changes in blood (WHO, 1997). It concluded that the capacity of the treatment plant in terms of process water portable for drinking was evaluated as good performances.

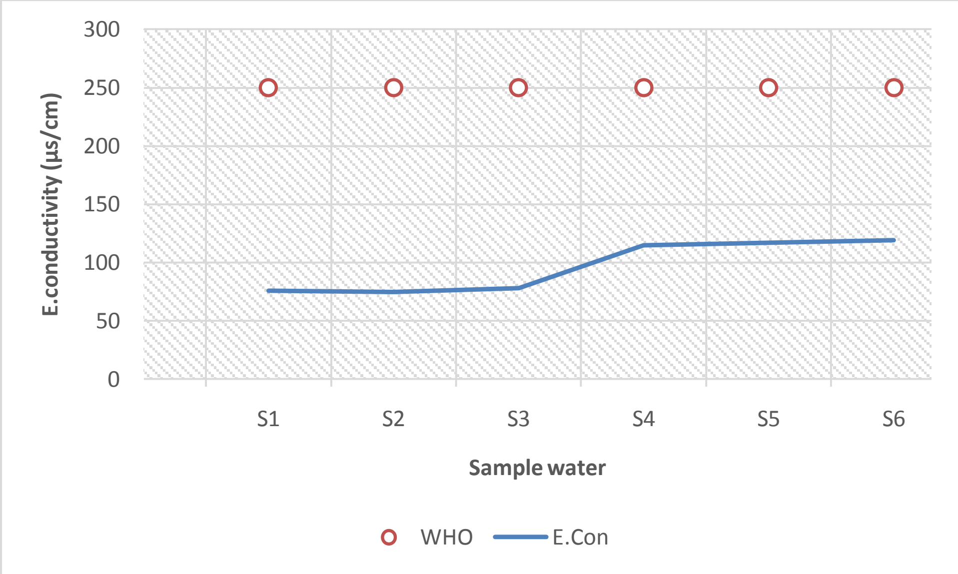

Figure 4.6 Electrical conductivity of collected sample water

4.3.1.4 Total dissolved solid (TDS)

In this study, the minimum TDS value of water was 38 mg/L which was recorded from the raw water source located in Jimma Boye. The maximum value was 60 mg/L which recorded at located in Disinfection. The mean TDS value was 51.67 mg/L. WHO recommended in 2004 water with TDS value above 500 mg/L do not use for drinking purpose. It concluded that all of the water samples were within permitted guideline values both by WHO and Ethiopian standards, therefore, it suitable for drinking purpose.

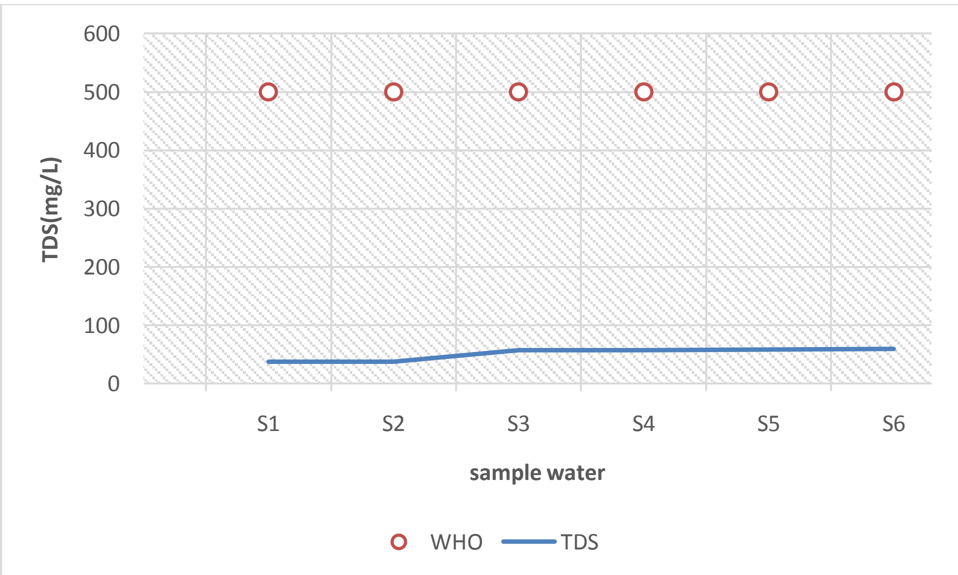

Figure 4.7 TDS of collected sample water

4.3.1.5 Turbidity

In this study, the turbidity values of all water samples from the raw water up to the treatment plant ranged from 0.4 NTU at filtration and disinfection to 729NTU at flocculation stage at the channel with a mean value of 278.7 NTU (Table 4.1). However, the permissible limit of turbidity for drinking water is 5 NTU (WHO, 2004). The high turbidity of water in the study area may be due to urban runoff, decaying plants, and animals. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria (Patrick et al., 2010). The turbidity of water affects other water quality parameters such as colour when it is imparted by colloidal particles. It also promotes the microbial proliferation, thus affecting negatively the microbiological quality of water.

However from the table 4.1 the result turbidity for each sample was presented show that the turbidity from raw water is decreased at the aeration stage the due to accumulation of silt the turbidity increases flocculation take place at the channel of the major treatment unit. Then at the clarifier sedimentation take place and reduce the maximum turbidity at the flocculation below the standard kept in (WHO,2004). The sample taken from both filtration and disinfection was decreased to 0.4NTU.Sedimentation and filtration permissible limit10NTU and 5NTU (WHO, 2004). This shows that the clarifier and the filtration performance were good.

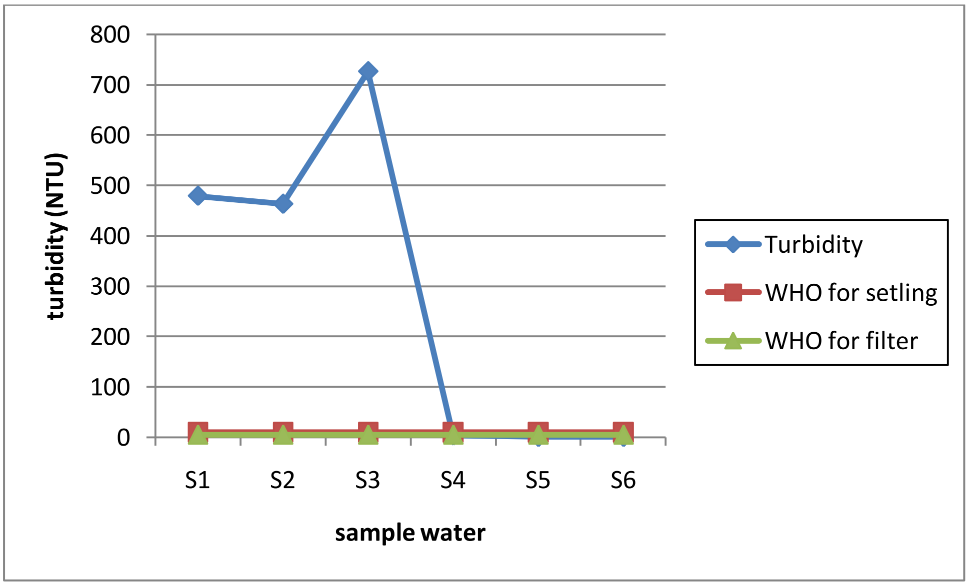

Figure 4.8 Turbidity values of collected water samples

4.3.2 Chemical water quality parameter

In this section chemical by product at each major unit process is evaluated depending up on the WHO standard for drinking water. The raw data are presented in the table 4.6.

Table 4.6 Result of chemical Parameters analysis laboratory results

Chemicals	Unit	Sample code					
		S_1	S_2	S_3	S_4	S_5	S_6
Mg^{2+}	Mg/l	24	26	14	10.2	16	18
Alkalinity	>>	125	142.8	333.33	500	500	500
Total hardness	>>	32	32	26	22.2	28	32
Ca^{2+}	>>	8	6	12	12	12	14
Fe^{2+}	>>	0.19	0.17	0.08	0.01	0.01	0.01
Mn^{2+}	>>	0.003	0.003	0.0021	0	0	0
NO_3^-	>>	5.978	5.092	5.756	5.756	5.867	5.978
Cl^-	>>	2.999	2.999	2.999	2.999	2.999	4.99
NH_4^+	>>	0.497	0.461	0.466	0.011.	0	0
SO_4^{2-}	>>	46	46	58	17	12	10

4.3.2.1 Total hardness

Hardness in water is usually expressed as the equivalent quantity of calcium carbonate. Depending on pH and alkalinity, hardness above about 200 mg/L can result in scale deposition, particularly on heating. Hardness is expressed in terms of milligrams of calcium carbonate equivalents per litter. The taste threshold for the calcium ion is in the range of 100–300 mg/L and the taste threshold for magnesium is probably lower. In some instances, consumers tolerate water hardness in excess of 500 mg/L. Soft water may also have a salty taste (UNICEF, 2008). The WHO standard guideline for hardness is 200 mg/L CaCO3. “The degree of hardness in water may affect its acceptability to the consumer in terms of taste and scale deposition (WHO, 2006).” In the study area the minimum hardness value 22.2 mg/L CaCO3 was observed in clarifier (sedimentation) and maximum value 32 mg/L CaCO3 was observed in the raw water intake, aerated water and disinfection . Average total hardness value is 28.7 mg/L CaCO3. It concluded that the concentration of total hardness failed under the category of soft water and the value of hardness in the study area was recorded below permissible limit of WHO guideline, for this reason, it is suitable for drinking purpose.

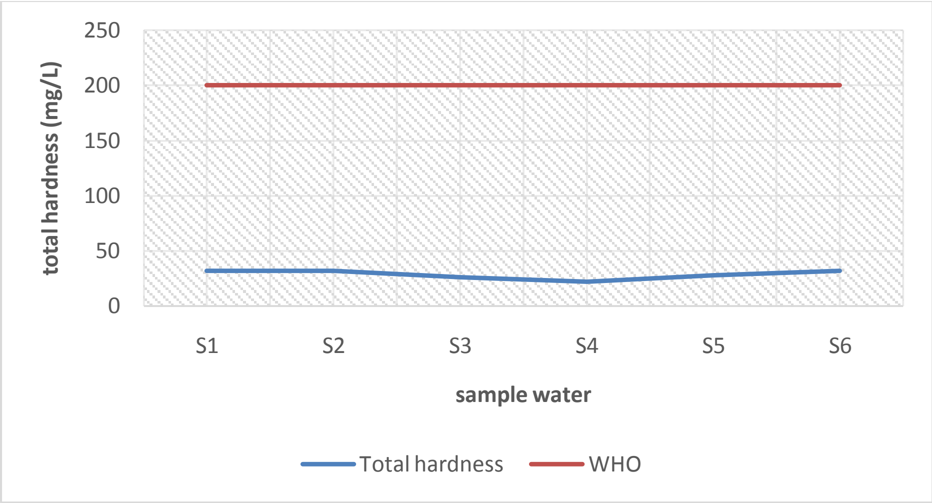

Figure 4.9 Total Hardness values of collected water samples

4.3.2.2 Magnesium (Mg^{2+})

The result obtained from water samples shows that the minimum concentration of Magnesium is 10.2 mg/L recorded in clarifier (sedimentation), the maximum Magnesium concentration value is 26 mg/L recorded in aeration water. Mean value of Magnesium concentration measured among all samples is 18.03 mg/L. According to WHO standards the permissible range of magnesium in water should be 50 mg/L. The measured values indicate all water samples were below the permissible limit WHO guideline and hence water samples of study area was suitable for drinking purposes.

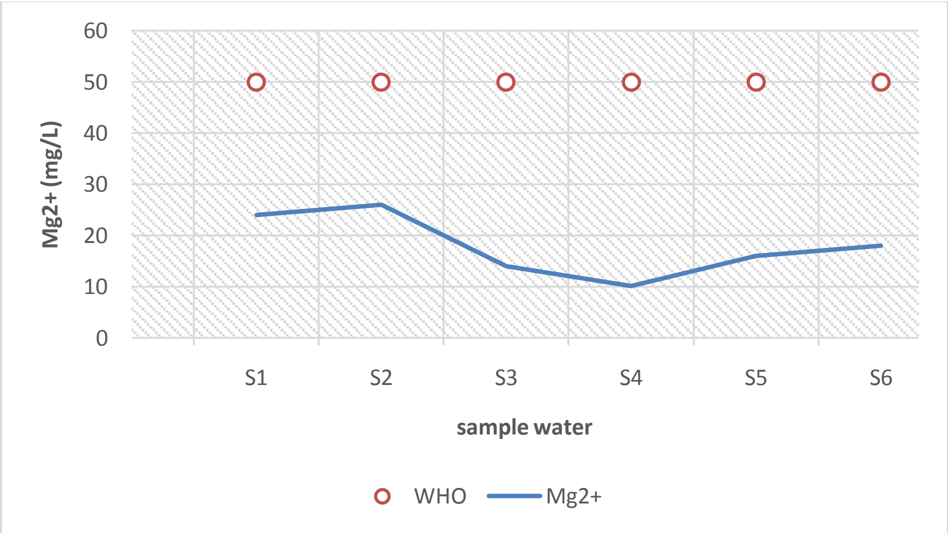

Figure 4.10Magnesium values of collected water samples

4.3.2.3 Calcium hardness (Ca^{2+})

It was observed that the minimum concentration of calcium in the study area was 6mg/l was recorded in the aeration and the maximum concentration 14m/L was recorded in disinfection. The average concentration of calcium in sampled water was 10.67 mg/L. The desirable limit of calcium concentration for drinking water is specified as 75mg/L (WHO, 2004).It concluded that all water samples contain the calcium concentration below the desirable limit so it was acceptable for drinking utility.

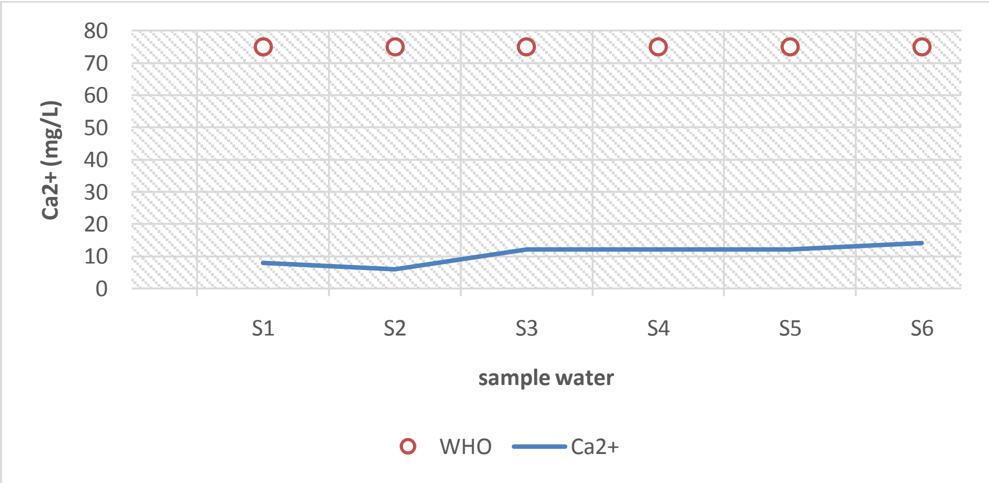

Figure 4.11 calcium values of collected water samples

4.3.2.4 Alkalinity

The result obtained from water samples shows that the minimum concentration of alkalinity is 125 recorded in raw water intake at the location Jimma gibe river and the maximum alkalinity concentration value is 500 mg/L recorded in sedimentation, filtration and disinfection water . Mean value of alkalinity concentration measured among all samples is 350.18 mg/L. According to WHO standards the permissible range of alkalinity in water should be 500 mg/L. From the measured value cleared water result was equal with maximum permissible limit of WHO guideline and so the water is not suitable to drink.

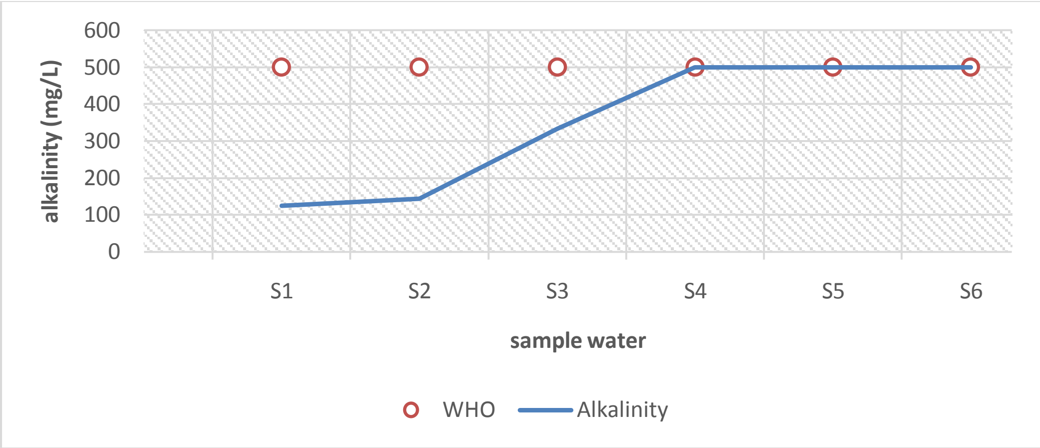

Figure 4.12 Alkalinity values of collected water samples

4.3.2.5 Chloride (Cl^-)

The result obtained from water samples shows that the minimum chloride concentration in sample water is 2.999 mg/L which was recorded in all sample taken except the disinfection water in the treatment plant. The maximum concentration of chloride was recorded in Disinfection with the value of 4.99 mg/L while the mean chloride concentration value is 3.33mg/L. This showed that the concentration of chloride starting from source to major unit process was same until the disinfection this indicates that the treatment plant is not effective in removing the chloride. The standards concentration of chloride should not exceed 250 mg/L (WHO, 2004). Even though according to WHO guideline the value of all water samples contain low chloride concentration. Therefore, the water is suitable for drinking purpose.

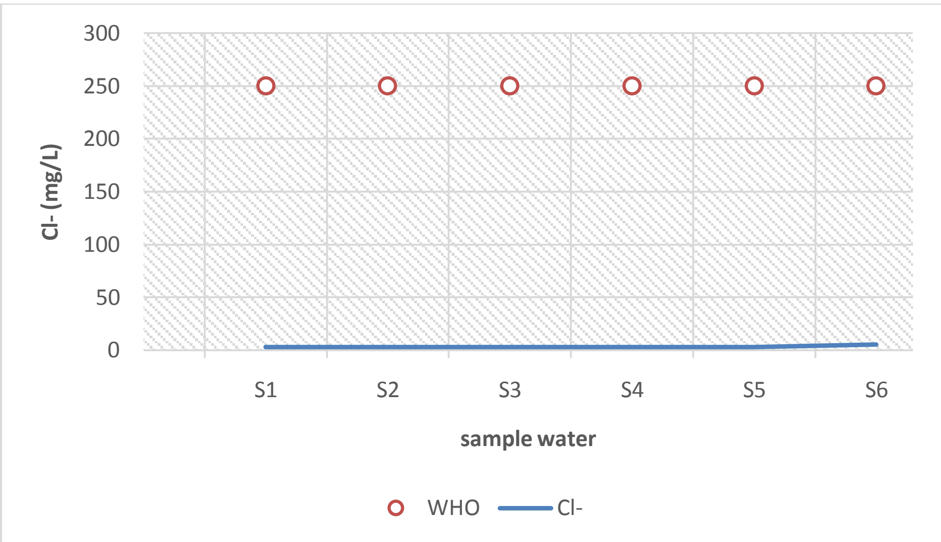

Figure 4.13 chloride values of collected water samples

4.3.2.6 Manganese (Mn^{2+})

It was observed that the minimum concentration of Manganese in the study area was 0 mg/L was recorded in clarifier, filtration and disinfection and the maximum concentration 0.003 mg/L was recorded in raw water intake and aeration water. The average concentration of Manganese in sampled water was 0.00135mg/L. The desirable limit of manganese concentration for drinking water is specified as 0.1 mg/L (WHO, 2004). High levels of manganese in water can cause neurological effects (Wasserman et al., 2006). It concluded that the minimum and maximum concentration of Manganese in the study area was below the WHO and it was suitable for drinking purpose.

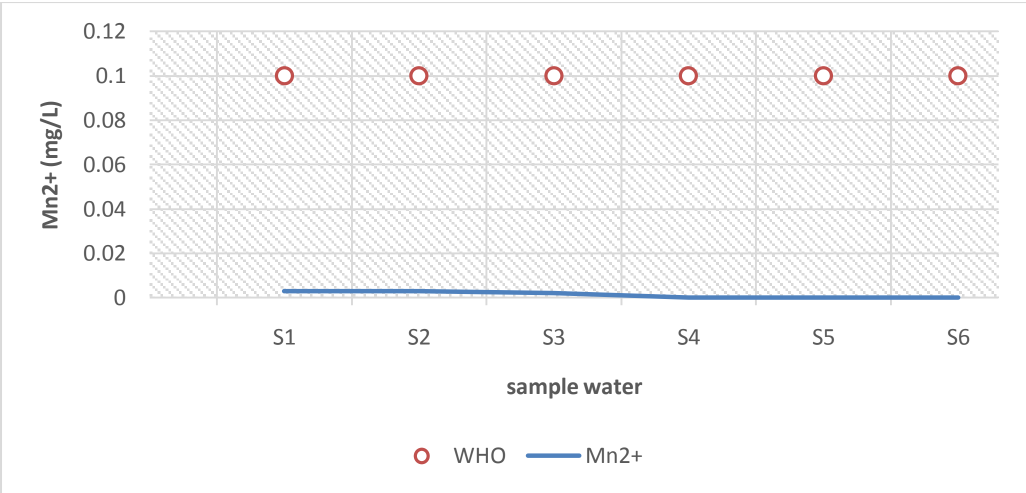

Figure 4.14 Manganese values of collected sample

4.3.2.7 Iron (Fe^{2+})

It was observed that the minimum concentration of iron in the study area was 0.01 mg/L was recorded in clarifier (sedimentation), filtration and disinfection and the maximum concentration 0.19 mg/L was recorded in raw water intake at Jimma Gibe River. The average concentration of iron (Fe^{2+}) in sampled water was 0.0783mg/L. All the sample water are below the standard permissible limit of 0.3(WHO, 2004) and was suitable for drinking purpose.

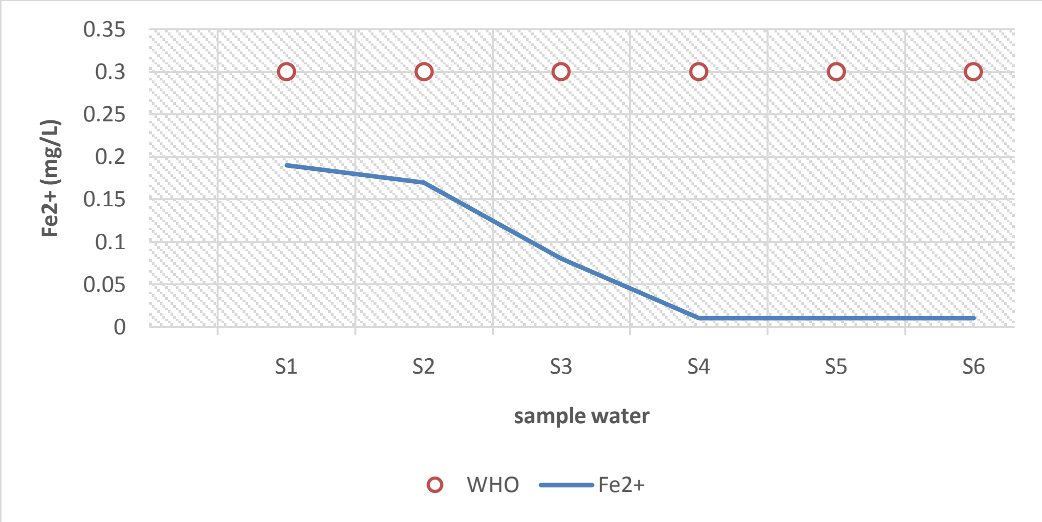

Figure 4.15 Iron values of collected sample

4.3.2.8 Ammonium (NH_4^+)

In this section the ammonia concentration of water evaluated intermesh its ionized form ammonium. The observed value of the study area show that the minimum ammonium concentration recorded was 0 mg/L and the maximum concentration recorded 0.497mg/L. Mean average concentration of NH_4^+ 0.239mg/L. From table 4.2 row number nine (9) show that the value of ammonia is reduced at sedimentation and filtration stage of the plant so the treatment perform good in removing ammonia from the raw water provided. All the sample water was below the permissible limit of ammonia for drinking water 1.5mg/L (WHO, 2004). So, the water is suitable for drinking purpose.

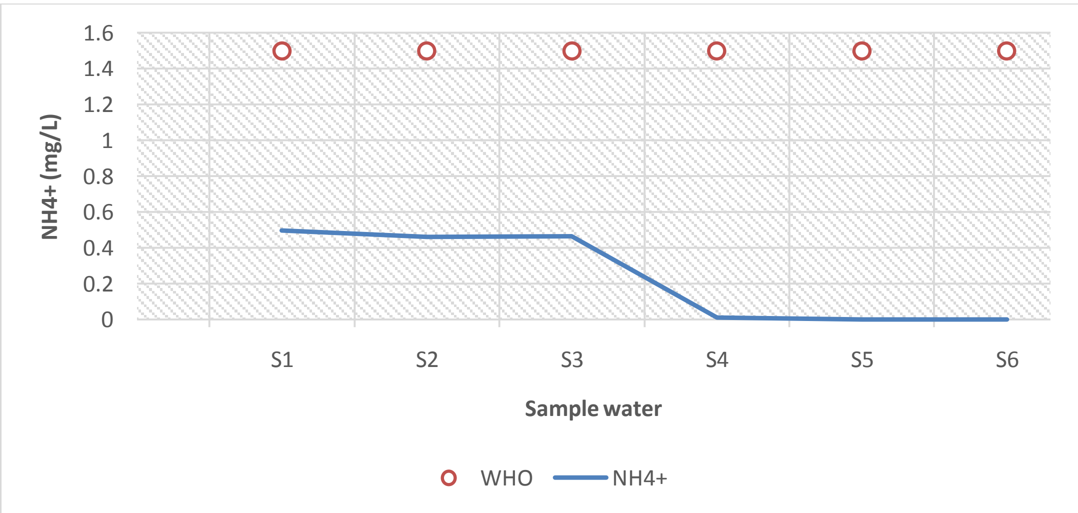

Figure 4.16 Ammonium values of collected sample

4.3.2.9 Nitrate (NO_3^-)

According to this study, the minimum nitrate concentration is 5.092 mg/L recorded in the aeration water and the maximum nitrate concentration is recorded in raw water intake and disinfection with the value of 5.978 mg/L. The mean nitrate concentration in the study area was 5.7378mg/L. The standard for nitrate is 10mg/L (WHO, 2004). Chemicals are used in agriculture on crops and in animal husbandry were the source of nitrate. The presence of nitrate and nitrite in water has been associated with methemoglobinemia, especially in bottle-fed infants or blue baby syndrome (WHO, 2006). Even though the concentration of nitrate in sample water is bellow WHO permitted value. It concluded that the plant treat water concerned with nitrate was efficient and makes it suitable for drinking purpose.

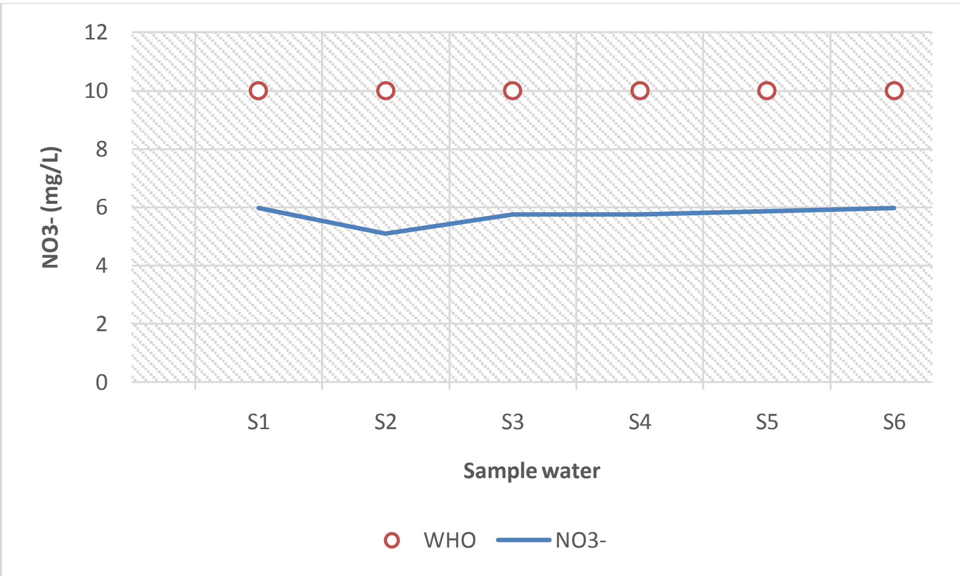

Figure 4.17 Nitrate values of collected sample.

4.3.2.10 Sulphate (SO_4^{2-})

It was examined that the minimum sulphate concentration in water sample was 10 mg/L recorded disinfection. And the maximum value 56 mg/L was recorded in Flocculation water sample. The mean concentration of sulphate in sample water is 31.167mg/L. The elevated value of sulphate in flocculation rather than raw water sample from the source was due to the addition of aluminium sulphate for coagulation purpose. It concludes that the concentration of sulphate was reduced through the top to down major unit process; it indicated the performance of treatment plant stayed in a good manner. Sulphate in drinking water can cause a noticeable taste above concentrations of about 250 mg/L (WHO, 2004). The results clearly indicate that the concentrations of sulphate in sample water are below WHO standard guideline; therefore, in the study area it was suitable for drinking purpose.

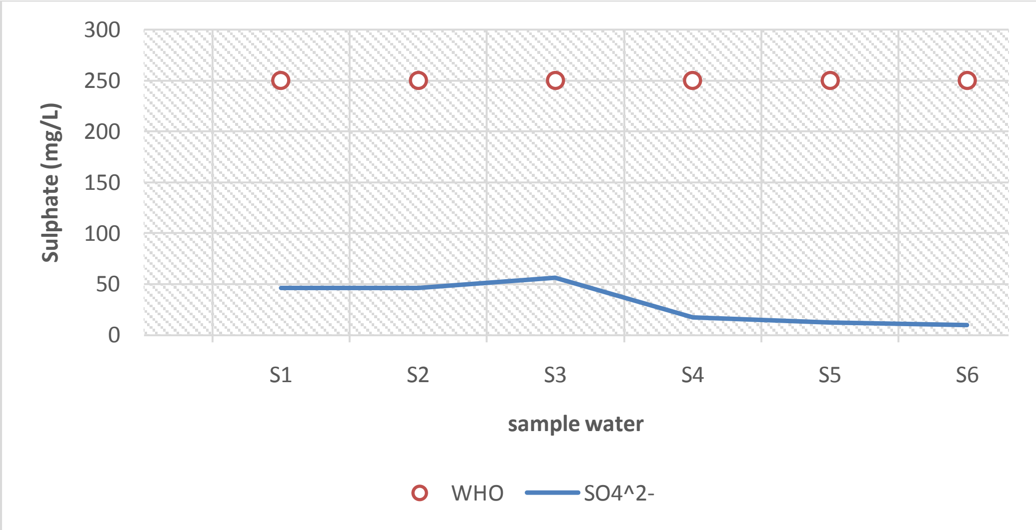

Figure 4.18 sulphate values of collected water sample.

4.3.3 Biological water quality parameter

This section talks about the performance evaluation of the treatment plant in removing the bacteria in the raw water to provide good quality of water to the public. The study shows fecal and total coli form bacteria which used as indicator of the presence of bacteria in the water by using membrane filtration technique. The raw data was presented in table 4.7.

Table 4.7 Result of Microbial (bacteriological) Measuring Parameters analysis results

Sample code	fecal coli form (CFU/1000ml	total coli form (CFU/1000ml)
S_1	550	1980
S_2	550	1980
S_3	220	1320
S_4	51	660
S_5	32	550
S_6	18	61

4.3.3.1 Fecal coli form

The results of the analysis indicated that the minimum values of fecal coliform (FC) 18CFU/100mL at the disinfection water sample and the maximum value550CFU/100mL at the intake and aeration water sample with a mean value of 236.8 CFU/100mL (Table 4.3).

This show that the raw water of Jimma gibe river had contaminated by bacteria from the result the found the bacteria the number of bacteria decreased through each section of the treatment plant specially at the disinfection stage but the WHO standard of fecal coliform in drinking water is zero (0) . The operator and chemist told me that they never measure the bacteriological test four around three years. The water did not satisfy the required range of fecal coliform bacteria within the range kept bay WHO.

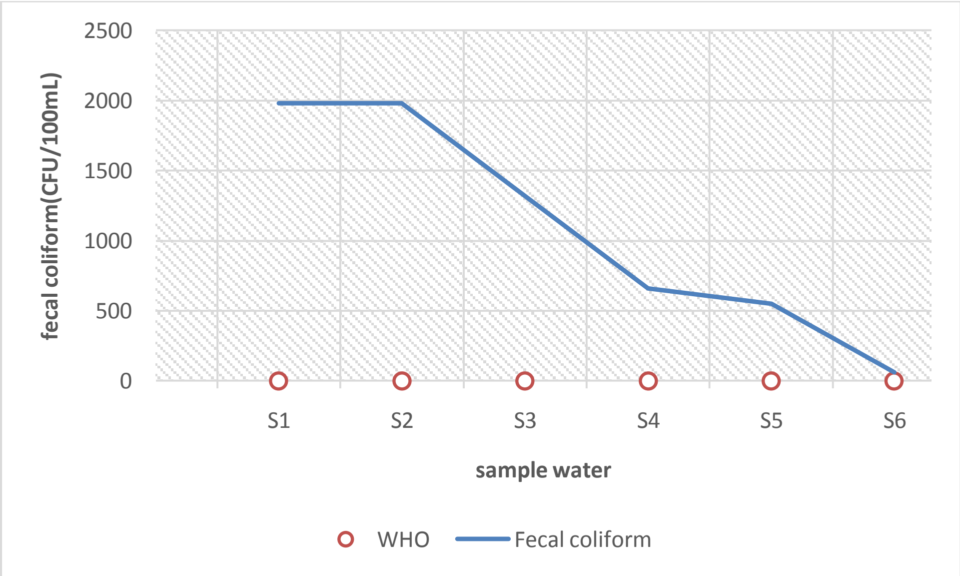

Figure 4.19 Fecal coliform bacteria indicator of collected sample

4.3.3.2 Total coliform

The results of the analysis indicated that the minimum values of total coli form (FC) 61CFU/100mL at the disinfection water sample and the maximum value1980CFU/100mL at the intake and aeration water sample with a mean value of 1091.83 CFU/100mL (Table 4.3).

This show that the raw water of Jimma gibe river had contaminated by bacteria and from the result found the bacteria number decreased through each section of the treatment plant specially at the disinfection stage but the WHO standard of total coliform in drinking water is zero (0) . The operator and chemist told me that they never measure the bacteriological test four around three years. The water did not satisfy the required range of total coliform bacteria within the range kept bay WHO.

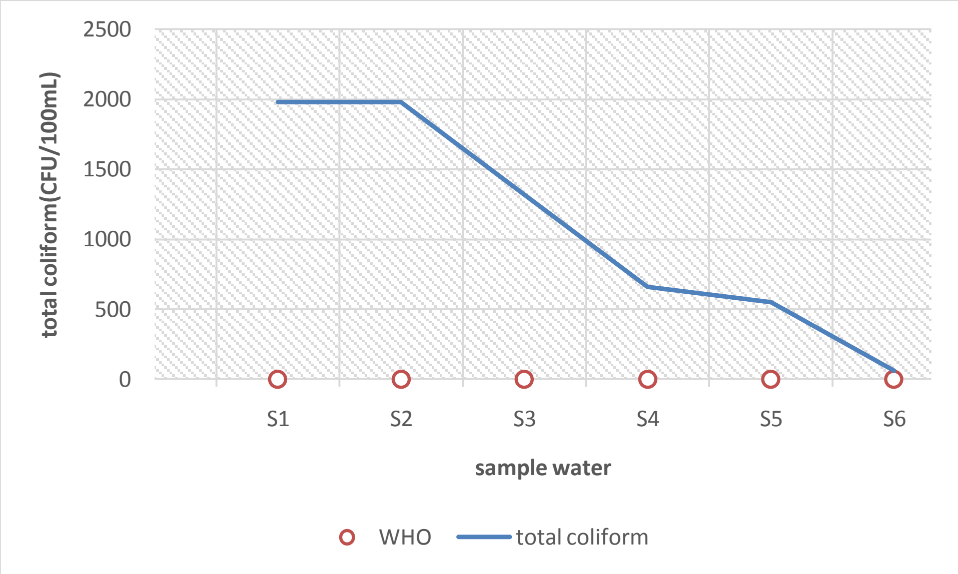

Figure 4.20 Total coliform bacteria indicator of collected sample

4.4 Management and control for major unit process

4.4.1 Management

In drinking water treatment management of the plant is crucial for the plant performance. In this study area the plant have it own lab but as the chemist told the laboratory have enough equipment but due to the limitation of management the shortage of reagents he never test the physical, chemical and biological parameter of the raw water this tends to fall the quality of water and during the visit time of Jimma water supply sector the management office had no the design paper in the sector this show that the management of the staff is weak in investigating the problem behind the plant and also they limit the performance of the plant in providing acceptable quality of water to the public

4.4.2 Control

In previous section of the study indicated that the plant staff had one skilled person this show that the control practice was weak. Except one person no one have knowledge in preparing stock solution by jar test for coagulation purpose this mean during rainy season the raw water changes it quality at that time no alum control the chemical dose in coagulation until the chemist arrive to the plant. There was no routine removal of sludge from sedimentation basins and the time taken for settling was not checked. The back washed were not controlled until the sand is clean as the standard kept. At the disinfection except one person no one have knowledge of determining the dose and the disinfection ret for the water provided. So this shows that the control practice was limited.

4.5 Performance limiting factors

Performance-limiting factors were identified for the plant by utilizing the factor lists based on the (G/Tsadik, 2013 by referring USEPA, 1991). Some modifications were made to fit with the actual conditions of the treatment plant under study. The following performance limiting factors were identified and were given ratings of "A", "B" or "C".

4.5.1 Design factors

I. Flocculation (B)

In this plant the flocculation take place in the channel from the rapid mixing to the clarifier and in the clarifier this makes the plant difficult to control the detention time this cause the floc formed is not good enough as designed. So this increased burden in the filtration unit.

II. Flow Proportioning (B)

In the plant there is only one professional person was the rest are less educated and do their work through experience due to this reason the influent flow to the plant was hydraulically fragmented to the flocculation trains, and uneven flow distribution causes overloading of one sedimentation train over the other. Also, the dose of chlorine is adjusted once and no flow monitoring to consider residual chlorine.

III. Filtration (B)

Filtration is the major unit process it needs good attention but during the visit time the back wash was operated by a person which had no knowledge about the operation. The steps (air water and combination) and time he was used for back wash the filter was not correct this affect the efficiency of the unit process in clearing the water

4.5.2 Operational factors

I. Process Control Testing (B)

Previously as discussed the TP only one chemist and maintenance profession but the rest were nonprofessional and perform activity though experience. As the chemist told me that the only done jar test during the raw colour of water changes. But due to the absence of reagent in the lab do not measure and record raw water pH, alkalinity, temperature, chemical parameter and coli form bacteria on a routine basis with changing raw water characteristics with season therefore, the impact of raw water quality on plant performance with seasonal variations were not assessed. each major unit of the plant were not controlled by skilled person and the backwash was done daily but not with knowledge and do not consider the standard of backwash only wash for remove some impurities but not fully removed, do not measure the quality of water before and after backwashed and analysis the progress of backwash.

II. Water Treatment Understanding (A)

Plant staffs do not have sufficient understanding of water treatment processes to make proper equipment or process adjustments. Specific performance objectives for each major unit process have not been established. Intermittent plant operations were observed that can negatively affect the overall performance of the treatment plant.

III. Application of Concepts and Testing to Process Control (A)

The staff member do not had knowledge in controlling and testing the dose of alum in coagulation for the plant efficiency. The reason behind this was except one person no one have knowledge to prepare a stock solution by jar test for coagulation process.

The sludge removal from the clarifier is not practiced yet and the sedimentation controlled by visual observation not by process control testing. Operations staff cannot determine the chemical feeder setting for a selected dose role and operations staffs do not adjust chemical feed rates for varying raw water quality conditions. Plant filters are placed back in service following backwash without consideration for effluent turbidity levels and also the filter back washed out of the standard this tends the filter to stay dirty for the next filtration.

IV. Training Program (B)

A training program does not exist for the operator in the plant due to the limitation of attention given to the plant from the management staff of the supply sector.

4.5.3 Maintenance factors

I. Preventive Maintenance Program (B)

Preventive maintenance was not performed on all equipment’s unless they stop working.

II. Corrective maintenance program (A)

During the visit period spare parts are available on the site and the mechanics live in the plant and take immediate action on the problem faced on the pump which pumps the water for the reservoirs.

4.6 Quantity of treated water

The design to the quantity of water depended up on the number of population, demand and design period so that the efficiency of treatment plant was evaluated in terms of quantity of water could be produced by considering the population density and required water.

The Jimma city drinking water treatment plant construction started in 2008 GC which has its own design period. During the time of construction, the number of the population was 175,237 required total water demand of 5,663m3/d. According to design based on population increase the total demand of water in 2015 at the end of contraction was 12196m3/day and from the design sheet the forecasted demand of water in 2025 was 21369m3/day. From the designed paper by using interpolation the current water demand for 2021 was calculated and the result was 19912.76m^3/day. The determination total demand of water was a combination of (domestic, industrial, commercial, institutional, residential and etc.). But this study focuses only on the required demand of the institutions from the TP supplied water

4.6.1 Demand of institutions

The determination of the institutional demand of water was determined from the demand of the town which was forecasted during the design period in the design sheet. The overall institutional demand during the design period in to 2007 was 2599 m3/day and at the end of construction in 2015 the demand of water to the institution was 4223.4m^3/day and from the design sheet the forecasted demand of water in 2025 was 21369m3/day from this the institutional demand kept for the future population was 6254 m^3/day. The current population of the town and the institution calculated by using (equation 2.18) the determined population number 2021 was 356912. By using interpolation demand of current institution was determined from the design paper given value at the year 2015 and 2025 which gave the result of 5441.76m^3/day. But in this study the data was collected in each institution and from JWSS by collecting bills and number of water mater of the institution and the monthly demand of institutions. This study classifies the institutions based on level of education; schools (0-12 class), private and governmental colleges and Jimma university (JU).

4.6.1.1 School demand

The number schools and student was growing from time to time due to urbanization the current density of population and numbers of school are 39975 and 44 the data was presented on Annex 7.

To determine the current demand of school in the city the study conducted the bill of water at each school and takes the measured water mater value and the result found was 222m^3/day this was the averaged result from 70 water meter used by all school. From the design sheet the estimated water distributed for schools 2021 was 469m^3/day. Even though, around 30-40% of schools have a shortage of water due to availability during the visit period they school manager told that the water was not available for a half of a month (15days/month). This shows the current water demand of school was less due to the availability of water. So the distribution system must be checked.

4.6.1.2 Governmental and private college

The number college in Jimma city was not increased since the treatment plant was constructed; around two colleges are closed and the city has three private and one governmental college**.**

This study conduct data by using the number of water meter used and measured value from each water mater and the private colleges; rift valley university college, dandi boru and afro Canadian college have three (3) water meter with a average demand of 15m^3/day and the governmental college; Teachers training college (TTC) have two (2) water meter with average demand of 103m^3/day and a total of 118m^3/day. From the design paper the demand of college in the year 2010 was 721m^3/day this show that the number of college and number of students in the college was decreasing and from the interview with the managers water was adequately available.

4.6.1.3 Jimma University

Jimma university (4 institutions) take the maximum water demand of institutions of the town by having total of 116 water meter with a demand of 1687.54m^3/day .from the design paper the demand of JU in 2015was 2500m^3/day and the predicted value for 2025 was 3300m^3/day from this by using interpolation the predicted amount of water for 2021 was 2980m^3/day. The found result from the water meter used currently was less than the predicted amount this was happened due to the decrease in population number in the campus as a result of corona virus the student in the campus was decreased by half from the previous years.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The capabilities of the major unit processes (Flocculation, sedimentation, filtration and disinfection) were evaluated in terms of their capacity to handle current peak demand of the population served and . Evaluated result show the capacity of each treatment unit was good in providing the expected amount of water but at the disinfection stage the quantity of treated water to the public was not satisfy the required demand of the town. Coagulation stage was done without measuring the physical parameters especially pH adjustment was not practiced.

The performance assessment of the treatment plant based on turbidity goals indicated the both sedimentation and filtration were good in removing turbidity.

Form the identified factors limiting plant’s performance; no single factor was responsible for poor plant performance, although in general the study found that all major factors influence the plant’s ability to work properly. The location of intake structure from the design factors, Water Treatment Understanding and application of Concepts and Testing to Process Control from the operational factors significantly affected the treatment performance

The by-product of the major unit was evaluated based on physical, chemical and biological parameter of water. Determined result shows all the physical and chemical parameter satisfy the WHO recommended standard of drinking water but the micro biological result found in the study indicate that the disinfected water was not under the limit of WHO recommended.

The management and control practice of the treatment plant was evaluated and the result shows the management practice at the treatment process was poor in managing the plant and also has a limitation in providing materials needed for the laboratory and safety of the plant. The control practice has limitation of skilled man power in each treatment unit process of the plant.

The efficiency of the treatment plant was evaluated based on the quantity of water provided to the institutions. In this study the demand of institution was less than the supply amount predicted on the design paper but during the visit time at different school there was limitation on availability of water this show that the plant did not provide the required amount of water to the institutions present in town.

5.2 Recommendations

- This section is recommending some points which are helpful for solving the problem identified on the study.
- The first one is create awareness to the public in protecting the river from being more polluted this help the plant in reducing impurities entering to the plant.
- From the study the required water was not provided to the public to overcome this the old water treatment plant should be maintained and give function to help the new JCWTP
- During an investigation the major operational problems; lack of interest for checking filtered water, major unit performance, lack of intensive care to redness of backwash water, inadequate operation and inadequate process monitoring and filter backwash practice and return to service until the filter is dirty. For this reason, set a training program to update operators' skill and upgrade the performance of the plant is critical.
- Remove sludge from intake structure up to each major unit process in short duration because it was one of the factors which hinder the performance of the plant.
- The plant needs its own manager (responsible) person who monitors and controls the overall activities of the plant. The staffs need to conduct the performance of plant considering all factors in seasonal variation and set the solution. The disinfection unit should be checked in removing the microbiological parameter by preparing solution chemical dose used until the result appears under the permissible level of WHO.

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ANNEXE

ANNEXE 1

Checklist for determining Performance Limiting Factors (adopted from G/Tsadik.T , 2013) Performance limiting factors are described by using the following format.

A. CATEGORY

1. Subcategory

a. Factor Name

Factor description

A. Design

1. Source Water Quality

a. Microbial Contamination

♦ does the presence of microbial contamination sources in close proximity to the water treatment plant intake impact the plant's ability to provide an adequate treatment barrier?

2. Unit Process Adequacy

a. Intake Structure

♦ "Does the design of the intake structure result in excessive clogging of screens, build up of silt, or passage of material that affects plant equipment?"

b. Raw Water Pumping

♦ does the use of constant speed pumps cause undesirable hydraulic loading on downstream unit processes?

c. Flow Measurement

♦ does the lack of flow measurement devices or their accuracy limit plant control or impact process control adjustments?

d. Chemical Storage and Feed Facilities

♦ Do inadequate chemical storage and feed facilities limit process needs in a plant?

e. Flash Mix (hydraulic jump)

♦ does inadequate mixing result in excessive chemical use or insufficient coagulation to the extent that it impacts plant performance?

f. Flocculation

♦ does a lack of flocculation time, inadequate equipment, or lack of multiple flocculation stages result in poor floc formation and degrade plant performance?

g. Sedimentation

♦ does the sedimentation basin configuration or equipment cause inadequate solids removal that negatively impacts filter performance?

h. Filtration

♦ Do filter or filter media characteristics limit the filtration process performance?

♦ Do filter rate-of-flow control valves provide a consistent, controlled filtration rate? ♦ Do inadequate surface wash or backwash facilities limit the ability to clean the filter? i. Disinfection

♦ "Do the disinfection facilities have limitations, such as inadequate detention time, improper mixing, feed rates, proportional feeds, or baffling, that contribute to poor disinfection?"

j. Sludge/Backwash Water Treatment and Disposal

♦ does inadequate sludge or backwash water treatment facilities negatively influence plant performance?

3. Plant Operability

a. Process Flexibility

♦ Does the lack of flexibility to feed chemicals at desired process locations or the lack of flexibility to operate equipment or processes in an optimized mode limit the plant's ability to achieve desired performance goals?

b. Process Controllability

♦ Do existing process controls or lack of specific controls limit the adjustment and control of a. process over the desired operating range?

c. Process Instrumentation/Automation

♦ Does the lack of process instrumentation or automation cause excessive operator time for process control and monitoring?

d. Standby Units for Key Equipment

♦ Does the lack of standby units for key equipment cause degraded process performance during breakdown or during necessary preventive maintenance activities?

e. Flow Proportioning

♦ Does inadequate flow splitting to parallel process units cause individual unit overloads that degrade process performance?

B. Operation

1. Testing

a. Process Control Testing

♦ Does the absence or wrong type of process control testing cause improper operational control decisions to be made?

b. Representative Sampling

♦ Do monitoring results inaccurately represent plant performance or are samples collected improperly?

2. Process Control

a. Time on the Job

♦ Does staff's short time on the job and associated unfamiliarity with process control and plant needs result in inadequate or improper control adjustments?

b. Water Treatment Understanding

♦ Does the operator’s lack of basic water treatment understanding contribute to improper operational decisions and poor plant performance or reliability?

c. Application of Concepts and Testing to Process Control

♦ Is the staff deficient in the application of their knowledge of water treatment and interpretation of process control testing such that improper process control adjustments are made?

3. Operational Resources

a. Training Program

♦ Does inadequate training result in improper process control decisions by plant staff?

b. Technical Guidance

♦ Does inappropriate information received from a technical resource (e.g., design engineer, equipment representative, regulator, peer) cause improper decisions or priorities to be implemented?

c. Operational Guidelines/Procedures

♦ Does the lack of plant-specific operating guidelines and procedures result in inconsistent operational decisions that impact performance?

C. Maintenance

1. Maintenance Program

a. Preventive

♦ Does the absence or lack of an effective preventive maintenance program cause unnecessary equipment failures or excessive downtime that result in plant performance or reliability problems?

b. Corrective

♦ Does the lack of corrective maintenance procedures affect the completion of emergency equipment maintenance?

c. Housekeeping

♦ Does a lack of good housekeeping procedures detract from the professional image of the water treatment plant?

2. Maintenance Resources

a. Materials and Equipment

♦ Does the lack of necessary materials and tools delay the response time to correct plant equipment problems?

A. Questionnaire for the plant operator to identify possible operational problems

Item	Question	Operator interview
1	Chemical pre-treatment	
	How does the operator determine proper chemical?	
	Jar tests	✓
	Visual observation of floc formed	
	Historical performance data	
	Checked pH	
	How does the operator make the chemical adjustments and procedure for checking and confirming proper dosages and how often (during changes in raw water quality characteristics)?	
	Visual observation of floc formed	
	Volumetric measurement	✓
	Checked pH	
	Do you frequently wash the alum preparation tank?	
	Yes: daily, weekly, monthly or No	Monthly

2	Flocculation	
	Is floc formed at an appropriate location?	
	After rapid mixing	✓
	Before middle of flocculation tank	
	At middle of flocculation tank	
	Not visible floc formed	
	Do you frequent wash the flocculation tank?	
	Yes: daily, weekly, monthly or No	No(3-4 month)
3	Sedimentation	
	Is sludge removal frequent enough to prevent short-circuiting?	
	Yes: daily, weekly, monthly or No	No (seasonally)
	Do you frequent wash the sedimentation tank?	
	Yes: daily, weekly, monthly or No	No (seasonally)
4	Filtration	
	Does the operator consider all three criteria (turbidity, head loss, and time) when establishing backwash timing?	
	Turbidity	✓
	Water level	
	Head loss indicator (1.50 m differential)	
	Filter run time (16 hrs)	

	Does the operator use the surface wash during the backwash?	
	Yes	
	Surface scraping	
	Surface scour (water jet)	
	Hand raking	
	No	✓
	Do you frequent check the filter depth?	
	Yes	
	No	✓
	Do you frequent sand added and re sand ?	
	Yes (how often	
	No	✓
	Do you frequently wash the filtration tank?	
	Yes, backwashing time: daily, weekly, monthly or No	Daily
5	Disinfection	
	How does the operator prepare calcium hypochlorite solution?	
	Direct mixed in feed tank	✓
	Other	
	How does the operator making the disinfectant adjustments and procedure for checking and confirming proper dosages and how often?	
	Checked free chlorine	
	Volumetric measurement	✓

	Other	
	No	
	Do you frequently wash the calcium hypochlorite feed tank?	
	Yes, hypochlorite sludge sediment on bottom tank	
	Daily	
	Weekly	
	Monthly	✓
	No	

Annex 2 Checklist of visual inspection on plant operation evaluation (adopt from, G/Tsadik.T,2013)

Item	Checklist	Visual observation
1	Chemical Pre treatment	
Alum Wastage (Solid alum in tank or not soluble)		
Corrosion or leakage in alum feed tank		
Plugging problem of alum feed pipe		
Alum sludge		✓
Mixer installed		✓
2	Flocculation	
Floc Characteristics and Floc settling		
Overflow between baffled channel		
No visible flocs formed		✓
Floc Formed		✓
Larger floc formed at downstream		
Floc settled		
Floc breakage at outlet		
Tank Cleaning and Maintenance		
Deposits in the flocculators		
Scum accumulation		
Algae growth		
3	Sedimentation	
Effects of turbulence, short circuiting, scour is high		
Floating sludge		

Excessive floc carry-over		
Algae growth		
Scum accumulation		
4	Filtration	
Algae growth		
Mud coated on filter sand		
Mud ball formation		
Media cracking, mounding		
5	Backwash	
Carryover of sand duringbackwashing		
All mud ball been removed		
Filtered had sand or broken underdrainsystem		
Startups occur on dirty filter		✓

Annex 3 Determination of major unit processes capacity

A) Clarifier (sedimentation and flocculation) Basin capacity

1. Basin Volume =236.8 m^3 $(LxHxW)$ = $8mx3.7mx8m$ = $236.8m^3$

2 Basin surface area = WxL = 8x8 =64m^2

3 detention time used during the visit period was = 1.61hour

4. Total capacity = $\frac{\text{number of basin x volume o}}{detentiontime}$ =$\frac{6x236.8}{1.61}$ m^3/hr = 882.48m^3/hr =**21,155.52 m^3/day**

B) Filtrationbasin capacity

1. Filter bed area = no of filter x depth$x$length =6 x6.8x4.4=179.52m^2

Selected filtration rate = 4.98m^3/m^2/hr

2 total filtration capacity = filtration rate $x$total filter bed area

= 4.98m^3/m^2/hr$x$ 179.52m^2= 897.6m^3/hr

Total filtration capacity (m^3/day) = **21,542.4 m^3/day**

C) Disinfection capacity

The treatment plant uses only post-disinfection and capacity of the unit process was projected based on the post-chlorination disinfection requirement.

1. Required Giardia log reduction/inactivation was determined based on surface water source 3.0log

2. Expected Log removals of Giardia Cysts by conventional filtration is 2.5 log

3. The required log inactivation by disinfection is the difference between Required Giardia log reduction/inactivation (step 1) and Expected Log removals of Giardia Cysts by conventional filtration (step 2).

$= 3.0 - 2.5 = 0.5\ loginactivation$ 4..CT required for 0.5 log inactivation of Giardia cyst was determined based on minimum water temperature and maximum treated water pH. Minimum Temperature of 21.3°C and maximum pH of 7.13 was selected, and the maximum free chlorine residual was set at 0.6 mg/L. then from tables of CT values, the CT was found to be 64 mg/L-min

5. Required contact time based on maximum free chlorine residual that can be maintained was determined by the following formula.

The required contact time= $\frac{\text{CT required for 0.5 log inactivation of Giardia cyst}}{\text{chlorine residual}}$

$$= \frac{64\ \text{mg/L} - \text{min}}{0.6\ \text{mg/L}} = 106.7\text{minut}$$

6. The effective volume of Clearwater-well was determined by the following formula: Effective volume = basin volume at minimum depth x baffling factor (T10/T) Basin is multiple baffled so T10/T factor of 0.5 was used, Minimum operating depth is 4.0 m. Therefore Effective volume = 3.14 x 225 m^2 x 4 m x 0.5 = 1413 m^3

Rated capacity= volume/ CT= 1413m^3/106.7min (converting to day)

= **19,069.54m^3/day**

Annex4 major unit process evaluation criteria adopted from (EPA, 1999)

Flocculation		Hydraulic detention time
Base		20 minutes
Single stage	Temp≤0.5oc	30 minutes
	Temp>0.5oc	25minutes
Multiple stage	Temp≤0.5oc	20 minutes
	Temp>0.5oc	15 minutes

Filtration	Air binding	Loading rate
Sand media	None	2.0gpm/ft
	Exist	1.0-1.5 gpm/ft^2
Dual/Moved	None	4.0 gpm/ft^2
	Exist	2.0-3.0 gpm/ft^2
Deep Bed (Typically anthracite>80in in depth	None	6 gpm/ft^2
	Exist	3.0-4.5 gpm/ft^2

Baffling condition	Factor	Baffling Description
Unbaffled	0.1	None; agitated basin, high inlet and outlet flow velocities, variable

		water level
Poor	0.3	Single or multiple un baffled inlets and outlets, no intra-basin baffles
Average	0.5	Baffled inlet and outlet with some intra-basin baffling
Superior	0.7	Perforated inlet baffle, serpentine or Perforated intra-basin baffles, outlet weir or Perforated weir
Excellent	0.9	Serpentine baffling throughout basin.
Perfect (plug flow)	1.0	Pipeline flow
Based on hydraulic detention time at minimum operating		

	Expected Log removal	
filtration	Giardia	Viruses
conventional	2.5	2.0
Direct	2	1.0
Slow sand	2	2.0
Diatomaceous Eart	2	1.0

Annex 5 Sedimentation basin Raw data of stalled water turbidity

day	Settled water turbidity (NTU)
1	3.4
2	3.8
3	3.6
4	3.2
5	3
6	3.4
7	3.4
8	3.5
9	3.7
10	3.4

Annex 6 Quantity of water

In order to evaluate the efficiency of the treatment plant in providing the required amount of water to the public so by using arithmetic method we can calculate the present population from the data provided during the design paper the population number forecasted were shown in the table

Item	Year	Unit	2007	2010	2025	2035
1	Population					
1.2	Population	No	167,359	192,123	360,733	522,248
1.3	Jima University population	No	31,000	35,000	55,000	55,000
1.4	College Student - from Jimma	No	4,519	5,187	9,740	14,101
1.5	Total population	No	193,840	221,936	405,993	563,147

From this it is possible to calculate the present number of population

$$Pf = P2 + \left(\frac{P2 - Po}{t2 - to}\right) tf - t2$$

P_{2025} = 405,993= P_f

P_{2008} = 193840= P_O

$P_{2 =}$? Present population

tf= 2025

t_o= 2008

t_2=2021

from this the calculated value of present population is

P_2= 352964

But from the interview with the chemist the demand of water provided daily was (19000-20000m^3/day)from the design paper

Item	Year	Unit	2007	2010	2025	2035
1	Demand					
1.1	Domestic Demand	m^3/day	2,451	3,603	12,092	17,496
1.2	Non-Domestic	m^3/day	1,352	1,906	5,977	8,649
1.3	Public	m^3/day	1,107	1,546	4,768	6,899
1.4	Schools	m^3/day	249	285	536	776
1.5	Other Public &Gov institutions	m^3/day	490	721	2,418	3,499
1.6	Jimma University	m^3/day	1,860	2,100	3,300	3,300
1.7	Total Demand	m^3/day	5,663	7,609	21,369	29,445

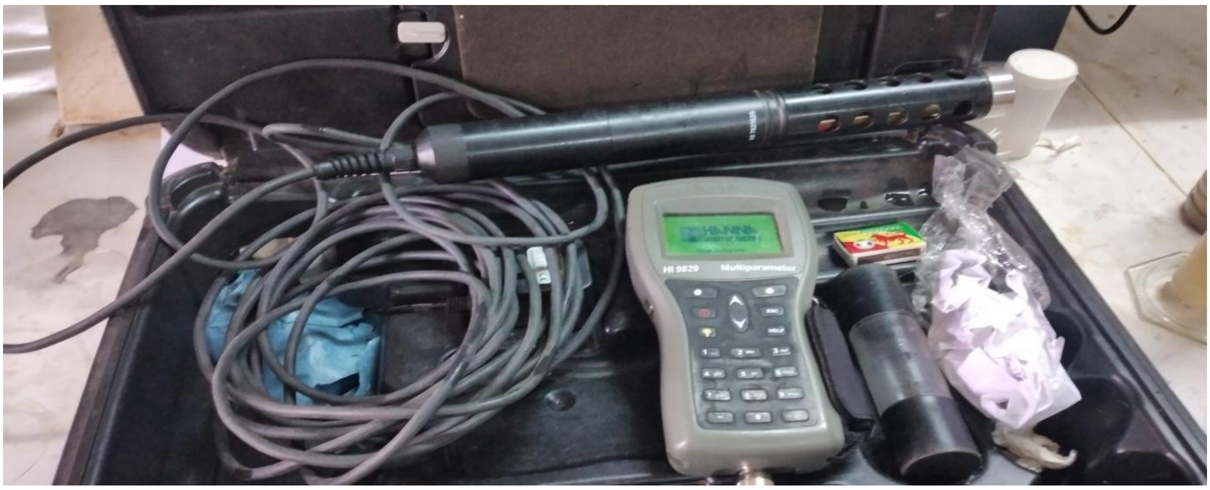
From the table the predicted amount of water for 2021 will be calculated by using interpolation the result calculated is 19912.76m^3/day.

All institutions including Other Public &Gov institutions schools and Jimma university the predicted amount calculated for 2021 is 5441.76m^3/day.

Annex 7 Number schools and students

No.	School name	Number of student
1	Manderaa	1780
2	Hibrat	3062
3	Jimma	1569
4	Jitu	473
5	Berkume	586
6	Dilfilee	1892
7	Kittoo	1471
8	Madrasa	227
9	Hirmata	2819
10	Hamile 19	1533
11	AbdiGudina	247
12	HawiiGudina	767
13	Iwukat Cora	333
14	SaxooYidoo	2731
15	Ginjoo	3688
16	Jiren	2439
17	Daamuu	956
18	mision	195
19	Jirennumber one	767
20	Abdibori	333
21	KemeleKitoo	441
22	Bore	2478
23	TuulamaQananii	354
24	Qofee	749
25	Abba ajifaar	332
26	EBFM	353
27	Abuneyohaniis	199
28	Amanu`eelBirhaan	294
29	Beeteseb	590
30	Burhaan	210
3	Eldan	876
31	FalegeXibeb	710
32	FalegeSelaam	186
33	Hilaal	187
34	JireenQaleehiwot	328
35	omiinitii	1065
36	Mawwaddaa	482
37	kiduusPhauloos	784
38	Sos	704
39	Yaahiwaanis	237
40	Yenegetesfaa	113
41	Yimaaruu genet	130
42	Yexibebmincci	37
43	TesfatewahidooLak 1	882
44	Waliif	274

Annex 8 Photo during research time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