T.C.
ONDOKUZ MAYIS UNIVERSITY
INSTITUTE OF GRADUATE STUDIES DEPARTMENT OF ENVIRONMENTAL ENGINEERING

EFFECT OF WATER CHARACTERISTICS ON PLANNING AND DESIGNING OF DRINKING WATER TREATMENT PLANTS

.

MASTER THESIS

Jemal NESRO

Prof. Dr. Feryal AKBAL

SAMSUN
2020

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THESIS APPROVAL

The thesis prepared by Jemal Nesro SHUKRA under the supervision of Prof.Dr. Feryal Akbal titled Effect *of Water Characteristics on Planning and Designing of Drinking Water Treatment Plants* has been accepted as Master's Thesis by the jury members on the day of 26/02/2020.

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Chair		
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This thesis was approved by the jury members whose names are written above and determined by the Institute Administrativ Board.

APPROVAL

……/……./…….

(Prof. Dr. Ali BOLAT)

Director of Institute

ETHICAL DECLARATION

I declare that I have prepared all the information in this thesis according to Ondokuz Mayıs University Institue of Graduate Studies thesis writting rules. The work provided in this thesis is correct, complete and unless otherwise refernced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

12/10/2020

Jemal NESRO

Özet

SU ÖZELLİKLERİNİN İÇME SUYU ARITMA TESİSİ PLANLAMA
VE TASARIMINA ETKİSİ
Jemal NESRO
Ondokuz Mayıs Üniversitesi
Lisansüstü Eğitim Enstitüsü Çevre Mühendisliği Bölümü
Yüksek lisans tezi, 10/2020
Danışman: Profesör Dr.Feryal AKBAL

Su hayattır", bize suyun gezegenimizdeki önem seviyesini kolayca gösterebilecek bir atasözüdür. Çünkü su, evrendeki tüm yaşamın hayatta kalması için temel ve en gerekli maddedir. Ancak herhangi bir arıtma/temizleme olmaksızın doğrudan su kaynağından kullanılması halinde tüketiciye zarar verebilecek birçok su kaynaklı hastalık da vardır. İnsanlar tarih boyunca suyla ilgili birçok sorunu aştı, hayatta kalmak için mücadele etti ve bugün sahip olduğumuz su arıtma seviyesine ulaşmak için büyük bir ilerleme kaydetti. Yine de, dünyanın dört bir yanındaki milyonlarca insanın güvenli içme suyu ve sanitasyona erişimi yok. Bu nedenle, içme suyunun arıtılması ve insanların yakınına getirilmesi, dünyadaki birçok ülke için ana sorunlardan biridir. Aslında içme suyunun arıtılması ve dağıtılması, özellikle nüfus artış hızı yüksek olan yoksulluk içinde yaşayan ülkeler için kolay bir iş değildir. Sahra altı Afrika ülkeleri, güvenli içme suyu ve sanitasyona erişim eksikliği yaşıyor. Etiyopya nüfusunun yarısından fazlasının güvenli içme suyuna erişimi yok. Silte bölgesi, güney ulusları ve milliyetler bölgesel eyaletinde (Etiyopya) bulunan bir ilçedir ve büyük ölçekli güvenli içme suyu sıkıntısı ve sanitasyon sorunları vardır. Bu çalışmanın temel amacı, farklı su kaynaklarının (silte bölgesi su ve enerji departmanı tarafindan yürütülen) laboratuvar sonuçlarını analiz etmek ve son olarak farklı kirleticiler için şematik diyagramı belirtip silte bölgesindeki su kaynaklarından biri için içme suyu arıtma tesisi tasarlamaktır.

Anahtar Sözcükler: Içme su , Su talebi , Tedavi süreçleri, Planlama , Tesarım.

ABSTRACT

Master's Thesis

EFFECT OF WATER CHARACTERISTICS ON THE PLANNING AND DESIGNING OF DRINKING WATER TREATMENT PLANTS

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Ondokuz Mayis University

Institue Of Graduate Studies

Department of Environmental Engineering. 10/2020

Advisor: Prof. Dr. Feryal AKBAL

'Water is life'' is the proverb that could easily shows us the level of importance of water in our planet. Because, water is the basic and the most essential substance for the survival of all life in the universe. But, there are also a lot of waterborne diseases that could harm the consumer, if it is used directly from the water source without any treatment. Humans passed a lot of water related problems throughout history, struggled to survive and get a big progress to reach the water treatment level we have today. Although, still millions of people around the world don't have access for safe drinking water and sanitation. Therefore, treatment of drinking water and bringing it near to their people is one of the main issues for a lot of countries around the world. Actually treatment and distribution of drinking water it is not easy job, especially, for countries living in poverty with high population growth rate. Sub- Sahara African countries are suffering with lack of access for safe drinking water and sanitation. More than half of Ethiopia's population doesn't have access for safe drinking water. Silte zone is a district found in southern nations and nationalities regional state (Ethiopia) and it has a large scale safe drinking water shortage and sanitation problems. The main goal of this study was to analyze the laboratory results of different water sources (conducted by silte zone water and energy department) and determine the schematic diagram for different contaminants; finally we design a drinking water treatment plant for one of the water source in silte zone.

Keywords: Drinking water, Water demand, Treatment processes, Planning, Design

ACKNOWLEDGEMENTS

Everything will happen if god allows it to happen", thanks god for helping me to start a task and finish it with strength and courage. I would like to thank all of the Environmental Engineering department staff members for their support and pleasant hospitality and for my friends. Especially, I would like to say" thank you ", to my respected advisor Prof. Feryal Akbal for her endless support and consultancy.

October, 2020, Samsun

Jemal NESRO

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LIST OF ABBREVIATIONS

UNICEF	United Nations International Children's Emergency Fund
BCM	Billion cubic meters
ESDA	Employment and Social Development Canada
WHO	World Health Organization
SNNPR	Southern Nations and Nationalities Peoples Region
ESA	Ethiopian standard agency
QESA	Quality and Standard Authority of Ethiopia
HSP	Hot spring
SW	Surface water
BH	Borehole
SP	spring
PH	Hydrogen Ion
Sr.No	Serial Number
ADF	Average daily flow
CD	Coefficient of drag
MDC	Maximum daily consumption
Lpcd	Liter per capital demand

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1. INTRODUCTION

Earth is the only planet in this vast universe to have a unique and precious substance called water, and of course life, which makes Earth precious too. The planet has a finite amount of water with the estimated total amount of about 1-2 km^3 and it covers almost 71 percent of the whole earth's area. The rest 29% is covered by continents and islands etc. The freshwater we have on the planet is only about 2-3% of the total amount of water that exists in this universe. Out of this freshwater, 1.6% is locked up in the polar ice caps and glaciers and the other 0.36% is found in underground aquifers and wells. Only about 0.036% of the planet's total water supply is found on lakes or rivers. Only about 0.036% of the planet's total water supply is found on lakes or rivers (https://science.howstuffworks.com).

The small amount presence of fresh water in this world is not the only problem; it also contains a lot of materials which could be harmful to human beings not to use it directly from its sources. Therefore, we even have to treat this fresh water in some way according to the material it contains before it reaches to the users. The worst thing is treatment of water is not easy task, especially when we want to treat the water for mass of people. That is reason why 1 in 3 or 2.2 billion people around the world still have lack of safe drinking water (UNICEF, 2017). According to this report 673 million people around the world still practice open defecation due to lack of sanitation, and they are increasingly concentrated in the so called high burden countries. Most of these high burden countries are found in sub-Saharan Africa, where many countries have experienced strong population growth over this period.

Therefore in order to achieve safe and potable water for the users around the world we have to treat and manage the raw water in appropriate way before it reaches from its sources to users. Every water source has its own characteristics and contaminants to be treated in specific treatment method according to their behavior. Treatment of water might seems easy when we treat on household level but if we want to treat and supply for a city or another larger population the process become very complicated and it has high initial cost. Since everybody needs and deserves one of the basic needs for life, water, the world has to be coordinated and work hard to give this precious gift for everyone around the world.

Ethiopia is one of the fastest growing countries in sub-Saharan African country and achieves a tremendous result in Accessing safe water for its people. Although still about 60 percent of the population do not have a basic water supply and with exceptionally low coverage of sanitation and hygiene facilities, and 27 percent of people practicing open defecation (Water Aid, 2019). The amazing thing is Ethiopia has plentiful amounts of water resource potential with estimated value of 124.4 BCM rivers, 70 BCM lakes and 30 BCM underground water with total amount of 224.4 BCM usable water resource potential (Brhanu, 2014). High population growth and poor water governance are the basic reasons for water supply problems the country facing now.

There are 94 towns and cities in Ethiopia and out of these, 1 city has over a million habitants, 9 towns over one hundred thousand and 84 towns between ten thousand and hundred thousand populations (Census Data Ethiopia, 2007). Only about 21 percent of the population of Ethiopia settles in urban areas, the rest 79 percent of Ethiopia's population lives in rural areas.

The water supply problems in rural areas are due to the lack of institutional, infrastructural and demographical coordination. Moreover, poor accountability and lacks of community participation in water projects were identified as constraints of sustainability (Yacob, 2010).

This study aimed to design an integrated drinking water treatment plant to improve safe drinking water supply for the research area.

The specific objectives of this research are:

- To provide adequate and sufficient water to Worabe city and three other neighborhood towns
- To solve the problem of water borne disease by providing potable water.

The aim of this research is to present the fundamental concept of drinking water treatment plant design that could be applied to Worabe City and its three neighborhood towns, Ethiopia, and to make it easy to visualize the benefits of this project in order to let the government administrators of that area think about it. The study will show detail design of drinking water treatment plant depending on the water analysis data taken from the area.

2. RELATED LITERATURE REVIEW

2.1. Overview

Since water is the basic need for life, world is trying in one or another way to make sure that at least everyone has access for safe drinking water on its near around. In order to achieve this goal, drinking water treatment plant has a vital role to reach out a lot of population in a single designed and constructed drinking water treatment plant. Well-designed drinking water treatment plant should produce safe and potable drinking water for its customers and also its supply capability should be well enough to ensure the present as well as the future population of the designed area. Besides, it should be economical and free from any socio-economic influences.

This part deals with the theoretical overview of drinking water treatment plant. It will assess the water sources for drinking water and finally highlights how and when drinking water regulations and standards starts.

2.2. Sources of Drinking Water

Safe and potable, constant supply of drinking water is essential to any community living in the big cities or in smaller villages. The sources of the water supply could be surface water sources such as lakes, rivers and reservoirs or ground water sources. To be economical it is preferred to use water sources which are closer to the community, if it is available. Otherwise we could go miles away to get better water sources. Generally; watershed is the main water source for surface and underground water sources. The watershed is the land area over which water flows into the river, lake, or reservoir (ESDA, 2013).

2.2.1. Surface Water Sources

Most surface water originates directly from precipitation in the form of rainfall or snow. Ground water from springs and seeps also contribute to flow of most of the streams. These are the common surface water sources.

2.2.1.1. Sea Water

Though, the oceans contain about 97% of the total water in the world, with high concentration of salts in solution, it becomes uneconomical to make this water potable. In some areas, where sea water is the only available source of water people are using desalination, which is a very expensive treatment method.

2.2.1.2. Streams and Rivers

A river is water collected from precipitation at a higher altitude and it is naturally formed that flows on a course. The river's shape is defined by its waterbeds. Its volume can be different from places to place depending on the shape of its riverbeds, and it can also vary in volume according to the season.

A stream is a flowing body of water which their shape is determined by their riverbeds and bends. Since streams flow starts from higher elevation, most of the time they have a fast current. The amount of water in the streams could be variable throughout the year. Generally, Streams and rivers complete their hydrologic cycle by returning to the oceans (Balasubramanian, 2017).

2.2.1.3. Natural Lakes and Ponds

Lakes are natural or artificial depressions which hold standing fresh water throughout the year. Ponds are generally small, temporary or permanent shallow water bodies and it also could be artificial or natural. Water from these sources is more uniform in quality than water from flowing rivers and streams (Elisha, 2017).

2.2.1.4. Artificial Impounding Reservoirs

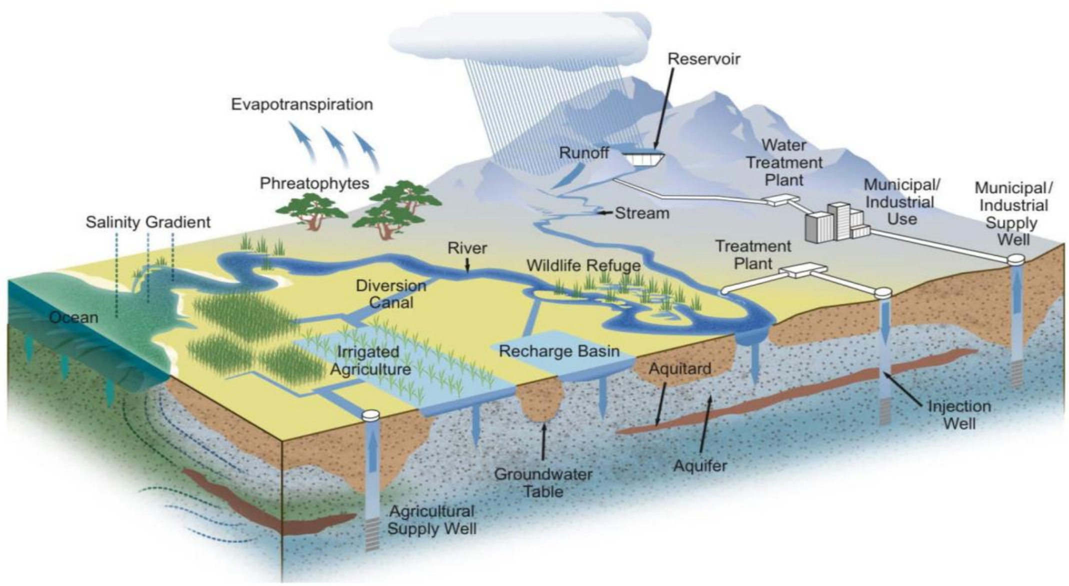
These water sources are formed by constructing hydraulic structures (like dams) across river valleys and its water quality is similar to that of natural lakes and ponds (Ratnayaka, 2009).

2.2.1.5. Ground water sources

Groundwater is an essential and vital resource for a lot of people around the world, especially for sub-Sahara African countries. It is their sole source for all their daily water needs.

Most of the earth's fresh water is found in 100 meter deep of the surface of the earth. After that depth, because of the weight of rock, the openings for water movement are much smaller, and therefore it contains considerably smaller quantities of water.

Groundwater usually flows down with the slope of the water table by gravitational force but it may move in different directions below the ground than the water flowing on the surface.



From CA Water Plan 2014

Figure 2.1. General water cycle on the earth

The illustration shows how the groundwater collected in the water table and a drilled artesian well and a flowing artesian well.

The quantity of groundwater in the earth would cover the entire surface of the globe to a depth of 120 meters. It is extremely difficult to estimate the volume of groundwater on the entire planet (Government of Canada, 2013).

2.3. The State of Urban Water Supply in Ethiopia

The water supply and sanitation sector in Ethiopia is one of the least developed and is mostly characterized by service deficiency of physical infrastructure as well as by inadequate management capacity to handle policy and regulatory issue and to plan, operate, and maintain the service. Regarding this, World Bank Group (2005:2) stated that though Ethiopia is often referred to as the "water to wer" of Africa, only a quarter of the country's population have improved access to water sources. Rushing streams from the Ethiopian highlands form tributaries of famous Blue Nile, Tekeze, Awash, Omo, Wabeshebele and Baro-Akobo-rivers which flow across borders to neighboring countries. Six billion cubic meters of water run out of Ethiopia as the Blue Nile River to the Sudan and Egypt.

Although, 62 million Ethiopians lack access to safe water and 97 million lack access to improved sanitation. Of those who lack access to improved sanitation, a staggering 23 million practice open defecation. In rural Ethiopia, many women and children walk more than three hours to collect water, often from shallow wells or unprotected ponds they share with animals. Recurring droughts result in famine, food shortages, and water-related diseases, as people are forced to rely heavily on contaminated or stagnant water sources (Water. Org, 2019).

2.4. Drinking Water Treatment Methods

There are basically two types of treatment process used in the water treatment process, namely physical and chemical processes. Physical processes: make use of the physical properties of the impurity such as particle size, specific gravity, viscosity etc. in removing them from water or wastewater. Examples of this process are screening, sedementation and filtration. Chemical processes: Chemical characterstics of impurities or the chemical properties of an added reagent is utilized for the removal of impurities.

For instance coagulation, preciptation, disinfection, ion exchange are typical chemical processes (MHW et al., 2012).

2.4.1. Aeration

Aeration is used to increase the oxygen content in the water by adding air into water through diffusors in a pipe, channel, or process basin; cascading water over stacked trays; or surface turbines and wheels that mix air into water at the top of basins. Cascade aerators are commonly used for treating groundwater and may be located at the groundwater source or reservoir. Cascade aerators are also called step aerators as water flows downward in a thin film over a series of steps or baffles, sometimes constructed of concrete (Moulick, 2010).

2.4.2. Rapid Mixing

Impurities in water vary in size by about six orders of magnitude, from a few size particles for soluble substances to a few hundred microns for suspended solids. Many of the impurities are too small in size for gravitational settling. Sedimentation can be used to remove suspended particles down to the size of about 50 micron depending on the particle density. Smaller particles (colloidal) have very low settling velocities so that removal by sedimentation is not feasible.

Practical way of making smaller particles settle is by chemical coagulation. When the size of a particle gets smaller, the static electrical charge that they carry around becomes a significant property responsible for the behavior of a suspension. A colloidal suspension is termed as stable when the suspension shows little or no tendency to agglomerate. The repulsive forces of the electrical charge around the colloidal particles prevent aggregation. By the addition of some chemicals called coagulants, the electrical repulsive forces on the particle surfaces are reduced, that means colloidal particles are destabilized. This process of destabilization is called coagulation. Coagulants are metallic salts which react with alkalinity in water to produce an insoluble metal oxide or hydroxide precipitate called floc. Bulky floc particles enmesh the colloidal solids present in the solution (Binnie et al, 2002).

2.4.3. Flocculation

In a destabilized suspension, every opportunity of collusion of particles will make them agglomerate and get larger size particles therefore settle reasonably faster. This process of increasing the opportunity of collusion by mixing gently is called flocculation. Gentle mixing causes velocity gradients, the intensity of which controls the degree of flocculation produced (Han and Lawler, 1992).

2.4.4. Sedimentation

Many of the impurities in water and wastewater are present as suspended particles. Sedimentation is the removal of these suspended particles from solution by gravity settling. Other terms used to describe this process are clarification and thickening. In water treatment, sedimentation is used to remove particulate matter, flocculated impurities and precipitates which are formed in operation such as water softening or iron removal.

The basic theory of sedimentation assumes the presence of discrete particles. When such particle is placed in a liquid of low density, it will begin to accelerate, under the action of gravity and will eventually reach a limiting terminal velocity at which the gravitational force is exactly balanced by the frictional drag force on the particle as it falls through the fluid (Boccelli et al., 2004).

2.4.5. Rapid Sand Filtration

Sand filters are an important means of purification for public and industrial water supplies. Mainly two types of sand filters are common in practice “slow” and “rapid” sand filters. These two types of filters differ from each other according to the rate at which water is filtrated and the basic removal mechanism of the impurities. Slow sand filters operate at a rate of about 0.71m/hr. and function biologically. Unless a biological surface mat called “Schumutzdeck” forms, these filters do not purify water properly. Rapid sand filters usually operate at a standard rate of 5 m/hr., and removal of impurities during filtration takes place because of phisico-chemical removal mechanism.

For filters to be effective in filtration, pretreatment or coagulation, flocculation is a necessity. Filtration of water without pretreatment cannot be accepted as a treatment operation. Because in this case depth filtration in the real sense do not take place and filter is being used as a straner. Under the action of phisico chemical removal mechanism, suspension particulates which are 2 to 3 order of magnitude smaller than the pore size are removed. This shows that depth filtration is different than straining. Straining is an insignificant mechanism in depth filtration.

In simple sand filters because of non-uniform size, grains are naturally graded from fine to course in the direction of filtration after backwashing. As a result of this gradation only the first one fifth or one sixth part of depth of the media effectively participates in the filtration process and the remaining major part of the media function as support to the thin but effective layer at the top (ACWWA, 2004).

2.4.6. Disinfection

The purpose of disinfecting water supplies is to kill pathogenic organisms and thus prevent spread of water- borne disease. Most pathogenic bacteria and many other microorganisms are destroyed or removed from water in varying degree by most of conventional treatment process. Chlorine and chlorine derivatives are the conventional disinfectants (Ramaley et al., 1981).

2.5. Water Quality Standards and Regulations

From the public health point of view the bacteriological quality of drinking waters is important parameters. Disease in man can be caused by the presence of certain microorganisms called pathogens. Pathogenic microorganisms may be of several origins like virus, bacteria, protozoa and worms. Water is the mode of transmission for several pathogens such as salmonella, typhoid, vibiocoma (cholera), Schigella (dysentery) and infectious tract. Continuous bacteriological examination of water supplies is one of the main duties of municipalities providing water to community (John et al., 2012).

Water quality standards and regulations are important to environmental engineers in order to selection of raw-water sources, choice of treatment processes and design criteria, range of alternatives for modifying existing treatment plants to meet current or future standards, treatment costs, and residuals management.

- Water quality regulation typically proceeds some logical stepwise fashion: Beneficial uses are designated
- Criteria are developed
- Standards are promulgated
- Goals are set

Although often used interchangeably, there are significant differences in the terms criteria, standards, and goals. However, these items all fit under the general category of water quality regulation.

Water quality criteria have been developed by various groups to define constituent concentrations that should not be exceeded to protect given beneficial uses. Until criteria are translated into standards through rule making or adjudication, criteria are in the form of recommendations or suggestions only and do not have the force of regulation behind them.

It is important to note that water quality standards, in contrast to criteria, have direct regulatory force. Quality standards in the past have been based on a number of considerations, including background levels in natural waters, analytical detection limits, technological feasibility, aesthetics, and health effects. The ideal method for establishing standards involves a scientific determination of health risks or benefits, a technical/engineering estimate of costs to meet various water quality levels, and a regulatory/political decision that weighs benefits and costs to set the standard.

Water quality goals represent contaminant concentrations, which an agency or water supplier attempts to achieve. Goals are typically more stringent than standards and may include constituents not covered by regulations but of particular importance to the goal-setting entity.

A number of agencies have developed drinking water regulations. These include standards for individual countries or groups of countries. The WHO has been at the forefront of developing standards. The WHO standards, known as the Guidelines for Drinking Water Quality (WHO, 1993, 2006), are meant for guidance only and are recommendations, not mandatory requirements. However, the WHO standards have been adopted in whole or in part by a number of countries as a basis of formulation for national standards. The WHO guidelines contain recommendations, health-based standards, monitoring, measurement, and removal for microbial quality and waterborne pathogens, chemical constituents, radionuclides, and aesthetic aspects.

The continued process of water quality regulation is expected to produce additional standards in the future, especially as new compounds are being developed and identified continually.

3. DESIGN AREA

3.1. Background

Ethiopia is one of ancient civilized countries in the world, located in the east of Africa with great history, beautiful landscapes and a lot of natural resources. Though, still one of the poorest, undeveloped and unsettled country for so many different reasons. Poor governance is the main and vital problem inherited from time to time not to handle and balance the amazing diversity of the country. There are about 86 different ethnic groups with their own different languages, culture and their local governance system.

Currently, Ethiopia is a federal democratic republic composed of 9 national regional states (kilil): namely Southern nations and nationalities and peoples (SNNPR), Tigray, Oromia, Afar, Amhara, Somali Gambela, Harare and Benishangul Gumuz, with two administrative states (Addis abeba city administration and Dire Dewa city council), and this structure continues down with zones, Weredas until it reaches the least government structure, Kebeles.

SNNPR regional state (kilil) is the most ethnically diversified region in Ethiopia by bracing about 56 different Ethnic groups out of 86 groups of the country. Silte is one of recently organized zone in SNNPR region with current estimated population of 1.4 million and also it divided in to 8 different weredas (districts). Worabe town is serving as a capital city for silte zone, suffering with lack of infrastructure and other socio-economic problems, especially water supply and sanitation are the worst conditions for the people living in the area. Therefore, this project intended to resolve or at least minimize the water supply and sanitation problems in worabe town and three other neighborhood cities by designing a water treatment plant that can supply the current and the future population of these cities.

3.2. Location and Topography

Silte zone is located 7^{0}51'09.6''N and 38^{0}11'04.9''E in SNNPR region of Ethiopia about 200 km south of the capital city of the country, Addis abeba. Worabe, Tora, Sankura and Dallocha are the four cities found in this zone and we are intended to design a drinking water treatment plant that can supply these cities and their geographical location is as follows.

Table 3.1. Geographical location of design area

City	Latitude	Longitude	Elevation(M) above sea level
Worabe	7^{0}51'9.57''N	38^{0}11'4.91''E	2090
Tora	7^{0}51'37.1''N	38^{0}25'28.3''E	3033
Sankura	7^{0}34'03.3''N	38^{0}10'36.4''E	2090
Dallocha	7^{0}47'37.1''N	38^{0}14'33.6''E	1952

Figure 3.1. Map of Ethiopia

Figure 3.2. Location of design area (Google Earth)

3.3. Climate

The whether condition is almost similar in silte zone, Woina Dega (Subtropical zone) - includes the highlands areas of 1830 - 2440 meters in elevation has an average annual temperature of about 22 ^{0}C with annual rainfall between 510 and 1530 millimeters.

Silte zone is characterized by high mean annual rain fall of 1367 mm. The highest rainfall occurs in June, July, August and September with March and April being the driest months. The mean monthly temperature of this zone ranges from 12.3 ^{0}C- 15.9 ^{0}C. The minimum and maximum temperature varies with in 1.6 ^{0}C-8.9 ^{0}C and 19.6 ^{0}C-24.7 ^{0}C, respectively. The lowest temperature recorded during the months of December, January and February. The highest temperature recorded during the spring season (February, March, April and May). The variation of the temperatures is minimal, which is typical for the climatic region.

3.4. Socio-economic Background

According to the 2007 national census data report a total population of silte zone was 982,727 of which, 501,324 were women and 481,399 were men. About 97 percent of the inhabitants in this zone are Islamic religion followers, 2 percent Orthodox Christians and the rest 1 percent worships other different religions. Since, about 90 percent of the population lives in rural areas, Agriculture is the back bone of the economy for settlers in this zone. The remaining 10 percent inhabitants live in the cities with different income sources, especially trade. The cities we mentioned before as our design area are part of this 10 percent urban settler. Education and health care are the two basic sectors tremendously growing in the past 10 years as a result there is at least one primary school and one health center in every kebele (least administration). The education and health coverage in 2018 was 90 and 85 percent respectively in silte zone (silte zone Administration office, January, 2019).

3.5. Existing Water Supply and Sanitary Service

The total safe drinking water supply coverage of silte zone is only 55 percent in the cities and 30 percent in rural areas (Silte zone water and energy department, December, 2018). Lack of good governance, abrupt growth of population and poor skilled man power are the basic reasons for the suffering the people facing now. The worst thing is the sanitation, there is no properly designed or constructed sewerage or drainage system to collect and dispose the waste from each residence houses. The main drinking water supply sources are mechanically dogged bore holes, by adding chlorine as disinfectant, without any further treatment, the water will be distributed to the people.

4. PLANNING OF WATER TREATMENT PLANT

4.1. Water Characteristics

The raw or treated water is analyzed by testing their physical, chemical and bacteriological characteristics:

Physical Characteristics:

- Turbidity
- Color
- Taste and odor
- Temperature

Chemical characteristics:

- pH
- Acidity
- Alkalinity
- Hardness
- Chlorides
- Sulphates
- Iron
- Solids
- Nitrates

Bacteriological Characteristics:

Bacterial examination of water is very important, since it indicates the degree of pollution. Water polluted by sewage contains one or more species of disease producing pathogenic bacteria. Pathogenic organisms cause water borne diseases, and many non-pathogenic bacteria such as E.Coli, a member of coliform group, also live in the intestinal tract of human beings. Coliform itself is not a harmful group but it has more resistance to adverse condition than any other group. So, if it is ensured to minimize the number of coliforms, the harmful species will be very less. So, coliform group serves as indicator of contamination of water with sewage and presence of pathogens.

4.2. Actual Water Sources

Quality of drinking water to be distributed to the consumer is evaluated according to these chemical, physical, and Bacteriological Characteristics. The treated water should fulfill the drinking water quality standards put by the government authorities of design area.

The Ethiopian Standards Agency (ESA) is the national standards body of Ethiopia established in 2010 based on regulation No. 193/2010. ESA is established due to the restructuring of Quality and Standards Authority of Ethiopia (QSAE) which was established in 1998. The objectives of this agency are to develop Ethiopian standards and establish a system that enables to check whether goods and services are incompliance with the required standards. Facilitate the country's technology transfer through the use of standards, and develop national standards for local products and services so as to make them competitive in the international market.

In 2013 ESA published a drinking water specification standard that should be fulfilled during designing of any drinking water unit. There are lists of physical, chemical, and biological characteristics of drinking water with their maximum allowable values of constituents.

Silte zone (district) water and energy department is one of governmental sectors, which works on collecting data, planning, designing and managing every water and other related resources in that zone.

4.3. Schematic Patterns of Drinking Water Treatment Systems

Water sources which are common for municipal water supplies are groundwater or surface water sources. Depending on the quality of the raw water, the extent of pollution and the regulations for safeguarding of public health, drinking water is treated by various methods before it reaches the consumer.

We have a laboratory analysis of different water sources found in silte zone, Ethiopia. The laboratory analysis was conducted by silte zone water and energy department for future design and construction of any water treatment plant. The analysis includes both groundwater and surface water sources and out of these, we select five water sources to determine their schematic pattern of treatment. The laboratory analysis of these water sources is given in the table below. Each of the water sources have different constituent which needs their own specific treatment method.

- The first site is found in Werabet dano village around werabe town and it contains higher amount of manganese than Ethiopian water authority standard. The allowable maximum allowable manganese presence in Ethiopian water authority standard is 0.5 mg/l, but in the actual water source (werabet dano) the amount of manganese is 0.9 mg/l.

First, we can introduce oxidizers like chlorine in to water in small amounts prior to the water filtration. Introduction of chlorine in to raw water will oxidize manganese in to manganese dioxide (the main ore of manganese) which is a black/brown solid. After adding oxidizers we let the water to pass through aeration unit and finally, we can filter it with anthracite and sand layers. The schematic diagram of manganese treatment process is shown in Figure 4.1.

- Bose is a village which we found our second water source and it is located about 15 km away from worabe town. This water source is surface water that contain excess amount of fluoride than allowable value.

Since, the water source is surface water we should put screen barrier to remove the floating materials then we let the water pass through aeration unit. For the treatment of fluoride we should use activated aluminum as an adsorbent, and finally we can filter through sand to get more clear water as shown in Figure 4.2.

- The water sources in Warsha Shanka and Kertef Gibato villages have excess iron and the removal of iron from drinking water is almost same as manganese removal as we have seen in the previous water source.

- The last water source is located in worabe town and it contains high amount of turbidity and iron. For the treatment of this water source, first we have to add oxidants to change iron into iron hydroxide which could easily precipitate. Then, we have to let the water to go through aeration unit in order to promote oxygen exchange between the water and the atmosphere. Addition of coagulants will allow the reaction to take plane between coagulants and residual constituents in the water. After addition of coagulants rapid and slow mixing processes are followed to create uniform solution of coagulants all over the volume of water and formation of flocs. The flocs formed will settle down and collected in the sedimentation tank and finally removed. Finally, filtration with sand filter would be the last process to make ready the treated water for disinfection as shown in the Figure 4.3.

Table 4.1. Laboratory analysis results of five water sources

No	Charactersitics	Werabet Dano	Bose	Warsha Shanka #2	Kertef Gibato/Wabo	Worabe town	Ethipian Standard	WHO standard
1	Source Hand Digging Well	HP	SW	SW	BH	SP		
2	Nature of sample	Untreated	Untreated	Untreated	Untreated	Untreated		
3	NorthingY-Coordinate	$7^0$44'36"	$7^0$44'36"					
4	Easting X-Coordinate	14094	38640	382306.3	381859.6	408178		
5	Altitude [m]			166	1988	1840		
6	pH	6.55	7.4	8.08	7.5	7.1		
7	Temp [°C]			24.1	22.3	23.9	25	25
8	Conductivity [µS/cm]	459	793	166	126.5	84.5		
9	Turbidity [NTU]	4	3	0	**60**	**150**	5	1.5
10	TDS [mg/L]	230	398	83.3	63.8	41.7	1000	
11	Fe^{2+} [mg/L]	0.02	0	**1.67**	**1**	**3**	0.3	0.1

12	Cu^{2+} [mg/L]	0.09	0.04	0.22	0.13	0.06	2.00	2.00
13	Cr^{6+} [mg\L]	0	0	0.02	0.39	0	0.05	0.05
14	NO_2^- -N [mg/L]	0.06	0.04	0	0.01	0	3	3
15	NO_3^- -N [mg/L]	8.3	14.96	0.06	10.1	6.3	50	50
16	SO_4^{2-} [mg\L]	1.2	1.1	1	5.9	13.5	250	
17	PO_4^{3-} [mg\L]	0.7	0.71	34.2	0.4	1.08		
18	F^- [mg\L]	1.15	**3.02**	0.11	0	0	1.5	1.5
19	T-Cl_2 [mg/L]	0.04	0.02	0	0.07	0.13	0.5	0.5
20	Br^- [mg/L]	0.05	0.04	0.03	0.02	0.13		
21	Dissolved NH_3 as N [mg/L]	0.05	0.05	0.01	1.31	1.18	1.5	
22	Mn^{2+} [mg/L]	**0.9**	0.2	0.2	0	0.2	0.5	0.4
23	K^+ [mg/L]	**1.6**	**1.7**	0.5	1	1.02	1.5	

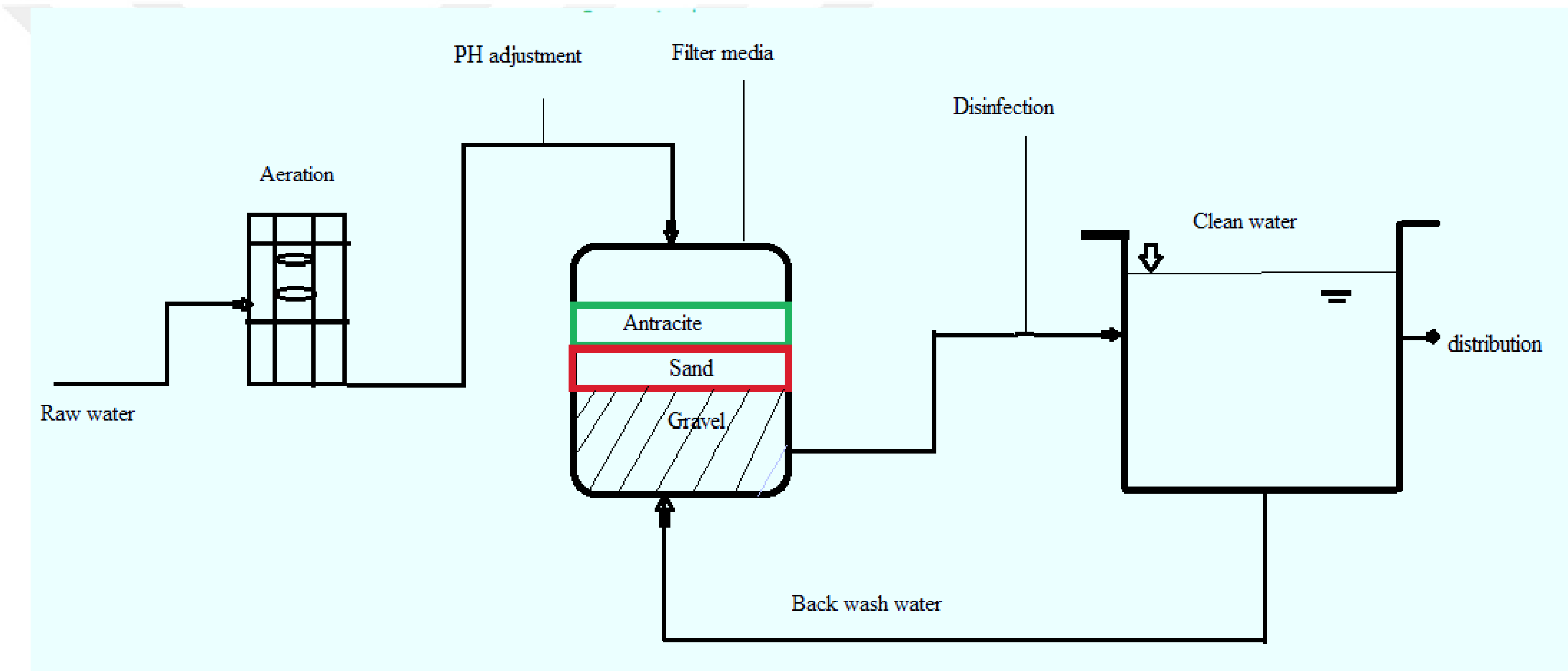


Figure 4.1. Schematic diagrams for treatment of manganese by antracite and sand filters

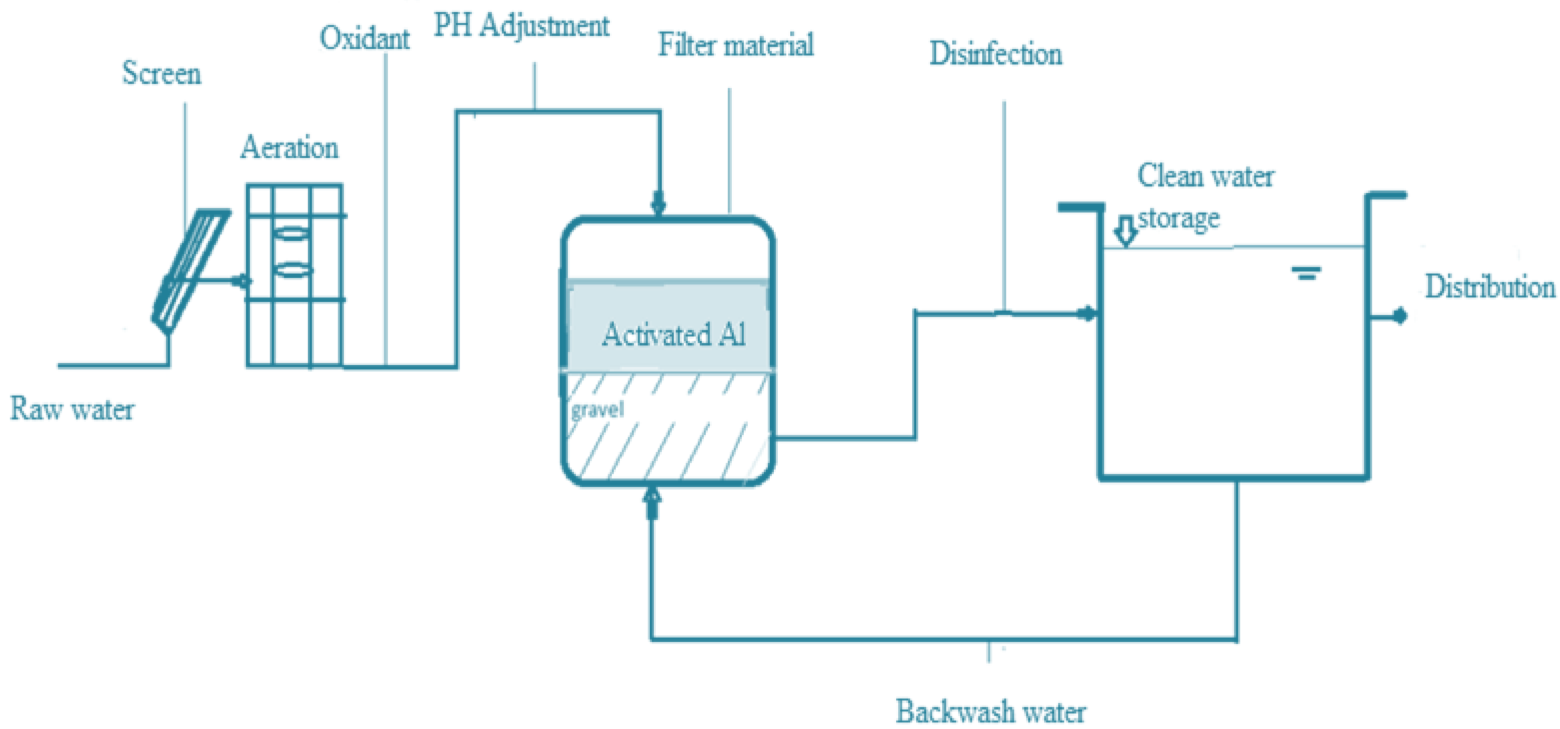


Figure 4.2. Schematic diagram for treatment of fluoride by activated aluminum

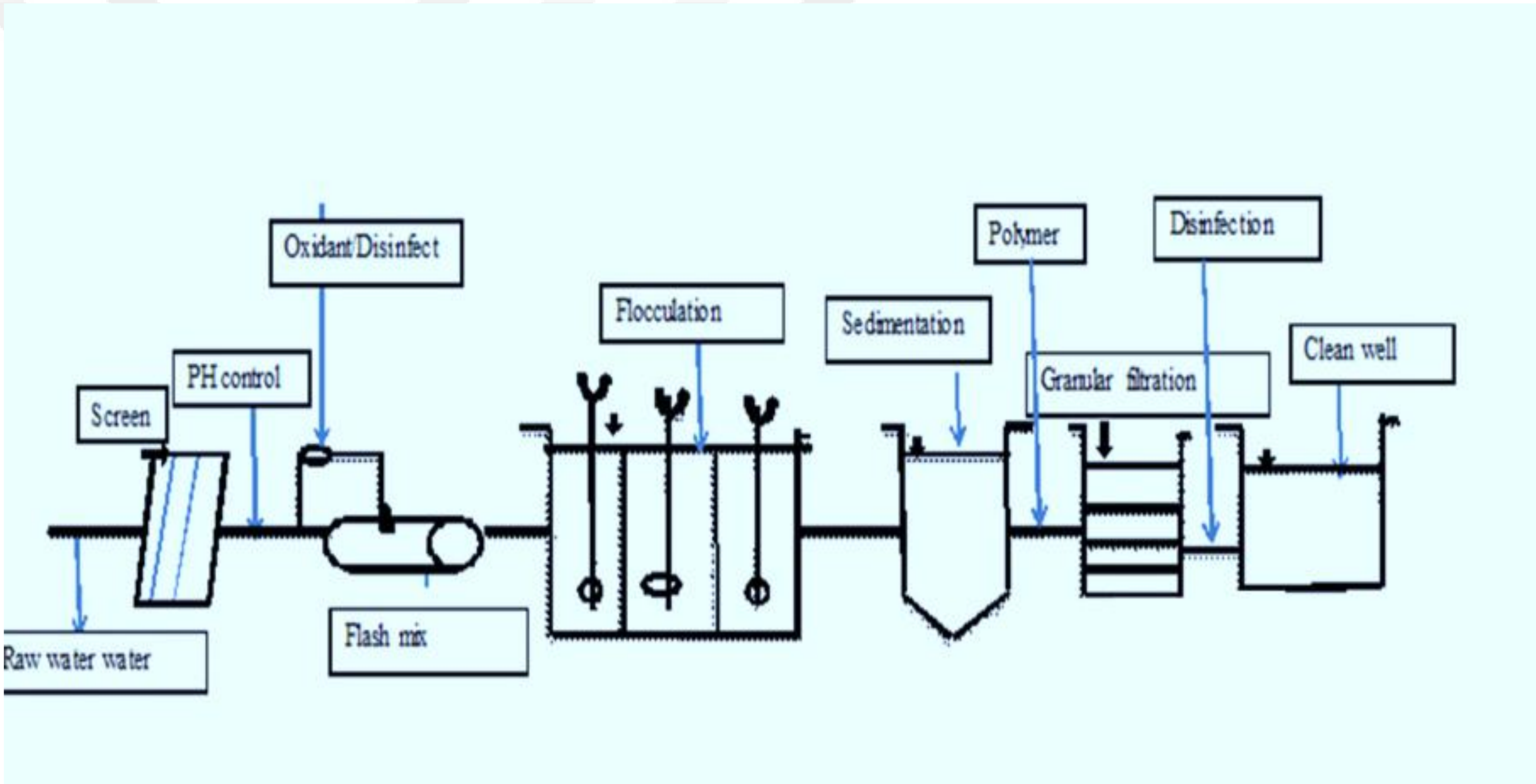


Figure 4.3. Schematic diagrams for the treatment of turbidity and iron

5. DESIGN OF WATER TREATMENT PLANT

5.1. Design Period

The number of years in the future for which the proposed facility would meet the demand of the community after their completion is called design period. Design period is dependent on life span of structure, fund for the completion of the projects, expected expansion of the project etc. and it should not be neither too long nor too short. Water supply projects usually designed with a design period of 22-30 years.

Table 5.1. Design period for different water treatment related units (Cpunmia, 2019)

No	Systems units	Recommended Design period (year)
1.	Pump house	30
2.	Pump	12
3.	Generator	25
4.	Water treatment units	25
5.	Distribution pipe	30
6.	Service reservoir	50
7.	Weir	50

Since our design area population expected to grow and by anticipating further expansion of the project in the future, we adopted 30 year design period.

5.2. Population Forecasting

5.2.1. General Consideration

The estimation of population to be served with in the design period should consider the future development of the city (cities) in industrial, commercial, educational, social and administrative angles. Sudden immigration or influx of population should also be considered as a special factor. In our case the design population is not from only one city, instead, we are intending to design for the population of four cities. Since, these cities are located in 30 km radius for each other, their climate is not variable that much and the socio- economic movement, and above all the population increasing rate is almost the same the design population will be consider as a single city population by summing up the individual population of four cities and because of werabe is the capital city of the district, as well as the nearest city for the water source we named it Worabe water treatment project.

Table 5.2. Population each towns of design area (1994 and 2007 census data of Ethiopia)

No	City	Population in 1994	Population in 2007
1	Dallocha	5513	6793
2	Sankura	2018	3656
3	Tora	5096	12447
4	Worabe	2198	10372
Total population for design		14825	33368

Lack of recent accurate population census data is the main problem we found in predicting the future population. As we can see from the above table, there are only two official population census data in Ethiopia and the 2007 census data was the latest one. The erupt increasing or decreasing of the population due to some administrational border changes is also another factor which could affect our population forecasting. In order to solve this problem, only the current population of the design area is considered.

The 2007 feasibility study by Ethiopian statistics agency shows how to predict the number of population in the future by extrapolating (Estimating or concluding something by assuming that existing trend will continue) the previous population data. Therefore we can use the 1994 and 2007 population census data to estimate the current population of the design area.

Table 5.3. Population of total design area (1994 and 2007 census data of Ethiopia)

Ser. No	Year	1994	2000	2007	2010	2015	2020
1	Population of design area	14825	24098	33368	38666	46613	54560

We have estimated total number of 53236 populations living in our design area, in 2020. By considering these data as starting point we can calculate the population for the design period of 30 years, which is the population of design area in 2050. For the successful design of the structures related to public use on a larger scale there is need to consider the most probable future population. Inaccurate or unsuitable methods of the population forecasting when used may result in increased cost of the construction or unable to satisfy the project requirements. There are various methods used for forecasting the population each assuming various factors and assumptions. Each method gives the different value of future population.

5.2.2. Calculation of Future Population with Different Methods

5.2.2.1. Arithmetic increase method

This method is more suitable for very big and older cities whereas in our case it is relatively smaller and new town and average rate of increase in population is assumed to be constant from decade to decade. Average increase per decade is found out from the previously available census data and it is given by (V.J.I.T, 2019).

$$P_n = P + nd$$

Where

P_n - Future population after n decades

P - Present population

n- No. of decades

d - Average increase per decade

Table 5.4. Arithmetic method population forecasting

Sr.no	**Year**	**Population**	**Increase in population**
1	1994	14825	
2	2000	24098	9273
3	2010	38666	14568
4	2020	54560	15894
Total			39735
Average			15283

Given

n = 3, (2020 – 2050)

$P = P_{20} = 54560$

d = Average increase per decade = 15283

Our population in 2050 will be

$Pn = P + nd$

$= 54560 + 3(15283)$

$P_{2050} = 100409$, individuals

$P_{2040} = 85126$, individuals

$P_{2030} = 69843$, individuals

5.2.2.2. Geometric increase methods

This method would apply to cities with unlimited scope for expansion. Average percentage increase in population is assumed to be constant from decade to decade in this method. Average percentage increase per decade is found out from the previously available census data (Hyndman, 2009).

$$Pn = p\,[1 + (r/100)]^{n}$$

Where

Pn – Future population

P – Present population

r – Average percentage increase

n – No. of decades

Table 5.5. Geometric method population forecasting

Sr.No	Year	Population	Increase in population	Percentage increase in population
1	1994	14825		
2	2000	24098	9273	62.54
3	2010	38666	14568	60.4
4	2020	54560	15894	41.1
Total			39735	164.04
Average per decade			15293	64

Where

r = average percentage increase = 64

n = Number of decades = (2050 – 2020)/10 = 3

Pn = P_{2050} = Population in future

P = Present population, P_{2020} = 54560

Therefore:

$Pn = P (1+ r/100)^{n}$

$P_{2050} = P_{2020} (1 + r/100)^{n}$

$= 54560 (1 + 64/100)^{3}$

$= 54560 * 4.41$

P_{2050} = 240662, individuals

P_{2040} = 146744, individuals

P_{2030} = 89479, individuals

5.2.2. 3. Incremental Increase Method

The advantages of both arithmetic increase method and geometrical increase method are included in this method. Average increase per decade is found out first of all and average percentage increase per decade is worked out as in arithmetic increase method and geometric increase method respectively (Billari, 2014).

$Pn = P + nd + \frac{n(n+1)}{2} * t$

Where

Pn – Future population

P – Present population

n – Number of decades

d – Average increase in decades

t – Average incremental increase

Table 5.6. Incremental increase method population Forecasting

Sr. No	Year	population	Increase in population	Incremental increase
1	1994	14825		
2	2000	24098	9273	
3	2010	38666	14568	5295
4	2020	54560	15894	1326
Total			39735	6621
Average			15283	2547

$Pn = P_{2050} = 54560 + 3*15283 + \frac{3\,(3\,+1)}{2} * 2547$

P_{2050}=115691, individuals

P_{2040} =92767, individuals

P_{2030} =72390, individuals

5.2.2.4. Ethiopian statistic authority

Method used by Ethiopian statistics authority The Ethiopian statistic authority uses the following formula for most water supply project in the country to project population at the end of required decade/year.

$P_n=p_o e^{kn}$

Where

Pn=population at n decades or year

Po=initial population (from census)

K=growth rate

n =decade or year due to given population data arithmetic increase, geometric increase, Incremental increase

From population growth rates found from CSA, the growth rates of silte zone town is tabulated below.

Table 5.7. Population growth rate of urban population in Ethiopia (CSA, 1994)

Year	2015	2016	2020	2026	2031	2036	2041	2050
Population	4.4	4.36	4.16	3.96	3.76	3.56	3.36	3.24

$P_{2050} = P_{2020}\, e\, (^{3.24/100)*(2050-2020)}$

$P_{2050} = 54560\, e\, (^{3.24/100)*(2050-2020)}$

$P_{2050} = 144214$

$P_{2040} = 104304$

$P_{2030} = 75438$

Table 5.8. Comparison of different Population forecasting methods

Sr.No	Methods	Calculated population in 2050
1	Arithmetic increase	100253
2	Geometric Increase	186868
3	Incremental increase method	108209
4	Bank of province method	169573
5	Ethiopian statistics authority method	144214

Each method has its accuracy depending on the existing character of the design area. As we can see from the above comparison table Geometric increase method is the highest number of population in the year 2050, but we use Ethiopian statistics authority method for our design.

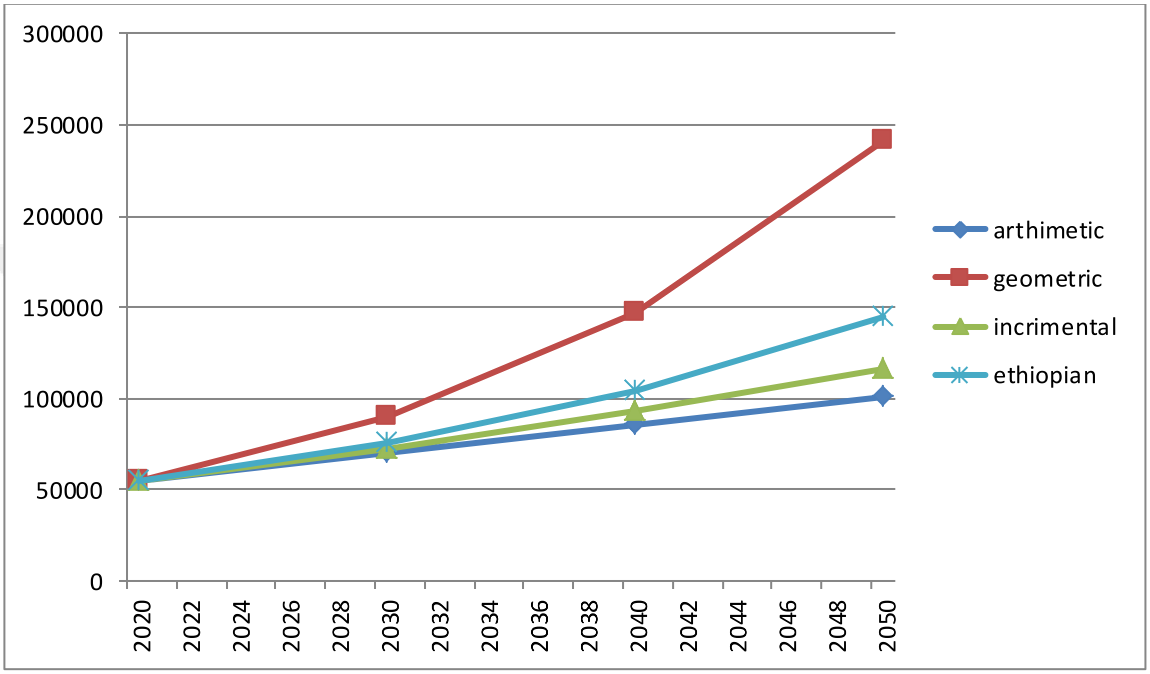


Figure 5.1. Graph of population growth for different forecasting methods

5.3. Design Water Wemand

5.3.1. Types of Water Demand

The amount of water utilized by the consumer is called water consumption. In theory, the word water demand concedes with water consumption. In practice, however, the water demand is often monitored at supply points where the measurements include leakage, as well as the quantities used to refill the balancing tanks that may exist in the system. It is very difficult to precisely assess the quantity of water demanded by the public, since there are many variable factors affecting water consumption.

Determination of water demand is indispensable when it comes to the design of a proper water work project. An accurate estimation of water demand helps to determine the quantities of water and moments when the water will be used therefore generating various demand patterns. The demand arises mainly for residential, institutional, industrial and public uses (Arjun, 2019).

Water demands can be classified into:

- Domestic water demand
- Industrial water demand
- Institutional and Commercial water demand
- Demand for public
- Fire demand
- Waste and Theft

5.3.1.1. Domestic Water Demand

Domestic or residential use: includes water for drinking, cooking, and bathing, washing of clothes, utensils and house and flushing of water closets. The demand varies from place to place and from country to country (Cushman-Roisin, 2019).

Table 5.9. domestic water demand list per day

No.	Purpose	Usage amount(l/d/p)
1	Drinking	15
2	Cooking	20
3	Bathing	47.88
4	Cloth washing	15
5	Utensil washing	10
6	House washing	10
Total		117.88

5.3.1.2. Industrial water demand

This consumption includes water used in factories, hotels, offices, hospital etc. The water requirements of industrial needs of a city are generally taken as 50 liter/day/person. This demand depends upon the nature of the city and types of industries.

Since we don't have bigger industries in silte zone and by considering future expansion plans factories we took 40 l/d/p as industrial water demand (Aisyah, 2017).

5.3.1.3. Institutional and commercial water demand

On an average, per capita demand of 20 lpcd is required to meet institutional and commercial water demand. For highly commercialized cities, this value can be 50 lpcd. 20 lpcd is enough for our design institutional and commercial water demand (Benoit, 2019).

5.3.1.4. Public water demand

Public demand includes the quantity of water required for public utility purpose such as watering of public parks, gardening, sprinkling on roads, use in public fountains etc. To meet the water demand for public use provision of 5% of the total consumption is made while designing the water works for a city. The per capita consumption for public and civic use can be taken as 10 lpcd (Gulbahar, 2016).

5.3.1.5. Fire demand

It is the quantity of water required for fighting a fire outbreak. The quantity of water required for fire should be easily available and kept stored in storage reservoir. In the city area fire hydrants are provided on the water mains at 100 to 150 m apart. The minimum water pressure available at fire hydrants should be 1.0 to 1.5 kg/cm^2. The quantity of water required for fire can be found by using some following empirical formula (Sharma, 2014).

- Kuching's Formula:

$$Q = 3182\sqrt{P}$$

Where Q=amount of water required in liters/minute

P=Population in thousands

- National Board of fire under Writers formula:

$$Q = 4637\sqrt{P}\,[1 - 0.01\sqrt{P}]$$

- Freeman's formula

$$Q=1136.5\,[P/10+10]$$

- Boston's formula

$$Q = 5663\sqrt{P}$$

5.3.1.6. Waste and Thefts

This consumption accounts for 55 lpcd. Even if the waterworks are managed with high proficiency, a loss of 15% of total water consumption is expected.

Table 5.10. Total water consumption per day per person

Sr.No	Purpose of demand	Amount of demand (lpcd)
1	Domestic water demand	117.88
2	Industrial water demand	20
3	Commercial water demand	10
4	Public water demand	10
5	Fire water demand	10
6	Loss compensate demand	20
Total		187.88

The following are the main factors which affect the per capita demand of the city.

1. Water supply system
2. Cost of water
3. Climatic conditions
4. Size of the city
5. Quality of water supply
6. Pressure in the water distribution system
7. Metering policy and charging method
8. Industrial and commercial activities
9. Development of sewerage facilities

5.3.2. Types of Water Demands Variations in Water Demand

There are different variations in water demands which are calculated for the specific design of pipe mains, service reservoirs, and source of supply, distribution system and pumps. Average daily water demand (q) of the area is given by

q = 117.88 + 20 + 10 + 10 +10+20 = 187.88lpcd

Average daily demand (Q) = 187.88 l/p/d x 144214 p

Q = 27094926.32 l/day

Q =27094.92 m^3/day

= 0.3136 m^3/s

5.3.2.1. Maximum daily consumption (MDC)

Maximum Daily Consumption

=180% of Average Daily Demand

= 1.8 (Q)

$=1.8 * (27094.92\ m^3/day)$

$= 48770.85\ m^3/day$

And by adding 10% of backwash water our design capacity will be

$= (48770.85 + 4877.085)\ m^3/day$

Design capacity $= 53647.935\ m^3/day$

$Q_{design} = 53647.935\ m^3/day$

$= 0.62\ m^3/s$

Maximum daily consumption is the design water consumption for source of supply and pipe mains.

5.3.2.2. Maximum hourly consumption

Maximum hourly consumption = 150% of avg. hourly demand of max.day

= 1.5 x (Maximum daily demand/24)

= 1.5 x (1.8q/24) = 2.7 x (q/24)

= 1.5 x (0.62/24)

= 0.0385 l/p/hr.

5.3.2.3. Coincident demand or coincident draft

Maximum daily demand plus fire demand gives the coincident draft. This design water consumption is used for distribution system.

5.4. Design of Drinking Water treatment Plant Units

Drinking water treatment process is a complex technical process which seeks a skilled man power starting from water source until it reaches to consumers. We have a lot of water sources and their laboratory analysis conducted by silte zone water and energy department as a design options. We put and analyze different criteria to select the best water source to our drinking water treatment plant design. The following table shows the actual raw water analysis of a spring, which is located in silte zone and we select it from the other options as a design water source to supply worabe (Capital city of silte zone) town and three other neighborhood towns. The design process starts with collecting the spring water to a spring box then designing a reservoir as a storage tank, finally we transport the water by pumping or gravity flow to treatment units, then distribution.

Table 5.11. Laboratory analysis of design water source

Sr. No	Parameters	Analysis result
1	Source Hand Digging Well	SP (spring)
2	Nature of sample	Untreated
3	Flow (l/s)	7.4
3	Northing Y-Coordinate	
4	Easting X-Coordinate	408178
5	Altitude [m]	1840
6	pH	7.1
7	Temp. [°C]	23.9
8	Conductivity [μS/cm]	84.5
9	Turbidity [NTU]	150
10	TDS [mg/L]	41.7
11	Fe^{2+} [mg/L]	3
12	Cu^{2+} [mg/L]	0.06
13	Cr^{6+} [mg\L]	0
14	NO_2^{-}N [mg/L]	0

15	NO_3^{-}–N [mg/L]	6.3
16	SO_4^{2-} [mg\L]	13.5
17	PO_4^{3-} [mg\L]	1.08
18	F^- [mg\L]	0
19	T-Cl_2 [mg/L]	0.13
20	Br^- [mg/L]	0.13
21	Dissolved NH_3 as N [mg/L]	1.18
22	Mn^{2+} [mg/L]	0.2

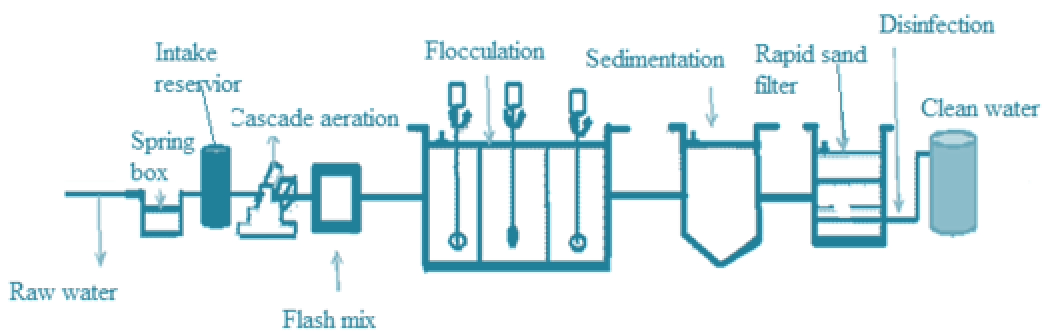


Figure 5.2. Schematic diagrams for the design parameters (Turbidity and Iron)

5.4.1. Intake Structures

Measuring the source flow should be done on numerous occasions, especially during the driest part of the year. There is a simple rule with regard to the quantity of source flow: cumulative inflow must be greater than outflow. Simply stated, this means that the minimum source flow should at least meet, and if at all possible exceed, the ADF. Generally the flow of spring should be greater than 2 gal/min (0.16 l/s) throughout the year. The flow rate of the design water source is 5 l/s, so we can design spring box and storage tank.

5.4.1.1. Spring box design

A spring box is a box intended to protect water flowing from a spring from surface contamination, and collect the water at a central point for use. Water flows into a box through a filter of rocks and gravel and then flows out through a delivery pipe (which often leads to a storage chamber). Specification of these dimensions depends primarily on the flow of water from the spring. For springs ranging in flow from one to ten gallons per minute, dimensions of 2' by 2' by 2' would be adequate. For larger flows, one meter cubed should be adequate. In most cases, spring boxes should not be designed to incorporate storage, as water might back up into the aquifer and seek another outlet. Water must always flow freely through a spring box; a separate reservoir can be built for storage. For discharge greater than 0.8 l/s the recommended basin yield is 2 m^3, we can use 2x1x1 size spring box (Adiningrum, 2017).

5.4.1.2. Reservoir

As a guideline, the storage capacity should equal ½ of the average daily use of the system. More exact calculations for estimating desired storage capacity will be needed if the system involves an extensive piped delivery system. By assuming 10 minute detention time and 4 m height;

Design criteria

Diameter = 5 to 10 m

Depth = 4 to 10 m

Number of units = 1 to 3 (max 4)

Detention time = 10 to 15 m

Reservoir capacity = ½ (Average daily demand)

= ½(53649.8m^3/day)

= ½ (0.62 m^3/s)

= 0.31 m^3/s

Volume of reservoir = 0.31 m^3/s x 10 min x 60 s

= 186 m^3

Cross-sectional area of reservoir = 186/4

= 46.5m^2

Diameter of reservoir (d) = $\sqrt{4} * 46.5/\pi$

= 7.69m <10 ……ok

$\approx 7.7m$

5.4.1.3. Intake pipe design

Pipes are designed to convey the raw water from the reservoir to treatment unit, directly to aeration process. The design of pipe is dependent on resistance to flow, available head quality of water, sediment transport etc.

Design criteria (Sengupta, 2017)

Velocity = 0.9 to 1.5 m/sec

Diameter < 0.9 m

Design calculation

Economic diameter, D = 0.9 $\sqrt{Q}$ to 1.2$\sqrt{Q}$

Given, Q = 0.31 m^3/s

Assume number of pipe is N = 1

Therefore D = 0.9 $\sqrt{(0.31/1)}$ to 1.2$\sqrt{0.31/}$)

= 0.354 m to 0.472 m,

This is less than design criteria, 0.9m so we can take pipe diameter as 0.472m

5.4.2. Aeration Unit

Design of aeration units

Design criteria (Moulick et al., 2010)

Surface over flow rate = 0.02 to 0.05 $m^2/m^3/hr$, (use 0.025 $m^2/m^3/hr$)

(72 – 180 $m^2/m^3/s$), (Use 90 $m^2/ m^3/s$)

Total height of aerator = 1.5 to 7m

Height of steps = 0.15 to 0.3 m

Width of steps = 0.3 to 0.6 m`

Inlet water velocity = 0.6 to 1 m/s

Design calculation

Design discharge (Q) = 0.62 m^3/s

Generally weir surface over flow rate (SOR) of cascade is 72 to 180 $m^2/(m^3/s)$. (Use 90 $m^2/(m^3/s)$.

$Q = 0.62\ m^3/s$, but we have to design the project in two phases with equal discharge for design period of 30 year. The first phase starts from 2020 to 2035 and, the second phase covers from 2035 to 2050.

Design flow $= Q_d = Q_{total}/2$

$= 0.31\ m^3/s$

Surface area of cascade aerator (A) $= Q_d$ x SOR

$A = 0.31\ m^3/s \times 90\ m^2/(m^3/s)$

$A = 27.9\ m^2$

Assume discharge velocity of water (V_0) is 1m/s

Area of discharge pipe $A_p = Qd / V_0$

$= 0.31\ m^3/s \times 1 m/s = 0.31 m^2$

Then we can calculate the diameter of central shaft by the formula

$A = \frac{\pi}{4} D^2$

$= 0.31 m^2 = \frac{\pi}{4} D^2$

$= 0.628$ m

The thickness of central shaft wall is approximately same as shaft diameter, therefore the outer diameter of central shaft will be

$D_{outer} = 0.628$ m+ 0.628 m+ 0.628 m, (center + 2 side thickness)

$= 1.884$m

Area of central pipe is found by

$A_{outer} = \frac{\pi}{4} D_{outer}^2$

$A_{outer} = \frac{\pi}{4} 1.884_{outer}{}^2$

$= 2.786\ m^2$

The total area of cascade aerator is summation of area central shaft and surface area of cascade aerator

$A_{cascade} = A_{outer} + A$

$= 27.9\ m^2 + 2.786\ m^2$

$= 30.686\ m^2$

Diameter of cascade aerator will be

$D_{cascade} = \sqrt{\frac{4*30.686}{\pi}}$

$= 6.25m$

Area of central shaft = 27.9 m^2

Surface area of cascade aerator = 2.786 m^2

Diameter of inlet pipe = 0.628 m

Diameter of aerator = 6.25m

Design of aerator dimensions

Height of steps = 0.15 to 0.3 m (use 0.3 m)

Total height of aerator = 1.5 to 7 m (use 2 m)

Number of steps (n) is determined by dividing total height of aerator ($H_{t)}$ by height of steps (H_s)

$n = H_t/H_s$

$= 2/0.3 = 6.667 \approx 7$ (number of steps) ok (< 10)

Width drop or width of steps (Ws) is determined by subtracting the outer diameter of central pipe from the total diameter of cascade aerator then dividing it by number of steps.

$$W_s = \frac{Dcascade - \text{Douter}}{n}$$

$$= \frac{6.25m - 1.884m}{7}$$

=0.623 m

This is higher than our design criteria of step width, (0.3 – 0.6 m). Let us make our total height 2.4 m

n = 8 and W_s= 0.545 m   it is ok

Calculation of step diameter

If total diameter of cascade aerator is 6.25 m and outer diameter of central shaft is 1.884 m then we can calculate the diameter of each step as follows

$D_{step\ (n)}$ = (diameter of central shaft + Ws/2)

D1st = 1.884 + 0.545/2 = 2.156 m

D2nd =2.156 + 0.545/2 = 2.428 m

D3rd =2.428m+ 0.545/2 = 2.701 m

D4th =2.701m + 0.545/2 = 2.9735 m

D5th =2.9735m + 0.545/2 = 3.246 m

D6th =3.246m + 0.545/2 = 3.5185 m

D7th =3.5185m + 0.545/2 = 3.791 m

D8th =3.791m + 0.545/2 = 4.063 m

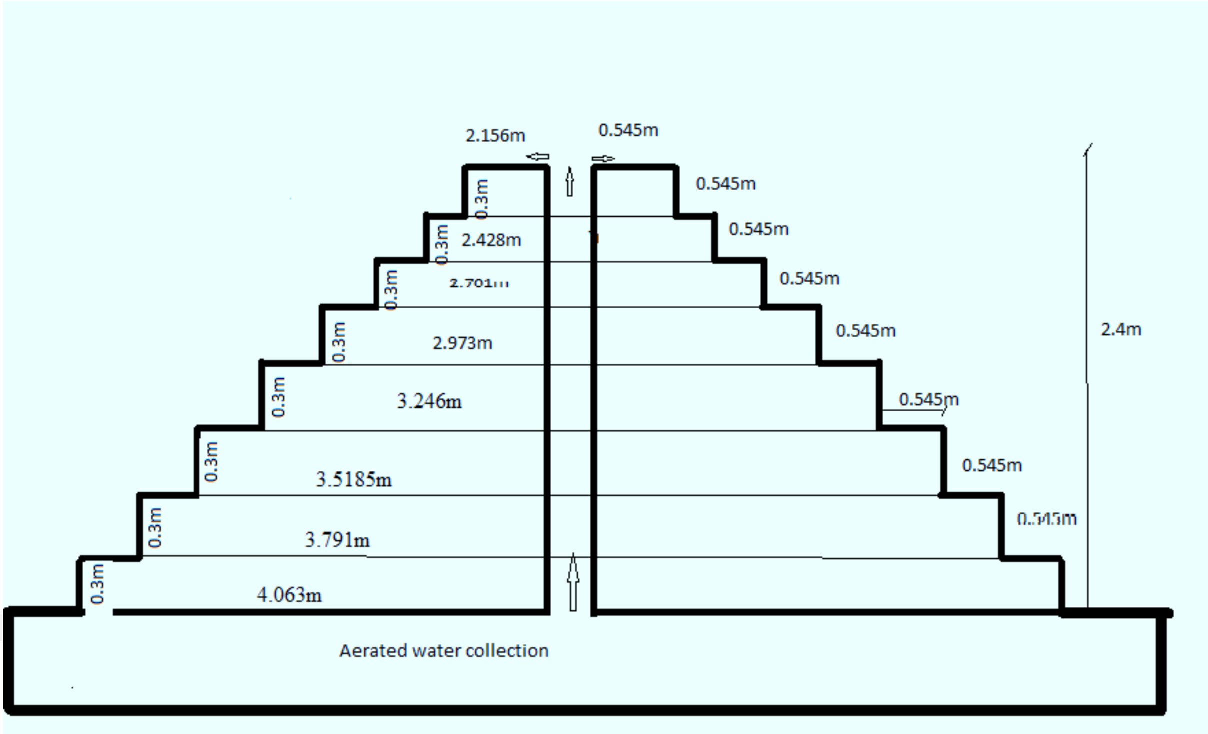


Figure 5.3. Cascade Aerator Elevation view

Aeration channel calculation

$Q = 0.31 m^3/s$

Assume velocity (V) =0.6m/s and width to diameter ratio is one

W/D =1

$Q = A \times V$

$A = Q/V$

$W \times D = Q/V$

$W \times W = Q/V$

$W^2 = Q / V$

$W = \sqrt{Q}/V = 0.718$ m

The depth of water on the aeration channel has also same dimension as width of channel

Water depth = 0.718m

Cascade efficiency

The efficiency of a cascade depends on the fall height of each cascade step and the number of steps

$$K = 0.45.(1 + 0.046T).h$$

Where

K = Efficiency for each step (constant)

h = Height (m)

T = Water temperature ($23.9^{o}C$)

We have assumed h as 30 cm and the temperature of water source is given that 23.9^{o}

$$K = 0.45 (1 + 0.046 * 23.9) * 0.3$$

$$= 0.2834$$

And also we have a formula

$$K = \frac{Cwe - Cwo}{Cs - Cwo} = 1-(1-k)^{n}$$

Where

C_{we} = Dissolved oxygen in step n

C_{s} = water oxygen saturation

C_{wo} = raw water oxygen concentration

n = Number of steps

For different temperature of water in cascade aeration the values of dissolved oxygen concentration is given in the following table

Table 5.12. Concentration of oxygen in aeration process with different temperature

Water temperature(°C)	**Water oxygen saturation(mg/l)**	**Aeration constant**	**Raw water dissolved oxygen amount(mg/l)**	**Aerated water dissolved oxygen amount(mg/l)**
4	13.13	0.2664	0	7.94
10	11.33	0.3285	0	7.90
15	10.15	0.3803	0	7.73
20	9.17	0.4320	0	7.49
23.9	8.55	0.4724	0	7.37
25	8.38	0.4838	0	7.23

From the above table, for 23.9 °C water temperatures the saturation concentration of oxygen is 8.55 and raw water dissolved oxygen amount is zero.

Therefore,

$$C_{we} = C_s – (C_s – C_w)\ (1\text{-}k)^{n}$$

$$=8.55\text{-}\ (8.55\text{-}\ 0)\ (1 – 0.2834)^{8}$$

$$C_{we} = 7.955\ mg/l$$

Weir Head design

$$Q= 0.67 * C_d\ x*L_{net} * \sqrt{(2g)} * h^{1.5}$$

Where

Q = Design discharge (m^3/s)

C_d = Coefficient depends upon weir type = 0.6

h = Weir head (m)

L_{net} = Length of weir (m)

g = Gravitational acceleration (m/s^2)

L_{net} = Q/Weir load

From various experiments it can be concluded that the efficiency of a cascade is almost independent of the weir loading. The advantage of this is that the gas transfer is still satisfactory at production flows that are lower than the design flow. With cascades the weir loading is generally between 50 and 100 m^3/(m.h) (Jiang, 2019), Use 75 m^3/(m.h)

$$= \frac{0.31\ m3/s}{\frac{0.02079m3}{m}.s}$$

L_{net} = 14.97m

h = $\left(\frac{Q*3/2}{Cd*L\prime*\sqrt{2g}}\right)^{2/3}$, assume L' = 14m < L

h = $\left(\frac{0.31*3/2}{0.62*14*\sqrt{2}*9.81}\right)^{2/3}$

h = 0.052m

5.4.3. Rapid Mixing Unit

Design criteria (UNICEF, 2009)

Detention time = 30 to 60 sec (use 40 sec)

Velocity of flow = 4 to 9 m/s

Depth = 1 to 3 m

Power required = 0.41 KW / 1000 cum/day

Impeller speed = 100 to 250 rpm

Head loss = 0.4 to 1 m

Assume temperature = 25^{o}C

G = Velocity gradient, sec^{-1}(G = 700 to 1000 sec^{-1}), assume G=790sec^{-1}

Design calculation

Volume of tank

Volume of tank = Q *Detention time

= 0.31 m^3/s*40 s

=12.4 m^3, this amount of water may be excess for mixing we have to add another tank. Let us use 4 tanks

Q = 0.31/4

= 0.0775 m^3/s (discharge per tank)

Volume = 0.0775 x40

= 3.1 m^3

Most of the time rapid mix basins are square shaped with a depth to width ratio of 1.5 gives excellent efficiency.

Volume = length x width x depth

=W x W x1.5 W

= 1.5 W^3

W^3= 3.1/1.5

Width = 1.273 m

Length = Width = 1.273m

Depth= 1.5 x 1.273 m

=1.9 m (height of tank)

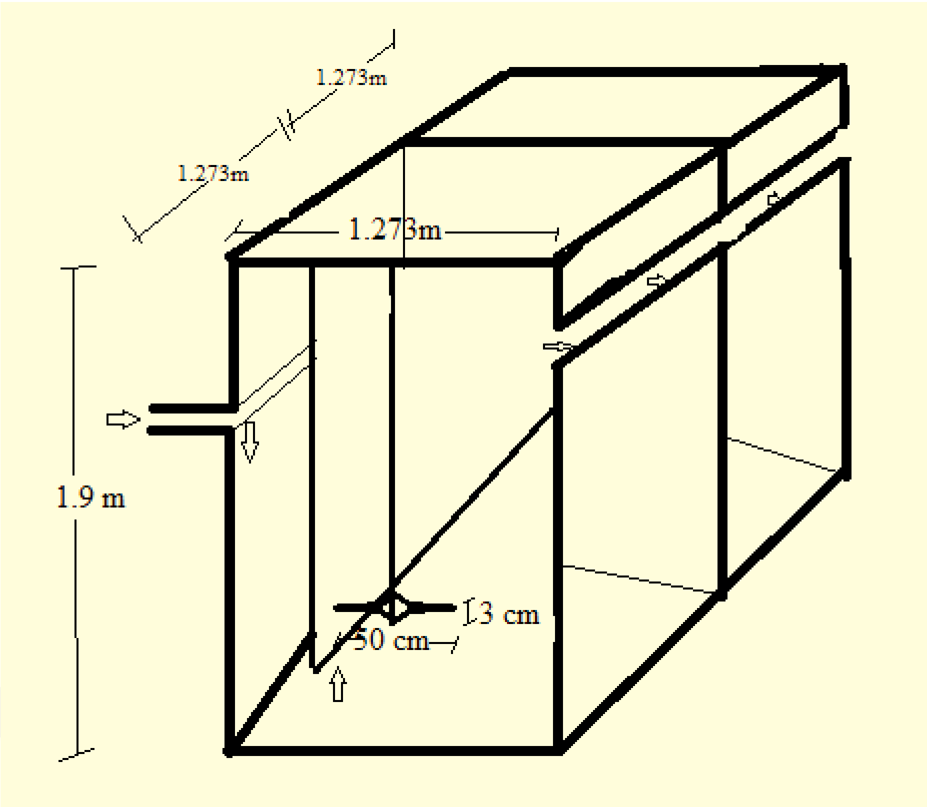


Figure 5.4. Flush mixing tank dimensions

Power calculation

The sustained temperature of raw water is accepted to be in the range from 5^o to $28^{\ o}$ the lowest temperature will present the critical condition in the mixer design

μ= 0.00089 Kg/m.s at 25^oC
ρ= 997.1 Kg/m3 at 25^o C

Then

$$G = \sqrt{\frac{P}{\mu V}}$$

Where

G = Velocity gradient, sec-1 (G = 700 to 1000 sec^{-1})

P = Power Imparted to the water, N-m/s or Watt or kg.m^2/s^3

V = Volume of the basin, m^3

μ = absolute viscosity of the fluid, N-s/m^2

$P = G^2 x \mu V$

$= (790)^2$ x 0.00089 x3.1

= 1722 N-m/s or Watt or kg.m^2/s^3

= 1.722 Kw

This is the amount of power imparted to the water, The power of the driver (P') is calculated by diving P by the efficiency of the gearbox, which is typically around 90 percent Calculate impeller size and rotational speed.

1.722/0.9 = 1.913kw

Impeller Design

Calculate impeller size and rotational speed. The rapid-mix basin will be an "up flow" type. Experience shown that radial-flow mixers perform better than axial-flow mixers in a vertical-flow basin. Use axial flow 45^o Pitched blade 4 blade mixer.

Blade width to diameter ratio = 0.2

$$N_p = 1.94$$

$$P = \rho Npn^3d^5$$

$$n = \left(\frac{P}{\rho d5Np}\right)^{1/3}$$

Where,

n = Rotational speed of impeller (rpm)

P = Power (watt), 1722 watt

(d) = Diameter of impeller 0.2 to 0.4D use 0.4D (m)

0.4*1.273= 0.5m

(D) = Diameter of mixing tank (m), 1.273 m

- Width of Rapid Mixing Tank

ρ = Gravitational density of water kg/m^3

$$n = \left(\frac{1722}{997.1*0.03125*1.94}\right)^{1/3}$$

n = 3.05 rps = 183 rpm ok ($> 100rpm$)

Checking of Reynolds number

$$N_r = d^2 n \frac{\rho}{\mu}$$

$$N_r = 0.5^2 *183 * \frac{997.1}{0.00089}$$

=51266772.921 $>$ 10000 ok

Since the equation is valid we can adapt the above dimensions

Diameter of impeller (d) = 50 cm

Width of impeller (W) = 3.05 cm and

Diameter of tank = width of tank = 1.273m

Depth of tank = 1.9m

Tank height/tank diameter

=1.9/1.273= 1.492 ok (1 to 3)

Impeller diameter/tank diameter

= 0.5/1.273

= 0.393 ok (0.3 to 1)

Impeller shaft torque control

$P = 2\pi nT$ or $T = P/2\pi*3$

$=1722/2\pi*3$

= 91.4 N-m

Select motor with gear speed of 183rpm

Head loss

$G = g\,\rho\sqrt{hl}\frac{1}{tN}$

$h_L = (G\ t\ \mu/g\rho)2$

$= (\frac{790*40*0.00089}{9.8*997.1})^2$

$= 8.265x10^{-6}$ m

5.4.4. Flocculation Tank Design

Design criteria

G = 10 to 100 s^{-1}, For

First stage G = 50 s^{-1}

Second stage G = 35 s^{-1}

Third stage G = 20 s^{-1}

Detention time (t) = 15 to 45 min (use 45 min)

Gt = $2x10^4$ to $2x10^5$

Number of sections = 2 to 6 (use 3)

Depth of tank = 3 to 4.5 m (use 3.5)

Design calculation

Discharge, $Q = 0.62/2\ m^3/s = 0.31\ m^3/s$

$= 1116\ m^3/hr$ and we have 3 parallel trains of flocculatores (Aech flocculator receives one third of the total flow), three flocculator stages of same dimensions for aech train (9 flocculatores)

Flow per train = $1116/3 = 372\ m^3/hr = 6.2\ m^3/min$

Assume temperature = 10^oC

Flocculation tank dimension design

$V = t \times Q$

$V_{sec} = Q_{sec} \times t_{st}$, tst is per stage detention time =45/3=15 min

$= 6.2\ m^3/min \times 15\ min$

$= 93\ m^3$

$V_{overall} = 9 \times V_{sec} = 9 \times 93$

$= 837\ m^3$

Since the depth of tank is 3.5 m, the width and length of tank combination will be

Area of tank = V_{sec} / depth $= 93/3.5 = 26.57 m^2$

Overall area = $V_{overall}$ / depth $= 837/3.5 = 239.14\ m^2$

Any combination of length x width that gives the above square meter is ok but the L/W ratio does not become too great, should be less than 10.

Assume we have square floc tank, then our (W x L x Depth) dimensions would be

= 5.15m x 5.15m x 3.5m, for individual tank

=15.46m x 15.46m x 3.5m, for over all tank

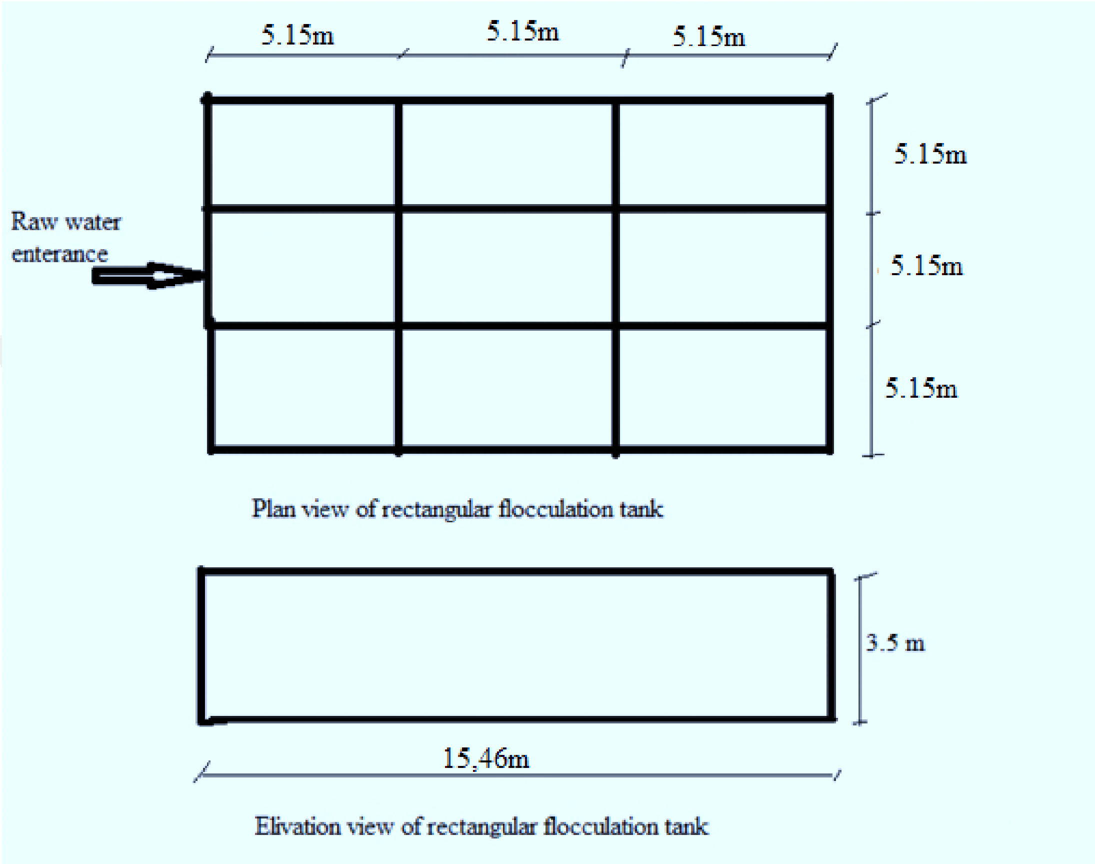


Figure 5.5. Rectangular flocculation tank dimensions

Power calculation

The power required for each stage, in kW is given by the equation

$$G = \sqrt{\frac{P}{\mu V}}$$

Where

G = Velocity gradient, sec-1, Average value of three stages

= (50+35+20)/3 = 35 s^{-1}

Gt= 35 s^{-1} x45 min (60s/min) = 94500 ok (it is between 50000 – 100000)

P = Power Imparted to the water, N-m/s or Watt or $kg.m^2/s^3$

V_{tank} = Volume of the basin, 93 m^3

μ = absolute viscosity of the fluid, (use μ = 0.00089N-s/m^2)

$P = G^2 x\mu V$

1 st stage, P =0.00089 x 93x $(50)^2$ = 206.925 w

2 nd stage, P =0.00089 x93 x $(35)^2$ = 101.39 w

3^{rd} stage, P =0.00089 x93 x $(20)^2$ = 33.108w

Size of paddle

Let us assume we have a

- Blade width of 0.2m with 3m blade length
- 6 blades per paddle wheel
- 4 paddle wheel per shaft

Blade area per shaft is given by

A_b = 0.2m x 3m x 6 x 4

= 14.4 m^2

Cros-sectional are of tank = total width x depth

A = 15.46m x 3.5 m

=54.11 m^2

Area ratio checking,

Area of blades/crossectional area should be between 20 and 25

Area ratio = A_b/A

$=14.4/54.11$

$=0.26 = 26$ %, it is ok.between 20 and 30%

Therefore we can use a blade si of 0.2m x 3m, 6 blades per paddle wheel and 4 paddle wheels per shaft.

5.4.5. Sedimentation Tank Design

Design criteria

The flow should be divided into at least two tanks and the flow through each tank should be calculated using the formula shown below:

$$Q_C = Q / n$$

Where:

Q_C = flow in one tank

$0.31/2 = 0.155\ m^3/s = 13392\ m^3/day$

Q = total flow ($0.62\ m^3/s$)

$= 53568\ m^3/day$

n = number of tanks (2)

Next, the required tank surface area is calculated. The surface area is calculated using the following formula:

A = Qc / O.R.

Where:

A = surface area, m^2

QC = flow, m^3/day

O.R. = overflow rate, (assume O.R =30 m^3/m^2-day)

A= 13392 m^3/day / 30 m^3/m^2.day

= 446.4 m^2

Volume of tank calculation

The optimal detention time for sedimentation basins depends on whether sludge removal is automatic or manual. We will consider a tank with automatic sludge removal, so the detention time should be 4 hours.

$$V = Q\ t$$

$$V = (13392\ m^3/day)\ (4\ hr)\ (1\ day/24\ hr)$$

$$V = 2232\ m^3$$

The tank's depth is calculated as follows:

$$d = V / A$$

Where:

d = depth, m

V = volume m^3

A = surface area, m^2

$$d = 2232\ m^3/446.4\ m^2$$

= 5m ok (5 to 7m)

Tank dimensions

The volume of rectangular object is calculated

$V = L\ W\ d$

Where:

V = volume

L = length

W = width

d = depth

The recommended dimension combination for sedimentation tank is

$L = 4\ W$

Combining these two formulas, we get the following formula used to calculate the width of our tank:

$$W=\sqrt{(\frac{V}{4d})}$$

Therefore, the tank width will be

$$=\sqrt{(\frac{2232}{4*5})}$$

W = 10.564m

Then length of the tank is

L = 4 x 10.56 =42.24m

Flow through Velocity

Then the flow through velocity of the tank is calculated

(Velocity) Vo = depth /detention time

= 5m/4hr

= 1.25 m/hr ok

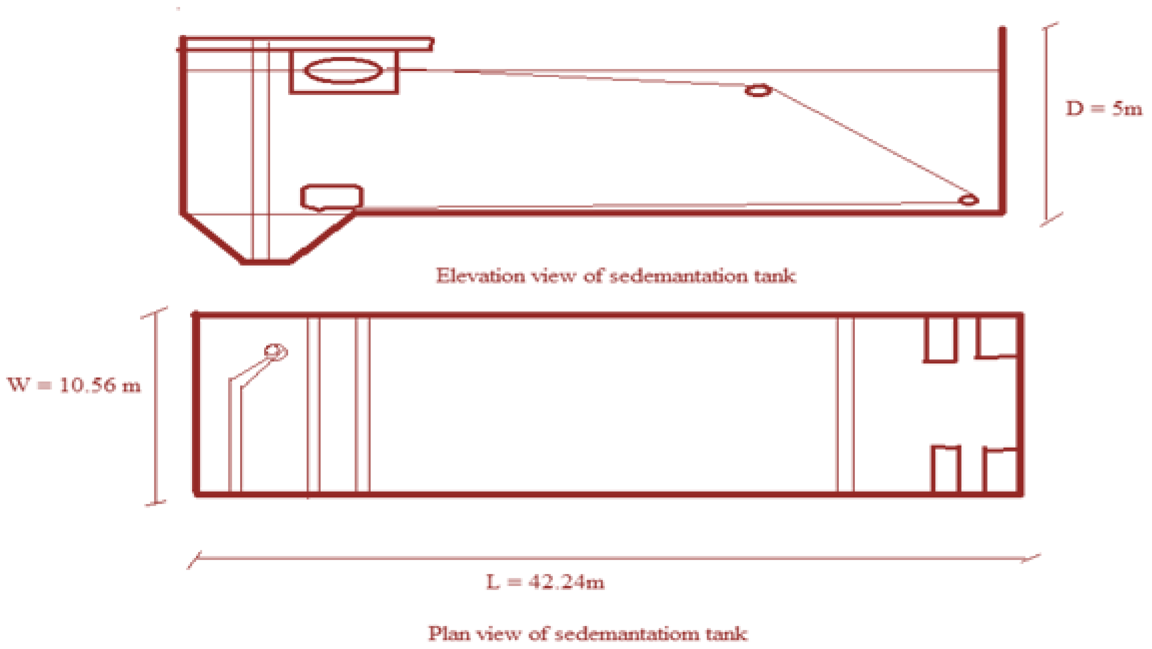


Figure 5.6. Elivation and plan view of sedemantation tank

5.4.6. Rapid Sand Filtration

Table 5.13. Design criteria for rapid sand filter (Sharma et al., 2013)

Rate of filtration	4.8 to10m/hr
Length to width ratio	1.25 to 1.33 ;1
Depth of sand layer	60 to 70 cm
Effective size of sand (d)	0.45 to 0.7 mm
Number of units	Minimum 2
Area of perforation ; area of filtered	0.3%
c/c distance of laterals	Closely proximate to spacing of perforation
Area of manifold; area of laterals	1.5 to 5
Diameter of perforation	5 to 12mm
c/c distance b/n troughs	1.2 to 2 m
Sand expansion	130 to 150 % of total depth
Rate of backwashing	4to5 times rate of filtration

Design calculation

Amount of water to be filtered is

$Q = 0.31 m^3/s = 1116\ m^3/hr$

By assuming 3 % of filter water will be used for backwash every day and this process will take 30 minutes, the amount of water to be filtered is given as

$Q_{filter} = 1.03 \times 1116 /24 -0.5$

$= 48.914\ m^3/hr$

The filtration rate in rapid sand filter is between 5 and 15 $m^3/m^2.hr$ and let us assume 5 $m^3/m^2.hr$, the area for filtration is

$A_{filter} = \frac{48.914\ m3/hr}{5\ m3/m2.hr}$

$= 9.78\ m^{2,}$ take 2 units of filtration

$A_{filter} = 9.78\ m^{2,} /2 = 4.89\ m^2$

From the design criteria the length to width ratio is 1.25 to 1.33:1, take 1.3 ratio factor

$L = 1.3B$

$A = 1.3\ B^2 = 4.89\ m^2$

$B = 1.939\ m$

$L = 1.3\ B$, $L = 2.52\ m$

Under drainage system design

Let us assume total area of perforations is 0.3% of whole filter area.

Total area of perforations $= 0.003 \times 4.89$

=0.01467m^2

Total cross section of laterals =2×Area of perforation

=2×Area of perforation

=2×0.01467m^2

=0.02934m^2

We know that cross sectional area of manifold =1.5×Total cross section of laterals

=1.5×0.0293=0.044m^2

Diameter of manifold =$\sqrt{4x0.044/\pi}$

= 0.2367 m

Provide 23.67 cm diameter manifold laid throughout the length of filter unit and by Assuming c/c spacing of lateral is 20cm,

Number of laterals =2.52×100/20= 13

Therefore, provide 13 laterals on both sides of manifold, total laterals of 26.

Length of each lateral

=(B−diameter)/2

=(1.939-0.2367)/2

= 0.851m

To determine the number and area of perforation, let us say n is the total number of perforation with 12mm diameter each in all 26 laterals.

n_t x $\frac{\pi}{4}(12)^2$ = 0.01467 $(1000)^2$

n_t= 129.78

Then, number of perforation in each lateral will be

n=129.78/ 26

n= 5, provide 5 perforation per lateral

In each lateral, the area of perforation is

$A = 5\ (\frac{\pi}{4})\ (12)^2 = 565.2\ mm^2$

Area of each lateral = 2 x area of perforation on each lateral

$A_{lateral} = 2 \times 565.2 = 1130.4mm^2$

Diameter of each lateral = $\sqrt{\pi}\frac{1130.4}{4}$ = 29.78mm

Hence, provide 30 mm diameter laterals at 20cmc/c, each lateral having 5 perforations of 12 mm diameter.

Check: As per design criteria, ratio of Length of lateral to Diameter of lateral should not be greater than 60.

0.53165 x1000/29.78 = 17.85<60 ok

Spacing of perforation = Length of lateral in cm/No of perforations per lateral

=0.53165×100/5 =10.63cm < 20 ok

Minimum depth of filter sand, assuming mean diameter of sand is 1mm

$L = Qd^3h/29323xB$

Where

Q = Rate of filtration (5m/hr)

B= break through index ($4x10^{-4}$ to $6x10^{-4}$) depending on response to coagulation

And degree of pre-treatment in filter influent.

d = Effective size of sand (assume 0.6)

h = Terminal head loss (1.8 to 2, use 2)

$L = 5 \times 0.6^3 \times 2/29323 \times 4x10^{-4}$

$=0.184m$

= 18.4 cm, which is less than 60 so we can use 60 cm depth of sand

Backwash Water Trough Design

Backwash water discharge (Q_{bw}) = rate of backwash x area of filter bed

But rate of backwash = 4-5 times rate of filter (take 4)

$=4x5 = 20m^3/m^2.hr$

$Q_{bw} = 20 \times 4.89 = 97.8m^3/hr$

Number of trough = 2.52/1.5 =1.68 ≈ 2

Discharge in each trough = 97.8/2

$=48.9m^3/hr = 0.01358m^3/s$

The height of water in the trough is

$Q = 1.376\ b\ h^{3/2}$

Where; $Q = 0.01358m^3/s$

b is the water width and it is effective value is 0.4-0.5m (use 0.5)

Finally; $h = (Q/1.376*b)^{0.667}$

$=0.72$ m

Clear water reservoir for backwashing

Duration of backwash for 4 h filter capacity,

Capacity of tank= 4 x filter rate x B x L x2

Capacity of tank =4 x 48.914 x 1.939 x 2.52 x 2

$= 1912\ m^3$

Take 5 m as depth of back wash reservoir, surface area of backwash reservoir is

$A = 1912/5 = 382.4\ m^2$

$L/B = 2$

$2B^2 = A = 382.4\ m^2$

B= 13.82m; L = 27.64 m

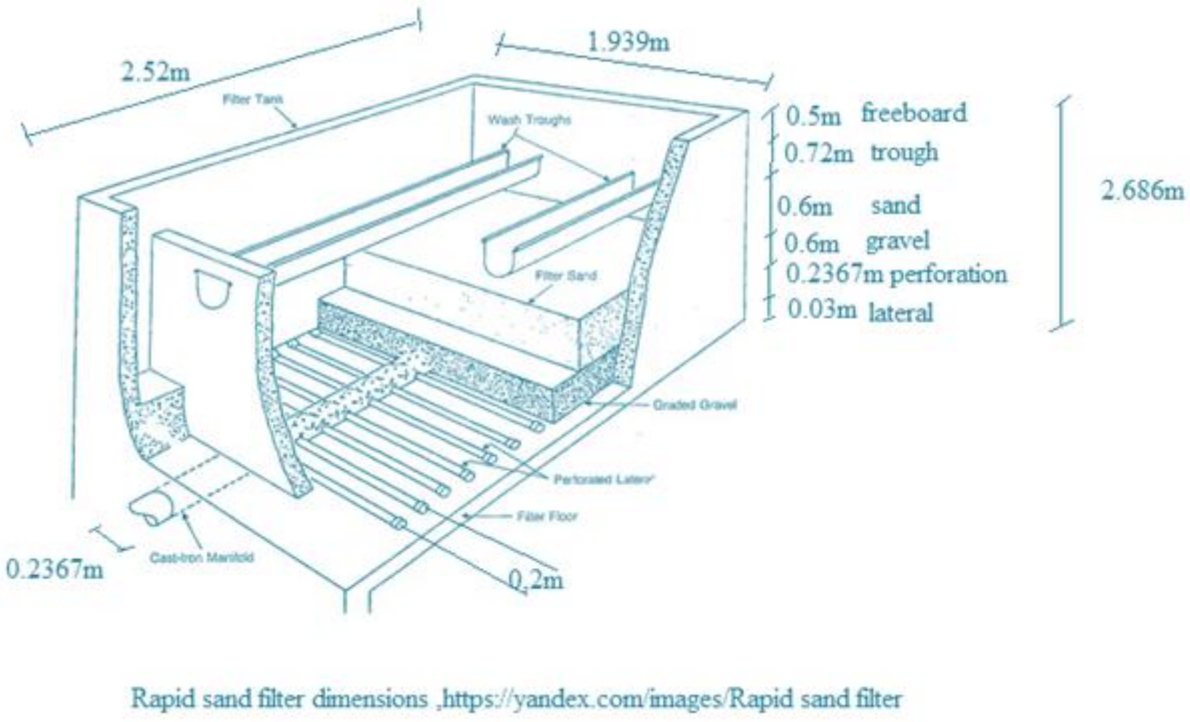


Figure 5.7. Rapid sand filter dimensions

5.4.7. Disinfection

- It is readily available as gas, liquid or powder
- It is cheap
- It is easy to apply due to its high solubility
- It leaves a residual in solution which is not harmful to man and provides protection in a distribution system.
- It is very toxic to most microorganisms, it stops metabolism activities

Chlorine demand is defined as the difference between the amount of chlorine added into water and the quantity of free and combined available chlorine remaining at the end of specific contact period.

Design criteria

Chlorine dose = 0.6 mg/l to 1.5 mg/l, use maximum one 1.4 mg/l (depending on turbidity, PH, temperature and contact time)

Residual chlorine (minimum) = 0.1 to 0.2 mg/l

Design calculation

Flow = 0.31 m^3/s

= 25920 m^3/day

Chlorine required per day = 25.920 x 10^6 x 1.4 x 10^{-6}

= 36.28 kg

Chlorine required for 6 month = 36.28 x 180

=6530.4 kg

5.4.8. Storage Tank

Distribution reservoirs are built to collect and store treated water from the treatment plant and distribute for the consumer when it is necessary. They should be designed with capability to store domestic, industrial and commercial demands, and also accommodate for emergency or firefighting. Depending open their elevation with respect to the ground they are classified as underground reservoir and elevated reservoir.

Underground Storage Reservoir (U.S.R)

Design capacities of ground storage tanks should provide storage equivalent to at least 4 to 6 hours supply at peak daily flow (2.5 times daily average). This amount will usually permit a uniform pumping rate throughout the day. Plants that operate on a part time basis may require additional clear well capacity to meet these peak flow demands. This storage capacity may range from several thousand gallons in small rural systems to several million gallons in very large ones (Ragsdale, 2018).

Design Criteria

Detention time = 4 to 6 hr (use 6 hr)

Free board = 0.4 to 0.6 m

Design calculation

Capacity of reservoir per day = peak daily flow

= 2.5 x average daily supply

$=2.5 \times 0.316\ m^3/s$

$= 0.79\ m^3/s$

For the detention time of 6 hr , the volume of reservior would be

$$V = 0.79\ m^3/s \times 6 \times 60 \times 60\ s$$

Volume of reservoir = 17064 m3

Assume 5 m depth of the reservoir

Area = volume / depth

= 17064/5

= 3412.8 m^2

It is difficult to build such big area reservoir, let us say 6 reservoirs compartments with equal volume

A= 3412.8/6

=568 m^2 (area of compartment)

And by assuming 15m width, the length of reservior tank is

= 568 m^2/15 m

Length = 38 m

Free board = 0.5

Provide 6 compartments with dimension of 38 m x 15m x 5 m

Elevated Reservoir

When the elevation of treatment plant site is less than the area to be supplied, we need to construct an elevated reservoir in order to collect treated water and distribute to consumers with gravitational force. The treated water should be pumped to elevated reservoir from the underground reservoir.

Design calculation

Assume elevated reservoir capacity is 1/10 of underground reservoir

= 17064/10 m^3

Capacity = 1707 m^3

Free board = 0.3m

Overall depth = 4 m

Number of reservoir = 2

Area one reservoir = 1707/2/4

= 214 m^2

Diameter = $\sqrt{4}x214/\pi$

= 16.5 m, Provide two reservoirs with a 12 m diameter and total height of 4.3m.

6. CONCLUSION AND RECOMMENDATION

The existing water supply system of worabe town and other nearby cities is not enough, due to rapid increase of population in the areas. Therefore, it is necessary to design and construct a new water supply project that could satisfy the water demand of the area. This project is designed for design period of 30 year 1n two phases. The first phase starts from 2020 to 2035 and, the second phase covers from 2035 to 2050. For the population forecasting, Ethiopian central statistics authority method is adopted even though, we had a limited data. We select one suitable water source from the options we had to design a water treatment plant that could supply the population of the area. There is no available data in Ethiopia for the water demand per person per day of domestic or other demands. In this case, we used other international standards and regulations in our design inputs for the water demand as well as for other parameters. Finally, we hope this project will improve the life standard of the people who live around the design area and we recommend that government officials of the design area should go on for its construction.

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