

**DESIGN OF WATER TREATMENT PLANT FOR A SEMI-URBAN WATER  
SUPPLY SYSTEM**

**BY**

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**CERTIFICATION**

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**PLAGIARISM**

This work **DESIGN OF A WATER TREATMENT PLANT FOR A SEMI URBAN WATER SUPPLY SYSTEM** by MGBECHI, Anthony Chiedu with Mat. Number ENG2006191 of the department of civil Engineering, Faculty of Engineering, University of Benin City, Edo State Nigeria has PASSED the PLAGIARISM TEST.

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## **DEDICATION**

I dedicate this project to my mum and dad Mr and Mrs Dominic Mgbechi, and also my siblings who have supported and guided me throughout my academic journey.

## ACKNOWLEDGEMENT

Firstly, I want to give thanks to God Almighty for the strength and guidance He provided during the course of this study.

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## **ABSTRACT**

The aim of this study is to undertake the design of a water treatment plant adequate in serving a semi-urban area based on a surface water supply system, this will enhance public health by providing safe and portable water to a semi-urban area. The project focuses more on surface water source and the contaminants found in surface water in a semi-urban area.

The method used to carry out this project includes; the determination of the population of a semi-urban area, water demand/requirements and characteristics of a surface water source in a semi-urban area. The various design units will be size accordingly to the requirements of a semi-urban area.

The result of this work includes complete design of the units in the treatment plant. Adequate design and sizing of the screening chamber, Pre-sedimentation tank, coagulation, flocculation and clarification, filtration and disinfection to contain the need for a semi-urban area. This result helps to improve the knowledge and understanding of the design of a water treatment plant for a surface water source in a semi-urban area.

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## ACRONYMS

UNICEF – United Nations Children’s fund

WHO – World Health Organisation

NDA –            DO –

Dissolved Oxygen

BOD – Biochemical Oxygen Demand

TDS – Total Dissolved Solids

ASTM – American Society for Testing and Materials

EPA – United States Environmental Protection

UNDP – United Nations Development Programme

DN – Nominal Diameter

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background of Study

Water is a clear, odourless and tasteless liquid substance that is essential for life on earth. It is a chemical compound that consist of hydrogen and oxygen atoms, with the molecular formula  $H_2O$ . Water can be in three (3) different forms which are solid, liquid and gas, these forms pass through different processes to get the various forms. Water is used for a variety of purposes like; drinking laundering, and other domestic purposes.it is also needed for commercial, industrial, public and agricultural uses. Study says that 97% of the earth is salt water, leaving only 3% as 'fresh water'. However, of that small 3% fresh water, only 1% of that is actually available for human consumption, this means that only 0.0003% of the total water on earth is actually fit for consumption, furthermore, the availability of this limited fresh water is not uniform, leading to unequal distribution. So many people in the world lack proper drinking water due some reasons like; water scarcity, geographical constraints, poverty and inequality, climate change and infrastructure limitations.

UNICEF along with the world health organisation (WHO), tracks progress on global water and sanitation goals through the Joint Monitoring Program (JMP) for water supply, sanitation and hygiene. The world is not on track to achieve Sustainable Development Goal (SDG) targets 6.1 and 6.2, which focus on universal access to safe drinking water and sanitation by 2030. (UNICEF, 2019).

A water treatment plant is a facility designed to eliminate impurities and contaminants from raw water sources, including surface and ground water. They purify raw water there by enhancing its quality to meet specific requirements for drinking, industrial use, irrigation and other purposes.

## **1.2 Statement of the Problem**

Access to portable water remains a critical challenge in many semi-urban communities in Nigeria where the residents rely on untreated water sources such as swallow wells, streams and rain water harvesting which are highly susceptible to microbial and chemical contamination.

Despite the growing population there is lack of infrastructure for treatment and distribution of water that meets WHO or National Standard for Drinking water. Dependence on raw water sources increases the percentage of water borne diseases (cholera and typhoid) which results in poor public health outcomes and increased medical expenses for low income households.

Many local sources often exhibits high level of turbidity and mineral contents making the water unsuitable for domestic use without proper processing. There is thus a need to design efficient water treatment plant to the geographical and demographic needs of the semi-urban area to ensure steady supply of safe and clean water.

## **1.3 Aim and Objectives**

The aim of this study is to undertake the design of a water treatment plant adequate in serving a semi-urban area based on a surface water system. The objectives of this study are:

1. To determine the typical treatment units of the system
2. Determine the sizes of the different units of the water treatment plant
3. Identify the water quality characteristics of a surface water source for the supply of water in semi-urban areas
4. Design a treatment plant layout that can provide safe drinking water to semi-urban

areas.

#### **1.4 Scope of Study**

This project focuses on a study area which comprises the following constituent elements:

1. To design a water treatment plant and develop a distribution system to provide safe and potable water to a semi-urban area.
2. Determine the characteristics of water quality of a surface water source in semi-urban areas
3. Design the various units of the treatment plant to meet the adequate sizes for a semiurban area
4. Additionally, recommendation will be provided to optimize outcomes and achieve greater effectiveness where possible.

#### **1.5 Justification of Study**

The project is of paramount significance and the importance cannot be over emphasized. Because the project enhance public health by providing safe and portable water to a semiurban area, by doing this improving the overall health and well-being of the community, as well as helping with the economic stability. Problems like water scarcity, poor sanitation, water borne diseases, food and water insecurity, environmental degradation and economic hardship will be tackled by this project. This project will foster a sense of community unity, promoting collective engagement and participation throughout its duration. It also contribute to the advancement of research and development in the field of water treatment and management, particularly in the context of semi-urban areas.

All these are why the relevance of this project cannot be overemphasized.

## **CHAPTER TWO**

### **2.0 LITERATURE REVIEW**

#### **2.1 History of Water use**

Water is one resources that has been available over the years, from the beginning of time till date. The ancient Greece, Rome and china used wastewater for irrigation while ancient Egypt

used water from the Nile River for drinking and irrigation as well. Also, the Medieval period (500-1500 CE) saw a huge transition in human history and relating to water as well, this period saw the introduction and development of primitive sewage system. The modern era which is till date has made vast improvement base on water usage, in this era, we has seen the development of advanced water treatment system and technologies, and also growing acceptance of portable water reuse.

Predictions are also made on future prospect of reuse of water, this include; increased adoption of water reuse technologies, integration of water reuse into urban planning and water management strategies, and continued research and development of innovative water treatment technologies. (Andreas N. Angelakis et al, 2018).

## **2.2 Water and its importance**

As said earlier, water is defined as a colourless, odourless, and tasteless liquid substance that is the most abundant compound on earth, essential for human survival and all known forms of life. (WHO, 2019). Water has two hydrogen atoms and one oxygen atom, which forms the chemical formula  $H_2O$ . The hydrogen atoms are connected to the oxygen atom through covalent bonds (oxygen atom shares its electrons with hydrogen atoms to create these bonds). The arrangement of the atoms in a water molecule is bent or V-shaped, with the hydrogen atoms at an angle of about 104.5 degrees to each other. This unique shape gives water its polar properties, meaning it has a slightly positive charge on the hydrogen atoms and a slightly negative charge on the oxygen atom. This polarity is responsible for many of water's amazing properties, such as its ability to dissolve a wide variety of substances and its high surface tension. It's also what makes water essential for life as we know it, allowing it to play a crucial role in many biological processes.

Water is essential for all known forms of life and covers 71% of the Earth's surface. The majority of the planet's water (96.5%) is found in oceans and seas, while 1.7% is stored in groundwater and 1.7% in glaciers and polar ice caps. Only a small fraction of water exists in other large bodies, the atmosphere, and precipitation. Notably, just 2.5% of the Earth's water is freshwater, with 98.8% of this freshwater trapped in ice and groundwater. A mere 0.3% of freshwater is found in rivers, lakes, and the atmosphere, and a negligible 0.003% is contained within living organisms and manufactured products. Interestingly, a significant amount of water is also stored in the Earth's interior (WHO & UNICEF, 2012).

It is essential that everyone has vast knowledge on water resources and how to make the usage better. The 'Water Literacy Review' emphasizes the importance of water literacy in addressing global water challenges. It encompasses knowledge, attitudes, and behaviors related to water, as well as highlights the need for water education programs that focus on building water literacy. Water literacy is essential for informed decision-making about water management and conservation. It promotes awareness and understanding of water issues, including scarcity and quality. Water-literate individuals can make informed choices about water usage and conservation. Integrating water literacy into school programs and community activities is essential for promoting water awareness and education. By promoting water literacy, we can empower communities to manage water resources sustainably. Water literacy is critical for achieving water security and sustainability. Ultimately, water literacy is essential for ensuring a water-secure future for all. (McCarroll and Hillary Hamann, 2020).

Water is a versatile resource with diverse applications, including domestic, industrial, commercial, agricultural, and emergency uses. The quality and quantity of water required for each use vary significantly. For instance, domestic water usage demands high-quality water in

relatively small quantities, whereas industrial and agricultural uses can tolerate lower quality water but require substantially larger quantities. Furthermore, water is utilized in various ways within residential settings, including both indoor and outdoor applications (Ogunsula, 1997).

### **2.3 The Hydrological/Water Cycle**

The hydrologic cycle is a perpetual process that circulates water throughout the earth's atmosphere and land. Essentially, it's the ongoing journey of water as it moves from the earth's surface to the atmosphere and then returns again. Key components of this cycle include several critical processes that drive the continuous movement of water. This include;

- i. **Evaporation:** Evaporation is the process by which a liquid transforms into a gas. In the context of meteorology, evaporation refers specifically to the transformation of water from a liquid to a gaseous state. This process requires energy, which can be sourced from various factors such as solar radiation, atmospheric heat, geothermal energy, or even human activity. Evaporation is a familiar phenomenon that occurs in everyday life. For instance, when the human body temperature rises due to environmental heat or physical exertion, it responds by sweating, releasing water onto the skin. As the sweat evaporates, it absorbs heat from the body, providing a cooling effect. This same principle is experienced when stepping out of a shower or swimming pool, as the evaporation of water from the skin's surface creates a cooling sensation.
- ii. **Transpiration:** Transpiration refers to the process by which plants release water vapor into the air through tiny openings called stomata, typically found on the underside of leaves. These stomata are connected to the plant's vascular tissues, enabling water to evaporate and escape into the atmosphere. In most plants, transpiration occurs passively, influenced primarily by atmospheric humidity and soil moisture levels. Interestingly,

only a small fraction (1%) of the water absorbed by a plant is utilized for growth, while the remaining 99% is released into the air through transpiration. iii. Condensation: Condensation is the process by which water vapor transforms into a liquid state. This phenomenon is observable in the atmosphere, manifesting as clouds, dew, or even the formation of water droplets on the exterior of a chilled beverage container. Condensation occurs when there is a disparity between two temperatures: the air temperature and the dew point temperature. The dew point represents the temperature at which the air becomes saturated with water vapor and can no longer hold any more moisture. When the air temperature cools to its dew point, condensation occurs, and additional cooling causes the water vapor to condense into liquid droplets. Fog formation often occurs when the air temperature and dew point converge. As the opposite process of evaporation, condensation involves the release of excess energy in the form of heat, which contributes to the development of hurricanes.

iv. Precipitation: Precipitation occurs when condensed water particles, having merged and expanded through collision and coalescence, become too heavy for ascending air currents to sustain, causing them to descend to the Earth's surface. Precipitation manifests in various forms, including rain, hail, snow, and sleet. Serving as the primary mechanism for replenishing the Earth's freshwater reserves, precipitation delivers an average of approximately 38.5 inches (980 mm) annually across the globe, encompassing both oceanic and terrestrial regions.

v. Surface Runoffs: Runoff occurs when precipitation exceeds the ground's absorption capacity, resulting in saturated soil. This excess water flows over the land, forming rivers and lakes. While some runoff evaporates into the atmosphere, the majority of water in

rivers and lakes eventually returns to the oceans. However, in instances where runoff flows into a lake with no outlet, evaporation becomes the sole means of water returning to the atmosphere. As water evaporates, impurities and salts are left behind, causing the lake to become saline, as seen in the Great Salt Lake and the Dead

Sea. The evaporation of runoff into the atmosphere restarts the hydrologic cycle. Additionally, some water percolates into the soil and recharges groundwater, which is then absorbed by plants, enabling transpiration to occur and continuing the cycle. (NDAA, 2023).

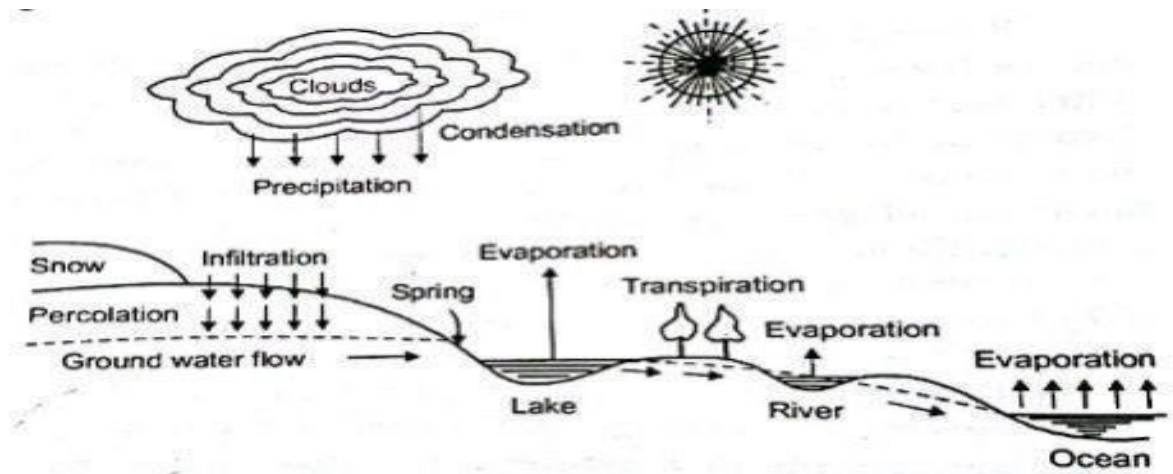


Figure 2.1 Hydrological cycle (Bradley, 2024)

## 2.4 Sources of Water

There are two main sources of water which are; ground water and surface water

### 2.4.1 Ground Water

Groundwater refers to the water that is formed by the melting of snow or rain and percolates through soil and rocks, serving as a precious natural resource for various purposes such as drinking, agriculture, and industry.

Ground water occurs almost everywhere beneath the land surface and is an integral part of a complex hydrologic cycle that involves continuous movement of water on Earth. The widespread occurrence of potable ground water is a major reason for its use as a source of water supply worldwide. Furthermore, much of the world's food is produced by irrigated agriculture, which relies on ground water. Ground water plays a crucial role in sustaining stream flow during dry periods and is vital to many lakes and wetlands. In addition to human uses, many plants and aquatic animals depend upon the ground water that discharges to streams, lakes, and wetlands. (Alley, 2009).

Groundwater plays a vital, yet often overlooked, role in both environmental and human systems. It serves as the primary source of drinking water globally and has enabled significant improvements in agricultural productivity, food security, and livelihoods for billions of people over the past five decades. However, the increasing reliance on groundwater has also created challenges, sparking concerns that this boom may soon lead to depletion. There are difficulties in the management approaches and governing of these resources and some effective solutions may require a more comprehensive perspective, incorporating broader resource systems rather than focusing solely on groundwater management. (Giordano, 2009).

The concept of groundwater encompasses not only water flowing through shallow aquifers but also includes other subsurface water components, such as soil moisture, permafrost, and water trapped in low-permeability bedrock. Additionally, deep geothermal or oil formation water is also considered part of the groundwater system. Research suggests that groundwater may play a crucial role in lubricating fault lines, potentially influencing their movement. It is likely that water is present in some form throughout much of the Earth's subsurface, often mixed with other fluids. Interestingly, the presence of groundwater may not be unique to Earth, as scientists

believe it may have contributed to the formation of certain landforms on Mars. (Arouna A. Dabbert S, 2010).

#### **2.4.2 Ground Water Pollution**

Groundwater pollution, also known as contamination, happens when pollutants seep into the ground and mix with groundwater. This can occur through human activities or natural sources. Human-induced pollution can come from various sources such as on-site sanitation systems, landfill waste, wastewater treatment plant effluent, leaking sewers, petrol stations, hydraulic fracturing, and the overuse of fertilizers in agriculture. Additionally, naturally occurring contaminants like arsenic or fluoride can also pollute groundwater. (Adelana and Micheal, 2014).

When pollutants enter an aquifer, they can create a contaminant plume that spreads through the movement of water and dispersion. As the plume expands, its boundary can intersect with groundwater wells, surface water, and ecosystems, posing a risk to human and wildlife health. To understand the movement of the plume, hydrological transport models or groundwater models can be used. Analysing groundwater pollution involves considering factors such as soil characteristics, site geology, hydrogeology, hydrology, and contaminant properties. Various mechanisms, including diffusion, adsorption, precipitation, decay, and others, influence the transport of pollutants in groundwater. (Costall and Harris, 2020).

A plume is a column or stream of fluids (such as water, air, or contaminants) that moves through a medium, like soil, rock, or air. In the context of groundwater pollution, a plume refers to a column or stream of contaminated groundwater that moves through an aquifer, often originating from a specific source of pollution. They can be characterized by their source, path, extent or concentration.

Some common types of ground water pollutant:

1. **Arsenic and Fluoride:** Arsenic and fluoride have been recognized by the World Health Organization (WHO) as the most serious inorganic contaminants in drinking-water on a worldwide basis. Arsenic in groundwater is a significant concern worldwide, particularly in rural and sub-urban areas where groundwater is a primary source of drinking water. It can be gotten from either; natural geological sources, industrial contaminations or agricultural activities and poses various effects like cancer risk, Neurological effects and cardiovascular disease. (Brindha and Elango, 2011). Fluoride can be released into groundwater from acidic volcanic rocks and dispersed volcanic ash, particularly in areas with low water hardness. This has resulted in high levels of fluoride in groundwater, posing a significant problem in regions such as the Argentinean Pampas, Chile, Mexico, India, Pakistan, the East African Rift, and volcanic islands like Tenerife. In areas where groundwater with naturally high fluoride levels is used for drinking, the prevalence and severity of dental and skeletal fluorosis can be significant. (custodio et al., 2013).
2. **Pathogens:** Improper sanitation and poorly placed wells can contaminate drinking water with pathogens found in feces and urine, leading to fecal-oral transmitted diseases like typhoid, cholera, and diarrhea. The soil matrix typically filters out larger helminth eggs, but bacteria, viruses, and protozoa from feces can commonly be found in polluted groundwater. (Wolf et al., 2015).
3. **Nitrate:** Nitrate is the most prevalent chemical contaminant in groundwater and aquifers worldwide, with alarmingly high levels found in some low-income countries, leading to severe health issues. Furthermore, nitrate remains stable and resistant to degradation, even in oxygen-rich environments. (Ross et al., 2010).

High nitrate levels in groundwater can result from various human activities, including onsite sanitation and sewage sludge disposal in urban areas, as well as agricultural practices, indicating that both urban and agricultural sources can contribute to nitrate contamination. (AGW-Net, 2016).

4. Organic Compounds: Toxic hydrocarbon derivatives have emerged as a perilous adulterant in subterranean water reserves. Their presence is often a consequence of reckless industrial methodologies. Notably, the detrimental effects of these substances remained obscure until the latter half of the 20th century, and it was only through concerted efforts to monitor groundwater quality that their presence in potable water sources was ultimately detected.

Insecticides and herbicides are among the organic pollutants that can contaminate groundwater. Due to their intricate molecular structures, pesticides exhibit varying levels of solubility, adsorption, and mobility within the groundwater system. As a result, certain pesticides are more prone to migration and can more readily reach drinking water sources, posing a potential threat to human health. (Smith et al., 2016).

5. Metals: Certain rock formations naturally contain trace metals, which can be released into the environment through weathering and other geological processes. However, human activities such as mining, smelting, waste disposal, and manufacturing processes can significantly increase the levels of toxic metals like lead, cadmium, and chromium, posing a risk of contamination to nearby groundwater sources. (AGW-Net, 2016). The movement of metals and metalloids in groundwater is influenced by various factors, particularly chemical reactions that control how contaminants distribute among different phases and

species. Specifically, the mobility of metals in groundwater is largely governed by two key factors: the pH level and the redox state. (Smith et al., 2016).

Also, Additional organic pollutants encompass a broad spectrum of contaminants, including organohalides, petroleum hydrocarbons, chemicals from personal care and cosmetic products, and pharmaceuticals along with their byproducts. Inorganic pollutants, on the other hand, may comprise excess nutrients like ammonia and phosphate, as well as radionuclides such as uranium and radon, which occur naturally in certain geological formations. Saltwater intrusion, while a natural phenomenon, is often exacerbated by human activities, exemplifying how natural contamination can be intensified.

Groundwater pollution is a pervasive global problem. In the United States, a comprehensive study of the country's main aquifers from 1991 to 2004 revealed that nearly a quarter of domestic wells contained contaminants exceeding safe levels for human health. Meanwhile, in Africa, research has identified the most pressing groundwater pollution issues as nitrate contamination, followed by the presence of pathogens, organic pollutants, salinization, and acid mine drainage, in order of significance. (Xu and Usher, 2006).

**Table 2.1 Ground Water Pollutant, its Sources and Treatment Methods**

S/N	POLUTANT	SOURCES	TREATMENT METHODS
1	Nitrate.	Agricultural runoff, septic systems, industrial processes	Reverse osmosis, ion exchange, de-nitrification, chemical reduction, Ultrafiltration.

2	Arsenic.	Mining, natural geological sources, geothermal activities, anthropogenic activities.	Coagulation/flocculation, sedimentation, filtration, chemical precipitation, activated alumina.
3	Bacteria.	Septic systems, animal waste.	Disinfection (chlorination, UV), filtration.
4	Heavy Metals.	Industrial contamination, mining activities.	Ion exchange, reverse osmosis, precipitation.
5	Chlorinated Solvents.	Industrial contamination, dry cleaning activities.	Air stripping, activated carbon filtration, bioremediation.
6	Volatile Organic Compounds	Industrial contamination, gasoline spills.	Air stripping, activated carbon filtration, bioremediation.
7	Radioactive pollutants	Mining, radioactive waste disposal, industrial processes, fossil fuel extraction, geothermal operations.	Ultrafiltration, ion exchange, electrocoagulation, advanced oxidation process, radioactive waste treatment.

Note: This is not an exhaustive list of pollutants or treatment methods, the effectiveness of treatment methods may vary depending on the specific contaminant, site conditions, and other factors. It's essential to consult with water treatment experts and follow local regulations when addressing groundwater pollution.

### **2.4.3 Aquifers**

Ground water is the water that is crammed in the tiny gaps between rocks and soil sand sediments under the ground, a full body of ground water is called an aquifer. The level under the ground that first hit the groundwater is called a water table. Below the water table, the soil on the ground is completely saturated with water. The area below the water table is called the saturated zone, while the area above the water table is called the unsaturated zone. Aquifers can be formed during the hydrological cycle, the water that remains on the surface sinks down below the water table to become an aquifer. (Kqed Quest, 2014).

If the surface of the ground dips below the water table, the ground water flows out into the surface creating a body of surface water, and if the water table rises so does the level of the surface water. A 'spring' is a place where ground water flows into the surface creating streams. Surface water can also sink down to fill the aquifers and become groundwater.

(Kqed Quest, 2014).

Groundwater can also leave underground by human activities. Boreholes are used to draw groundwater out of the aquifers into distribution channels to be sent to storage tanks, reservoirs or homes. Groundwater can also help when farming, as some farms depend heavily on the water that's underground. (Kqed Quest, 2014).

### **2.4.4 Surface Water**

Surface water refers to any body of water found on the Earth's surface, including streams, rivers, ponds, lakes, and reservoirs. River flow is influenced by various factors, such as surface runoff, direct precipitation, interflow, and water table discharge (aquifers). The relationship between flow and precipitation can be complex, with geology also playing a significant role in

determining flow rates. In general, river flow is higher in temperate climates and during the rainy season in tropical and subtropical regions.

The chemical, physical, and biological composition of river water is shaped by various flow inputs, influencing its overall quality. Historically, civilizations have relied on rivers as a source of freshwater for human activities, such as irrigation. However, surface water quality can be unreliable and is more susceptible to contamination by fecal microorganisms than groundwater. (Taylor, 2003).

The "run-off ratio" measures the percentage of rainfall that contributes to river flow, varying significantly depending on location. For instance, in the UK, this ratio can range from 30% in lowland England to 80% in parts of Scotland and Wales. Groundwater inputs also impact river flow, helping to mitigate the effects of summer droughts. Surface runoff can contribute significantly to the turbidity of river water, particularly in areas with impervious geology. In contrast, water-table discharge plays a more significant role in chalk lowland rivers, resulting in generally clearer and more consistent water quality. Turbidity is caused by suspended particles, including organic and inorganic material, which can originate from surface runoff, re-suspended sediments, and planktonic microorganisms. Larger microbial assemblages can also remain suspended in fast-flowing rivers. (Taylor, 2003).

#### **2.4.5 Surface Water Pollution**

Surface water pollution arises from a multitude of sources. Pathogens, nutrients, and plastics, as well as chemical contaminants like heavy metals, pesticides, antibiotics, and industrial waste, all contribute to this issue. Additionally, illegal dumping of waste into waterways plays a significant role. Urban storm-water runoff is a significant contributor to surface water

pollution, posing a potential threat to groundwater quality as well. The dispersion and concentration of these pollutants vary based on several factors, and their presence can fluctuate with the seasons. (Gobel, 2007).

The various pollutants present in surface waters have distinct and far-reaching environmental consequences. For instance, antibiotics can contribute to antibiotic resistance, while excessive nutrients can trigger harmful algal blooms. Pathogens pose significant human health risks, and chemical pollutants can have toxic effects. (Rekha Singh, 2022).

Some types of surface water pollutants:

1. **Chemical Pollutants:** Chemical pollutants, including heavy metals, pesticides, industrial waste, and other synthetic chemicals, can contaminate surface water. Chemical pollutants can harm aquatic life, contaminate food chains and also damage ecosystems.
2. **Biological Pollutants:** Biological pollutants, including pathogens, bacteria, viruses, and other microorganisms, can cause illness in humans. Biological pollutants mainly can cause waterborne diseases like cholera, typhoid, and dysentery.
3. **Physical Pollutants:** Physical pollutants, including sediment, silt, and other suspended solids, can cloud water and harm aquatic life. They can reduce water clarity making it difficult for aquatic life to survive and they can also increase water treatment costs as additional treatment steps may be required.
4. **Nutrient Pollutants:** Nutrient pollutants, including excess nutrients like nitrogen and phosphorus, can lead to harmful algal blooms (HABs). Nutrient pollutants can cause HABs which can produce toxins that harm aquatic life and humans.

**Table 2.2 Surface Water Pollutant, its Sources and Treatment Methods**

S/N	POLLUTANT	SOURCES	TREATMENT METHODS
1	Chemical Pollutants	Industrial effluent, agricultural runoff, domestic wastewater, atmospheric deposition.	Coagulation/flocculation, filtration, sedimentation, activated carbon, ion exchange, advanced oxidation.
2	Biological Pollutants	Domestic waste water, agricultural runoff, animal feedlots, septic systems, wildlife.	Coagulation/flocculation, sedimentation, disinfection (chlorination/UV light), biological treatment.
3	Physical Pollutants.	Sedimentation from construction sites, erosion from landfills, debris from engineering activities.	Filtration, sedimentation, Coagulation/flocculation, screening.
4	Nutrients Pollutants.	Agricultural runoff, domestic waste water, industrial effluent.	Ion exchange, reverse osmosis, alum treatment.

### 2.5 Factors Affecting Choice of Water Source

Chosen an adequate and reliable water source depends on these various factors;

1. Distance and Accessibility: The proximity of the water source to the area of need and its accessibility by road, pipeline, or other means.
2. Quantity: The amount of water available from the source, including its yield, flow rate, and storage capacity.
3. Water Quality: The physical, chemical, and biological characteristics of the water, including its taste, odor, turbidity, and contaminant levels.
4. Cost and Economics: The financial costs of developing, operating, and maintaining the water source, including construction, treatment, and transportation costs.
5. Reliability and Security: The dependability of the water source, including its vulnerability to drought, contamination, and other disruptions.
6. Environmental Impact: The potential environmental effects of developing and using the water source, including impacts on ecosystems, wildlife, and aquatic habitats.
7. Social and Cultural Acceptability: The acceptance and preferences of local communities and stakeholders regarding the water source, including cultural and social values.
8. Technical Feasibility: The practicality of developing and operating the water source, including the availability of suitable technology, expertise, and infrastructure.
9. Regulatory Framework: The laws, regulations, and policies governing the development and use of the water source, including permitting requirements and environmental standards.
10. Sustainability and Resilience: The long-term sustainability and resilience of the water source, including its ability to adapt to climate change, population growth, and other future challenges.

These factors interact and influence one another, and the relative importance of each factor may vary depending on the specific context and location. (Nazari and Mohamadi, 2023)

## **2.6 Water Requirement in an Area**

Factors Influencing Water Requirements in an Area:

1. Population size: The number of people in the community.
2. Climate: Temperature and rainfall patterns.
3. Energy availability: Access to energy for pumping water.
4. Water pressure: Pressure in pipes.
5. Water cost: The expense of providing water.
6. Metering cost: The cost of measuring water usage.
7. Socio-cultural factors: Local norms, habits, and culture.
8. Water availability: Current and projected water supply.
9. Community growth: Anticipated growth and development.
10. Water management: Effectiveness of water organization management.
11. Alternative water sources: Availability of alternative supplies.
12. Standard of living: Local living standards and expectations.
13. Distribution patterns: Water distribution networks and patterns.
14. Government policies: Relevant laws, regulations, and policies.
15. Water quality and treatment: Provision of treatment and maintenance costs.
16. These factors interact to determine the overall water requirements of an area. (WHO, 2019)

## 2.7 Water Quality

Water quality refers to the physical, chemical, and biological characteristics of water that determine its suitability for various uses, such as drinking, irrigation, industrial processes, and recreational activities. Maintaining good water quality is essential for human health, environmental sustainability, and economic development. (WHO, 2017).

Physical Characteristics of water quality include:

1. Temperature: Temperature affects the solubility of gases and the metabolism of aquatic organisms.
2. Turbidity: Turbidity measures the clarity of water, with high levels indicating the presence of suspended solids.
3. Color: Color can indicate the presence of dissolved organic matter or other substances.
4. PH: This measures the acidity or alkalinity of water, with most aquatic organisms preferring a PH between 6.5 and 8.5.

Chemical characteristics of water quality include:

1. Dissolved Oxygen (DO): DO is essential for aquatic life, with levels below 5 mg/L indicating poor water quality.
2. Nutrients: Excess nutrients, such as nitrogen and phosphorus, can lead to eutrophication and harm aquatic ecosystems.
3. Heavy Metals: Heavy metals, such as lead, mercury, and arsenic, can be toxic to humans and aquatic organisms.
4. Pesticides and Herbicides: These chemicals can contaminate water sources and harm aquatic life.

Biological characteristics of water quality include:

1. **Bacteria:** The presence of bacteria, such as *E. coli*, can indicate fecal contamination and pose health risks.
2. **Viruses:** Viruses, such as rotavirus and norovirus, can cause waterborne illnesses.
3. **Protozoa:** Protozoa, such as *Giardia* and *Cryptosporidium*, can cause gastrointestinal illnesses.

Several factors can affect water quality, including:

1. **Agricultural Runoff:** Fertilizers, pesticides, and manure from agricultural activities can contaminate water sources.
2. **Industrial Effluent:** Industrial processes can release pollutants, such as heavy metals and chemicals, into water sources.
3. **Domestic Sewage:** Untreated or poorly treated sewage can contaminate water sources and pose health risks.
4. **Climate Change:** Climate change can alter water temperature, precipitation patterns, and extreme weather events, affecting water quality.

Water quality is a critical aspect of environmental and public health. Understanding the physical, chemical, and biological characteristics of water quality, as well as the factors that affect it, is essential for maintaining healthy ecosystems and protecting human health. Effective monitoring and management strategies, including wastewater treatment, BMPs, and education, are necessary to ensure good water quality.

### 2.7.1 Test for Water Quality

In order to know the quality of water several test are to be carried out, the categories of this test area;

- i. Physical Test: Indicates properties detectable by sense or visible to the naked eye like color, Taste and Odor, turbidity and temperature (EPA, 2024).
- ii. Chemical Test: This test involves the chemical characteristics of water, which is its pH, hardness, presence of a selected group of chemical parameter, biocides, highly toxic chemicals like nitrates and pesticides, heavy chemicals and B.O.D. PH is a measure of hydrogen ion concentration. It is an indicator of relative acidity or alkalinity of water, values of 9.5 and above indicate high alkalinity while values of 3 and below indicate acidity. Drinking water should have a pH between 6.5 and 8.5. Harbor basin water can vary between 6 and 9. B.O.D denotes the amount of oxygen needed by microorganisms for stabilization of decomposable organic matter under aerobic conditions. High B.O.D. means that there is less of oxygen to support life and indicates organic pollution. (Ogunsola, G.O, 1997).

Some standard methods for chemical testing of water quality include:

- a. ASTM D4520-18: Standard Practice for Determining Water Injectivity Through the Use of On-Site Floods.
- b. ASTM D4025-18: Standard Practice for Reporting Results of Examination and Analysis of Deposits Formed from Water for Subsurface Injection.
- c. ASTM D5463-18: Standard Guide for Use of Test Kits to Measure Inorganic Constituents in Water.

These tests and standards help ensure that water is safe for drinking, domestic activities, and other uses.

**iii. Bacteriological Test:** Bacteriological testing is crucial for detecting harmful organisms in water that pose health risks to humans. This test is essential for routine water quality monitoring. However, it's important to note that bacteriological analysis has limitations, as it can only indicate the presence or absence of contamination at the time of testing. **Table 2.3**

**Impurities in Water (WHO)**

S/N	Impurities	Causes	Effect
a)	Bacteria (E. coli, Salmonella)	Human/animal waste, contaminated soil	Diarrhea, cholera, typhoid fever.
b)	Viruses (Rotavirus, Norovirus)	Human/animal waste, contaminated soil	Human/animal waste, contaminated soil.
c)	Lead	Corroded pipes, contaminated soil	Neurological damage, developmental delays.
d)	Mercury	Industrial waste, contaminated fish	Neurological damage, kidney damage
e)	Arsenic	Natural occurrence, industrial waste	Skin discoloration, cancer risk
f)	Fluoride (excessive)	Natural occurrence, water treatment	Dental fluorosis, skeletal fluorosis
g)	Chlorides	Industrial waste, seawater intrusion, from treatment process	Taste/odor issues, corrosion of pipes.

h)	Sulfates	Industrial waste, natural occurrence	Taste/odor issues, gastrointestinal problems.
i)	Turbidity	Suspended particles, algae blooms	Aesthetic issues, interference with disinfection.
j)	PH (extreme)	Industrial waste, natural occurrence	Corrosion of pipes, skin/eye irritation.

## 2.8 Water Treatment

Water treatment is a crucial process that improves water quality, making it suitable for various uses, including drinking, industrial supply, irrigation and domestic uses. The processes involves the removal of contaminants and undesirable components or reducing their concentration to make it fit for its intended use.

Drinking water treatment removes impurities from raw water, producing safe water for human consumption. The treatment process eliminates suspended solids, microorganisms such as bacteria, viruses, and fungi, algae, and excess minerals like iron and manganese.

Treatment combines physical processes like settling and filtration, chemical processes like disinfection and coagulation, and biological processes like slow sand filtration. To ensure water quality, treatment is complemented by the use of residual disinfectants to prevent bacterial growth during distribution, as well as proper conveyance and distribution systems.

The World Health Organization (WHO) provides general guidelines for drinking water quality, while more stringent standards apply in Europe, the USA, and other developed countries.

(WHO, 2017), (EPA, 2022).

## **2.10 Surface Water Treatment Process**

### **1. Screening**

The initial step in the treatment process at water treatment plants typically involves the use of physical barriers to prevent large debris and contaminants from entering the plant. This is achieved through the installation of strainers in intake wells or pipes, which block large floating matter. Fine floating matter is controlled using screens with small openings, typically 0.95cm. In some cases, cast screens with openings between 2.5 and 7.5 cm may be used preceding the final screens. These pre-treatment measures help protect the treatment plant's equipment and ensure efficient operation by removing large debris and contaminants from the water.

### **2. Sedimentation**

This is a process that utilizes gravity to separate particles suspended in water, allowing them to settle to the bottom. The settled particles form a sediment, referred to as sludge in the context of water treatment. As the sediment continues to settle, it undergoes consolidation, becoming increasingly dense.

In water treatment sedimentation might be used to reduce the concentration of particles in suspension before the application of coagulation, to reduce the amount of coagulating chemicals needed, or after coagulation and, possibly, flocculation. When sedimentation is applied after coagulation, its purpose is usually to reduce the concentration of solids in suspension so that the subsequent filtration can function most effectively (Samal and Sneha, 2020).

Sedimentation tank: It is also called settling tank or clarifier is a component of a modern system of water supply or wastewater treatment. A sedimentation tank allows suspended particles to

settle out of water or wastewater as it flows slowly through the tank, thereby providing some degree of purification. A layer of accumulated solids, called sludge, forms at the bottom of the tank and is periodically removed. In drinking-water treatment, coagulants are added to the water prior to sedimentation in order to facilitate the settling process, which is followed by filtration and other treatment steps. The movement of water is slow enough to allow quiescent settling for a large percentage of the suspended particles. Thus in general terms, the water remains in the tank for only a few hours before it reaches the tank outlet.

The geometry of the sedimentation basin can be rectangular, square or circular.

#### Types of sedimentation tanks

- a. **Horizontal Flow Tanks:** The most basic method of sedimentation involves filling a container with water, allowing particles to settle, and then carefully pouring off the clear water, leaving the sediment behind. However, this approach is impractical for large-scale water treatment, such as for townships, due to the time and space required. As a result, sedimentation tanks are designed to operate continuously. The simplest type of sedimentation tank is a rectangular tank with horizontal flow. Water containing suspended particles enters one end of the tank and flows to the other end, allowing particles to settle to the bottom. The goal is for a significant portion of the settling particles to reach the tank floor before the water is discharged from the tank.
- b. **Radial Flow Tanks:** To facilitate sediment removal, these tanks typically have a gently sloping floor that leads to a hopper at the inlet end. A scraping mechanism is also installed to collect sediment from the outlet end and transport it back to the inlet end, where it can be hydraulically discharged. Radial flow tanks are circular in shape, featuring a central inlet for water and a peripheral outlet. To ensure efficient operation, careful attention must

be paid to the design of the inlet, which should facilitate uniform distribution of flow throughout the tank. Sediment collected at the bottom of the tank is scraped towards a central hopper for discharge. (Reinsel, 2018).

### **3. Coagulation**

Coagulation is a chemical process that involves adding polymers to water, causing small, destabilized particles to clump together into larger aggregates. This makes it easier to separate them from the water. Coagulation works by neutralizing the charge on the particles. Certain chemicals called coagulants are rapidly mixed in the water and the mixture slowly stirred before allowing sedimentation to occur, the particles will settle. An important property of colloidal particles that keeps them perpetually in suspension is the fact that they carry small electrostatic charges which make them repel each other. The coagulant chemical neutralizes the effect of colloidal charges. Once the colloidal charges are neutralized, the colloidal particles can collide and agglomerate (stick together) forming larger and heavier particles called flocs. After the initial flash mix of the coagulant with the water, a gentle agitation achieved by slow stirring helps to enhance the growth of the flocs by increasing the number of particle collisions.

The coagulation-flocculation process is often used as a preliminary or intermediary step in water or wastewater treatment, alongside other processes like filtration and sedimentation.

Commonly used coagulants include iron and aluminium salts, but other metals like titanium and zirconium have also been found to be effective. (Nystrom and Fredrik, 2020)

Coagulants: Since in a colloidal suspension, particles will settle very slowly or not at all because the colloidal particles carry surface electrical charges that mutually repel each other.

A coagulant (typically a metallic salt) with the opposite charge is added to the water to

overcome the repulsive charge and "destabilize" the suspension. The commonly used metal coagulants fall into two general categories: those based on aluminium and those based on iron. The aluminium coagulants include aluminium sulphate, aluminium chloride and sodium aluminate. The iron coagulants include ferric sulphate, ferrous sulphate, ferric chloride and ferric chloride sulphate. Other chemicals used as coagulants include hydrated lime and magnesium carbonate. (Ramavandi and Bahman, 2014).

Some factors influencing coagulation process

1. Temperature
2. PH value of water
3. Water quality
4. The quantity and characteristics of colloidal
5. Characteristics of the ion in the water
6. Type of the coagulant used
7. Alkalinity of the water
8. Coagulant dosage
9. Coagulant feed concentration
10. Final pH
11. Type and dosage of chemical additives other than primary coagulant (e.g polymers)
12. Intensity and duration of mixing at rapid mix stage
13. Flocculation geometry
14. Sequence of chemical addition and time lag between dosing points
15. Flocculation retention time (Viklander and Maria, 2020).

#### 4. Flocculation

Flocculation involves mechanical stimulation to agglomerate destabilized particles into compact, fast-settling particles or flocs. This process results from velocity differences or gradients in the coagulated water, causing fine moving particles to come into contact and form large, flocs that can settle.

After coagulation, it's often necessary to add a flocculant to aggregate the coagulated particles into larger, easier-to-settle or float particles. This is typically achieved by adding synthetic polymers, usually made from acrylamide monomers, which bridge together coagulated particles into denser particles.

Although often used interchangeably with coagulation, flocculation is a distinct process that aids in sediment and contaminant transport. Typically, flocculation follows coagulation and helps remove colloidal particles or flocs through rapid settlement or flotation.

The common practice in flocculation involves:

1. Rapid or flash mixing: is the process by which a coagulant is rapidly and uniformly dispersed through the mass of water. This process usually occurs in a small basin immediately preceding or at the head of the coagulation basin.

Generally, the detention period is 30 to 60 seconds and the head loss is 20 to 60cms of water. Here colloids are destabilized and the nucleus for the floc is formed.

2. Slow mixing: brings the contacts between the finely divided destabilized matter formed during rapid mixing. (Jiang and Jia-Qian, 2015).

## 5. Filtration

Filtration in water treatment involves passing water through a bed of granular media. As water flows through the media, suspended particles are trapped in the pore spaces, effectively removing them from the water stream.

Filtration is a time-tested water treatment method, replicating nature's own purification process. In the natural world, water flowing slowly through porous sand and rock formations is cleaned and purified. Filtration can be described as the process of passing water through granular materials to remove impurities.

Some filter materials include; sand (either fine or coarse), gravel and other materials e.g anthracite, activated carbon etc.

There are different types of filter but the two mainly used are slow-sand filter and rapid-sand filter. (Ahmed and Arslan, 2020).

### a) Slow Sand Filter

These are types of water filtration system that uses a slow and deliberate process to remove impurities from water.

In slow sand filtration the rate of filtration is intentionally slow with use of sand that is smaller than sand used in rapid sand filters, so that particles are not driven far into the bed of sand held within the filter shell. The principal mechanisms taking place in slow sand filter's accumulation of a layer of debris on the surface of the filter (straining) and capture within about the top 20 cm of the sand. This debris is allowed to develop biological activity which contributes to the treatment of the water passing through it. This biologically active layer is often called the 'schmutz' (dirt or filth). Because the filtration rate is relatively slow the

resistance to flow through slow sand filters develops slowly and may take up to 3 months before it becomes unacceptable. Because filtration rate is slow a large area for filtration is needed. Consequently, the large filters are cleaned by removing the schmutz {dirt or filth} with about 5cm of sand usually by mechanical means. Eventually the depth of sand remaining becomes too shallow and the remaining sand is removed, cleaned and replaced with additional clean sand back to the original starting depth.

Advantages of slow sand filter:

- i. Suitable where sand is readily available
- ii. Effective in bacteria removal (up to 99% of bacteria)
- iii. Preferable for uniform quality of treated water
- iv. They require minimal maintenance, as the sand bed can be cleaned and replaced as needed

Disadvantages of slow sand filter:

- i. Large area is required for the filter beds as well as for settling tanks
- ii. Unsuitability for treating highly turbid waters (raw water turbidity should not exceed
- iii. Less flexibility in operation due to seasonal variations in raw water quality.
- iv. Slow sand filters are unsuited for treating water containing large quantities of organic matter.
- v. They have a slow filtration rate, typically 0.1-0.3 meters per hour. (Spellman, 2008)

b) Rapid sand filter

Rapid sand filter is a widely used filtration system that consists of a layer of carefully sieved sand on top of a bed of graded gravels. Although the pore openings between sand grains are often larger than the particles being removed, the filter still effectively removes particles through various mechanisms.

The filter requires regular cleaning, which typically occurs once a day, to remove accumulated particles. This involves shutting down the filter and forcing water backward through the sand for a short period. After cleaning, the sand resettles, and operation resumes.

Rapid sand filters are preferred over slow sand filters, particularly in urban areas, due to their higher filtration rates and smaller space requirements. These filters use coarse sands and can yield significantly higher results than slow sand filters.

Water from coagulation-sedimentation tanks is treated using rapid sand filters, and the filtered water is then disinfected to produce potable supplies.

Advantages of rapid sand filter:

- i. Higher filtration rates compared to slow sand filters
- ii. Smaller space requirements, making them okay for urban
- iii. Can yield significantly higher results than slow sand filters
- iv. Effective in removing particles and contaminants from water
- v. Can be used to treat water from coagulation-sedimentation tanks

Disadvantages of rapid sand:

- i. Require regular cleaning, typically once a day, to maintain effectiveness
- ii. Can become clogged if not cleaned properly, reducing filtration rates
- iii. May not be as effective in removing certain types of contaminants, such as dissolved solids
- iv. Can be more expensive to operate and maintain than slow sand filter (Spellman and Frank, 2008).

**Table 2.4: Comparison between Rapid and Slow Sand Filter (UNDP, 2015).**

S/N	ITEM	SLOW SAND FILTER	RAPID SAND FILTER
1	Filter sand (effective size)	0.25mm-0.35mm	0.45mm-0.70mm
2	Base material	Gravel base of 30mm-75mm depth with 3mm-65mm size graded gravel	Gravel base of 45mm-50mm depth with gravel size varies between 3mm-50mm
3	Pre treatment	Not important except plain sedimentation	Coagulation, flocculation and sedimentation
4	Rate of filtration	100 to 200 Lph/sq.m (slow filtration rate)	4800 to 7200Lph/sq.m (fast filtration rate)
5	Cost (installation)	High	Low
6	Cost (operation and maintenance)	Low	High
7	Efficiency (removal of bacteria)	98-99%	80-90%
8	Suitability	For water supply to rural areas and small towns	For public water supply to towns and cities
9	Post treatment	Slight disinfection	Complete disinfection
10.	Ease of construction	Simple	Difficult
11.	Skilled supervision	Not essential	Essential

12	Cleaning interval	Three to four months	One to two days
13.	Method of cleaning	Scrapping and removing schmutz	Back washing with or without compressed air agitation (simple and easy).

## 6. Disinfection

Filtered water may still contain harmful bacteria that can cause diseases. To make the water safe for drinking, these bacteria must be eliminated through a process known as disinfection or sterilization. Disinfection destroys pathogenic organisms, making the water safe for human consumption.

Although some microorganisms are removed during settling, chemical addition, and filtration, disinfection is necessary to ensure the water is safe to drink. The purpose of disinfection is to kill any remaining pathogens after conventional treatment, requiring a minimal amount of disinfectant that is non-toxic to humans.

Disinfectants, such as chlorine gas and chlorine compounds, are commonly used due to their prolonged action and affordability. When added to water, disinfectants react chemically, releasing products that attack and deactivate the cells of pathogens.

In addition to its germicidal effects, chlorine also eliminates taste and odor-producing compounds, algae, and related water blooms and organisms. Furthermore, chlorine helps oxidize iron, manganese, and hydrogen sulfide, making the water safer and more palatable for consumption.

## **Disinfection Methods**

1. **Physical Method:** These are methods which involves agents like heat, light. Boiling of water kills disease causing organism in 15-20 mins, although for safety water should be boiled for a longer period. Sunlight is a natural disinfectant because of ultra violet rays.
2. **Chemical Method:** This involves the use of chemicals to kill or inactive microorganisms like; Oxidizing agents such as potassium per magnate (which is used in hospitals), Ozone and Halogen groups such as; Chlorine (which is universally used), Bromine (which is used in swimming pool), Iodine, acids and alkalis. (Kurniawan and Agustiono, 2006).

### **Disinfection by Chlorine**

Chlorine is commonly used in water treatment as a disinfectant, and it can be employed in various forms, including hydrochlorides or free chlorine. However, free residual chlorine is only present as molecular chlorine at a pH value of 5 or higher. When chlorine is added to water, it initially remains as chlorine for a short period before reacting with water to form hypochlorous acid and hypochlorite ions.

The degree of dissociation of hypochlorous acid into hydrogen ions and hypochlorite ions depends on the pH and temperature of the water. Chlorination is an effective and inexpensive method for disinfecting water, especially in emergency situations where there is an overload of pathogens. The process is relatively easy to implement and can eliminate pathogens quickly.

Chlorine inactivates microorganisms by damaging their cell membranes, disrupting cell respiration and DNA activity. The addition of chlorine to water results in the formation of

hypochlorous acid and hypochlorite ions, which are the primary disinfecting compounds. The pH level of the water determines the presence of these compounds, with hypochlorous acid dominating at lower pH levels.

The combination of hypochlorous acid and hypochlorite ions is referred to as "free chlorine," which has a high oxidation potential and is a more effective disinfectant than other forms of chlorine. Chlorination also has additional benefits, including oxidizing iron, manganese, and hydrogen sulfide, removing color and taste, and aiding other water treatment processes.

There are methods of chlorination which include:

- A. Pre-chlorination: Involves applying chlorine to the water immediately after it enters the treatment facility. This step eliminates algae and other aquatic life that could cause problems in later stages of treatment. Chlorine is usually added directly to the raw water or in the flash mixer, ensuring quick and uniform dispersion. It helps remove tastes and odors, controls biological growth, and prevents growth in sedimentation tanks and filtration media. Additionally, chlorine oxidizes iron, manganese, and hydrogen sulfide, making it easier to remove them in subsequent treatment steps. Chlorination can also be done just before filtration and after sedimentation to control biological growth, remove iron and manganese, eliminate tastes and odors, control algae growth, and remove color from the water.
- B. Post-chlorination: On the other hand, involves adding chlorine as the final step in the treatment process. This step disinfects the water and maintains chlorine residuals that remain in the water as it travels through the distribution system. Chlorinating filtered water is more economical since it requires a lower concentration and contact time to achieve the same effectiveness.

By the time the water has gone through sedimentation and filtration, many unwanted organisms have been removed, making it easier to achieve the desired level of disinfection. To maintain the chlorine residual, re-chlorination may be done within the distribution system to ensure proper chlorine residual levels are maintained throughout. (Frank P, Josep, 2017).

## **2.10 Chlorine Demand by Water**

The amount of chlorine required to disinfect water depends on the level of impurities present. Chlorine must first react with these impurities before a chlorine residual can be achieved. The amount of chlorine needed to satisfy these impurities is referred to as the "chlorine demand." This can be thought of as the amount of chlorine required before free chlorine can be produced. Once the chlorine demand has been met, breakpoint chlorination occurs, and any additional chlorine added will result in a free chlorine residual proportional to the amount of chlorine added. Chlorine and chlorine compounds react with organic and inorganic impurities in water, consuming chlorine before any disinfection can occur.

The amount of chlorine consumed in this process is known as the chlorine demand of the water. After this demand is fulfilled, chlorine appears as free available chlorine, which serves as a disinfectant to kill pathogens in the water. It is essential to provide sufficient time and dose of chlorine to satisfy various chemical reactions and leave some unreacted chlorine as a residual for disinfection.

Chlorine demand is influenced by water quality characteristics, pH, temperature, amount of oxidant applied, and contact time. Generally, waters are satisfactorily disinfected if the free available residual chlorine is about 0.2 mg/l at the end of a 10-minute contact period.

Chlorine dose for disinfection depends on the factors like; Organic matter present in the water to be disinfected, The PH value of water, Temperature, Contact time and The amount of carbon dioxide present in water (Edzwal and James, 2011).

## **2.11 Importance of Water Treatment**

- i. Improvement in the aesthetic quality of water by removing unpleasant taste, color and odor from the water.
- ii. Making the water non corrosive and suitable for industrial processing and recreational use.
- iii. Removal of dissolved mineral matter.
- iv. Removal of settle-able suspended matter and non settleable colloidal Impurities.
- v. Removal of harmful bacteria, viruses, and parasites.
- vi. Removal of toxic substances like lead, mercury, and arsenic.
- vii. Maintenance of water quality by removing contaminants and preventing recontamination.
- viii. Protection of the environment by removing pollutants and contaminants that can harm aquatic life.

The amount of water treatment required depends on quality and quantity of the raw water source and required standard of purified water by WHO.

## **2.12 Requirement for a Treatment Plant**

1. The system layout should be compact so that less space and less piping is required
2. There should be sufficient space for future expansion
3. The plant should be made as hygienic as possible

4. The plant must be provided with essential services such as approach roads, supply and telephone facilities
5. Provision must be made at the plant for a store and laboratory and shelter for the working personnel
6. Various units of the plant should be located in a proper sequence to ensure that water flows by gravity from unit to unit without pumping.
7. If the source is at lower elevation from the distribution area, the plant may be located near the sources
8. It is preferable to locate the plant as near as possible to the area of distribution to avoid the risk of water getting contaminated in the transit
9. In large cities, small disinfection units may be installed, scattered over the city to guard against possible contamination during conveyance
10. It is preferable to locate the plant as near as possible to the area of distribution to reduce the number of pipes required thereby reducing cost.

### **2.13 Water Storage**

A reliable water supply system requires treated water storage to cater to demand fluctuations, maintenance, and potential source or treatment issues. Storage options include covered reservoirs or storage tanks positioned to supply water under gravity. The storage capacity should accommodate peak demand and potential supply interruptions without allowing water to stagnate, which can lead to aesthetic and quality issues.

Before use, the storage tank and system must be disinfected using a chlorine solution, followed by thorough rinsing with treated water. Insulation is necessary to prevent freezing and excessive warming, which can encourage issues with the water's appearance and microbiology. To prevent contamination and damage, the storage tank should be fitted with a robust and lockable lid that excludes light and pollutants. Additionally, openings must be protected to prevent the ingress of insects and animals.

Regular inspections are crucial to maintain the quality and safety of the stored water. These inspections enable the identification and removal of accumulated silt and the disinfection of the system as needed. (Nyong and Kanaroglou, 2001).

## **2.14 Distribution system**

A distribution system, also known as a distribution network, refers to the complex arrangement of pipes, channels, vessels, reservoirs, and tanks that store and convey treated water to consumers. The integrity of this system is crucial in maintaining the quality of drinking water, as any compromise can lead to contamination and adverse health effects.

Even with effective treatment, the quality of drinking water at the point of consumption can be compromised if the distribution system is not properly maintained. Identifying risks within the system can be challenging due to the underground or hidden nature of pipes and tanks, making inspection difficult. As a result, water quality issues may only become apparent through monitoring or when consumers notice objectionable taste, odor, or appearance.

Distribution systems vary greatly in complexity and physical construction, ranging from simple to complex networks that span distances from a few meters to several miles. Consequently, the

potential hazards and risks to water quality are numerous and diverse, emphasizing the need for adequate construction, management, and maintenance.

Mitigating risks to water quality requires awareness of potential hazards and sensible management and maintenance practices. This includes routine cleaning of storage facilities, using suitable storage tanks and reservoirs, periodic flushing of the system, and utilizing approved water fittings. Additionally, incorporating backflow protection devices is essential to prevent contaminants from entering the system. (Nyong AO, Kanaroglou PS, 2001).

## **2.15 Maintenance**

Effective management and maintenance of small water supply systems are crucial to ensuring safe and clean drinking water. A proactive approach to maintenance is essential, rather than simply reacting to equipment failures and quality issues as they arise.

Some key maintenance practices are;

1. Regular checks: Perform daily or more frequent checks on disinfection equipment, such as verifying UV lamp operation and measuring chlorine residual.
2. Investigate anomalies: Investigate instances of dirty or discolored water to identify potential system failures.
3. Filter maintenance: Regularly clean filter according to manufacturer recommendations.
4. Site inspections: Conduct routine site inspections to check for signs of water source pollution.
5. Structural inspections: Perform regular structural inspections of treatment plants, storage tanks, and pipelines.

Maintenance should only be performed by competent individuals (trained, experienced, and familiar with the equipment). Ideally, maintenance should be carried out by the supplier's servicing contractors.

Upon installation and commissioning of a water treatment plant, the supplier should provide training on routine operation and maintenance tasks, covering:

1. Treatment operation: Checking treatment operation correctness.
2. Chemical maintenance: Topping up chemicals as required.
3. Equipment maintenance: Routine maintenance of equipment.
4. Simple repairs: Making simple repairs. (Edzwald, 2011).

## **2.16 Review on Previous Related work**

- i. Development of a Sustainable Water Treatment System for Rural and Semi-Urban Communities (2021).

This research by Okechukwu et al. focused on designing a sustainable and adaptable water treatment system for semi-urban regions in Nigeria. The design utilized a combination of slow sand filtration and solar-powered disinfection, aimed at minimizing energy consumption and maintenance needs. The system served a population of about 10,000 people and targeted raw water with moderate turbidity and microbial contamination. Results showed that slow sand filtration effectively reduced turbidity from 50 NTU to less than 5 NTU, while solar disinfection achieved significant pathogen reduction.

Key Contribution: Proposed an energy-efficient and environmentally friendly alternative to conventional chlorination-based systems, aligning with sustainable development goals for rural and semi-urban water supply.

ii. Design and Implementation of a Community-Based Water Purification System in Northern Nigeria (2019).

This study by Ibrahim et al. (2019) focused on developing a low-cost community managed water purification system for rural settlements in Northern Nigeria. The system combined coagulation–flocculation, rapid sand filtration, and chlorination. The treatment plant was designed to serve approximately 5,000 residents using locally sourced materials to reduce construction costs. Results showed a reduction in turbidity from 65 NTU to below 3 NTU, while total coliform levels were reduced to WHO acceptable limits.

Key Contribution: Demonstrated the effectiveness of integrating conventional treatment methods with community participation to enhance sustainability and operational continuity in rural water supply systems.

iii. Performance Evaluation of Solar-Powered Borehole Water Treatment Systems in Sub-Saharan Africa (2020).

A study conducted by Mensah et al. (2020) evaluated the efficiency of solar-powered borehole treatment facilities across selected Sub-Saharan African communities. The system incorporated sedimentation, activated carbon filtration, and UV disinfection. Findings revealed significant improvement in water quality parameters, including a 90% reduction in microbial contamination and improved taste and odor characteristics.

Key Contribution: Highlighted the viability of renewable energy-powered treatment technologies in off-grid rural communities with unreliable electricity supply.

iv. Application of Slow Sand Filtration for Rural Water Treatment in Developing Countries (2018).

Okafor and Adeyemi (2018) investigated the use of slow sand filtration as a cost-effective water treatment method for rural communities. The study demonstrated that biological layer (schmutzdecke) development significantly enhanced pathogen removal efficiency. Turbidity was reduced from 40 NTU to less than 5 NTU, and E. coli counts were reduced by over 95%.

Key Contribution: Provided empirical evidence supporting slow sand filtration as a sustainable and low-maintenance option for small-scale water treatment facilities.

v. Assessment of Chlorination Efficiency in Small-Scale Water Treatment Plants in Nigeria (2022).

Adebayo et al. (2022) assessed the operational performance of small-scale chlorination units in semi-urban areas of Nigeria. The study evaluated residual chlorine levels, contact time, and microbial removal efficiency. Results indicated that proper dosing and monitoring ensured compliance with WHO drinking water standards, though operational challenges such as inconsistent chemical supply were identified.

Key Contribution: Emphasized the importance of proper monitoring, operator training, and maintenance planning in ensuring long-term effectiveness of chlorination-based treatment systems.

## **CHAPTER 3**

### **3.0 METHODOLOGY**

### 3.1 Study Area

A semi-urban area is a transitional zone between rural and urban areas, characterized by a mix of rural and urban land uses, livelihoods, and lifestyles. It's also known as a peri-urban zone. This is a place that shares characteristics of both urban and rural environments. In semi-urban areas, you'll often find a combination of residential areas, Agricultural lands, Commercial establishments, Infrastructure etc.

Semi-urban areas are often formed as a result of urban expansion, where cities grow outward and engulf surrounding rural areas. This can lead to a range of challenges, including managing growth, providing services, and balancing rural and urban interests. The population of a semiurban area typically ranges from 5,000 to 20,000 inhabitants. This is a general estimate, but the actual population can vary depending on factors such as location, economic activities, and infrastructure development.

Some characteristics and attributes of a semi urban area:

Physical Attributes;

- i. Population Density: Semi-urban areas have lower population densities than urban areas but higher than rural areas.
- ii. Land Utilization: These areas feature a mix of residential, commercial, industrial, and agricultural land uses.
- iii. Infrastructure: Basic infrastructure like roads, electricity, water supply, and sanitation is available, although it may not be as extensive as in urban areas.

Socio-Economic characteristics;

- i. Population Size: Semi-urban areas have smaller populations than urban areas, with a mix of urban and rural livelihoods.
- ii. Economic Diversity: The economy is diversified, with a mix of formal and informal sectors, including agriculture, industry, and services.
- iii. Education: Access to education is available, although it may not be as comprehensive as in urban areas.
- iv. Healthcare: Basic healthcare facilities are available, although they may not be as extensive as in urban areas.

Environmental Attributes;

- i. Natural Resources: Semi-urban areas are characterized by the presence of natural resources like forests, water bodies, and agricultural land.
- ii. Environmental Concerns: These areas may face environmental concerns like pollution, waste management, and conservation of natural resources.

All these characteristics can vary depending on the specific context and location of the semi urban area.

### **3.2 Method of getting Design Parameters**

The design criteria or parameters considered in the designing of the water treatment plant for semiurban area is as follows:

- i. Population of the semi-urban area
- ii. Water demand/requirements of the area
- iii. Characteristics of the water source

### 3.3 Water Demand/Requirement

Water demand is the amount of water needed in a certain area. The amount of water used in a locality is directly related to the size of the population. In estimating the total water demand of people in the semi-urban area, the average water demand per person is multiplied by its total population. The equation used for the estimation of total water demand of water by the area is;

$$Q = P \times q$$

Where,

Q = Total annual water demand required in litre P

= Population of the community q = Average

water demand per person

Note: the minimum water required by a semi-urban area is between 100-150 liters/person/day.

### 3.4 Characteristics of The Water Source

Surface water assumed to be the water source for a semi-urban area, will have several characteristics.

Surface water contains large amounts of suspended particles mainly caused by human activities.

Also, the change in temperature and water quality occurs daily, seasonally, depending on the amount of sunlight, the temperature difference between seasons or happens randomly due to rainstorms, pollution.

All these make up the characteristics of a surface water source, some characteristics like

1. Temperature: Surface water temperature varies with climate, season, and time of day. (e.g tropical region; 24<sup>0</sup>C-30<sup>0</sup>C).

2. Turbidity: Surface water can be clear or turbid, depending on sediment loads, algae growth, and human activities (Average turbidity for fresh water rivers; 0-50 NTU)
3. PH and Alkalinity: Surface water pH and alkalinity can influence its ability to neutralize acids and support aquatic life. PH can range from acidic to basic, depending on surrounding geology and vegetation. (Average PH for fresh water rivers can range from 6.5-8.5 which can mean slightly alkaline).
4. Total Dissolved solid: Refers to the concentration of dissolved substances in water (for fresh water rivers it ranges between 0-300mg/L).
5. Color: Surface water color can range from clear to colored, depending on dissolved organic matter, sediments, and algae.
6. Total Hardness: Surface water hardness can vary with geology and affect its suitability for industrial and domestic uses.

### 3.5 Design Units

1. Screening chamber: the first stage when treating surface water is the bar screening chamber, this is where must the larger floating materials or particles are removed.

Design Criteria;

- i. Peak flow =  $3.2 \times 10^3 m^3/day = 0.037 m^3/sec$
  - ii. Velocity through screens (at peak flow) = 0.8m/s    iii. Spacing of bars = 5cm = 0.05m
  - iv. Diameter of bars = 1cm = 0.01m
  - v. Depth = 1m    vi. Width = 1m    vii. The chamber is inclined at  $60^\circ$     viii. Head loss
- $$h = 0.0729(v_1^2 - v_2^2)$$

Procedures:

- i. Determine the area of the bar screen
  - ii. Determine the number of bars
  - iii. Determine the inclined width and length of the screen
  - iv. Analyze and determine the head loss before and during screening
2. Design of plan Sedimentation tank: Pre-sedimentation is done before the actual sedimentation and coagulation in order to reduce the amount of visible contaminants in the raw water.

Design criteria;

- i. Plain sedimentation required,
- ii. Velocity of flow: assumed uniform throughout, generally not exceeding 30 cm per minute.
- iii. Detention period: 3 to 4 hours for plain sedimentation
- iv. Settling tank efficiency; The efficiency of the basin is reduced by currents induced by the inertia of the incoming water, it is expressed mathematically by the equation;  
$$\frac{h}{H} = 1 - \left[1 + n \frac{V_o}{Q/A}\right]^{\frac{1}{n}}$$
- v. Overflow rate: for plain sedimentation tank surface loading is 15,000 - 30,000l/m<sup>2</sup>/day
- vi. Depth of flow: ranges from 3-6 m
- vii. Weir loading: generally up to 300,000l/m/day
- viii. Rectangular tank: a length and width of ratio 1:4 is ideal.

3. Coagulation: This section sees the addition of chemicals to the raw water, the chemical create flocs which reduces the turbidity of the water.

Design criteria;

i. The type of coagulant to be used is aluminium sulphate [ $Al_2(SO_4)_3$ ] also called alum ii.

The mixing of the chemical (alum) is to be done in mixing basins iii. Velocity of flow in the channels between baffles = 15 – 45cm/sec iv. Detention period = 20-50 minutes

v. Distance between channels = 45cm minimum vi. Depth of the channel = crosssectional area of each channel/distance between baffles vii. Average velocity of flow = 22.5cm/sec = 0.225m/sec Procedures:

- i. Analyze water source characteristics
- ii. Determine the design flow rate
- iii. Select a coagulant (Alum)
- iv. Calculate the coagulant dosage

v. Calculate the size the mixing basin

4. Flocculation and Clarification: This sees the combination flocculation and clarification in a single unit. One section does the flocculation afterwards the water flows to the clarification section for sedimentation to take place.

Design criteria;

i. Velocity gradient: ranges from 10-75  $sec^{-1}$  ii.

Detention time:  $G \times t = 4 \times$  (ranges from  $10^4 - 10^5$ ) iii.

Depth of flocculator unit: Ranges from 3 – 4.5m iv.

Circular tank is required

- v. Velocity of flow: assumed uniformed throughout, generally not exceeding 30 cm per minute.
- vi. Detention period: 2 to 2.5 hours for chemically aided sedimentation
- vii. Depth of flow: ranges from 3-6 m
- viii. Weir loading: generally up to 300,000l/m/day
- ix.

Good performance:  $n = 1/4$

5. Filtration: This a very important aspect of water treatment, this unit sees the removal of smaller particles and a decent amount of micro-organisms.

Design Criteria;

- i. Filtration rate: typically ranges between 0.1 – 0.4 m<sup>3</sup>/m<sup>2</sup>hr
- ii. Effective size of sand ( $d_{10}$ ): 0.15 – 0.35mm (finer sand gives better removal but increases head loss).
- iii. Depth of sand bed: 0.6 – 0.8 m (Minimum 0.6 m of fine sand is essential for)
- iv. Depth of gravel support: 0.25 – 0.40 m (Graded layers from fine (2–5 mm) to coarse (20–40 mm))
- v. Water depth above sand: 0.5 – 1.0 m
- vi. Freeboard above water level: 0.3 – 0.5 m (Allows for maintenance and flow variations)
- vii. Total filter depth (tank): 1.5 – 2.0 m

Procedures:

- i. Determine the filter area
  - ii. Determine the number of filters
  - iii. Select a filter media (sand size, sand depth, support gravel)
  - iv. Analyze the and design the filter unit
6. Disinfection Unit: This is the final stage of treatment, in this stage chlorine is added to the water to kill or deactivate pathogenic micro-organisms such as bacteria, viruses and protozoa.

Design criteria;

- i. Capacity of chlorination tank = flow rate x contact time x Volume of tank
- ii. Chlorine dosage of 2mg/l (WHO standard).

Procedures:

- a. Select a disinfectant (chlorine)
- b. Determine the disinfectant dose and contact time.
- c. Design the disinfection system.

## **CHAPTER 4**

### **4.0 DESIGN OF WATER TREATMENT PLANT FOR SEMI-URBAN AREA**

Here the various parameters used for the design of the treatment plant are presented. They include population of the semi-urban area, water demand/requirements of the area and the characteristics of the water source.

#### **4.1 Population of the Area**

As defined in previous chapters, a semi-urban area is a transitional zone between rural and urban areas with characteristics of both rural and urban areas. The population of a semiurban area varies based on different factors like; accessibility to urban amenities, migration or urbanization, economic opportunities and environmental factors. The population of a semiurban area ranges from 5,000-20,000, for this study a population of 15,000 is used.

#### **4.2 Estimation of Water Demand**

To estimate the total water demand of a community per year, some considerations will be taken into place like; domestic demand, institutional/commercial area, public water use, water unaccounted for and wastage.

The following assumptions will be used for this study;

Domestic demand: 100lpcd

Public water use: 10%

Wastage: 5%

Average daily demand = 100%

Domestic daily demand =  $100\% - (10 + 5)\% = 85\%$

For domestic demand,

$15,000 \times 100 = 1,500,000\text{l/day}$

Domestic daily demand =  $1,500\text{m}^3/\text{day}$

$$\text{Average daily demand} = \frac{1,500}{85\%} = 1765m^3/\text{day}$$

Assuming maximum daily demand is 180% of the average daily demand

$$1.8 \times 1765 = 3,177m^3/\text{day}$$

Approximately 3,200m<sup>3</sup>/day

### 4.3 Characteristics of the Water Source

In the design of a water treatment plant for any area the water source is a huge factor to consider when deciding the design plan. It is important to determine the water quality characteristics of the water for which a treatment plant is to be designed. For the purpose of this study, the water quality characteristics of a surface water source derived from the work of Ikediashi (2018) will be utilized for the design of a treatment plant

**Table 4.1 Characteristics of a surface water source. (Ikediashi, 2018)**

S/N	PARAMETER	UNITS	SAMPLE A	SAMPLE B	SAMPLE C
1.	Color		ND	ND	ND
2.	Odour		ND	ND	ND
3.	Taste		ND	ND	ND
4.	Temp	°C	26.8	27.9	25.6
5.	PH		6.0	5.4	5.8
6.	TS	mg/l	18.0	9.7	16.2
7.	Turbidity	NTU	0.05	0.02	0.03

8.	Acidity	mg/l	26.4	33.8	30.0
9.	Alkalinity	mg/l	20.7	15.3	18.71
10.	Hardness	mg/l	4.00	2.00	3.50
11.	Chloride	mg/l	9.57	3.48	7.72
12.	Nitrate	mg/l	<0.001	<0.001	<0.03
13.	Sulphate	mg/l	1.50	1.17	1.12
14.	BOD	mg/l	0.00	0.00	0.00
15.	Free NH <sub>3</sub>	mg/l	0.08	0.01	0.04
16.	DO	mg/l	4.4	5.6	4.8
17.	Manganese	mg/l	0.01	0.00	0.00
18.	Iron	mg/l	0.70	0.61	0.63

**Table 4.2: WHO Standard for Drinking Water**

<b>Parameters</b>	<b>Units</b>	<b>Permissible Limit</b>	<b>Recommended Limit</b>	<b>Excessive Limit</b>
Temp	°C	25°C	-	28°C
Ammonia	mg/l	-	0.5	-
Calcium	mg/l	75	100	200
Chloride	mg/l	200	300	600
Copper	mg/l	0.5	0.05	1.5

Fluoride	mg/l	-	1.5	-
Iron	mg/l	0.1	0.3	1.0
Magnesium	mg/l	50	125	150
Manganese	mg/l	0.05	0.1	0.5
Nitrate	mg/l	0.1	0.05	0.3
PH		7-8.5	-	6.5-9.5
Sulphate	mg/l	200	250	400
Suspended solids		0.0	0.0	25.0
Turbidity	NTU	-	-	5.0

#### 4.4 Treatment Plant

Depending on the water source, the design units may be classified with the treatment plan to be chosen. A treatment plan for a surface water source will require the process of screening, pre-sedimentation (plain), rapid mix, flocculation, sedimentation, filtration and disinfection as shown in fig 4.1.

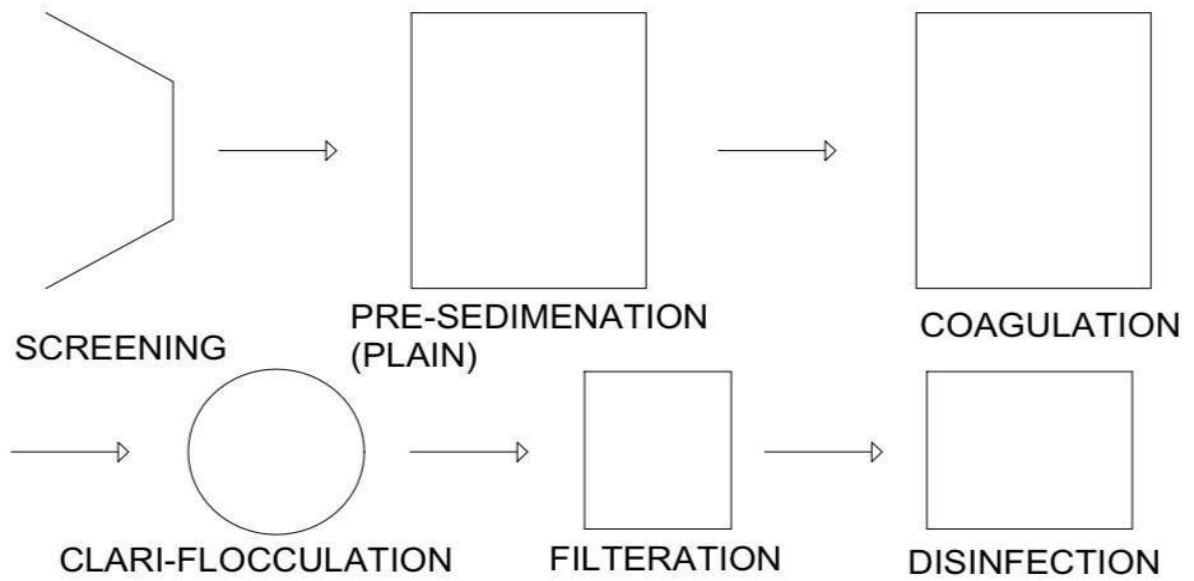


Fig 4.1: The treatment plan for a surface water source.

#### 4.5 Design of the Treatment Units

The units to be designed consist of;

1. Design of a screening chamber
2. Design of a plain sedimentation tank
3. Design of coagulation unit
4. Design of flocculation and clarification unit
5. Design of filtration unit (slow).
6. Design of disinfection (chlorination).

#### 4.6 Screening Chamber

In water treatment, screening chamber is the first unit to be encountered by the raw water (surface water). It is a preliminary treatment unit designed to intercept larger floating materials that can cause damage to the remaining treatment units.

To design a screening chamber the following design criteria will be adopted; unit (Punmia, 2005).

i. Peak flow =  $3.2 \times 10^3 \text{m}^3/\text{day} = 0.037 \text{m}^3/\text{sec}$  ii.

Velocity through screens (at peak flow) =  $0.8 \text{m/s}$  iii.

Spacing of bars =  $5 \text{cm} = 0.05 \text{m}$  iv. Diameter of bars =

$1 \text{cm} = 0.01 \text{m}$  Depth =  $1 \text{m}$

v. Width =  $1 \text{m}$  vi. The

chamber is inclined at  $60^\circ$

vii. Head loss  $h = 0.0729(v_1^2 - v_2^2)$

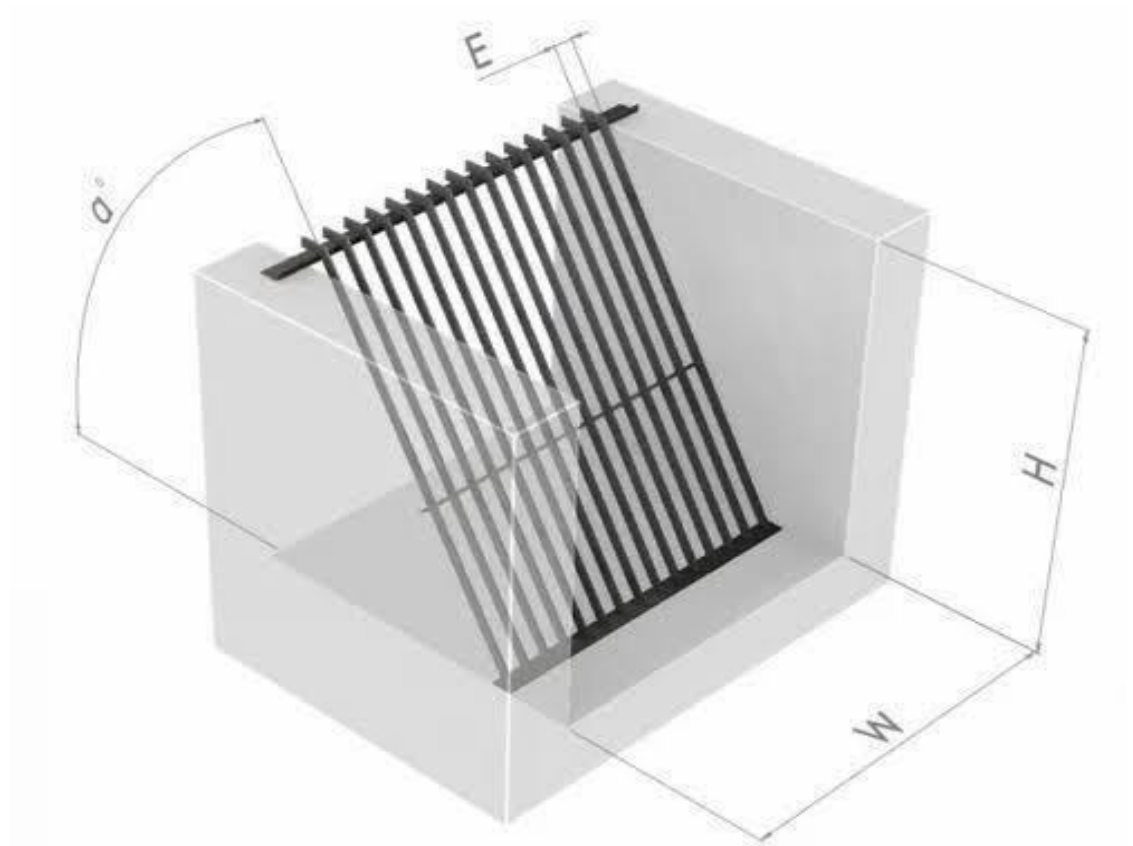


Fig 4.2 Bar screen chamber

Design;

I. Peak flow =  $3.2 \times 10^3 m^3/day = 0.037 m^3/sec$  velocity through screen =

0.8m/sec

$$Q = VA$$

$$\text{Area of screen, } A = \frac{Q}{v} = \frac{0.037}{0.8}$$

$$= 0.046m^2$$

$$\text{No. of opening} = \frac{\text{width}}{\text{clear spacing}} = \frac{1}{0.05}$$

$$= 20 \text{ openings}$$

$$\text{No of bars} = 20 - 1 + (2 \text{ bars at the end})$$

$$= 21 \text{ bars}$$

$$\text{Actual width of screen} = (\text{no of opening} \times \text{clear spacing}) + (\text{no of bars} \times \text{dia of bars})$$

$$= (20 \times 0.05) + (21 \times 0.01)$$

$$= 1.21m$$

When the screen is inclined at  $60^\circ$  with the horizontal

$$\text{Length} = \frac{1}{\sin 60}$$

$$= 1.15m$$

$$\text{Area of inclined screen} = 1.21 \times 1.15 = 1.39m^2$$

II. Head loss

$$Q_1 (\text{before the screen}) = Q_2 (\text{through the screen})$$

$$V_1 b_1 = V_2 b_2 \quad b_1 = 5\text{cm}, \quad b_2 = 5+1$$

(diameter of bar)

$$v_2 = \frac{0.8 \times 5}{6} = 0.67\text{m/s}$$

$$h = 0.0729(v_1^2 - v_2^2) \quad \text{where, } v_1$$

= velocity before screen  $v_2 =$

velocity during screening

$$h = 0.0729(0.8^2 - 0.67^2)$$

$$= 0.0134\text{m}$$

When the screen is half clogged (max head loss)

$$h = 0.0729[(0.8 \times 2)^2 - 0.67^2]$$

$$= 0.1538\text{m}$$

#### **4.7 Design of a Plain Sedimentation Tank (Rectangular)**

Surface water source typically contains higher turbidity and has larger particles compared to ground water source, this larger floating particles can be removed during screening but then after this screening the water turbidity can still be reduced by Pre sedimentation (plain).

There are several advantages of Pre sedimentation in surface water treatment which are; unit It reduces the raw water turbidity

1. Improves the coagulation efficiency
2. Protects downstream units

3. Reduces operating cost
4. Decreases sludge production in later stages

To design the plain sedimentation tank the following design criteria will be employed; (K.N. Duggal, 2007)

- i. Velocity of flow: assumed uniform throughout, generally not exceeding 30 cm per minute.
- ii. Detention period: 3 to 4 hours for plain sedimentation

Settling tank efficiency; The efficiency of the basin is reduced by currents induced by the inertia of the incoming water, it is expressed mathematically by the equation;

$$\frac{h}{H} = 1 - \left[1 + n \frac{V_o}{Q/A}\right]^{\frac{1}{n}}$$

- iii. Overflow rate: for plain sedimentation tank surface loading is 15,000-30,000l/m<sup>2</sup>/day iv.

Depth of flow: ranges from 3-6 m

- v. Weir loading: generally up to 300,000l/m/day vi.

Rectangular tank: a length and width of ratio 1:4 is ideal.

Maximum daily quantity of water to be treated = 3,200,000liters

Assume particle size = 0.025mm

Assume specific gravity = 1.9

Temperature at 20°C

Kinematic viscosity at this temperature = 1.01 centistokes (PH 5.0-8.0)

Assume efficiency = 80%

- i. Settling velocity:

Settling velocity using stokes law:

$$v = \frac{d^2 \times g \times G_s}{18 \times U}$$
$$= \frac{0.025^2 \times 9.81 \times 1.8 \times 1000}{18 \times 1.01}$$
$$= 0.607 \text{ mm/sec}$$

$$\text{Renolds number (Re)} = \frac{vd}{U}$$
$$= \frac{0.607 \times 0.025}{1.01}$$
$$= 0.015 < 1 \text{ (stokes flow or creeping flow)}$$

Surface overflow rate for ideal settling basin, assuming 100% removal of minimum size particles

Settling velocity = theoretical surface overflow rate

$$V = V_o = 0.607 \text{ mm/sec}$$
$$= 52.44 \text{ m/day}$$

ii. Design of surface flow rate

From the equation of efficiency,

$$\frac{h}{H} = 1 - \left[1 + n \frac{V_o}{Q/A}\right]^{\frac{1}{n}}$$
$$\frac{h}{H} = 0.8 \text{ and } n = \frac{1}{4} \text{ (good performance)}$$

We have,

$$\frac{v_o}{Q/A} = \frac{1}{n} \left\{ \left( \frac{1-h}{H} \right)^{-\frac{1}{n}} - 1 \right\}$$

$$= 4 \times \{(1 - 0.8)^{\frac{-1}{4}} - 1\}$$

$$= 1.98$$

$$\begin{aligned} \text{Design SOR} &= \frac{Q}{A} = \frac{V_o}{1.98} \\ &= \frac{52.44}{1.98} \end{aligned}$$

Surface overflow rate = 26.47 = 27 l/m<sup>2</sup>/day (ok, as it lies within 15,000 – 30,000 l/m<sup>2</sup>/day) iii.

Dimension of the tank:

$$\text{surface area of tank} = \frac{\text{design flow}}{\text{design SOR}}$$

$$= \frac{3.2 \times 10^3}{27} = 119m^2$$

$$\frac{B}{L} = \frac{1}{4}, \quad L = 23m, B = 5.2m$$

Taking detention time = 3.5hr

$$\text{Depth of flow} = \frac{3.2 \times 10^3 \times 3.5}{24 \times 23 \times 5.2}$$

$$= 3.9m$$

Taking 0.5 sediment depth

Total depth = 4.5m

With surface loading = 27 m/day

$$\text{Plan area of tank} = \frac{3,200}{27} = 119 m^2$$

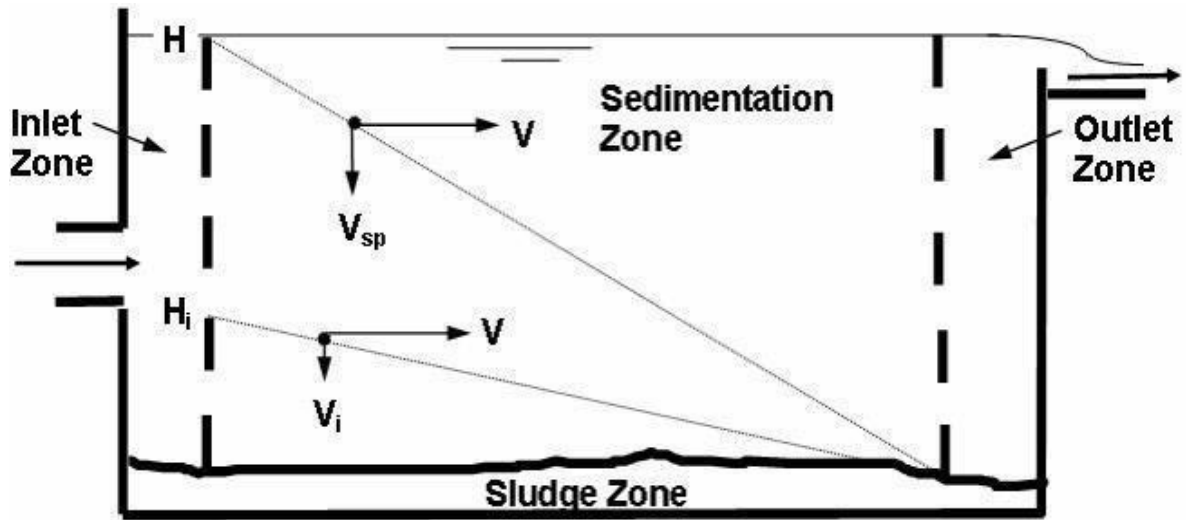


Fig 4.3 cross sectional view of a sedimentation tank Check,

$$\text{Horizontal velocity, } v = \frac{Q}{B \times H}$$

$$= \frac{3.2 \times 10^3 \times 100}{24 \times 60 \times 3.9 \times 5.2}$$

$$= 10.96 \text{ cm/min (against 30 cm/min max)}$$

$$\text{Weir loading} = \frac{3.2 \times 10^3}{23}$$

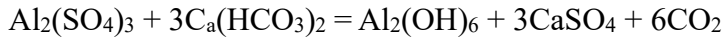
$$= 139,130.43 \text{ l/m/day (against 300,000 l/m/day max)}$$

#### 4.8 Design of the Coagulation Unit (Rapid Mix)

In this design, coagulation involves the rapid mixing of a coagulant, there are different types which are alum, ferric chloride and other metal salts

Type of coagulant: aluminium sulphate  $[Al_2(SO_4)_3]$  also called alum The

chemical reaction involve:



Thus the viscous precipitate of flocs formed is aluminium hydroxide. The coagulation process takes place in two distinct stages.

In the first stage, the coagulant (AL) dissolves and releases positively charged ions, which neutralize the negatively charged particles of turbidity, clay, and color. This causes the particles to combine into a single mass. Rapid and thorough mixing is essential for this stage.

In the second stage the initially formed particles are small and molecular in size. Gentle stirring causes these particles to flocculate and grow larger through agglomeration. As the floc grows, it envelops larger colloidal particles, becoming heavier and more easily removed through sedimentation.

The dosage of the coagulants depends upon a number of factors such as turbidity, color, PH, time of settlement and temperature. The optimum dosage of a coagulant is determined using the jar test.

#### **4.8.1 Mixing Basin**

A mixing basin is where the coagulants is rapidly dispersed into the raw water. The basin type used is a baffle basins, the following criteria are to be used for the design of the baffle basin;

(Duggal, 2007)

- i. Velocity of flow in the channels between baffles = 15 – 45cm/sec
- ii. Detention period = 20-50 minutes
- iii. Distance between

channels = 45cm minimum iv. Depth of the channel = cross-sectional area of each channel/distance between baffles

v. Maximum daily quantity of water to be treated =  $3.2 \times 10^3$  liters vi.

Average velocity of flow = 22.5cm/sec = 0.225m/sec Design: vii.

Quantity of water to be handle in the basin

$$= \frac{3.2 \times 10^6 \times 20 \times 60}{24 \times 60 \times 60}$$
$$= 45\text{m}^3$$

For detention period of 20mins and a velocity of flow of 0.225m/sec the total distance of flow be water is

$$= 20 \times 60 \times 0.225$$

$$= 270\text{m}$$

Cross-sectional area of the channel between baffles

$$= \frac{45}{270}$$
$$= 0.167\text{m}^2$$

Let distance between channels be 0.45m

$$\text{Depth of channel} = \frac{0.167}{0.45} = 0.37\text{m}$$

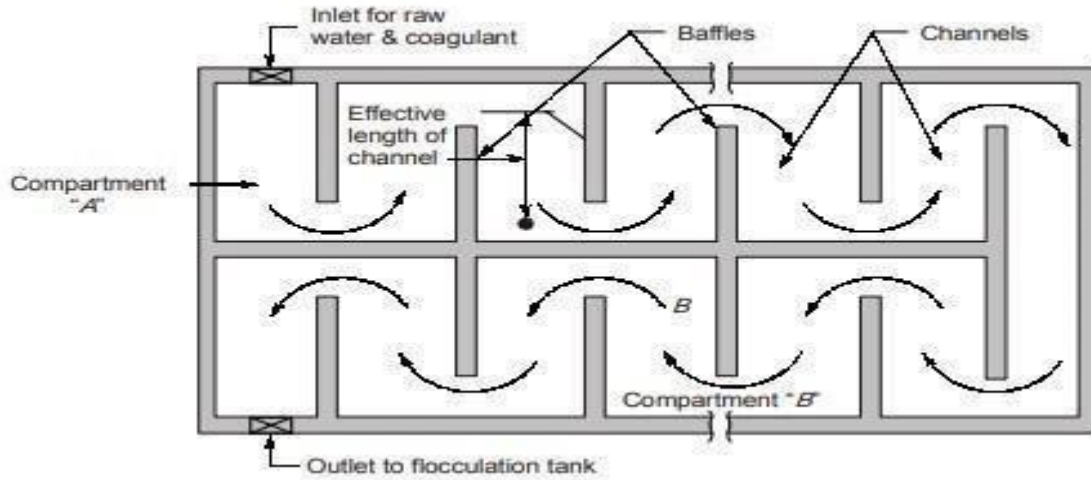


Fig 4.4 A baffle mixing basin

Assume the basin is divided into two halves by a central longitudinal wall, the width of each half being 3.5m. If the clear distance between baffle and at the end of wall is taken as 1.5 times the distance between baffles.

$$1.5 \times 0.45 = 0.675\text{m}$$

The effective length of each channel

$$= 3.5 - 0.675$$

$$= 2.825\text{m}$$

$$= \frac{270}{2.825} = 96$$

48 channels in each half of the basin

Clear length of basin excluding baffles

$$= 48 \times 0.45 = 21.6\text{m}$$

Assuming 7cm as width of each baffle total inside length of basin

$$= 21.6 + 47 \times 0.07$$

$$= 24.89\text{m}$$

#### **4.9 Clarification and Flocculation**

This is the combined process of clarification and flocculation in a single treatment unit, after the raw water has been mixed with the coagulants, the raw water flows to the flocculator section where flocs are formed then to the clarification section where the flocs settle to form sediments on the ground of the tank.

##### **4.9.1 Design of Flocculator unit of Clari-flocculator**

This section sees the combination of flocculation and clarification (sedimentation) in a single tank. There are two tanks where inner tanks serves as flocculation basin and the outer tank serves as clarifier.

In this unit, water gets admitted to flocculation where the water is dispersed by rotating paddles so as to obtain stable floc and water ever impurities gets entrapped in the floc. Then the water containing these flocs moves further into the sedimentation tank where the flocs settle at the bottom of the tank.

Design criteria;

i. Velocity gradient: ranges from  $10-75 \text{ sec}^{-1}$  ii. Detention time:  $G \times t = 4 \times$  (ranges from  $10^4 - 10^5$ ) iii. Depth of flocculator unit: Ranges from 3 – 4.5m iv. Total area of paddles is usually taken between 10% - 25% of the vertical cross sectional area of the tank. (Punmia, 2005).

Design:

i. Dimensions of the flocculation unit

$$Q = 3200\text{m}^3/\text{day} = 2.22\text{m}^3/\text{min}$$

$$G \times t = 4 \times 10^4$$

Assuming G to be  $30\text{sec}^{-1}$

$$30 \times t = 4 \times 10^4$$

$$t = \frac{4 \times 10^4}{30} \text{sec}^{-1} \times \frac{1}{60} \text{sec}/\text{min}$$

$$= 22.22 \text{ min}$$

Detention time = 22.22 minutes volume

of tank (V) = Q x detention time

$$= 2.22 \frac{\text{m}^3}{\text{min}} \times 22.22 \text{ min} = 49.33\text{m}^3$$

Assume a depth of 3.5m

$$\text{Area of tank} = \frac{\text{volume}}{\text{depth}}$$

$$\frac{\pi D^2}{4} = \frac{49.33}{3.5}$$

$$D = 4.24\text{m}$$

Tank diameter = 4.24m Providing a

free board of 0.2m Total

depth = 3.7m ii. Power input by

paddles to

water,

$$\text{Power, } P = G^2 v \mu$$

Absolute viscosity of water ( $\mu$ ) =

$$0.89 \times 10^{-3} \text{ N}\cdot\text{s}/\text{m}^2$$

$$= 30^2 \times 49.33 \times 0.89 \times 10^{-3}$$

$$= 39.51\text{watt}$$

Power (P) = 40 watt = 0.040KW iii. Determination

of size and number of paddles

Assume total area of paddles = 20% of vertical cross sectional area of tank Using vertical cross

sectional area

$$D = \text{diameter, } d = \text{depth}$$

$$= 0.2 \times 4.24 \times 3.7 = 3.14\text{m}^2$$

Assuming 4 paddles with spacing from top and bottom = 0.4m

Depth of paddle = total depth – (2 x clearance space)

$$= 3.7 - (2 \times 0.4)$$

$$= 2.9\text{m} = 290\text{cm}$$

Total area of paddles = No. of paddles × width × depth

$$3.14 = 4 \times b \times 2.9$$

$$= 0.27\text{m} = 27\text{cm}$$

To increase efficiency, the paddles should be divided into axis, 2 paddles per axis and assumed thickness of 5cm

Dimension of paddle = 290cm × 27cm × 5cm

#### **4.9.2 Design of Clarification section of a Clari-flocculator**

As stated earlier, flocs are generated during flocculation and these flocs will be removed by clarification (chemically aided sedimentation).

Design criteria:

- i. Circular tank is required
  
  
  
  
  
  
  
  
  
  
- ii. Velocity of flow: assumed uniform throughout, generally not exceeding 30 cm per minute.
  
  
  
  
  
  
  
  
  
  
- iii. Detention period: 2 to 2.5 hours for chemically aided sedimentation
- iv. Flow rate: 3200m<sup>3</sup>/hr

v. Depth of flow: ranges from 3-6 m vi.

Weir loading: generally up to 300,000l/m/day vii.

Good performance:  $n = 1/4$

Maximum daily quantity of water to be treated = 3,200,000liters

Assume minimum size of alum floc = 0.8mm

Specific gravity of alum floc ( $S_s$ ) = 1.002

Temperature at 20°C

Kinematic viscosity at this temperature = 1.01 centistokes Expected efficiency

= 75% (Punmia, 2005).

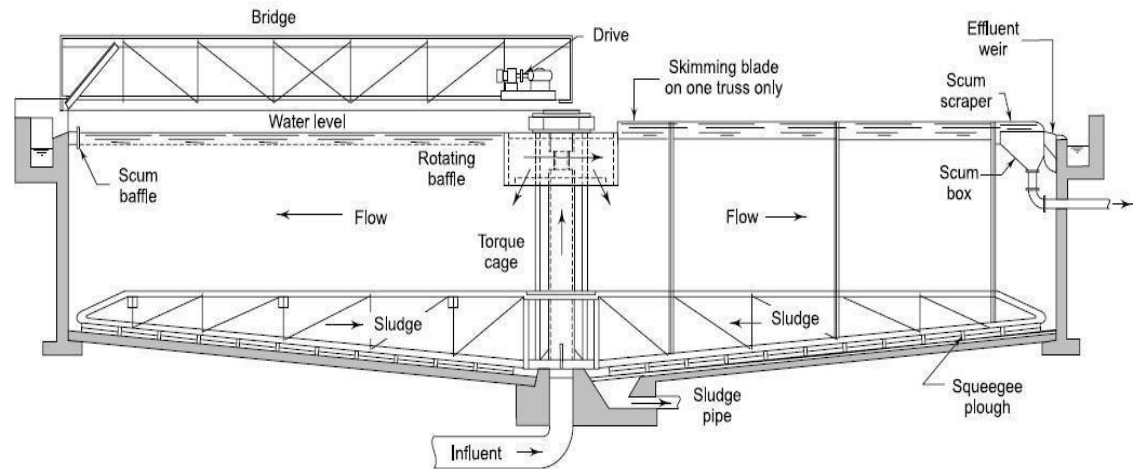


Fig 4.5 clariflocculator

Design;

i. Design of influent pipe:

Assume velocity of flow in the pipe = 1m/s

$$\text{Area of pipe} = \frac{Q}{v}$$

$$= 2.22\text{m}^3/\text{min} = 0.037\text{m}^3/\text{s}$$

$$= 0.037\text{m}^2$$

$$0.037\text{m}^2 = \frac{\pi D_v^2}{4}$$

ii. Diameter of pipe = 0.22m = 220mm

Provide a pipe with diameter of 250

Settling velocity of minimum size particles

Using stokes law,

$$v = \frac{d^2 \times g \times G_s}{18 \times U}$$

$$= \frac{0.8^2 \times 9.81 \times 1.002 \times 1000}{18 \times 1.01}$$

$$= 0.691\text{mm}/\text{sec}$$

$$= \frac{0.8^2 \times 9.81 \times 1.002 \times 1000}{18 \times 1.01}$$

$$\text{Reynolds number (Re)} = \frac{vd}{U}$$
$$= \frac{0.691 \times 0.8}{1.01}$$

$$= 0.547 < 1 \text{ (stokes flow or creeping flow) iii.}$$

Determination of surface overflow rate;

For an ideal tank of 100% removal of minimum size particles, the surface overflow rate will be equal to the settling velocity of minimum size particles

$$= 0.691 \times 3600 \times 24 = 59.7 \text{ m/day}$$

From the equation of efficiency,

$$\frac{h}{H} = 1 - \left[1 + n \frac{V_o}{Q/A}\right]^{-1/n}$$

$$\frac{h}{H} = 0.75 \text{ and } n = \frac{1}{4} \text{ (good performance)}$$

We have,

$$\begin{aligned} \frac{v_o}{SOR} &= \frac{1}{n} \left\{ \left( \frac{1-h}{H} \right)^{-1/n} - 1 \right\} \\ &= 4 \times \left\{ (1 - 0.75)^{-1/4} - 1 \right\} \\ &= 1.514 \end{aligned}$$

$$\begin{aligned} \text{Design SOR} &= \frac{Q}{A} = \frac{v_o}{1.514} \\ &= \frac{59.7}{1.515} \end{aligned}$$

= 39.43 m/day (ok, as it lies within 30 – 40 m/day for circular tank)

iv. Dimension of the tank

$$\text{volume of tank} = Q \times t$$

$$= 133.33 \text{ m}^3/\text{hr} \times 2.5 = 333.35 \text{ m}^3$$

$$\begin{aligned} \text{Area of tank} &= \frac{\text{discharge}}{\text{SOR}} \\ &= \frac{133.33 \times 24}{39.43} = 81.15 \text{ m}^2 \end{aligned}$$

Clarifier tank surface area (ring form),

$$\frac{\pi}{4}(D_2^2 - D_1^2) = 81.15m^2$$

$D_1$  = diameter of flocculation unit = 4.24m

$D_2$  = diameter of clarifier

$D_2 = 9.24m$

$$\begin{aligned} \text{Depth of clarifier} &= \frac{\text{vol of tank}}{\text{Area of tank}} \\ &= \frac{333.35}{81.15} = 4.12m \end{aligned}$$

Assume depth of sludge bed = 0.5m

Provide free board at the top of clarifier = 0.2m

Total depth = 4.82m or 5m

#### 4.10 Design of Filtration Unit (Slow sand filter)

Slow sand filter also called gravity filter is a biological filtration unit used for the purification of water, especially in small to medium-sized water treatment plants. It operates at a low filtration rate and relies on both physical straining and biological purification.

To design a slow sand filter here are the design criteria: (Davis, Cornwall, 2013).

- i. Filtration rate: typically ranges between 0.1 – 0.4 m<sup>3</sup>/m<sup>2</sup>hr
- ii. Effective size of sand ( $d_{10}$ ): 0.15 – 0.35mm (finer sand gives better removal but increases head loss).
- iii. Depth of sand bed: 0.6 – 0.8 m (Minimum 0.6 m of fine sand is essential for)
- iv. Depth of gravel support: 0.25 – 0.40 m (Graded layers from fine (2–5 mm) to coarse (20–40 mm))

v. Water depth above sand: 0.5 – 1.0 m vi. Freeboard above water level: 0.3 – 0.5 m (Allows for maintenance and flow variations) vii. Total filter depth (tank):

1.5 – 2.0 m Design:

1. Filter surface area:

$$\frac{3200}{24} = 133.33m^3/h$$

Assuming a filtration rate of 0.2m/h

$$\text{surface area} = \frac{133.33}{0.2} = 666.67m^2$$

So for this area lets provide 8 filter beds, this will give operational flexibility.

$$\text{Area per bed} = \frac{666.67}{8} = 83.33m^2$$

Using a filter geometry ratio of 3:1

$$L = 15.8m, B = 5.3m$$

2. Media and volume quantities:

Sand: using a depth of 0.7m

$$\text{Volume} = 0.7 \times 83.33 = 58.33m^3$$

$$\text{Total} = 8 \times 58.33 = 466.64m^3$$

Gravel: using a depth of 0.3m

$$\text{Volume} = 0.3 \times 83.33 = 25m^3$$

$$\text{Total} = 8 \times 25 = 200m^3$$

Clear water volume: using a depth of 0.50m

$$\text{Volume} = 0.5 \times 83.33 = 41.67m^3$$

$$\text{Total} = 8 \times 41.67 = 333.36m^3$$

Let's use a freeboard/working depth of 0.3m

Total depth of each filter bed = 0.7 + 0.3 + 0.5 + 0.3 = 1.8m

3. Inlet pipe sizing;

Flow = 400m<sup>3</sup>/day per filter bed

$$= \frac{400}{86400} = 4.6 \times 10^{-3} \text{ m}^3/\text{s} \text{ (86400 seconds per day)}$$

Try an inlet pipe size of DN100 (Nominal diameter = 100mm)

$$\begin{aligned} \text{Area} &= \frac{\pi d^2}{4} \\ &= \frac{\pi \times 0.1^2}{4} = 7.854 \times 10^{-3} \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \text{velocity in inlet pipe} &= \frac{Q}{A} = \frac{4.6 \times 10^{-3}}{7.854 \times 10^{-3}} \\ &= 0.59 \text{ m/s} \end{aligned}$$

4. Underdrain Lateral layout;

Try lateral pipe size of DN75 (Nominal diameter = 75mm)

$$\text{Area} = \frac{\pi \times 0.075^2}{4} = 4.42 \times 10^{-3} \text{ m}^2$$

Unit flow = 4.6 × 10<sup>-3</sup> m<sup>3</sup>/s

Let's use 9 laterals

$$\text{Flow in lateral} = \frac{4.6 \times 10^{-3}}{9} = 5.14 \times 10^{-4} \text{ m}^3/\text{s}$$

$$\text{velocity in lateral pipe} = \frac{Q}{A} = \frac{5.14 \times 10^{-4}}{4.42 \times 10^{-3}}$$

= 0.12m/s (very low, low velocity reduces risk of sand entrainment)

Length of the filter bed = 15.8m = 16m

Length of each lateral = 16m

Each lateral should have holes (perforations) to release filtered water evenly to avoid uneven flow and headloss.

Assuming spacing between each hole = 200mm

$$\text{number of holes per lateral} = \frac{16}{0.2} = 80 \text{ holes}$$

$$\begin{aligned} \text{Flow per hole, } Q_{\text{hole}} &= \frac{Q_{\text{lat}}}{\text{number of holes}} \\ &= \frac{5.14 \times 10^{-4}}{80} = 6.4 \times 10^{-6} \text{ m}^3/\text{s} \end{aligned}$$

Using diameter of each hole = 10mm

$$\text{Area} = \frac{\pi \times 0.01^2}{4} = 7.85 \times 10^{-5} \text{ m}^2$$

$$\begin{aligned} \text{Velocity through each hole (perforations)} &= \frac{Q_{\text{hole}}}{A_{\text{hole}}} \\ &= \frac{6.4 \times 10^{-6}}{7.85 \times 10^{-5}} = 0.08 \text{ m/s} \end{aligned}$$

Velocity in the holes are very low which is expected, so as not to scour the sand.

##### 5. Manifold sizing and slope;

Collect all the 9 laterals into a central manifold and then to the outlet,

$$Q_{\text{lat}} = 5.14 \times 10^{-4} \text{ m}^3/\text{s}$$

Flow in manifold =  $5.14 \times 10^{-4} \times 9 = 4.63 \times 10^{-3} m^3/s$

Take size of the manifold to be DN150 (Nominal diameter = 150mm)

$$\text{Area} = \frac{\pi \times 0.15^2}{4} = 1.77 \times 10^{-2} m^2$$

$$\text{Velocity of manifold} = \frac{Q}{A} = \frac{4.63 \times 10^{-3}}{1.77 \times 10^{-2}}$$

= 0.26m/s

Also, provide a slope (1:200 – 1:500) towards the outlet.

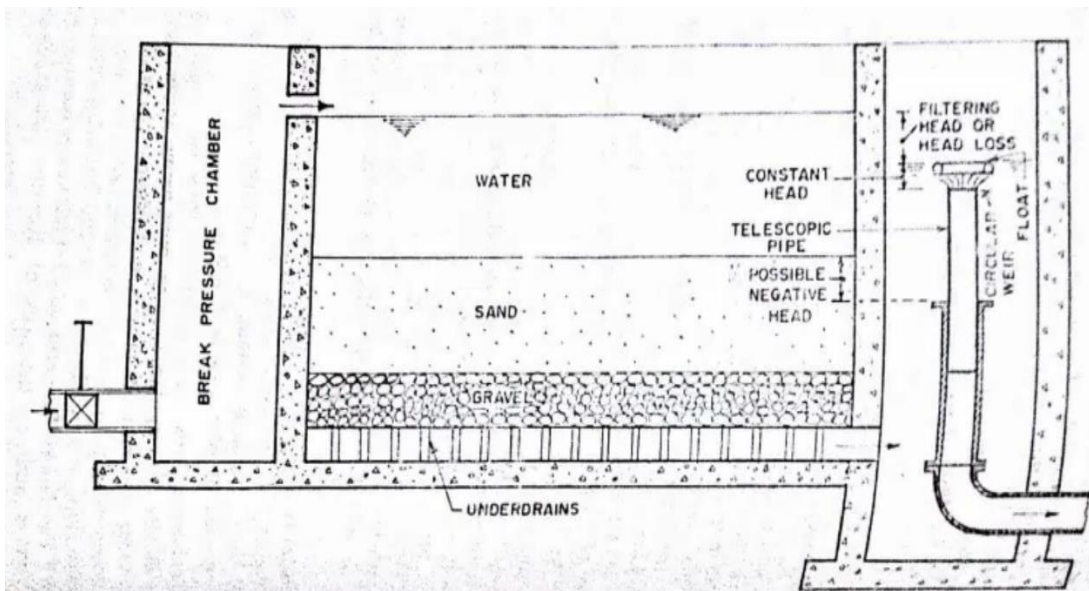


Fig 4.6: cross-sectional view of a slow sand filter (Punmia, 2005)

#### 4.11 Design of Disinfection Unit (Chlorination)

This is the final stage of treatment and also a very crucial part, in this stage the aim is to kill or inactivate micro-organisms left in the raw water after filtration. Chlorination will be used for this water source.

Some advantages of chlorination over other disinfection methods.

- 1) Unlike UV or ozone, chlorine leaves a residual concentration in the water, protecting it against recontamination in pipelines and storage.

- 2) Chlorination is relatively cheap in terms of installation, operation, and maintenance compared to ozone or UV systems.
- 3) Easy to apply as gas, liquid (sodium hypochlorite), or solid (bleaching powder), with straightforward dosing equipment.
- 4) It is very reliable, used worldwide for over a century with a strong track record of reducing waterborne diseases.
- 5) Kills most bacteria and viruses efficiently, though less effective against some protozoa.
- 6) Suitable for small rural systems, large municipal plants, and even emergency disinfection (e.g., using household bleach).
- 7) Besides disinfection, chlorine helps control tastes, odors, slime, algae, and some iron and manganese problems

Design:

From the characteristics of the water source (Ikediashi, 2018);

PH = 6.0

Temperature = 20°C

Percentage distribution of HOCL,

Ionization constant for temperature of 20°C =  $2.5 \times 10^{-8}$  moles/l

$H^+ = 10^{-6}$  at PH = 6.0

$$HOCL = \frac{100}{1 + \frac{k_i}{H^+}}$$

$$= \frac{100}{1 + (2.5 \times 10^{-8} / 10^{-6})} = 97.56\%$$

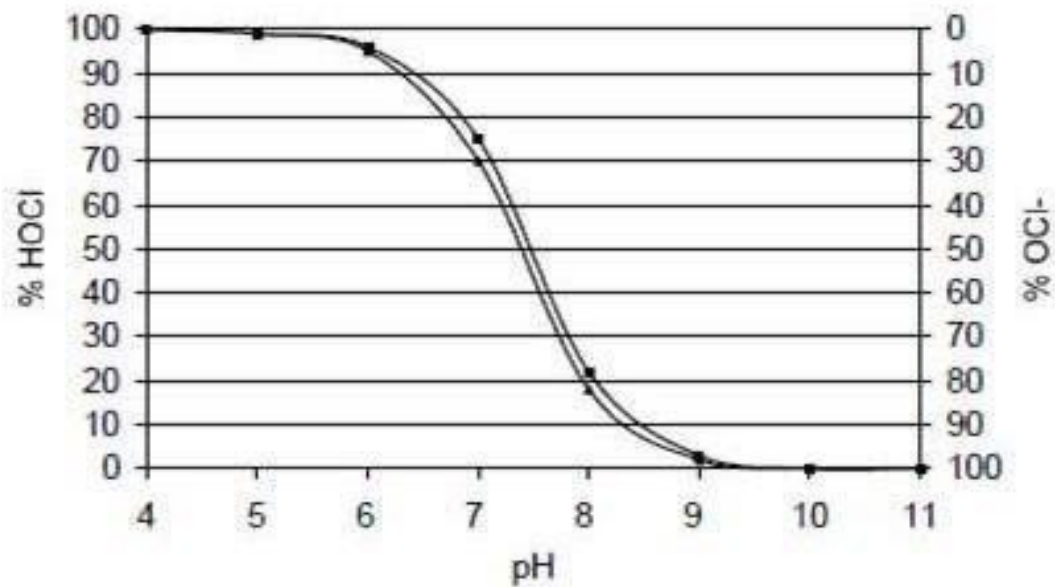


Fig 4.2 variation of HOCL and OCL<sup>-</sup> at different PH (Mohammed Machkor, 2018)

i. Chlorine Dosage

Daily supply = 3,200,000 litres

0.5 ppm of chlorine

Assume the disinfectant in form of bleaching powder containing 30% of chlorine

Dosage of chlorine = 3,200,000l X 0.3mg/l = 0.96kg

Amount of bleaching powder required;

$$0.96 \times \frac{100}{30} = 3.2\text{kg of bleaching powder}$$

ii. Design of chlorination tank

Flow rate = 3.2 X 10<sup>3</sup>m<sup>3</sup>/day

Volume of tank (V) = flow rate X detention time

Detention time = 30 minutes

$$\text{volume of tank (V)} = 3.2 \times 10^3 \times \frac{30}{3600} = 26.67\text{m}^3$$

Assume depth of tank = 1.5m

$$\begin{aligned}\text{surface area} &= \frac{V}{H} \\ &= \frac{26.67}{1.5} = 17.78\text{m}^2\end{aligned}$$

Assume length of tank = 1.5B

Area = L X B

$$1.5B^2 = 17.78\text{m}^2$$

$$\begin{aligned}B^2 &= \frac{17.78}{1.5} = 11.85 \\ B &= 3.44\text{m}\end{aligned}$$

$$L = 1.5 \times 3.44 = 5.16\text{m}$$

#### **4.12 Discussion**

The design of the water treatment plant for the selected semi-urban area demonstrates a comprehensive approach to ensuring adequate, safe, and sustainable potable water supply. The results obtained from the design calculations show that each treatment unit was sized to accommodate the projected population demand and the expected raw water characteristics, while maintaining compliance with national and World Health Organization (WHO) standards for drinking water.

The estimated water demand of the study area indicates that the system must handle both current and future needs over the design horizon. The selected design flow rate provides a sufficient safety margin to address population growth and variations in daily consumption. This proactive approach ensures that the plant will remain effective and reliable throughout its lifespan without frequent redesign or expansion.

Overall, the discussion highlights that the designed system satisfies the dual objectives of technical feasibility and public health protection. The selected treatment units are appropriate for the raw water quality, and the adopted design parameters ensure effective removal of physical, chemical, and biological impurities. Moreover, the project supports Sustainable Development Goal 6 (Clean Water and Sanitation) by providing a scalable model for safe water supply in developing semi-urban areas.

## **CHAPTER 5**

### **5.0 Conclusion**

Water treatment is a very crucial and important aspect of civil engineering and a proper design of this system can hold a huge impact in the environment. During the course of this research here are some observations discussed:

- i. Characteristics of a semi-urban area: Like discussed in different chapters, a semiurban area is characterized by urban and rural qualities and the design of the treatment plant is based on these qualities.
- ii. The two main sources of water: Surface water and Ground water are the two sources of water and the treatment of these sources varies. The knowledge of the differences of

these two sources plays a huge role when designing a treatment plant. For this design, a surface water source was proposed for this design.

- iii. Water qualities: The qualities of these water affects the design processes, the two different water sources has two different treatment processes and there will be difference in the values from these two water sources.
- iv. Design of the different treatment units: This research saw the design of four treatment units which are; screening chamber, pre-sedimentation, coagulation, flocculation and clarification, filtration and disinfection. All these units were designed base on a surface water source.

The result from the design of the treatment plant shows the following requirements; water demand of  $3,177\text{m}^3/\text{day}$ . Screening chamber with 21bars and inclined length and breadth of 1.21m and 1.15m. Plain sedimentation tank with dimensions: length = 32.7m, width = 8.23m, total depth = 4.5m. Coagulation mixing basin with dimensions: depth of channel = 0.84m, length of basin = 21.6m, 48 channels in each half of the basin.

Flocculation and clarification with a ring like plan. The flocculation section consists of 4 paddles and tank diameter of 4.24m while the clarification section has a diameter of 9.24m.

Slow sand filter with properties: 8 filter beds with dimensions;  $L = 15.8\text{m}$ ,  $B = 5.3\text{m}$ . Chlorine disinfection with chlorine dosage of 0.96kg and bleaching powder of 3.2kg.

- v. A good design and execution of the project may not yield its expected results unless proper maintenance culture are cultivated.

## 5.1 Recommendation

- i. Make provision for proper storage of treated water and proper piping network should be constructed.

- ii. Qualified personnel should be employed to operate the treatment plant.
- iii. Recycling and treatment of waste water should also be considered in the semi-urban area.
- iv. More awareness on good environmental hygiene should be provided for consumers.
- v. Constant inspection should be done in the treatment plant to avoid damage to any of the treatment units or machines.
- vi. Proper maintenance should be done before and after use of each material in the treatment plant.

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