CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Proposal of Proper Technologies for Water Purification in Asuogya, Bono Region-Ghana

MASTER'S THESIS

Prague 2023

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Declaration

I, Yaa Adu-Pokua, hereby declare that I have done this thesis entitled Proposal of Proper Technologies for Water Purification in Asuogya, Bono Region of Ghana independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged using complete references and according to the Citation rules of the FTA.

In Prague, 22/04/2023

Yaa Adu-Pokua

Acknowledgements

I want to express my gratitude to my supervisor Doc. Ing. Vladimir Krepl, CSc., for his assistance during this project as well as for his time, advice and coaching. Additionally, I would like to thank the Ghana Water Company Limited (GWCL) in the Sunyani Municipality for their assistance in my data collection process as well as necessary navigation in the acquisition of secondary data.

I want to express my gratitude to Dr Ing. Abraham Kabutey,Ph.D for his support and as sistance during this research process**.** My family, especially my brother Owusu Adu-Boahene, deserves a very special thank you for their help throughout my entire academic period.

Abstract

The study's goals were to assess the level of water pollution in three water sources in the village of Asuogya, Bono Region, Ghana, and to recommend methods that would help the area maintain good water quality while considering local conditions and WHO criteria. It was identified which water purifying techniques were accessible by a review of the literature. Additionally, a decision was made to test the three water samples to ascertain the water quality in Asuogya, as well as the population density and the effects of the technologies on the locals and the environment. Three water bodies in Asuogya and the surrounding area were used to collect information on pollution levels. The Ahanyaso River, the Kwasikorankurom borehole, and the Asuogya stream provided the water samples. The data complied with Ghanaian water quality rules and WHO recommendations. The results showed that the heavy metal concentrations in the water samples, particularly those of chlorine (Cl), iron (Fe), and manganese (Mn), were high and that there was significant turbidity.

Reverse osmosis, ion exchange, activated carbon, distillation, and other technologies are therefore suggested for usage in Asuogya, Sunyani West Municipality, in the Bono Region of Ghana. Since water is the most crucial resource for both human development and national development, the adoption of these technologies would aid Asuogya and its surroundings in reducing physical, chemical, and biological risks in their water bodies.

Keywords: wastewater, water purification, technologies, pollution, Asuogya, Ghana, heavy metals

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List of Abbreviations

Al	Aluminium
As	Arsenic
Br-	Bromides
℃	Degree Celsius
Ca	Calcium
Cd	Cadmium
CL	Chlorine
Cl-	Chlorides
Cr	Chromium
Cu	Copper
F-	Fluorides
FAO	Food and Agriculture Organization
Fe	Iron
GDP	Gross Domestic Product
GWCL	Ghana Water Company Limited
Hg	Mercury
IC	Inorganic Carbon
Mg	Magnesium
mg/l	Milligrams Per Litre
Mn	Manganese
N-NH4+	Nitrogen in Ammonium ions
N-NO2	Nitrite nitrogen
N-NO3	Nitrate Nitrogen
N03-	Nitrates

NGO	Non-Governmental Organizations
NO2-	Nitrites
NTU	Nephelometric Turbidity Unit
Pb	Lead
PO43-	Phosphates
RO	Reverse Osmosis
SDGs	Sustainable Development Goal
SO42-	Sulphates
TC	Total Carbon
TDS	Total Dissolved Solid
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	total Phosphorus
TSS	Total Suspended Solid
UN	United Nations
UNICEF	United Nations Children’s Fund
WHO	World Health Organization
Zn	Zinc
µg	Micrograms

1 Introduction and Literature Review

One of the most significant problems in the world face currently is the availability of safe and clean water. According to UNICEF-WHO, the absence of reliable and secure drinking water services affects almost 2.2 billion people globally. Access to water from a source that has been improved, such as piped water, protected dug wells, boreholes or tube wells, packaged water, or delivered water, is included in drinking water services (el Banco Mundial 2015). For human civilization to exist, services for providing drinking water are essential. However, 297,000 children under the age of five die from diarrheal diseases every year as a result of poor sanitation, poor hygiene, or polluted water (WHO, 2019). For instance, more than 80 % of human-generated wastewater is directly discharged into rivers or the ocean without any pollution remediation.

It takes more than just having access to water to keep kids healthy. Water also needs to be accessible, safe, and affordable. This means that it must be accessible for at least 12 hours a day, come from a dependable source such as a well, tap, or hand pump, be free of faecal matter and chemical contamination, and be situated on the property of a child's household or within practical reach (UNICEF n.d.). Most people around the world rely on water sources that are either contaminated or have a significant risk of contamination because of inadequate sanitation, hygiene, and sewage systems. Chemical contamination is another critical threat to water bodies that is present in many parts of the world.

According to WHO standards, millions of people drink water that includes dangerous levels of fluoride and arsenic. Water is necessary for life. For all living things to survive, water is essential. The functioning of the planet depends on it. Access to clean water is crucial for ecosystem health, social and economic growth, and human health, according to United Nations Water (United Nations Water 2020). Access to water is essential for global development (United Nations n.d.). Consequently, there should be a simple access to a sufficient supply of drinking water., trustworthy, clean, acceptable, and safe. Access to clean water for drinking has been deemed a fundamental human right and a crucial first step in improving living conditions by the United Nations (UN) and other nations. The Millennium Development Goals (UN-MDGs) and the Sustainable

Development Goals (SDGs) both emphasized the importance of access to water (Dinka 2018).

There is a greater need for access to clean water for several reasons as a result of the rise and continued growth in population. There is a water deficit as a result. Water scarcity is calculated by dividing the number of sectoral freshwater resources with acceptable quality by the amount of water that is available (H van Vliet et al. 2021). Worldwide, water scarcity is an issue that has affected many people and regions, particularly rural ones. From an annual average of 30 % (water quantity only; monthly range: 22 % to 35 %) to 40 % (water quantity and quality; monthly range: 31 %), the proportion of people worldwide who now face acute water scarcity rises. This is so that water quality, which also considers factors like water temperature, salinity, organic contaminants, and nutrients, can be well-thought-out (H van Vliet et al. 2021).

Poorer locations often have higher rates of poverty, and it is well-known that there is a correlation between poverty and a lack of water. The less developed regions, where access to sanitary facilities and clean water is most restricted, are home to more than one billion and two billion people, respectively (Nnamani 2018).

Ghana is one of the developing countries located in the West of Africa with Accra as its capital city. Ghana is a country that is enriched with lots of water bodies, despite all the water resources in the country, the country still faces the challenge of access to safe and potable water, especially in the rural areas. One of the country's most notable geographical features is the 8,900 square-kilometre-long Volta Lake, the largest artificial lake in the world. It extends for 520 kilometres north of the town of Yapei, from the Akosombo Dam in southeast Ghana. The dam produces enough electricity to power the entire country of Ghana as well as some exports to nearby nations. The lake is a potentially vital resource for irrigation and fish farming and functions as an inland canal. The need for conventional water transportation is still evident in some parts of the nation. In other words, water from wells, rivers, lakes, or rain is collected and then cleansed using techniques like boiling. This challenge arises as a result of a national absence of the requisite distribution networks and infrastructure. Getting access to safe and potable water has been and is still a challenge for most rural folks in Ghana, and Asuogya, a rural community in the Bono Region of Ghana is no exception. Due to a lack of access to potable water in the area, the Asuogya village has been sharing their lone supply of water with domestic animals for years. For the people of Asuogya, getting access to drinking water has been quite tricky. Since it is primarily a farming community, their primary supply of water is a small, unclean stream on the ground, which they share with their cattle and use to water their crops. As a result, several waterborne diseases including cholera have been spread throughout the population, which has caused the death of some Asuogya inhabitants. Additionally, the stream dries up during the dry season, leaving no water for the people for home and agricultural usage. The water needed for cooking, bathing, washing, all domestic chores, and farming is from the same source. On rare occasions, cattle herders bring their animals here to drink from the same creek.

The goals of this study are to locate any possibly harmful chemical contaminants in the water used in Asuogya, a community in Ghana's Bono region, and to describe the water quality in the district chosen by Ghanaian water standards. It also seeks to provide groups or government representatives with guidance on the best technologies to keep Asuogya's residents' access to clean water for drinking and other purposes intact. Since the author believes that access to safe and potable water should be a significant concern for any government in a developing country, the difficulties that rural inhabitants in the Bono region face in acquiring access to safe and clean water served as the inspiration for this study.

This diploma thesis tackles the question; **What purification technology can be used to provide safe and portable water for the people of Asuogya?**

The study is broken down into three categories: theoretical, practical, and findings about the research question stated above. The theory focuses on Ghana's history, especially its topography, climate, and water supplies. It also addresses the water sources, delivery, and treatment in Asuogya.

The methodology, the procedure for gathering data, and the techniques for data analysis, such as testing and comparisons, are all included in the practical side. Primary and Secondary data are both employed. The technology utilized in water treatment is also covered in this section. Conclusions and recommendations are given following the functional area to accomplish the goal and objective of this research.

All living organisms require water to survive, which is vital to life. Anywhere in the world, water is essential for maintaining a healthy lifestyle. Despite this, the world's quality and quantity of resources remain a significant burden, especially in developing countries where access to safe and potable water is a big problem (Pandit & Kumar 2022). Water is divided into two groups—both surface water and groundwater. Groundwater plays a critical role in the water cycle. This element is present in rainwater, which enters the soil and eventually reaches saturated rock material. It is additionally known as aquifer water. Gravity makes subsurface groundwater move slowly and unevenly, where it may overflow into rivers, lakes, and seas. Boreholes and drilled wells are used to depict groundwater. Pesticides, fertilizers, effluent from septic tanks, and waste from landfills are just a few contaminants that can contaminate an aquifer and render the groundwater unfit for drinking. Surface water is any water that exists at the earth's surface, including the ocean, rivers, streams, and lakes. Surface water plays a significant role in our daily lives. Surface water is mainly used for drinking and other public purposes, such as agriculture and energy production (Water Education Foundation n.d.).

According to the WHO, an estimated 2 billion people live in countries with polluted water, and as the population grows and the climate changes, that figure will undoubtedly increase. People use and drink faeces-tainted water, risking the safety of drinking water. The bulk of health risks in drinking water is caused by heavy metals including arsenic, fluoride, nitrate, lead, and other contaminants such as drugs, pesticides, and microplastics. These chemicals are causing a lot of anxiety among the general populace. Physical, chemical, or biological pollutants can contaminate water.

WHO states that contamination of drinking water can cause diseases like cholera, diarrhoea, typhoid, polio, etc. It is estimated that 485 000 individuals per year pass away from diarrhoea. Since their economies are not nearly as developed as those of affluent ones, developing nations cannot afford most water purifications purchased and used by developed countries (WHO 2023a).

Chemical, physical, or biological contaminants make up most water contaminants; all three have a negative impact on human health. Chemically toxic industrial effluent makes its way into bodies of water. These include organic pollutants like Acrylamide, Vinyl Chloride, and others and heavy inorganic metals like Fluoride, Arsenic, Lead, and Manganese. Disinfecting water purification agents are another chemical pollutant that can contaminate water at more significant levels. Chemical contaminants in water must be appropriately identified and treated since if ignored; they pose a serious hazard to human life. Raw water has long been discovered to include residues from various pollutants, including pesticides, fertilizers, medicinal compounds, and their derivatives. Organic, inorganic, and radioactive chemical compounds are among the many different types (Pandit & Kumar 2019). Chemical pollutants that have recently been introduced pose a more significant concern. For instance, arsenic levels in the water beyond WHO quality standards may cause blood and lung cancer, diabetes, cardiovascular disease, and skin blemishes. Early childhood exposure to high levels of arsenic has been linked to delayed cognitive growth and an increase in young adult mortality (WHO 2023b).

One of the effects that physical contaminants have is increased turbidity. Water bodies with physical impurities change colour and have an unpleasant odour. The term "physical contamination" refers to the pollution that modifies the appearance, flavour, or PH of the water. Physical contamination can be hazardous when used in household settings, even though it may not immediately harm a person. Pollution from metals like aluminum, copper, iron, and manganese, as well as dyes and soil particles, frequently cause water bodies to change colour. Iron or manganese contamination of a water source affects the water's flavour. Metals and bacteria that emit musty aromas can also alter the taste and smell of water. Water with a PH value that is far from neutral affects the growth of living organisms in the environment and contributes to high soil acidity (Inamori & Fujimoto 2005).

Furthermore, biological contamination poses a serious threat to human life in water sources, as is well documented. The most typical contaminants found in water bodies include viruses, bacteria, algae, and protozoa. Numerous diseases in people can be brought on by these contaminants. Drinking water tainted with dangerous bacteria is the leading cause of most waterborne illnesses. Among the conditions that can be found in bodies of water are enteroviruses, Norwalk viruses, adenoviruses, reoviruses, and astroviruses. Meningitis, paralysis, rash, fever, and diarrhoea are among the ailments brought on by enteroviruses. The Norwalk and Astroviruses can both cause common illnesses like diarrhoea. It is well known that adenoviruses can spread conditions like respiratory problems and eye infections. Typhoid, diarrhoea, bloody diarrhoea, renal failure, acute pneumonia, Pontiac fever, skin infection, pulmonary disease, and cholera are only a few of the watery illnesses caused by bacteria like Salmonella, Shigella, Yersinia, Yersinia, Legionella, Pseudomonas, and Vibrio cholera. Amebic dysentery, Giardiasis, acute and chronic diarrhoea, keratitis, encephalitis, and muscular and renal abnormalities are among the illnesses caused by protozoa that are frequently found in water bodies. Schistosomiasis, trichuriasis, cow tapeworm, and human ascariasis are also caused by helminths (Singh et al., 2020).

1.1 Physical and Chemical Indicators of Drinking Water

It is a set of fundamental indicators that describe the composition of water as well as the levels of basic cations and anions in water.

1.1.1 pH (reaction of water)

The geological features of the rocks in each place determine the pH of groundwater (water from a well). pH, a gauge of acidity or alkalinity of water, is established by the presence of dissolved salts and carbon dioxide. Water or an aqueous solution has a neutral reaction at pH 7, acidic below 7 and basic above 7. According to Decree 252/2004 Sb, drinking water should have a pH between 6.5 and 9.5. Waters with a pH between 6.0 and 6.5 are also considered sufficient before treatment, but one must consider their more aggressive impact on boilers, pipelines, etc.

1.1.2 Colour

Drinking water needs to be colourless. Per Decree, 252/2004 Coll, the colour of drinking water must be less than 20 mgPt/l. The hue also relates to mg Pt (because the colour scale used to assess the water's colour is produced from a platinum compound). The colour of natural waterways depends on the quantity of dissolved or undissolved substances present. Entirely clear water appears blue at depths above 1 m. Yellowing is the most common hue of a supply of drinking water, and it can be caused by either an elevated iron concentration or wet materials (so-called "peat water"). An increase in manganese concentration can cause the appearance of greasy wheels on top of standing water.

1.1.3 Taste

Drinking water must taste good to consumers, as per Decree 252/2004 Coll. The kind and concentration of ions dissolved in water define its flavour; water alone has no flavour. Mineralized water, sometimes referred to as water with more dissolved substances, tastes better than soft water. The flavour is also positively impacted by the water's dissolved carbon dioxide content. The pH also affects flavour; for example, water with a pH above 8 could have a soapy aftertaste. A higher percentage of sodium or chlorides or sulfates in water gives it a salty flavour, whereas a higher concentration of sulfates or magnesium (or both) gives it a bitter flavour. A higher metal concentration (iron, manganese, and other metals) may potentially contribute to the alleged metallic taste and other issues.

1.1.4 Smell

Consumers must be able to endure the smell of their drinking water, according to Legislative Decree 252/2004 Coll. There is no flavour or scent to the water itself. The water smells because volatile substances that have been dissolved in it are slowly liberated from it. In naturally occurring, unpolluted waters, hydrogen sulfide, which has a smell akin to that of rotten eggs, is the most common odorant. Faeces-contaminated water may also smell like urine, urea, faeces, or other unpleasant substances. The so-called chlorine can also be present often in drinking water that has undergone chlorination treatment.

1.1.5 Water turbidity

Turbidity (reduction of water transparency) is a summary indicator of the content of undissolved and colloidally dissolved inorganic and organic substances in water (sand, oxides of iron, manganese, clay). In Decree 252/2004 Coll. a maximum turbidity value of 5 ZF is allowed for drinking.

1.1.6 Conductivity

A marker whose variation is directly proportional to the amount of dissolved inorganic salts in the water. By Decree 252/2004 Sb, drinking water is permitted to have a conductivity of no more than 125 mS/m. Conductivity standards for drinking water range from 25 to 50 mS/m. Higher conductivity water, sometimes known as "mineral water," should not be consumed regularly since it could be damaging to your health. However, even so-called soft water (rainwater, demineralized water, water from mountain areas) without dissolved salts or with a low salt concentration is not healthy for long-term ingestion since the body loses the necessary minerals.

1.1.7 Ammonium ions (NH_4^+)

Ammonium ion concentrations rising indicate possible urea, cesspool, or inorganic nitrogen fertilizer pollution intrusion. According to Decree 252/2004 Coll, the maximum ammonium ion concentration permitted for drinking water is 0.5 mg/l.

1.1.8 Chemical oxygen demand (COD)

A summary indicator called Chemical Oxygen Consumption – Kubel's method (CHSKMn) correlates with how much organic matter is dissolved in water. These substances may originate from plants or animals. A high COD reading typically indicates bacterial infection as well. The signal may also increase if there is seepage of industrial contamination. Usually, it has bacterial contamination. Decree 252/2004 Coll allows for a maximum CHSKMn content of 3 mg/l in drinking water.

1.1.9 Iron (Fe^{2+} or Fe^{3+})

The well's boosted iron content results from natural sources, specifically the rocks from which the water originates. Additionally, iron may be found in corroded water-flowing equipment or pipelines. Iron is often found dissolved in water in the divalent form (Fe^{2+}), but it can also be found in the trivalent form (Fe^{3+}) when it encounters oxygen from the air. Rusty turbidity results from the increasing precipitation of trivalent iron out of the water. A maximum amount of iron of 0.2 mg/l is mandated by Decree 252/2004 Coll. for drinking water. Although there is no health risk from having more iron in water, it can have negative sensory (colour, smell, turbidity) and practical (discolouration of clothing, staining of sanitary ceramics, obstruction of pipes and appliances with precipitated iron, etc.) effects. Long-term consumption of iron-rich water may be detrimental to your health.

1.1.10 Nitrates (NO_3^-)

Inorganic nitrogenous fertilizers used in fields, gardens, and grasslands that have higher nitrate concentrations are a sign of fertilizer contamination. Decree 252/2004 Coll. states that the maximum nitrate concentration for drinking water is 50 mg/l, but that the limit for water for newborns is just 10 mg/l.

1.1.11 Nitrites (NO_2^-)

When Nitrite pollution is faecal in origin, ammonium ion pollution may also coexist. Increasing nitrate level usually occurs in conjunction with nitrite pollution (they come from reduction). Decree 252/2004 Coll allows for a maximum nitrite concentration of 0.5 mg/l drinking water.

1.1.12 A sum of Calcium and Magnesium ("Total Water Hardness")

With the justification that this is beneficial for human health, Decree 252/2004 Coll. proposes a water hardness range of 2.0-3.5 mmol/l for drinking water. Higher hardness does not pose a health risk, but it can reduce the water's practical qualities due to the build-up of so-called limescale, which can damage home appliances and lead to pipe overgrowth, among other issues. Using water with a hardness below 2.0 mmol/l as your primary source of drinking water could potentially cause problems. After then, the body gradually loses calcium and magnesium, necessitating the need for external sources of replacement. The optimal calcium-to-magnesium ratio is 2:1 to 3:1. The amount of calcium that can be used is constrained by the prolonged use of fluids with the opposite ratio (a magnesium predominance). water hardness scale and water type very soft hardness overall concentration Soft, 0–0.7 mmol/l; medium hard, 0.7–1.3 mmol/l; hard, 1.3–2.1 mmol/l; and extremely hard, greater than 5, 3.5, 5.3, and 3 mmol/l, between 2.1 and 3.2 mmol/l

1.1.13 Calcium (Ca^{2+})

A minimum calcium concentration of 30 mg/l is advised for drinking water according to Decree 252/2004 Coll. Total hardness can be used for anything else.

1.1.14 Magnesium (Mg^{2+})

In Decree 252/2004 Coll. a minimum magnesium concentration of 10 mg/l is recommended for drinking water. For everything else, see total hardness.

1.1.15 Manganese (Mn^{2+})

Manganese, which has a comparable impact on water quality, is usually present with iron. Elevated manganese concentration in water sources such as wells results from natural sources, specifically the rocks from which the water originates. Manganese is frequently dissolved in water, and at greater concentrations, it can cause the development of "greasy wheels" or black deposits on the water's surface. According to Decree 252/2004 Coll, the maximum manganese concentration for drinking water is 0.05 mg/l. However, for naturally occurring untreated sources (wells), this quantity can increase to 0.1 mg/l. What do drinking water specifications mean? Although there is no health risk from increased manganese in water, it can harm the sensory (colour, smell, turbidity) and practical (colouring of clothing, staining of sanitary ceramics, and at high concentrations, clogging of pipes and appliances) characteristics of water. Water that has more manganese than 1 mg/l may be harmful to your health if taken frequently.

1.1.16 Sodium (Na^{+})

Drinking water contains sodium ions, both naturally occurring from the bedrock and artificially produced by road salting. According to Decree 252/2004 Coll, the maximum sodium ion level for drinking water is 200 mg/l. As the quantity increases, the water's flavour changes.

1.1.17 Chlorides (Cl^{-})

Chlorides in drinking water may originate in the bedrock naturally, via sewage contamination, or from salting roadways. The maximum chloride concentration for drinking water is 100 mg/l according to Decree 252/2004 Coll., but wells may have a higher value of up to 250 mg/l. Even higher concentrations of chlorides may not pose a severe health risk, but they do change how the water tastes. Water with a greater chloride concentration shouldn't be consumed by newborns, young children, or people with hypertension. The high chloride concentration additionally exacerbates the corrosiveness of the water (corrosion of pipes and water-using devices).

1.1.18 Sulphates (SO42-)

Sulfates frequently show up in drinking water due to water pollution from fertilizing fields and other agriculturally active areas or because they are present naturally in the bedrock. According to Decree 252/2004 Coll, the maximum sulphate concentration for drinking water is 250 mg/l. While higher sulphate concentrations can make water taste terrible, they primarily affect its positive qualities. The so-called persistent hardness of water, which is unaffected by boiling, is caused by sulfates, which are frequently found in water along with calcium and magnesium (for more information on hardness problems, see the keyword hardness). Drinking water can make you sick if it has high levels of sulfates and magnesium.

1.1.19 KNK 4.5 (alkalinity)

Acid neutralization capacity, or KNK 4.5 (acid neutralization capacity), is a quantitative measure of water's ability to interact with hydrogen ions. Depending on the pH of the water, it is mainly caused by bicarbonates and carbonates (also known as bound carbon dioxide). There are no limitations on KNK's worth under Decree 252/2004 Coll. However, a higher KNK value of 4.5 is often associated with the presence of calcium and magnesium. Boiling can get rid of temporary hardness, which is produced when calcium or magnesium bicarbonate dissolves in a solution (for more information on hardness problems, see the word "hardness").

1.1.20 Fluorides (F-)

The fluorides found in drinking water typically arise naturally from bedrock. By Decree, 252/2004 Coll., the maximum fluoride concentration for drinking water is 1.5 mg/l. Since fluoride prevents tooth decay, especially in children, water should have a low fluoride content. Most groundwater in European territories frequently has fluoride concentrations that are between 0.1 and 0.3 mg/l, which is considered optimum. Fluoride in the water is a problem in Africa (like Senegal) due to its high level.

1.1.21 Bacteriological indicators

1.1.21.1 Coliform bacteria Control

It is a group of bacteria that coexists in soil and warm-blooded mammals' intestines. It can be assumed that the water supply has been contaminated by faeces if they are found in the water. In the case of treated water supply, they help control water disinfection and provide evidence of the treatment's effectiveness. For drinking water, Decree 252/2005 Coll. mandates 0 KTJ in 100 ml of tested water.

1.1.21.2 Escherichia coli Control

Escherichia Coli is part of the coliform bacteria group. They are derived from warm-blooded animals, and their presence in water is an obvious sign of faecal contamination. It is impossible to tell whether an animal (sewage seepage from a cesspool) or a person (the pollution) is to blame. For drinking water, Decree 252/2005 Coll. mandates 0 KTJ in 100 ml of tested water.

1.1.21.3 Enterococci Control

The presence of Enterococci is another sign of faecal contamination and is found in the digestive tracts of warm-blooded animals. They serve as a sign of recent contamination because they don't last long in the water. Decree 252/2005 Coll. requires 0 KTJ in 100 ml of tested water for drinking purposes.

1.1.21.4 Colony counts at 22°C and 36°C Control

These are non-specific groups of bacteria that represent a general indicator of possible bacterial water pollution. Their source can be e.g., seepage from compost or rotting leaves, etc. For large, treated sources of drinking water (water supply, company well serving as a source of drinking water) decree 252/2005 Coll. allows a maximum of 200 KTJ in 1 ml of water for bacteria cultured at 22 °C and 20 KTJ in 1 ml of water for bacteria cultured at 36 °C.

For water from small non-disinfected sources (e.g., privately owned wells), a higher content of these bacteria is allowed, i.e., 500 KTJ in 1 ml of water for bacteria cultured at 22 °C and 100 KTJ in 1 ml for bacteria cultured at 36 °C.

1.2 Water Pollution in Ghana

Ghana has a wealth of freshwater, marine, and coastal resources. The abundance of freshwater, marine, and coastal resources available to Ghana is a blessing. The basin of the Volta River contains over 70 % of the country's drainage system. Additional river basins include the White Volta Basin, Ankobra Basin, Pra Basin, Tano Basin, and Densu River Basin. The remaining 30 % is in the Densu River Basin (Water Resources Commission of Ghana 2023). However, these resources have been investigated and used to meet the socioeconomic and environmental needs of the community. Take the proportion of people who live in coastal areas that go fishing as an example. The nation's fish productivity is strongly influenced by this (Bawakyillenuo 2020). In Ghana, population growth, urbanization, a lack of environmental awareness, traditional farming practices that are not sustainable, industrial activity, and municipal and domestic waste like plastic waste, oil production spills, liquid waste, and other such waste are the leading causes of water pollution (Bawakyillenuo 2020).

Natural factors and human actions both affect the availability of water. Most of Ghana's freshwater resources are contaminated as a result of mining, urbanization, and agricultural land use. In Tarkwa, Ashanti region, in 2022, Zhou et al. conducted a study on the impacts of human endeavours, including urbanization, agriculture, and industrialization on the Bonsa River and the health of the residents in 2022 (Zhou et al. 2022). The results showed that land use change had a significant impact on the depletion of freshwater resources and the poor health of the population in the study area. According to the study, there is a direct link between typical agricultural practices including improper pesticide use and the use of harmful chemicals for fishing and water contamination. It went into great length about how runoff has a significant impact on water pollution. Herbicides, pesticides, insecticides, and other inorganic fertilizers are delivered by irrigation, drainage, or precipitation, contaminating rivers and streams. These synthetic pesticides, herbicides, and fertilizers may include hazardous metals that, over time, may cause deadly diseases in humans. Additional research findings demonstrated that household activities can contribute to water pollution. Diarrhoea, cholera, and skin cancer can be brought on by drinking from bodies of water that have been contaminated with sewage, household trash, and other new substances. There have also been claims that the contamination of the Bonsa River was caused by the discharge of industrial waste as a result of industrial activities. Industrial waste is waste produced by manufacturing or industrial activities.

There are many various types of industrial waste produced, including cafeteria waste, soil and gravel, masonry and concrete, scrap metals, trash, oil, solvents, and chemicals, as well as weeds, grass, trees, and scrap lumber (Safe Drinking Water Foundation 2017). Enterprises situated close to rivers frequently release their effluent into them, contaminating the water with dangerous compounds that threaten aquatic life and human health (Zhou et al. 2022). It is well knowledged that the main contributor to water contamination in industrial areas is industrial waste.

One of the leading causes of water contamination in Ghana is the operations of illegal mining. The environment has a tremendous impact on people's lives in Ghana because it is essential to their means of subsistence and activities. Due to the extensive use of chemicals, wastewater, ore processing methods, as well as spills from tailings and waste rock impoundments, mining operations have a detrimental effect on and constitute a threat to freshwater bodies of water (Emmanuel & Dzigbodi 2018). Due to the nature of mining, water supplies can become severely contaminated. Acid mine drainage, heavy metal contamination and leaching, chemical processing pollution, erosion, and sedimentation are the four primary ways that mining affects water quality. Small-scale miners are prevalent along riverbanks, which causes the banks to erode and the rivers to flood during periods of heavy rain. Locals in Tarkwa have expressed their displeasure, alleging that the natural course of the river has been significantly altered by the activity of the area's illicit miners. In contrast to earlier observations, it is noted that their river is now an opaque shade of brown. If a river's colour changes, turbidity has likely increased, lowering the pH and making the water unfit to drink (Emmanuel & Dzigbodi 2018).

There is a legitimate concern that illegal mining could gravely impair Ghana's water supply given the closure of multiple water treatment facilities throughout the nation. Mining is the process of removing minerals and metals from the planet. Gold, diamond, bronze, bauxite, manganese, copper, tin, and other materials have been extracted together with other minerals and metals (Duncan 2020). Although mining has historically helped to increase economic prosperity and job opportunities, it is coupled with several environmental issues and concerns due to surface and groundwater pollution. These mining processes release harmful chemicals like cyanide and other organic ones required to process mineral ores into the environment. If these contaminants cause excessive acid levels to penetrate subterranean water or flow into surface water bodies, both the lives of those who consume this water and the surrounding population may be in danger. Mining operations occasionally cause heavy metals like zinc oxides and lead to enter water bodies, putting aquatic life and the people that depend on these water supplies in jeopardy (Duncan 2020).

The illicit small-scale mining operations in Ghana's Ashanti Region's Fena River encountered a lot of difficulties, according to Ebo Ducan's research (2020). Two of the problems caused by this include the drying out of the river and the introduction of enormous quantities of suspended liquids, which may contain heavy metals and thus raise the cost of treatment at water treatment facilities. The natural flow of the river was further hampered by the mud and gravel produced by these unlawful mining operations. According to others, these issues pose a severe risk to locals in the Fenaso hamlet and its surroundings, especially to those who depend on the river for their survival. The results revealed a significant number of heavy metals were present in the Fena River. Among those discovered were heavy metals like Cd, Pb, Fe, Zn, Cu, and Hg. The water was unfit for consumption because three of these metals were above the threshold for safe drinking water. The investigation revealed that the Fena River and its environs' water was unsafe for human consumption due to the public health risk. Before the general population may use the water, it must first be filtered. On a national, regional, and worldwide level, heavy metal poisoning of the water supply is a significant problem. Like many other countries, Ghana has a problem with heavy metal contamination.

Hadzi et al. (2018) claim that mining, industrial effluent discharge, and other human activities are mostly to blame for this. Over the years, studies have revealed that the bulk of the country's water bodies has excessive levels of heavy metals.

The fact that mining operations significantly contribute to the heavy metal contamination of Ghana's water systems is now widely acknowledged. As was said earlier, mining waste can release metals and hazardous compounds into the environment. Toxic metals found in mining effluents include zinc (Zn), lead (Pb), aluminium (Al), cadmium (Cd), nickel (Ni), iron (Fe), manganese (Mn), and arsenic (As). These metals can pollute soil, food, surface and groundwater, and pose substantial health concerns to humans, animals, and plants (Okereafor et al. 2020).

Geoge Yaw Hadzi, David Kofi Essumang and Godwin Ayoko conducted a study on water bodies in the central mining communities in eight regions of Ghana in 2018 to investigate heavy metal contamination of water bodies near goldmines, compare the metal levels, and assess the risk of human health and the environment from this contamination (Hadzi et al. 2018). The results showed that the water bodies included substantial quantities of heavy metals such as Zn, Co, Ni, Fe, Al, Pb, V, Cu, and Cr. To better understand the consequences of mining activities on the ecology and the health of individuals living near mining sites, the study provided in-depth details on heavy metal pollution in mining and pristine environments.

1.3 The Need for Water Purification

Ghana has a lot of dirty water, although other African nations struggle with a lack of it. The issue is a dearth of working water filters. Although the government wants to restore these damaged filters, doing so could cost up to $35 million. Despite this, the government is pushing ahead with the project with assistance from non-governmental organizations and firms like Native Energy. Ghana's fast urbanization is to blame for the country's water poisoning. Waterways are contaminated by unsafe housing and substandard plumbing, including a lack of sinks and toilets. Families are therefore forced to buy their water from unclean sellers. As a result, more individuals become ill, leading to a cycle of water poisoning (Collin Williams 2019).

Cholera is one of the illnesses that Ghanaians suffer from most frequently. It mainly spreads when people use outdated toilets and pipes. 30,000 people were affected by a flash flood in 2014 that got worse when large amounts of dirty water got mixed up with the water sources. The harmattan dry winter winds in Ghana are another factor in the country's water shortage. Water restrictions follow, which inevitably lead to public unhappiness and demonstrations. The issue is exacerbated by deforestation and illegal gold mining, which further degrade the scarce water supply (Collin Williams 2019).

A basic human necessity and a crucial human right, access to clean drinking water is essential for preserving good health. Approximately 70 % of the water that makes up the surface of the Earth is included in oceans, seas, rivers, lakes, and underground streams. However, data reveals that more than half of the world's population, or 1,000 million individuals, suffers from health issues as a result of not having access to clean drinking water. People in underprivileged regions and nations with weak economies frequently consume water straight from ponds and rivers, which has led to the spread of typhoid, cholera, diarrhoea, hepatitis, polio, dysentery, and tapeworms. Focusing on freshwater resources that are contaminated by trash is crucial. The risk of waterborne diseases must be decreased by cleaning up these resources. Various physicochemical and microbiological qualities of raw water in the accessible water resources must be safely limited by engineering schemes. Coagulation, flocculation, sedimentation, and chemical disinfection of natural water are a few examples of methods for cleaning the water in these resources (Ahmad & Azam 2019).

1.4 Background of the Republic of Ghana

1.4.1 Basic Information

Ghana, a country in West Africa with Accra as its capital city and a location on the Gulf of Guinea, has achieved significant advancements toward democracy over the previous 20 years while employing a multi-party system, and the populace now has faith in its independent judiciary. Ghana consistently places among the top three nations in Africa for press and speech freedom, according to (World Bank n.d.). Ghana, originally the Gold Coast, became the first nation in Sub-Saharan Africa to declare its independence from Britain. Kwame Nkrumah served as Ghana's first president. The name of the country derives from the large medieval commercial empire that governed the region northwest of the current state until it vanished in the 13th century. Commodities like cocoa, gold, and more recently oil, which has fuelled an economic boom, are the foundation of the Ghanaian economy (BBC News 2020).

Her abundant natural resources are well-known. In the country, there are 30.8 million inhabitants, according to the Ghana Statistical Service. Most of the responders (71.3 %) claim to be Christians. Muslims make up 19.9 % of the population, whereas traditionalists make up 3.2 %, others make up 4.5 %, and others make up 1.1 %. Although English is the nation's official language, many regional tongues, including Twi, Dagomba, Ga, Kokomba, and Dagarte, are also widely acknowledged and used (CIA Factbook 2013). Nana Akufo-Addo is in power as a result of his victory in the nation's

2020 presidential election. The private press and broadcasters are allowed to operate in Ghana, where there is a high level of media freedom. Ghana has a vast radio audience, but social media and improved access to television are threatening radio dominance (BBC News 2020).

1.4.2 Geography

Ghana borders Burkina Faso, Togo, and Côte d'Ivoire and is situated in West Africa. Both the Atlantic Ocean and the Gulf of Guinea are to the south. With a land area of 238.533 square kilometres, Ghana is about the same size as Great Britain. Cape Three Points, which is located on its southernmost coast, is about 4 30' north of the equator. The country continues inland for a further 670 kilometres, or 11 north, from this point. Between longitudes 1 12' east and 3 15' west, the region's widest point is around 560 kilometres wide. The eastern Ghanaian city of Tema is on the Greenwich Meridian, which also runs through London. Ghana is a country with a total area of 238.533 square kilometres, of which 227.533 are land and 11.000 is water. water covers square kilometres. Several rivers and streams drain Ghana. A variety of coastal lagoons, the sizable artificial Lake Volta, and Lake Bosumtwi, which is southeast of Kumasi and has no outflow to the sea, are also present. The river and stream patterns in Ghana's wetter south and southwest are water-sit-denser; yet they are much more open in the area north of the Kwahu Plateau, making access to water more challenging. During the dry seasons, numerous streams and rivers either dry up or only sporadically run, whereas there is a lot of flooding during the rainy seasons (CIA Factbook n.d.).

Flat plains make up most of Ghana's geography, with a few uplands and a vast plateau in the south-central area—elevations on Mount Afadjato range from sea level to 885 m. Lake Volta, the largest artificial lake in terms of surface size, is in Ghana (8,482 sq km). The three Sudan Savanna ecoregions (WSS, CSS, and ESS) in the north are characterized by a single rainy season, open tree savannas, and dispersed rainfed croplands, which contribute to the region's typically dry climate. The vast forest savannas of the Closed Guinea Anna (CGS), which is located to the south, are typical of the Guinean Region (The Earth Resources Observation and Science Center - United States Geological Survey 2016).

1.4.3 Climate in Ghana

Ghana's tropical climate, which is affected by the West African Monsoon, is found in a latitude of 4–12 N. Ghana's wet and dry seasons are influenced by the annual movement of the tropical rain belt, commonly referred to as the Inter-Tropical Conversion Zone (ITCZ), between the northern and southern tropics. South-westerly winds dominate in the area south of the ITCZ, bringing humid air from the Atlantic to the continent. The dominant northeastern currents transport the hot and dusty Sahara Desert (also known as the "Harmattan") into the region north of the ITCZ.

The most significant seasonal temperature changes occur in the north of Ghana, with AMJ (the hot, dry season) having the highest temperatures at 27–30 °C and JAS having the lowest at 25–27 °C. While the coldest season, JAS, sees lows of 22–25 °C, the milder JFM season farther south sees temperatures reach 25–27 °C (McSweeney et al. 2008).

1.4.4 Economy of Ghana

In 1957, Ghana became the first nation in Sub-Saharan Africa to declare its independence (Dzorgbo 2017). There are both public and private companies in the economy. Around three-fifths of the GDP is made up of the services sector, with agriculture and industry making up the remaining one-fourth and approximately one-fifth, respectively. Before the nation's independence, the government's primary responsibilities were limited to providing essential services like water, electricity, roads, and mail delivery. Apart from agriculture, each of these sectors—banking, trade, and industry—was primarily run by private enterprises. To increase its control over the economy soon after gaining independence, the government began establishing a sizable number of state-owned enterprises in manufacturing and agriculture. More than half of the population works in agriculture, forestry, and fishing in addition to producing most of the nation's income. Ghana routinely ranks among the top cocoa producers in the world and is renowned for the superior quality of its sun-dried chocolate (Britannica n.d.). Ghana's GDP is projected to be $175.2 billion, growing at a 0.9 % annual pace (2020), 5.0 % over the previous five years, and $5,693 per person (The Heritage Foundation 2022).

Inflation soared, rising from 12.6 per cent at the end of 2021 to 31.7 per cent year over year in July 2022 (a record high). The collapse of the cedi, which has already lost 24 per cent of its value against the dollar in 2022, has made the effects of rising global commodity prices—Ghana purchases 40 % of its fertilizers from Russia—even more severe. The government and Bank of Ghana (BoG) have attempted to lower inflationary expectations by decreasing spending, increasing the monetary policy rate (MPR) to 22 %, and increasing the critical reserve requirements for banks from 12 to 15 % (World Bank 2022). Due to currency devaluation and rising inflation, living expenses have increased, especially for food. The fact that people experiencing poverty spend more than half their income on food has a significant influence on household budgets. Increases in the cost of inputs like fertilizer have also hurt farmers in rural areas (World Bank 2022).

1.4.5 Hydrogeology and Water Situation in Ghana

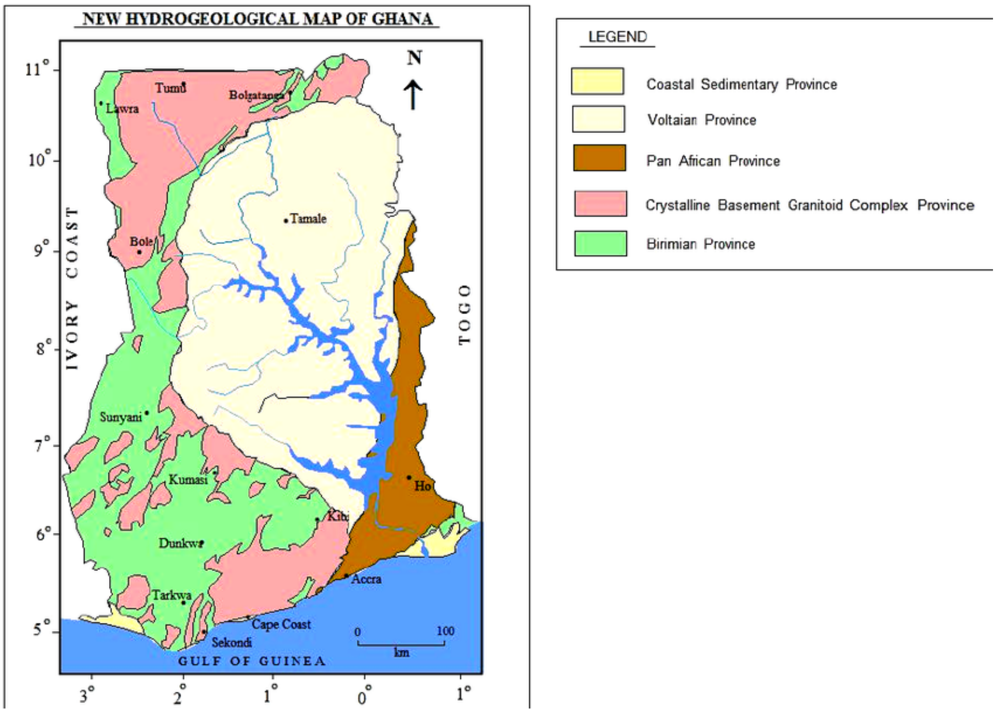

Figure 1 The Hydrogeological map of Ghana showing the Volta Basins

Source: (Yidana et al. 2011)

Ghana has a lot of water resources; however, the amount that is accessible varies drastically from year to year and from season to season. The nation's resources are not distributed equally, with the southwest receiving better water than the coastal and northern regions. Water supply, however, is declining as a result of erratic precipitation (climate change), rapid population growth, worsening environmental degradation, river pollution, and the draining of wetlands. In Ghana, every river empties into the Gulf of

Guinea (Figure 1). About 70 % of Ghana is drained by the Volta River, which is by far the country's greatest river. It runs across the country's whole north, centre, and east. The remaining rivers, all of which are in the south and southwest, drain about 30 % of the nation. The Black and White Volta Rivers, the Oti River, and the Lower Volta, which includes Lake Volta, are a few of the primary sub-basins of the Volta. The Bia, Tano, Ankobra, and Pra Rivers are part of the South-Western Rivers System, whilst the Ochi-Amissah, Ochi-Nakwa, Ayensu, Densu, and Tordzie/Aka Rivers are a part of the Coastal Rivers System. The Volta River basin is also shared by Cote d'Ivoire, Burkina Faso, Togo, Benin, and Mali. Ghana and Cote d'Ivoire are separated by the lower Tano River and the Bia River (Water Resources Commission n.d.).

Most of the nation is covered by the Volta Basin, which is essential for agriculture, hydroelectricity generation, and fisheries. However, the usage of water for agriculture and the age of hydroelectric power depends on the abstractions and releases from the upper basin dams of Burkina Faso and is susceptible to drought. Flooding is more likely when floodgates on upstream dams open sporadically. Resources for groundwater are scarcer than those for surface water. For residential and drinking water needs, groundwater is frequently used in rural regions, notably in northern Ghana (USAID & Sustainable Water Partnership 2021).

Table 1 Water Resource Data

Variable	Year	value	Unit
Dam capacity per capita	2019	4882,144554	m3/inhab
Dependency ratio	2019	46,08540925	%
Overlap: between surface water and groundwater	2019	25	10^9 m3/year
Produced municipal wastewater	2019	0,28	10^9 m3/year
The total area of the country (excl. coastal water)	2019	23854	1000 ha
Total dam capacity	2019	148,50437	km3
Total population	2019	30417,856	1000 inhab
Total renewable groundwater	2019	26,3	10^9 m3/year
Total renewable surface water	2019	54,9	10^9 m3/year
Total renewable water resources	2019	56,2	10^9 m3/year
Total renewable water resources per capita	2019	1847,598989	m3/inhab/year

Source: FAO Aquastat (“Workbook: Review Dashboard-v1” n.d.)

One in ten individuals in Ghana still must wait more than 30 minutes to acquire a better supply of drinking water, despite a considerable improvement in water access. Surface water and other potentially hazardous water sources are nevertheless consumed by 11 % more individuals. Poverty and collection time are directly correlated; impoverished people are nearly 20 times more likely than wealthy people to take longer than 30 minutes to collect water. Rural communities' limited availability of water within 30 minutes is probably caused in large part by the lack of a reliable water supply. Even though there are many strategies used to deliver a consistent and long-lasting supply of water, there is not enough information on system sustainability and water quality to allow these strategies to be scaled up (UNICEF 2019).

1.4.6 Water Quality in Ghana

Mining and agricultural practices have severely lowered the quality, making residential treatment costly (Yeleliere et al. 2018). The quality and quantity of Ghana's freshwater resources are deteriorating. For residential usage, about 1 % of this freshwater is accessible in lakes, river channels, and underground. Agriculture, tourism, irrigation, transportation, and industry all have significant economic potential when it comes to water resources. Contrary to other resources, most water uses cannot be entirely or quickly replaced. People still struggle to find clean, safe water, especially those who reside in rural locations where infrastructural access is sometimes hampered. Only 4 % of households correctly treat water before consumption, and 93 % of houses do not treat water at all. According to UNICEF 2019, putting 76 % of homes are in danger of consuming water that is polluted with excrement. Numerous studies have revealed that there is a sizable quantity of microbial contamination in surface water because it has been demonstrated that almost all surface waters are polluted with *E. coli,* faecal coliforms, total coliforms, or all three. However, surface water was more frequently impacted than groundwater. The physical indicators of water quality had also drastically declined, causing surface waters to become more turbid with total suspended particles as well as an unpleasant odour and hue. In contrast to groundwater, the pattern was obvious. While 20 % of the borehole supplies included Fe, Mn, or both, the bulk of the surface waters had high arsenic concentrations (Yeleliere et al., 2018).

Urbanization, population increase, a lack of environmental awareness, conventional farming methods, and industrial activity are the leading causes of freshwater contamination in Ghana. While freshwater has many well-known uses and advantages, it is also becoming terrifyingly more contaminated, putting its ability to support life in peril. A few examples of this pollution include high levels of nutrients, high faecal coliform counts, low dissolved oxygen levels, and organic and inorganic waste components. Freshwater contamination in Ghana influences the availability of drinkable residential water, health care, and transportation services (Bawakyillenuo 2020). 60% of Ghana's water bodies, many of which are in critical condition, are polluted, according to the Water Resources Commission (WRC). At a workshop in Ho, Mr Ben Ampomah, the Executive Secretary of the Commission, asserted that most of the country's polluted water bodies were in the southwest regions, where illegal mining (galamsey) was pervasive. He stated that in addition to illicit mining, agriculture, household waste disposal, and industrial waste were the most significant contributors to water contamination in the nation. He urged officials from the traditional and municipal governments to contribute to the protection of water resources. He praised the Ministry of Lands and Natural Resources for combating illicit mining and urged a coordinated effort to continue the project to raise the calibre of the water resources in certain areas (WRC-Ghana 2017).

1.5 Asuogya

1.5.1 Basic Information

The Sunyani West Municipal/District is home to the little village of Asuogya, which is situated in Ghana's Bono Region. The Sunyani West Municipal, one of Ghana's 261 Metropolitan, Municipal, and District Assemblies (MMDAs), is one of the 12 municipalities and districts that make up the Bono Region, with Odomase serving as the administrative center. The Sunyani West Municipal Assembly (SWMA) was established in November 2007 and inaugurated on February 29, 2008 (Districts 2019a).

The main occupation of the people in Asuogya is farming. Farmers in the area raise crops and animals. Around 60 miles, or roughly an hour's journey, separate Asuogya from the regional hub of Ghana's Bono Region. Four hundred twenty people, excluding those under the age of 18, make up the community's total population, according to data from Ghana's most recent voter registration, which took place in 2020. Farming is the primary industry of the residents of Asuogya. Crop and animal farming is practised by the locals.

1.5.2 Geography

On the fringes of the Sunyani West Municipality, in the Bono Region, is a little settlement known as Asuogya. The area is located between latitudes 7°19 and 7°35 N and longitudes 2°08 and 2°31W (Figure 2). Along with Tain District, Berekum and Dormaa East, Sunyani Municipality, Tano North and Ofinso North districts, and Wenchi Municipality, it shares its northern and eastern boundaries as well as its western, southern, and northern borders with Wenchi Municipality. A total of 1,658.7 square kilometres make up the Sunyani West District (Ministry of Food & Agriculture Ghana, 2023). Notable is the Precambrian rock formation, which is exclusive to the Sunyani West District and is thought to hold abundant mineral deposits. The district has schools, which are normally fertile and suitable for growing cocoyam, maize, cassava, cocoa, plantains, and yam. The tract contributes significantly to local corn production.

Around 60 miles, or roughly an hour's journey, separate Asuogya from the regional hub of Ghana's Bono Region. The only source of water for the village is a little creek on the outskirts. For all their requirements, they can only acquire water from the stream. The creek also serves as a boundary between the towns of Asuogya and Agyakojokurom.

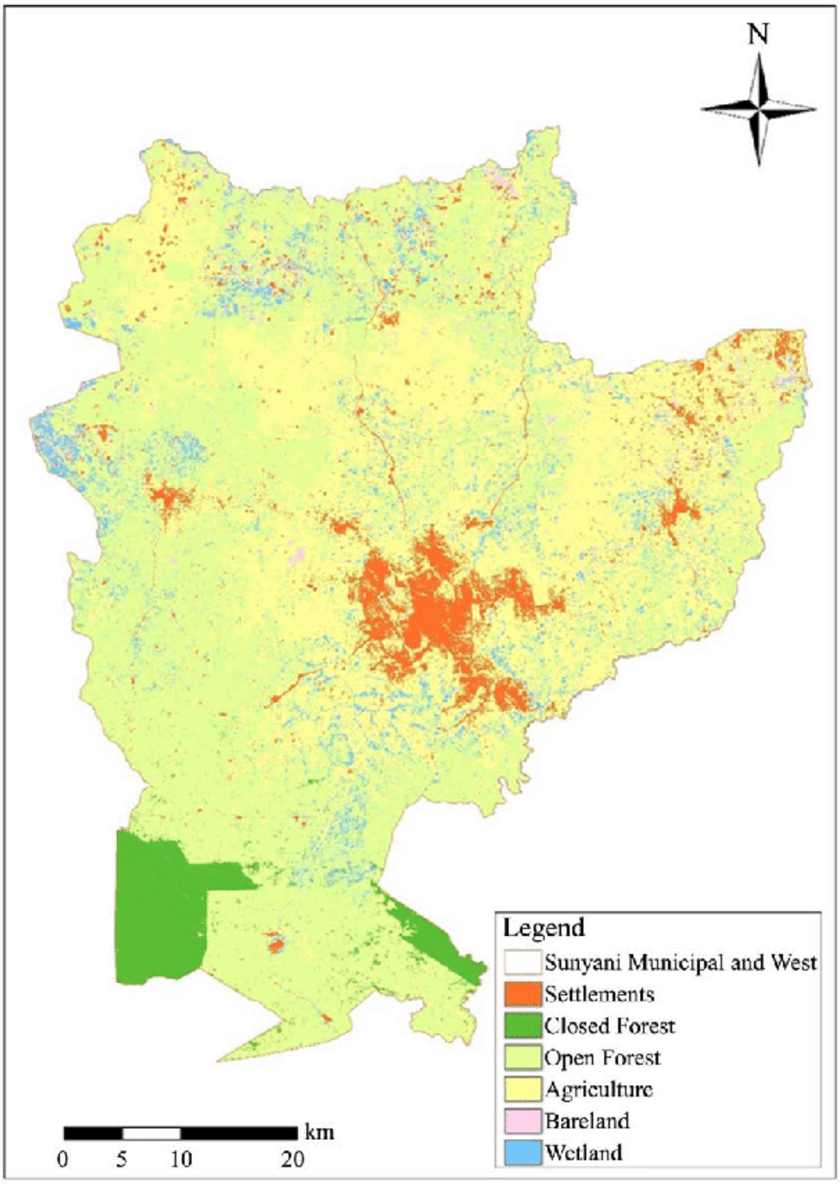

Figure 2 Map of classified land use and cover of Sunyani Municipal

Source: (Höflinger et al. 2020)

1.5.3 Climate

The Wet Semi- Equatorial climate zone, where Sunyani West District is located, has two wet seasons every year. While the minor rainy season lasts from September to October, the primary rainy season lasts from April to July. The average annual rainfall is 170 cm. From mid-November to mid-March each year, there are five months of dry weather. The district receives a lot of rain, which is beneficial to produce forestry and agriculture (Ministry of Food & Agriculture Ghana 2023). Sunyani Municipality is in Ghana's Wet Semi-Equatorial Climatic Zone. Monthly temperatures range from 23 °C to

33 °C, with August having the lowest temperatures and March and April having the highest. Precipitation for the entire year is 88.99 cm. With the significant rainy season occurring between March and September and the minor rainy season coming between October and December, the district features a double maximum rainfall pattern. The relative humidity should be less than 70 % during the dry season and between 75 % and 80 % during the wet season for lush, vegetative development. The Moist - Semi Deciduous Forest Vegetation Zone, which is mostly where Sunyani Municipality is located, has the majority of the valuable timber species. The Yaya and Amoma reserves are the two most important forest reserves. Citrus and cocoa may grow well in this location due to the vegetation. Seasonal waterbodies include the Tano, Amoma, Kankam, Benu, Yaya, and Bisi rivers. According to the 2021 Population and Housing Census, 136,022 people are living in the Municipality, including 67,251 males and 68,771 women (Districts 2019b).

Asuogya is in the Sunyani West municipality and therefore experiences the same climate condition as every community in the municipal.

1.5.4 Population

Since 1970, the district's population has been steadily increasing; as a proportion of the regional population, the district's population climbed from 3.8 % in 1970 to 4.9 % in 2010. The community had a population of 78,020 in 2000, up 3.5 % from the year before, according to the people and housing census (Ministry of Food & Agriculture Ghana, 2023). According to the 2021 Population and Housing Census, the Municipality has 136 022 residents, 67 251 of whom are men and 68 771 of whom are women (Districts 2019a). The district's population appears to be steadily increasing. The population of the community seems to be growing steadily. Four hundred twenty (420) people live in the Asuogya village, excluding those under the age of 18.

1.5.5 Economy

The district's economic backbone and a significant source of livelihood for the populace is agriculture. According to the findings of the 2010 population and housing census, 48.2 per cent of people who are 15 years of age or older who are employed are in the agricultural, forestry, and fishing business, followed by 14.7 per cent in wholesale and retail commerce, and 7.4 per cent in the manufacturing sector. 17 more industries operate in the district, taking up the remaining part. There are roughly 14 food markets in the municipality, some of which are open both weekly and daily to give customers access to essential foods. Odomase (daily), Nsoatre (weekly & daily), and Chiraa (weekly & daily) are the most significant of these marketplaces, and both local households/traders and foreign traders use them. There are two maize markets in Odumase (Awuah Domase maize market and Odumase No. 1 maize market). Minor markets primarily serve the needs of locals and traders. Infrastructure facilities in some significant markets are pitiful, while facilities in minor markets are pitiful. Most major markets lack proper water and sanitary infrastructure, whereas minor markets have both. Complementary facilities must be accessible to ensure consumer food safety (West 2020). The Asuogya community does not currently have any market centres for food or anything else. Farming is the primary industry of the residents of Asuogya. Crop and animal farming is practised by the locals.

1.5.6 Water Situation in Asuogya

For domestic, non-domestic, and productive purposes, early Sunyani West District dwellers used unofficial sources of water, such as wells, rivers, and streams. The usage of these unofficial sources led to several occurrences of water-related disorders, according to personal interactions with the district water and sanitation team (DWST). In most settlements throughout the district, the District Assembly was compelled to provide traditional water sources (boreholes with a hand pump, and piped water systems). The district's incidence of water-related illnesses has decreased as a result of this contribution increasing the population's access to the potable water supply. In addition to official water point systems, hand-dug wells, primary boreholes with hand pumps, and a few communities with piped water, the district also has these resources. Now, most people who live in areas without traditional water sources rely on various unofficial water sources such as rivers, streams, and rainfall.

Households use these unofficial water sources for all their everyday activities, including drinking, according to a Sunyani West DWST interview. Residents of communities having access to traditional water sources also use unofficial water sources to supplement their everyday domestic and non-domestic activities (Sector et al. 2012).

The Asuogya village is comprised of households without access to a formal water supply. A little creek on the outskirts of town is essential to the community (Figure 3). The brook serves as their only water source for all their operations. Residents of Asuogya must walk for roughly 15 minutes to get to the creek. All domestic tasks, including farming, cooking, bathing, and washing, use the same water supply. On rare occasions, herders may bring their livestock to the same stream to drink. The creek also serves as a boundary between the towns of Asuogya and Agyakojokurom. People practically had to walk across the water to get to the other village. Not only do people cross the lake to get to the next town, but so do cars and motorcycles. As a result, the creek is seriously polluted. Because they lack the resources to filter the water themselves, people are forced to utilize contaminated water in that way. During the dry season, most of Ghana's rivers dry up, and the stream in Asuogya is no exception. And as a result, getting water during the dry season is difficult for the populace.

Figure 3 Stream located in Asuogya

Source: (Author 2023)

Hand pumps are currently running at a rate of more than 80 % in the Sunyani District. Only one in five of these handpumps, however, provide dependable, accessible, and high-quality services. Handpumps were found to be inferior to piped schemes in terms of functionality and service standards. Many Water and Sanitation Management Teams fall short of the benchmarks for governance, operations, and financial metrics set by the service providers. Only five of the Limited Mechanized Boreholes (LMBs) in Sunyani West Municipality are community-managed, whereas 76 % of them are managed privately (by Water and Sanitation Management Teams). Others are overseen by institutions (such as churches, hospitals, or schools). About half of the handpumps in Sunyani West Municipal are controlled by Small Community Water and Sanitation Management Teams (WSMT-SC), and the remaining 20 % are managed by private persons. The remaining handpumps are either not managed (15 %) or are run by healthcare facilities, churches, or schools. Less than 50 % of the WSMT-SC achieved most of the benchmarks for governance, operational, and financial indicators over the past three years.

1.5.7 Water Supply Status

Table 2 Water Supply Status for Sunyani West Municipal

Area Council	Number of handpumps	Number of small-town water system	Number of limited mechanized
Awua dumasi	44	1	32
Odumasi No 1	58	0	20
Fiapre	52	1	27
Nsuare	53	0	35
Chiraa	58	1	26
Koduakrom	55	0	0
Dumasua	35	0	8
Total	**355**	**3**	**158**

Source: (Author, 2023)

Table 2 displays the water supply situation for Sunyani West Municipality. Over 80 % of the time, hand pumps have been the source of water in the Sunyani District.

However, just one out of every five of these handpumps provides dependable, easily accessible, and high-quality services.

A piped system was found to have better functioning and service levels than handpumps. In terms of governance, operations, and financial service provider KPIs, many water and sanitation management teams fall short of objectives. The table illustrates how insufficiently GWCL distributes water in comparison to the local population. Most of the communities nearby and on the periphery of the city suffer from water scarcity as a result of the absence of water distribution expansion. Management must be improved, and major efforts must be made into improving water distribution systems, if there is to be adequate supply to meet the population's demand. The development and presentation of alternative water treatment methods that could help provide Asuogya's population with safe and sustainable water will be the main topic of this essay. Additional conditions must be satisfied to maintain water usage effectively and to guarantee cleanliness.

1.5.8 Water Services in Sunyani West District

Water for Odomase's public standpipes, Kwatire, Fiapre, Chiraa, and Dumasua is provided by the Ghana Water Company Ltd. The small community of Nsoatre received water as a result of another GWCL project (Figure 4). The district also receives water via a sizable number of handpumps and sparsely automated boreholes (LMBs). In the previous three years, more water supply infrastructure has been built. The District Assembly and groups like the Catholic Secretariat and the African Assistance Plan have donated more handpumps. Private initiatives have regularly been used to establish new LMBs. Over the past three years, the quantity of non-operational handpumps has varied between 12 and 20 %. This rising backlog can be primarily attributed to the steady growth in the number of broken-down handpumps that went unrepaired between 2013 and 2014 (Agbemor 2014).

Figure 4 Sunyani Mechanised Water Project – Anglican Aid

Source: (Anglican Aid n.d.)

The two GWCL piped schemes that supply water to the district were discovered to have continued to run throughout the previous three years at the time of assessment. The standpipe functionality of these plans, however, decreased from 100 % in 2012 to 81 % in 2013 and 64 % in 2014. It was seen that GWCL standpipes were being abandoned because residents of towns like Kobedi had hand-dug wells inside their homes. Out of a total of 14 limited mechanized boreholes (LMBs), only one (2 %) and two (2 %) were not in use in 2013 and 2014, respectively. A disproportionately high number of LMBs were therefore operating as a result. The District Assembly and groups like the Catholic Secretariat and the African Assistance Plan have donated more handpumps. Private initiatives have regularly been used to build new LMBs (Agbemor 2014).

20 % of the handpumps are administered by private individuals, and 50 % are controlled by Small Community Water and Sanitation Management Teams (WSMT-SC). About 15 % of the hand pumps that are still in use are either unmanaged or are under the control of institutions like churches, schools, or medical facilities. Less than 50 % of the WSMT-SC met the benchmarks for the bulk of the governance, operational, and financial measures over the past three years. Several WSMT-SCs performed exceptionally poorly in several categories, including financial management, water quality testing, and WSMT-SC composition. They asserted that there was no political interference with their business

operations and that more than half of WSMT-SCs often met the threshold on the breakdown repairs indicator. The proportion of WSMT-SC that meets the criteria has decreased in several ways. It was underlined that between 2012 and 2014, the District's Works Department assumed leadership in organizing water, sanitation, and hygiene (WASH) operations and complied with a set of hiring criteria when choosing people from other linked district units to do WASH activities. Between 2012 and 2013, the district's spending on water and related operations increased by 64 %, making it possible to finally achieve the indicator for "budget allocation and utilization" in 2014 (Agbemor 2014).

Figure 5 Sunyani Water Supply System

Source: (News Ghana 2022)

The Ghana Water Company Limited (GWCL) and Ghanaian authorities are collaborating on a project to improve the region's capital, Sunyani, and other areas' access to drinking water. The project entails building infrastructure to raise the Sunyani water treatment facility's daily capacity from 6,819 cubic meters (m3) to 55,000 m3 (Figure 6). The 1962-built Sunyani was unable to provide the 6 million gallons (27,000 m3) of water needed each day by the almost 200,000 residents in the broader Sunyani area. The project will reduce strain on the water table by storing rainwater because Sunyani currently relies on groundwater pumping facilities to supply its water demands (Moraes 2022).

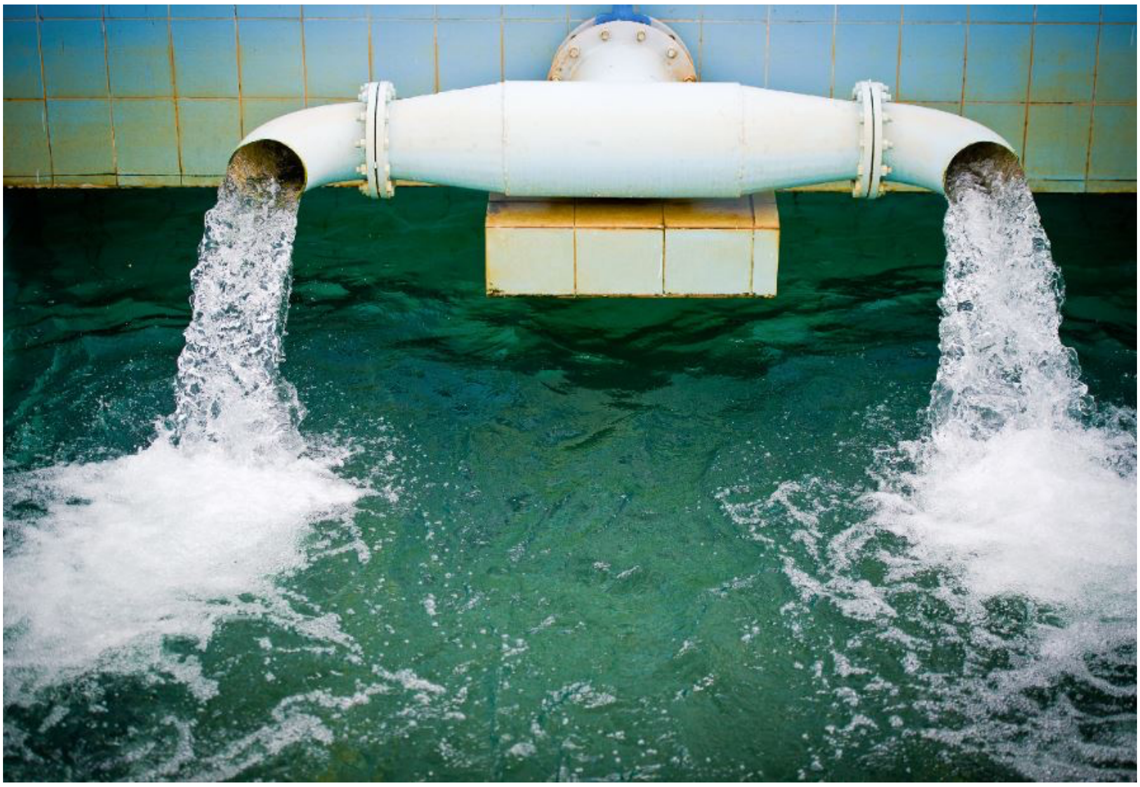

Figure 6 Sunyani water supply extension project in Ghana to commence
Source: (Anyango 2023)

A power line to feed the entire site will also be built, along with 93 km of transmission pipes, 10,000 residential meters, lab and chemical storage facilities, two booster stations and standpipes, and 10,000 residential meters. Locals in the Sunyani West Municipality's surrounding communities of Chiraa, Fiapre, Nsoatre, Mantukwa, Dumasua, Odomase, Kwatire, and others would benefit from the project's overall completion by November 2025. In addition, 93 km of transmission pipes, 10,000 residential meters, lab and chemical storage facilities, two booster stations and standpipes, and a power line to supply the entire site will all be installed. The general completion of the project by November 2025 will help the locals in the nearby settlements of Chiraa, Fiapre, Nsoatre, Mantukwa, Dumasua, Odomase, Kwatire, and other communities in the Sunyani West Municipality (Anyango 2023).

2 Aims of the Thesis

The aim of this study is to examine the level of water contamination in three water sources in Asuogya, Bono Region, Ghana, and to propose technologies that would help the locals maintain safe and sustainable water quality. To accomplish this, we analyze and classify many water treatment methods. The suggested approaches must follow WHO guidelines for safe drinking water. These told technologies should be able to produce water that complies with WHO standards for safe drinking water.

Specific Objective

The thesis also aims to:

- To identify the water purification technologies available through a literature review.
- To analyze the quality of water in Asuogya by testing the three water samples to find out the level of population.
- To propose water purification technologies which will provide safe and sustainable water for the people of Asuogya (in terms of cost, efficiency and the people in general).

3 Materials and Methods

The study begins with the collection of water samples in Asuogya for use as primary data as shown in Figure 7. The secondary data which is gathered from scientific literature, articles and publications about water treatment, comes next. After acquiring preliminary data, it is examined at the labs of the Ghana Water Company (Sunyani West Municipal) and the Czech University of Life Sciences Prague to compare the results of the two tests.

The data is then analyzed, rated, and processed to determine the quality of the water samples. The use of secondary data supports the use of primary data. By WHO recommendations, the final phase is to propose several technological possibilities for water purification that could maintain the water quality at a safe and sustainable level.

Figure 7 The researcher fetching water from the Asuogya stream

Source: (Author, 2023)

3.1 Study Area

There are about 420 people living in Asuogya, a small town in the Bono Region's Sunyani West District (Figure 8). The Bono region is made up of 6 districts and 6 municipals (Bono Regional Co-ordinating Council 2021). Most of the population relies primarily on agriculture for employment. The primary water sources used by the inhabitants of Asuogya for drinking, farming, and other activities are the river in Kwasikorankurom, the borehole nearby, and the stream. A tiny percentage of the village's residents use rainwater for household duties during the rainy season. Boiling and borehole water sources provide the majority of the village's safe drinking water. Even though the water quality from GWCL is acceptable and may be directly consumed, towns like Asuogya are not included in the distribution of this sustainable and safe water.

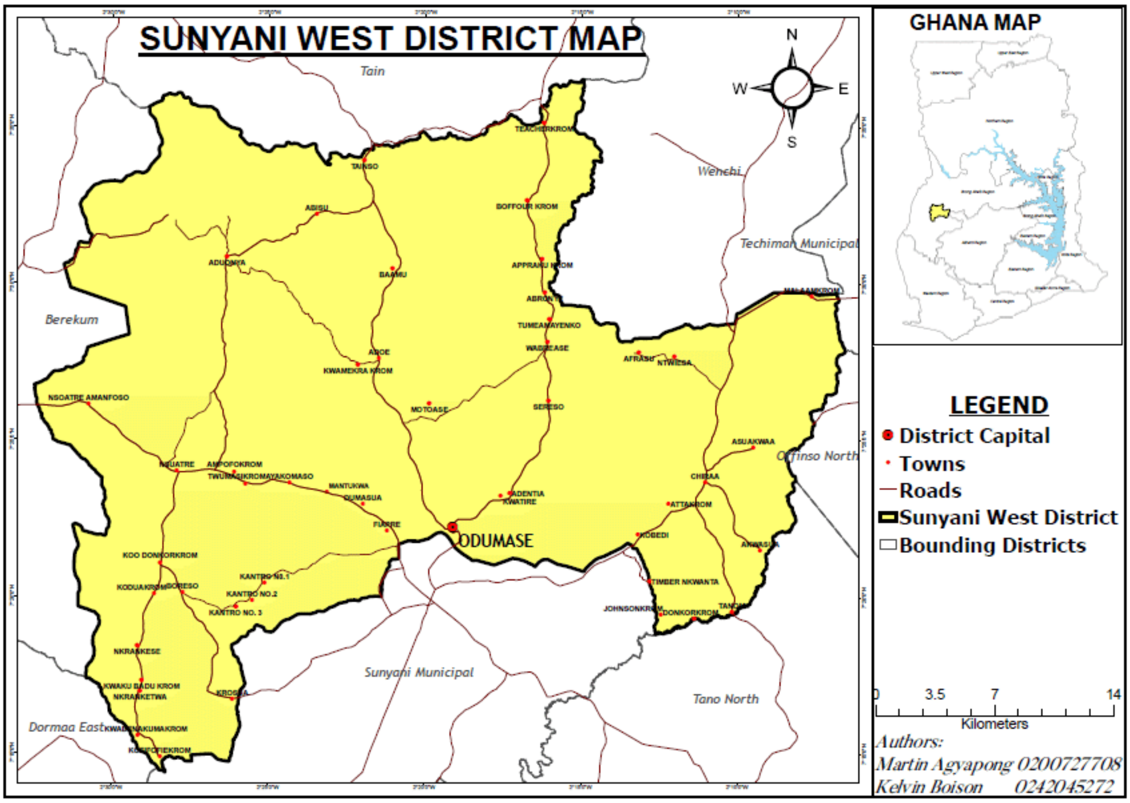

Figure 8: Sunyani West District Map

Source: (Agbemor et al. 2017)

3.2 Data Collection

The study's data was collected in Asuogya in the Sunyani West of the Bono Region of Ghana. This research thesis is led by Doc. Ing. Vladimir Krepl CSc. This research aims to learn about the water composition in Asuogya from various sources and propose a safe and sustainable water treatment for the village. The origins of water are the Kwasikorankurom River, the Asuogya Stream and a borehole (Figure 9). Each analysis sample was collected in 2-litre plastic bottles by the researcher. Information from various scientific literature on water tested from primary sources was also acquired. Ghana Water Company Limited - Bono Region provided the initial findings from the test performed on the water samples.

Figure 9: Borehole and stream from Asuogya

Source: (Author, 2023)

3.3 Data Analysis

The information gathered was summarized and transformed into the primary goal of the research study. To determine the components, levels of contamination, and levels of pollution in the three water sources, samples were immediately sent to Ghana Water Company Ltd. - Bono region for testing. The Ghana Water Standards provided support for these analyses. The remaining water samples were then transported to the Czech Republic while being frozen to maintain their parameters. To compare and control the variations in the results and determine how the parameters of the various water bodies differ from one another, the water samples were tested once more at the Faculty of Agrobiology in CZU. The outcomes of the two tests are then compared to WHO standards. Scientific analysis of the data will also be done, and the results will be compared to studies that have already been published.

3.4 Limitations

One of the numerous challenges the research faced was the length of time the samples were kept until the tests were conducted, which may have impacted the detection levels of most elements in the water samples utilized in this study. Due to a lack of recent statistics from GWCL and other scientific water bases, secondary data sources on water quality in Asuogya and Sunyani West Municipal were also constrained. In these circumstances, the researcher was unable to obtain the GWCL yearly water test sample results report; staff indicated that these results were no longer accessible to the general public, which included researchers. Finally, due to limitations in the test devices, GWCL was unable to test for several parameters in the water samples.

4 Results

4.1 Water Test Report

Table 3 Water test report by Ghana Water Company Limited

Parameters	Unit	Methods	Ghana GDL	WHO GDL	Borehole	Asuogya Stream	Ahanyaso River
Temperature	℃		-	-	27.8	28.1	25
pH	-	Electrometric	6.5 - 8.5	8	7.2	7.7	8.2
Turbidity	NTU	Nephelometric	5	5	0.14	17.6	18
Conductivity	µS/cm	Electrometric	-	-	708	312	219
Total Dissolved Solids	mg/l	Electrometric	1000	600	354	156	110
Alkalinity	mg/l	Titrimetric	-	-	590	222	144
Ca	mg/l	Titrimetric	-	100	40.8	25.6	24
Mg	mg/l	Titrimetric	-	-	56.86	13.12	5.35
Cl-	mg/l	Argentometric titration	250	-	96	84	56
NO2-	mg/l	HACH 10019	3.0	3	0	0	0.01
N03-	mg/l	HACH 8039	50	50	4	2.2	1.7
SO42-	mg/l	HACH 8051	250	250	7	1	2
F-	mg/l	HACH 8029	1.5	1.5	0.1	0.27	0.14
Fe	mg/l	HACH 8008	0.3	-	0.01	0.52	1.26
Mn	mg/l	HACH 8034	0.4	0.5	0.1	0.3	0.4
Cr	mg/l	HACH 10218	0.05	0.05	0.05	0	0
Al	mg/l	HACH 8012	0.2	0.2	0.08	0.04	0.06
As	mg/l	2822800(EZ arsenic)	0.01	0.01	0	0	0

Source: (Author 2023)

Table 3 illustrates the water test report done by the Ghana Water Company Ltd in Ghana. The researcher gathered the sample from three water bodies in Asuogya and its surroundings. The results suggest that there are various pollutants in the water sources.

Table 4 Water Test Report from CZU

Parameters	Unit	Ghana Standard Specification	WHO Standard	K Borehole	Asuogya Stream	Ahanyaso River
TOC	mg/l	-	-	0.05796	8.32235	9.663951
TC	mg/l	-	-	136.7511	56.26735	71.42897
IC	mg/l	-	-	136.6932	61.76502	47.945
TN	mg/l	-	-	5.294785	1.195179	1.81293
F-	mg/l	1.5	1.5	0.09	0.269	0.255
Cl	mg/l	-	5	50.037	49.581	43.746
NO2-	mg/l	3.0	3.0	0.646	1.106	2.2742
N-NO2	mg/l	-	-	0.1938	0.3318	0.8226
Br-	mg/l	-	-	0.17	0.247	0.292
N03-	mg/l	50	50	24.43	1.592	2.56
N-N03	mg/l	-	-	5.52118	0.359792	0.57856
P043-	mg/l	-	-	0.28	0.327	0.26
TP	mg/l	-	0.009	0.098	0.159	0.137
S042-	mg/l	250	250	25.62	0.416	6.891
N-NH4+	mg/l	-	-	0.017723	0.019517	0.017224
PH		6.5-8.5	8	6.94	8.7	8.61
Conductivity	µS/cm	-	-	1270	548	657
Norg	mg/l	-	-	5.732703	0.711109	1.418384

Source: (Author,2023)

Table 4 illustrates the water test report done by the Agrobiology faculty at the Czech University of Life Sciences.

Temperature, conductivity, pH, turbidity, and other chemical and physical parameters were evaluated in this study. A range of 6.5 to 8.5 is frequently required by Ghanaian water rules, but the WHO recommends pH values of 8. Water tastes more acidic when the pH is higher than 8.5. Although a higher pH may not be hazardous to you, it might cause dryness, itchiness, and inflammation of the skin (Robert Ashley 2018). With results of 8.7 and 8.6, respectively, the test report in Table 5 (water test report by CZU) revealed a somewhat different finding, indicating that the pH of Asuogya stream and Ahanyaso river were slightly above the WHO standard limit and the Ghanaian legal limit as well. All three samples in Table 4 (water report test by Ghana Water Company Ltd.)

had pH values that were within WHO and Ghana Standard tolerances. Any contaminants, such as chemicals, minerals, pollutants, soil, or bedrock composition, that interact with a water source will lead to an imbalance in the water's natural pH. Whether the PH of the water is high or low, environmental factors have a considerable impact on it (Eldorado Marketing 2022). The slight change in pH also may be due to the means of storage and transportation as mentioned previously.

Current conductivity health recommendations from the WHO and the Ghana Water Guideline are absent. Any measuring standards were absent from any conductivity values. Even though there are no specific requirements for this, water should have a conductivity of less than 1400 S/cm. Water conductivity is influenced by both suspended contaminants and the number of ions present (O. Sakyi et al. 2018). The test results for conductivity in Table 3 showed 708 for the Kwasikorankurom borehole, 312 for the Asuogya stream and 219 for the Ahanyaso River, while in Table 4, the results showed 1270, 548 and 657 respectively. Conductivity can reveal a lot about the quality of the water. Significant changes in conductivity can be used as a sign of poor water quality due to runoff or other pollution sources. On a conductivity meter, an increase or decrease can be a sign of pollutants that are lowering the water's quality (Atlas Scientific 2021).

The WHO deems water temperatures between 28 and 29 °C to be suitable (Hadzi et al. 2018). All temperatures recorded were below or within the WHO standards range.

The turbidity readings in Table 4 were 0.14, 17.6, and 18 NTU. The WHO and Ghana Water have established a turbidity standard of 5 NTU. The Asuogya Stream and Ahanyaso River's high turbidity may be brought on by the fact that they are surface waters, which are known to have higher turbidity than groundwater. Asuogya Stream and Ahanyaso River are surrounded by farms, so there may be a substantial amount of turbidity in these bodies of water as a result of these farmers' activities. Water appears cloudy or murky when turbidity, or suspended or dissolved particles, are present. High turbidity can have a negative effect on aquatic life, raise the cost of water treatment for drinking in the food processing industry, and drastically reduce the aesthetic value of lakes and streams. Recreation and tourism are impacted by these factors (Peterson & Gunderson 2008).

The results of the heavy metal concentration in the 3 water bodies are presented in Tables 3 and 4. In assessing the heavy metal concentration from the 3 water samples, the levels were compared with the Ghana Water Standards (Ministry of Water Resource Works and Housing 2015) and WHO quality guidelines (Herschy 2012). The trace of the heavy metals Cl-, NO2-, NO3-, SO42-, F-, Cr, Ca, As, and Al from the 3 water samples was relatively lower as compared to the WHO guidelines and Ghanaian quality standards. The research also analysed other trace elements in the water samples which are not so commonly found in water bodies in Ghana. These elements were TC, IC, TN, Br-, Mg, and N-NH4+. There are currently no guidelines from WHO or Ghana Water Guideline for these elements to measure up to. A high-level concentration of Mn of 0.1 mg/l was found in the Kwasikorankurom borehole, 0.3 mg/l in the Asuogya stream and 0.4 mg/l in the Ahanyaso River. Although these concentrations did not violate Ghana's water standards and WHO's guideline for Mn, manganese in water supplies that are higher than 0.1 mg/l stains clothing and causes unfavourable tastes in water. The WHO norm of 0.5 mg/l and the identified health risks surpass the allowed limit of 0.1 mg/l base value of 0.4 mg/l in Ghanaian water standards because concentrations of 0.2 mg/l frequently result in a coating on pipes that may flake off as a black precipitate (Herschy 2012). Manganese is an essential mineral for our bodies; thus, they need trace amounts of it. It aids the body's enzymes in carbohydrate, protein, and lipid digestion (Harvard 2019). Although our bodies need manganese to be healthy, too much of it can be dangerous. Children and adults may experience memory, attention, and motor ability impairment after consuming manganese-rich water over an extended period. When a newborn is younger than one year old, drinking water with a high manganese level may result in learning and behavioural problems (Minnesota Department of Health 2016).

Trace elements of Fe were found in high levels in the water samples from the Asuogya Stream and Ahanyaso River as shown in Table 3. The story of Fe in the Asuogya stream was 0.52 mg/l and 1.26 mg/l in that of the Ahanyaso River which exceeds the Ghana water standard of 0.3 mg/l. However, the Fe level in the Kwasikorankurom borehole had a shallow level of 0.01 mg/l. Iron is a necessary component of human nutrition. (Fe) is a naturally occurring substance in both plants and animals (World Health Organization 2003). Iron in water often doesn't present a health danger. Iron is required by the organism to carry oxygen through the blood. When drunk, water with a high iron level may taste metallic (MN Dept. of Health 2022). If excessive levels of iron are absorbed because they are stored there, the liver, lungs, and heart may suffer. Iron may not be as dangerous when used alone as it is when mixed with other substances. Lung disease may be brought on by iron dust (Lenntech B.V 2010).

Each sample from one of the three water bodies had a sizable concentration of Cl. Results from Kwasikorankurom were 50.037 mg/l for the Ahanyaso River, 49.581 mg/l for the Asuogya stream, and 43.746 mg/l overall. More chlorine above the WHO health standard of 5 mg/l is present in these water bodies. Chlorine (Cl) is produced in large quantities and is commonly used as a disinfectant in both commercial and residential settings (Herschy 2012). When the researcher was collecting data, there may have been a wastewater discharge into nearby water bodies, which may have contributed to the high concentration of chlorine in these water sources. Despite having a practical purpose, chlorine can nonetheless be harmful to people. Stomach pains, vomiting, and diarrhoea may occur if you consume excessive chlorine amounts. Additionally, it may cause dry and itchy skin. Trihalomethanes (THMs), which are produced when chlorine reacts with water, have been linked to heart disease, eczema, asthma, and even cancer (Hanson 2018). Due to these factors, it's imperative to routinely keep the amounts of chlorine in drinking water sources within a safe range.

The significance of the relationship between the heavy metals found in the 3 water samples was conducted by a statistical analysis Anova: Two-Factor without Replication based on the test results shown in Table 3, the water test report by Ghana Water Company Limited. The outcome is shown in Table 5. The significance of the link was acknowledged based on the p-value at a 5 % significance level ($P<0.05$). According to the findings, the results showed that the level of heavy metals differ from each other and there is no significant relationship between the heavy metals in the water bodies. The data revealed a value of 0.000002, indicating that the p-value is less than 0.05, demonstrating that the heavy metal concentrations in the three water samples are not the same.

Table 5 Statistical Analysis showing the level of heavy Metals in the Water samples

P>0.05	There is no difference
P<0.05	There is a difference

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	759230.98	17	44660.65	6.488778	0.000002	1.933207
Error	234013.54	34	6882.751			
Total	1043981.99	53				

Source: (Author 2023)

These results demonstrated that the inhabitants of Asuogya and its surroundings may be at risk of acquiring health issues due to the concentration of components in these bodies of water. It would be preferable if we suggested water-purification technologies that could help provide the population with clean drinking water and enhance their standard of living.

Before knowing the outcomes of the tests, the researcher decided to propose alternative methods for removing heavy metals from the contaminated water sources in Asuogya. Several technologies and implements will be covered in more detail below with an emphasis on trace elements including Mn, As, Fe, and Cl. Water must be managed and maintained as a natural resource for distribution, consumption, and sanitary purposes to maintain public health and agricultural output. Ensuring that people have access to clean drinking water, can be encouraged. Asuogya residents must make efficient use of the limited water resources to ensure that others who are less fortunate have access to safe drinking water. Many people must travel a considerable distance to get access to water because it is so limited in many areas.

Based on the results of the water sample testing, we must choose a purification technique that is suitable for the area and economically viable so that this project can be completed in the future and benefit the populace. To achieve WHO drinking water standards, the water needs to be regulated. Due to a lack of resources, technology, and government cooperation, the region has experienced water shortages and has been unable to address the problem. The suggested technique must be used to reduce the levels of Mn, Fe, Cl, and turbidity seen in water samples from Asuogya.

4.2 Turbidity Removal in Water.

The research must address how to lower the level of turbidity found in the water samples because the study's objective is to diminish the various heavy metals found in water. High turbidity levels can significantly increase the need for chlorine because they can encourage bacterial growth, protect microorganisms from disinfection, and promote bacterial development. Light cannot pass through turbid water because of the suspended particles that are responsible for it (Herschy 2012). According to the WHO, turbidity may not necessarily be harmful to your health, but it does indicate the presence of pollutants, particularly in untreated surface water, that are harmful to your health.

The acceptable level of turbidity is 5 NTU. The Ahanyaso River and Asuogya Stream tested positive for higher concentrations of 17.6 and 18 NTU, according to the test results. Data indicate a connection between turbidity and an increased risk of digestive disorders. This may be the case because turbidity needs to be studied and its causes handled because a high level of turbidity could be an indicator of microbial contamination source (Herschy 2012). This inspired the researcher to look into water purifying methods to aid the Asuogya people. Colloids in water are destabilized by the Coagulation flocculation process, which causes them to aggregate and then be physically removed from the water. This method, together with filtration and sedimentation, can minimize turbidity (Olszak 2022). Both flocculation and coagulation are methods for overcoming the forces holding suspended particles in place. To make it easier to remove the particles from the liquid, coagulation and flocculation reduce the charges of the particles and increase their diameters (James Greenwood 2022). Organic and Inorganic coagulants are the 2 most common types used in the treatment of wastewater. The two kinds of coagulants that are most frequently employed to treat wastewater are organic and inorganic. Polyamines, polytannates, and Polydiallyldimethylammonium chlorides (poly DADMACs) are examples of organic coagulants, whereas ferric sulphate and aluminium coagulants such as aluminium sulphate and aluminium chloride are examples of inorganic coagulants. Ferrous, ferric chloride, and ferric chloride sulphate are referenced. (James Greenwood 2022).

The processes of settling and decanting are another method for removing turbidity from water. During the decanting and settling procedure, moisture is left to sit for two to twenty-four hours to allow particles to sink to the bottom of the container. The water and the particles can be separated by pouring the clear water at the top of the container into another container. Although only a small amount of equipment is required, this approach takes a very long time for technologies to Reduce Cl, Fe, and Mn Levels Proposed.

4.3 Proposal of Technologies to Mitigate the Level of Cl, Fe and Mn.

The planned technologies are going to be consistent with 3 essential aspects learned from the study: pollution levels mitigations, geographic region and the country's native conditions. In areas where the water contains unsafe levels of Cl, Fe and Mn, the immediate concern is to find them a secure supply of water. There are 2 options: To find a replacement safe supply or remove these heavy metals in contaminated sources. There are many ways to reduce Cl, Fe and Mn from water, the following vital ways are mentioned below:

- Distillation
- Ion Exchange
- Activated Carbon Treatment
- Reverse Osmosis

4.3.1 Distillation

Distillation is the process of selectively evaporating and condensing each component from a liquid mixture (Kelly 2022). It is commonly considered one of the earliest purifying techniques. It is the process of removing pure elements from a variety to purify a chemical (Figure 10). Distillation is an efficient method for removing bacteria, viruses, heavy metals, and other dissolved contaminants from water. Using this technique, it is possible to get rid of a wide range of pollutants in water, including nitrate, iron, lead, hardness, and some microorganisms. It takes a lot of labour to distil water. One gallon of filtered water is typically produced by a countertop water distiller in 4 to 6 hours. Water is created one drop at a time (Campbell 2022).

There are several different distillation techniques, including fractional, simple, steam, and vacuum. The distillation procedure can be broken down into three simple steps: selecting a liquid from a mixture, purifying it, and then collecting the condensed liquid (CLIFTON Jessica 2021).

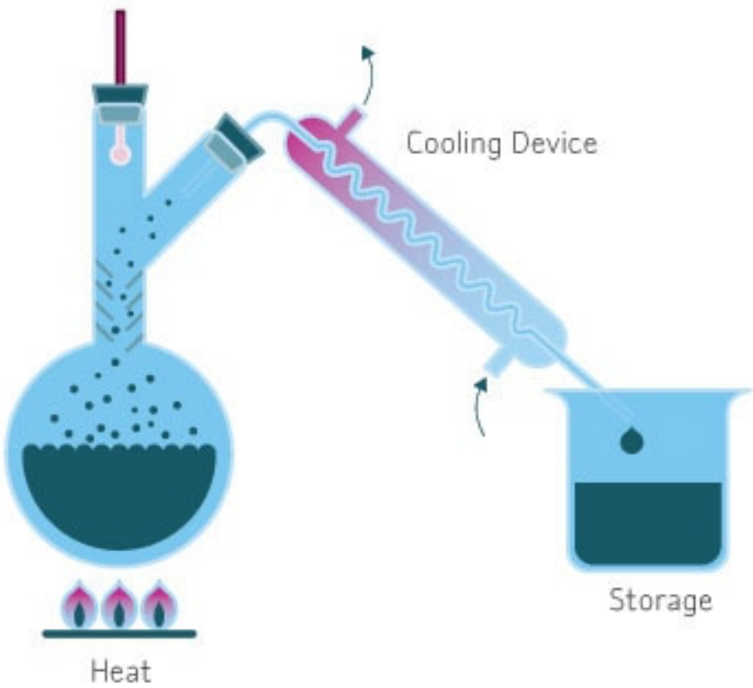

Figure 10 Distillation Process.

Source: (Merck 2018)

Most of the dissolved components are typically removed during distillation treatment (Figure 10). The boiling method also gets rid of biological contaminants. Distillation may, however, fail to remove some organic compounds. While organic contaminants that boil below water's boiling point will remain in the final product after filtering, those that boil over water's boiling point can be efficiently eliminated from the water. The two most popular techniques for treating distillation water are solar distillation and multistage flash distillation (IWA Publishing 2023).

The process of harnessing sunlight energy to separate pure water from salts or other impurities is known as solar distillation (Figure 11). The temperature of untreated water progressively increases as a result of heat absorption. Heat causes the water to evaporate, calm, and condense into vapour, leaving the contaminants behind. Solar distillers are frequently used in isolated locations with limited access to fresh water. A solar distiller relies on the scientific concepts of evaporation and condensation. Most distillers are simple, black-bottomed jars with water inside that have transparent glass or plastic tops. Evaporation is accelerated by sunlight that is absorbed by a dark substance. The glass top then keeps the evaporation in check and funnels it away. Most pollutants don't evaporate; thus, they stay in place (Hancock 2016). Distillers powered by the sun have many benefits. They come with a low-maintenance design that doesn't require energy or moving parts, and they are priced. They can be implemented at the household level and scaled up using programmable methods. Both reducing and adapting to climate change have benefits. There are certain drawbacks, though. The material needed for the distiller may be challenging to locate in some areas. It is unsuitable for higher consumption requirements because the distribution rate is frequently instead slow (6 litres of water each sunny day). Solar energy is only accessible during the day, and the waste stream from the distillation process might potentially create environmental pollution if it is not properly disposed of (Hancock 2016).

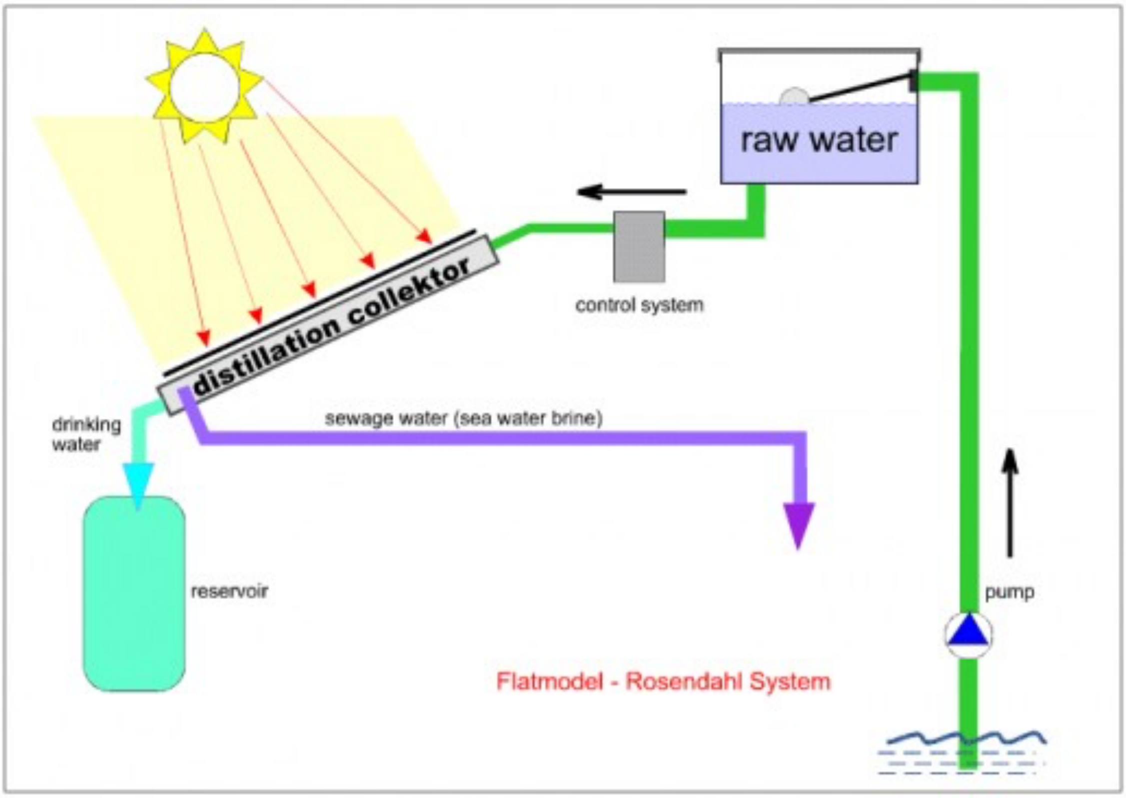

Figure 11 Solar Distillation

Source: (IWA Publishing 2023)

A multi-phase process is a multi-stage flash (MSF) distillation (Figure 12). Evaporation is used to extract fresh water from brine. A brine heater oversees heating the liquid till the initial inlet temperature value is reached before the first phase. Hot steam produced by a steam generator powers the brine heater. Since more vapour can be collected from salt water at a higher temperature, the distillation rate essentially increases more quickly. Integrated brine preheaters are also installed on top of each flash evaporator to slightly raise the temperature of the brine before it enters the heater. Preheating occurs as a result of the condensation of the vapour withdrawn from the same stage transferring its vaporization enthalpy to the liquid in the preheater pipes (Nannarone et al. 2017).

The parameters for flash evaporation in each flash chamber are fixed as soon as the brine enters the stage and falls below the saturation temperature value at that pressure. Because as it expands, the vapour fraction in the vapour-liquid combination widens as well, correlating to the amount of freshwater extracted from brine in the stage, this temperature gap, which is created by the depression, is related to the generation of freshwater. The drained brine must be returned to the reservoir while still protecting the environment and ecosystem, hence the output temperature cannot go beyond set parameters. Since the drain temperature is quickly achieved, the number of steps lowers for more considerable temperature differences (Nannarone et al. 2017).

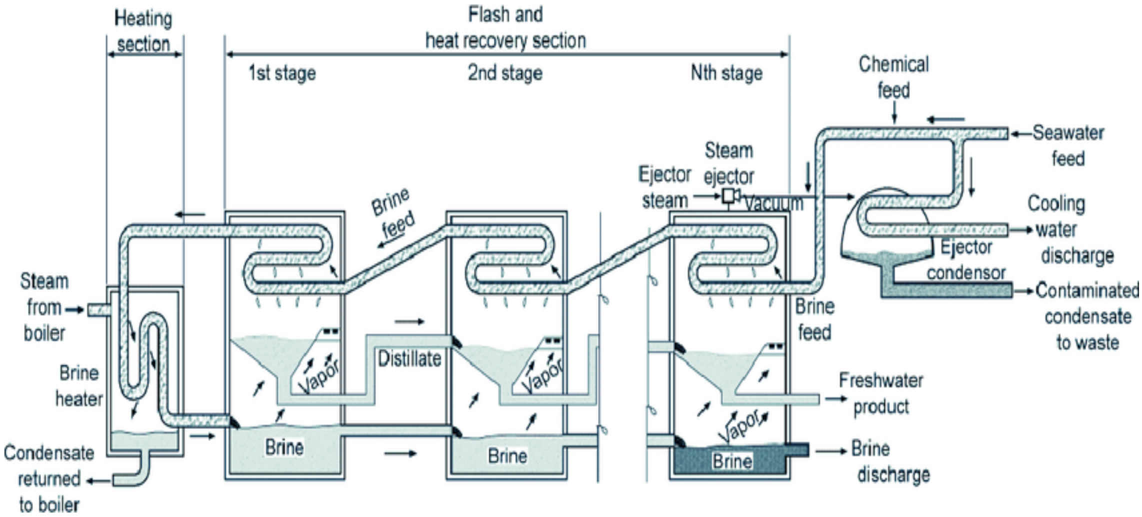

Figure 12 An illustration of the multi-stage flash distillation process

Source: (Aliku 2017)

4.3.2 Ion Exchange

Before use, water must be treated to remove many types of contaminants. Water can be filtered, and pollutants successfully removed using a variety of techniques and methods. Ion exchange is one of these treatments (John Victoria 2021). Water is passed through one or more beds of ion-exchange beads while it is deionized using the ion-exchange process. The beads absorb impurity ions from the water and exchange them for hydrogen and hydroxyl ions, so purifying it (Figure 14). Water pollutants are removed via ion exchange. It is said to be particularly effective and can minimize ionic levels in product water (Veolia 2021). The chemical process of ion exchange cleans water by removing dissolved ionic contaminants. Superior ions are used in their place, ones that won't damage the water's purity. The ion process occurs between a liquid (water) and a solid (zeolite or a resin material). Anions and cations are the two different categories of ions. Cations are positively charged whiles anions have a negative charge (John Victoria 2021).

The use of ions in technology has various benefits. It can regenerate the resin used and is very good at eliminating inorganic ions from water. Ions are employed in technology for a variety of reasons. It is more affordable than other water treatment methods in terms of initial expenditure. It is surprisingly good at removing inorganic ions from water. Additionally, it can replenish the used resin. But there are also disadvantages. The ineffectiveness of ion exchange technology to effectively remove microorganisms from water, high long-term running costs, and the release of salty water into the environment during ion exchange bed renewal are only a few of the disadvantages. It is regarded as being less expensive to start with than other water treatment techniques. There are, however, drawbacks as well. The regeneration process of ion exchange beds discharges salty water into the environment, it is unable to remove microorganisms from water efficiently, and operating ion exchange equipment has a high long-term cost (Sensorex 2022).

Figure 13 DI Water Recycle Ion Exchange System

Source: (Belmar Technologies 2023)

Zeolite or resin and water interact through an exchange mechanism. Throughout the process, the less desired molecules are exchanged for the more appealing ones. These beneficial ions are provided to the resin material. To remove ionic contaminants from water, these resins can be used singly or in tandem. Sodium ions are often employed to exchange positively charged ions with other positively charged ions that are present on the surface of the ion exchange resin while treating water. The anion exchange procedure involves the exchange of negatively charged ions, frequently chloride, that are present on the resin's surface (Fluence 2021).

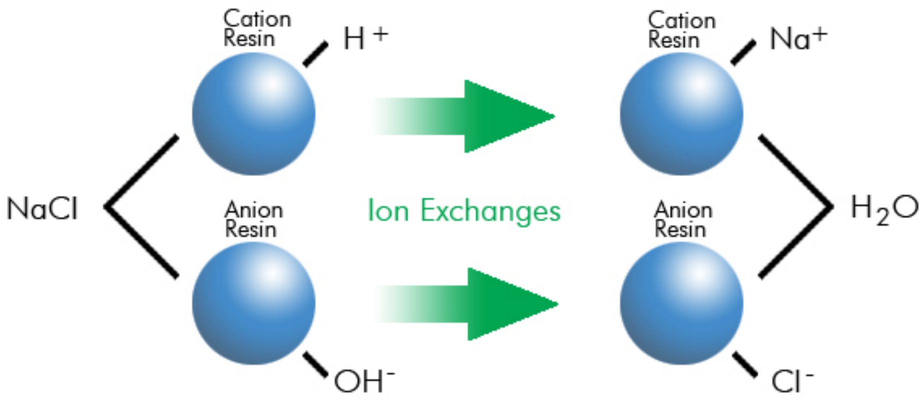

Figure 14 Ion Exchange Process

Source: (APEC Water 2023)

Resin material exchange is only partially possible. Each exchange site's usage will increase with time. The resin must be recharged or regenerated to return to its initial state after becoming unable to exchange ions due to usage. This can be accomplished using a chemical like sodium chloride, hydrochloric acid, sulfuric acid, or sodium hydroxide. The main by-product of the technique is referred to as "spent regenerant." It has a high concentration of total dissolved solids and retains all the removed ions as well as any extra regenerant ions. Regenerant can be treated in municipal wastewater treatment plants, but the outcomes may require monitoring (Fluence 2021).

Surface clogging, resin fouling, and mineral scaling can all reduce the efficiency of ion exchange for water treatment. Pre-treatment techniques like filtration and chemical additions can assist solve these issues.

Water softening (Figure 15) and deionization are the two most used ion exchange processes for treating water. Water softening aims at magnesium and calcium ions by replacing them with sodium ions. Because of its better ion exchange and absorption rates, sodium zeolite softening is the most used ion exchange water treatment (Atlas Scientific 2022).

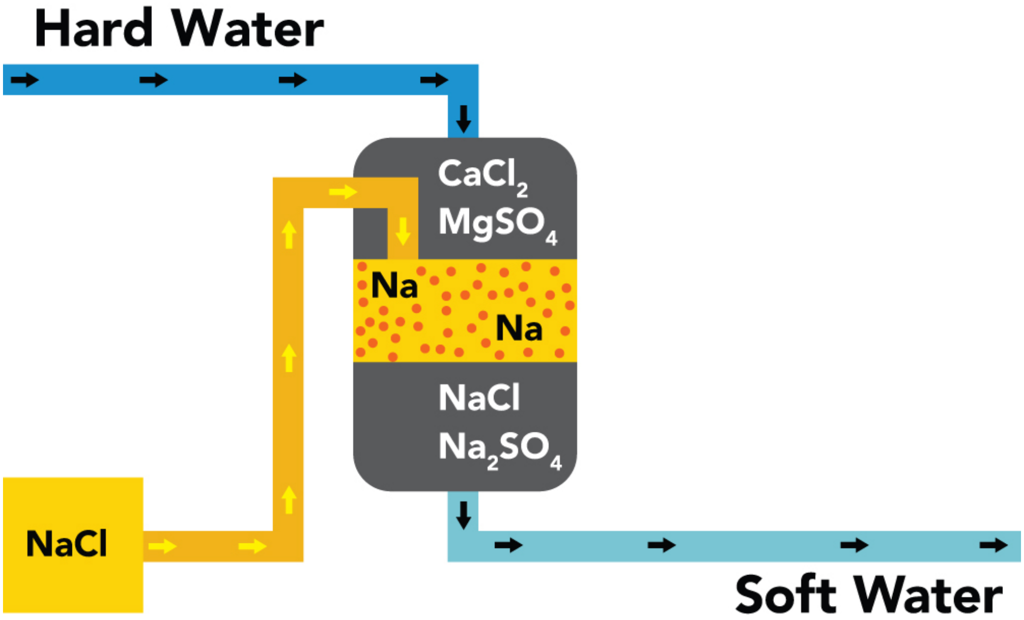

Figure 15 Water Softening

Source: (Atlas Scientific 2022)

In order to remove unwanted dissolved particles from water through ion attraction and exchange, synthetic resins are utilized in water deionization (Figure 16). Since the resin already contains positively charged hydrogen or hydroxide ions, it releases them for exchange (Atlas Scientific 2022).

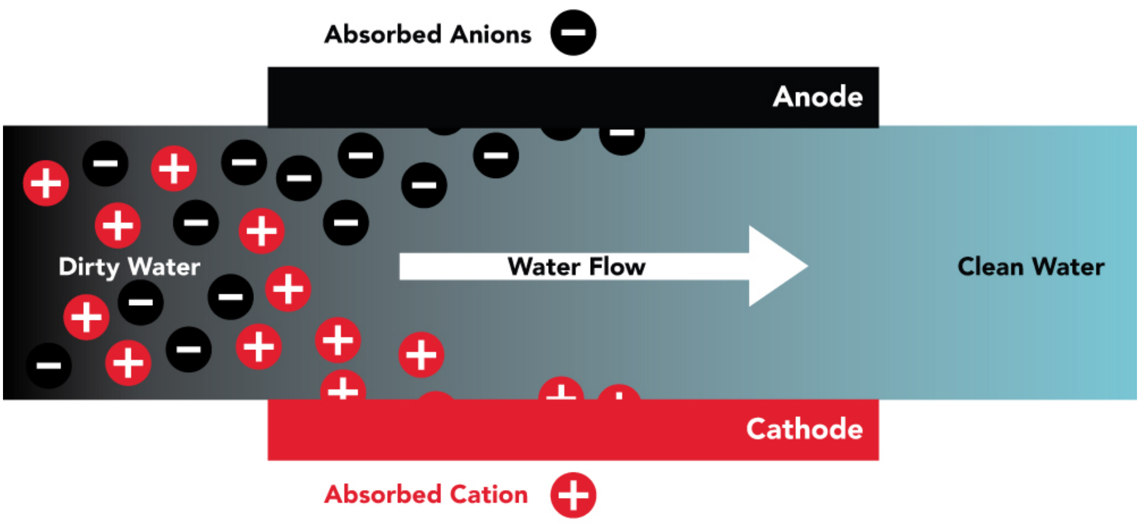

Figure 16 Water Deionization

Source: (Atlas Scientific 2022)

4.3.3 Activated Carbon Treatment

To remove dangerous contaminants from contaminated water and air, a material known as activated carbon is utilized. Granules of dark coal, wood, nutshells, or other carbon-containing elements make up this substance (Figure 17). Pollutants stick to the surface of the activated carbon granules as contaminated water or air travels through them and is drawn out of the water. Activated carbon may remove a variety of contaminants from water, including heavy metals (U.S. EPA 2012). The fundamental principle behind activated carbon purification is a phenomenon referred to as adsorption, in which molecules of liquid or gas are trapped by either the exterior or internal surface of a solid. The spectacle resembles an iron filings-holding magnet. Due to its substantial inner surface area, activated carbon is an excellent adsorption material (Desotec 2023). Both benefits and drawbacks might be associated with activated carbon. The flavour and smell of your drinking water might even be improved by using this filter media to remove contaminants. In addition to eliminating iodine and chlorine residues, it can also get rid of radon, detergents, some artificial contaminants (often pesticides), and volatile organic compounds (commonly paint thinners). Water sources can also be cleaned of heavy metals like lead, but only with a specific kind of activated carbon filter. The drawback is that activated carbon won't be able to eliminate some pollutants from the water supply, such as nitrates, fluoride, salt, bacteria, and compounds that make water harder. Many people need additional tools, a water softener, or both to get rid of them, especially if the water where they live is hard (Terry 2017).

Figure 17 Activated Carbon forms and shapes
Source: (DESOTEC 2023)

4.3.3.1 Physical Structure of Activated Carbon

Graphite microcrystals, single-plane reticular carbons, and amorphous carbons are the three elements that make up activated carbon, with graphite microcrystals constituting most of the substance. Activated carbon differs from graphite in that it has a distinct microcrystalline structure. The microcrystalline structure has an interlayer spacing of 0.34 and 0.35 nanometres (nm). It is challenging to convert into graphite even at temperatures over 2000 °C. Non-graphite microcrystals are this kind of microcrystalline structure, and they make up most of the activated carbon (Jiang et al. 2019).

Processing can transform the graphite structure, which has a constant microcrystalline arrangement, into graphite. Due to its non-graphite microcrystalline structure, activated carbon has a developed pore structure that can be seen in the pore size distribution. One nanometre to thousands of nanometres is the wide range of pore diameters seen in activated carbon. The size of activated carbon pore can be categorized into three groups: lower than 2 nm, mesoporous between 2 and 50 nm, and greater than 50 nm (Jiang et al. 2019).

4.3.3.2 Chemical Structure of Activated Carbon

The fundamental chemical structure of activated carbon closely mimics that of pure graphite. Layers of fused hexagons are held together by weak van de Waals forces to form the graphite crystal. Carbon-carbon bonds have layers together (Desotec 2023). Activated carbon's chemical makeup as well as its physical structure affects how well it can adsorb substances.

The aromatic sheet's edge chemical connection breaks during the carbonization stage, creating an edge carbon atom with unpaired electrons. These marginal carbon atoms contain unsaturated chemical bonds that can interact with heterocyclic atoms like oxygen, hydrogen, nitrogen, and sulfur to create a variety of surface groups. Undoubtedly, these surface groups have an impact on the adsorption capabilities of activated carbon. Activated carbon has acidic, alkaline, and neutral surface groups (Jiang et al. 2019). With carboxyl, lactone, hydroxyl carbonyl, phenol, and ether, activated carbon can facilitate alkaline adsorption. Cyclic ketones and their derivatives are the main components of primary external functional groups, which help the features of acidic adsorption on activated carbon.

4.3.3.3 Carbon Filters

Activated carbon filtration (Figure 18) is a popular method that relies on the adsorption of impurities onto a filter's surface. This method can be used to successfully remove some contaminants from drinking water or wastewater, such as pollution, fluorine, chlorine, and foul tastes and odours (Mazille & Spuhler 2018). Through the removal of impurities from water, carbon filters serve as barriers. Because carbon filters eliminate water pollutants, foods and beverages taste and smell better. By adsorption, carbon filters eliminate contaminants. Adsorption takes in the particles in a similar way to how a sponge takes in water. Since they have a large surface area and are very porous, carbon filters are effective at removing undesirable tastes, odours, and other contaminants from water Microns are used to measure the tiny pores. As the micron size gets smaller, the filtering gets finer (Woodard 2019).

Figure 18 Activated Carbon Filters

Source: (Pharmaceutical Guidelines 2013)

The two primary forms of activated carbon used in water filtration are carbon blocks and granular activated carbon (GAC). Both types of carbon use carbon that has been finely powdered. GAC's source carbon is ground into particles larger than 0.30 mm and smaller than 0.84 mm. To produce carbon blocks, the particles are further crushed to a "fine mesh" that is 7 to 19 times smaller than GAC (0.045 mm 0.18 mm) (CBtech 2019).

An organic carbon filter medium, such as wood, coconut shells, coal, or peat, called granular activated carbon (GAC), is used to purify water. It is frequently used in applications involving fixed beds. A GAC filter (Figure 19) can be used to remove some substances from water, including organic contaminants and chemicals that give water a bad taste or smell, such as chlorine or hydrogen sulfide. Organic compounds with high molecular weight can be easily absorbed. Per- and poly-fluoroalkyl substances (PFAS), a pollutant that authorities are growing more concerned about, can be significantly reduced with the use of granular activated carbon (Tuser 2021). The loose activated carbon granules in GAC filters make it simple for water to travel through them. One way that water enters the cartridge is in contact with the carbon (Woodard 2019).

For many organic chemicals, GAC is a well-known method with excellent removal effectiveness (up to 99.9 %). The simplicity with which the adsorption media may be reclaimed is another benefit of regenerated carbon beds (US EPA 2021). The simplicity with which the adsorption media may be recycled is another benefit of regenerated carbon beds (US EPA 2021). Water also passes through carbon more quickly. Although GAC provides many advantages for treating water, it also has drawbacks. Water may be able to penetrate carbon, allowing pollution to spread (Woodard 2019). The media must be removed and replaced or regenerated when the GAC capacity is exhausted. In certain circumstances, disposing of the media may require obtaining specific permission for handling hazardous waste. The GAC capacity of a target contaminant can be decreased by other adsorbable pollutants in the water (US EPA 2021).

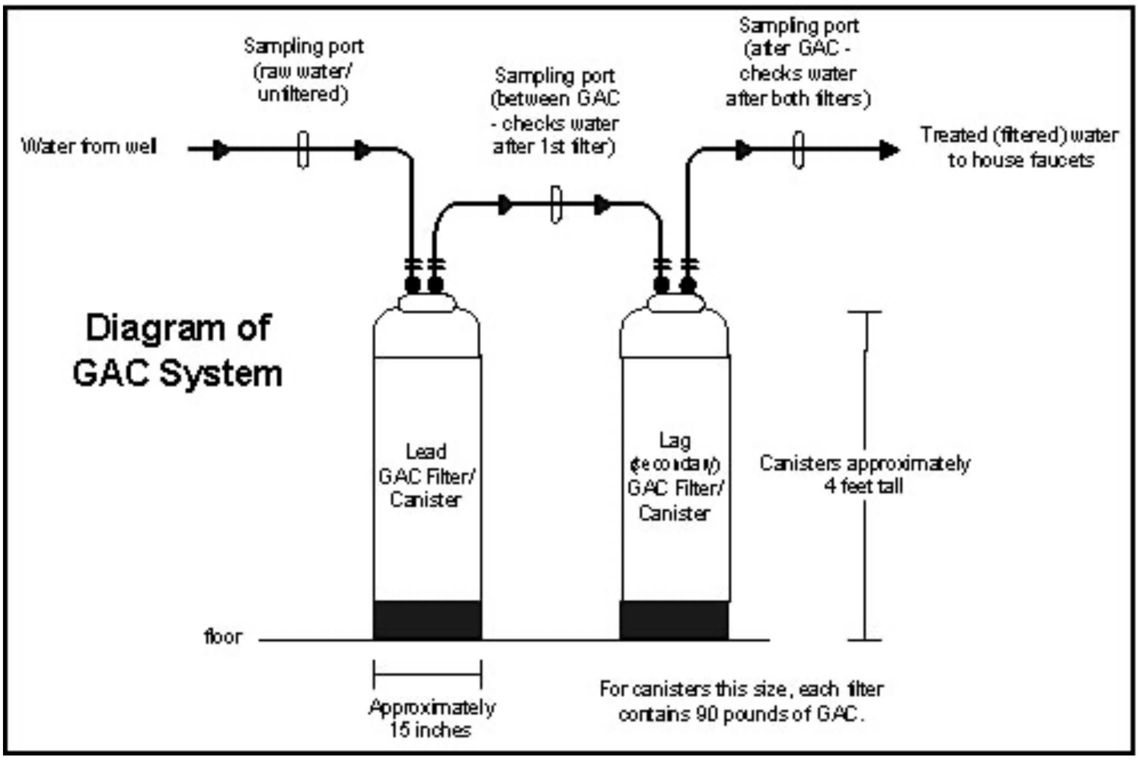

Figure 19 Diagram of GAC System

Source: (MinnesotaGov 2022)

The bonding ingredient that makes up only 15 % of the surface area of the small grains that make up Carbon Block holds them together. Filtered water exits the filter through the top after passing through the filter and entering through the side. When carbon is pulverized into a smaller, more specific granule, its surface increases (Woodard 2019). Particles of carbon are immobilized by carbon blocks, which improve performance uniformity and stop water from channelling. The loose carbon column is moved through by water, which takes the path of least resistance. A cartridge with predetermined dimensions is created from a carbon block. End caps are used to drive water through the static pores of the carbon block. The varied carbon granules all have the same pore structure, which makes carbon blocks more efficient in removing pollutants. The carbon block's continuous pore structure extends the time it is in contact with the filter media, improving its ability to remove contaminants (CBtech 2019).

Water filters with carbon blocks use a variety of techniques to remove impurities from drinking water. Mechanical filtration is the most obvious filtering method. Mechanical filtration removes particles that are too large to pass through the filter's pores, much like a sieve would. Particles, as fine as 0.5 microns can be mechanically filtered using carbon blocks (submicron).

Another filtration technique used in some carbon blocks with a specially constructed outer wrap is electrokinetic adsorption. The material creates a positive molecular charge that draws negative ions of contaminants when water travels through the outer wrap.

Physical adsorption is used in carbon block filters as well. Carbon attracts pollutants in this way. Particles of activated carbon attract and hold impurities due to their large surface areas. Compressed carbon blocks can avoid hiding the surface of the carbon by using specially designed binders, which increases the carbon's capacity to reduce pollution (CBtech 2019).

The advantage of carbon block filters is that they are more efficient than GAC. Compact carbon prevents channelling and is known to give 7–10 times more surface area in filters than GAC. It's not suited for circumstances where a lot of water needs to be filtered because it has the drawback of being slower and more flow-restrictive (Woodard 2019).

4.3.4 Reverse Osmosis Technology

Demineralize or deionize water by using the reverse osmosis (RO) technique, which involves pushing water through a semi-permeable membrane (Figure 20). It is a technique that removes the bulk of contaminants by pushing water against a semi-permeable membrane under pressure. The opposite of osmosis is reverse osmosis.

Reverse osmosis must be activated to occur, in contrast to osmosis, which naturally happens without energy (PureTec 2022). Reverse osmosis is a process that removes filths from unfiltered water, or feed water, by forcing water through a semipermeable membrane under pressure. To produce clean drinking water, water flows across a RO membrane from one side, which contains more impurities, to the other, which has fewer contaminants. Brine or rubbish is the term for residual concentrated water (John Woodward, 2022). Water molecules can flow by reverse osmosis, but most dissolved salts, chemicals, pathogens, and pyrogens cannot. Although pure water can pass through while most pollutants are kept at bay, demineralization or deionization of water requires pressure that is greater than the osmotic pressure that naturally occurs (PureTec 2022).

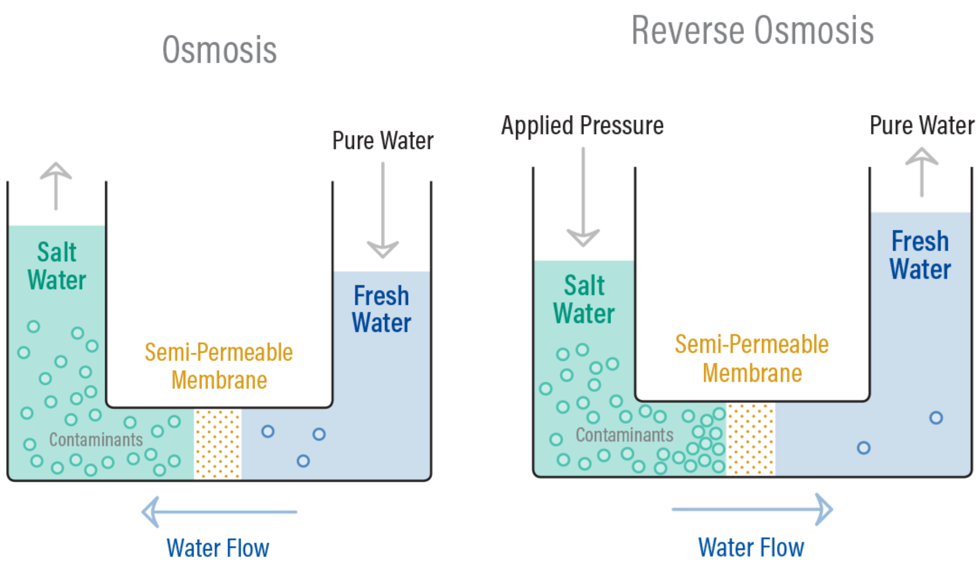

Figure 20 Osmosis and Reverse Osmosis Diagram

Source: (PureTec 2022)

The semipermeable membrane has minuscule pores that permit water molecules to pass through but bar passage of impurities. In other to achieve equilibrium on both sides, water must concentrate as it passes across the membrane during osmosis. Reverse osmosis, on the other hand, stops contaminants from piercing the side of the membrane with lower concentrations. For instance, when pressure is applied to a volume of seawater, only pure water passes through, and the salt is left behind (John Woodward, 2022).

4.3.4.1 Functions of Reverse Osmosis

Reverse osmosis works by utilizing a high-pressure pump to increase pressure on the salt side of the RO and force water past the semi-permeable RO membrane, leaving almost all the dissolved salts (between 95 % and 99 %) in the reject stream. The amount of pressure necessary depends on the salt concentration of the input water. The more concentrated the feed water is, the more force is needed to overcome the osmotic pressure. Permeate is the name for the collected freshwater. Brine or wastewater is the term for leftover concentrated water (PureTec 2022).

The typical filtration stages in reverse osmosis include a sediment filter, pre-carbon block, reverse osmosis membrane, and post-carbon filter (Figure 21). The sediment filter removes the largest particles, like dirt, sand, and rust, to prevent blockage of subsequent filters. The pre-carbon filter employs activated carbon to stop anything bigger than a grain of flour from passing through. In order to prevent the passage of chemical substances like chlorine and chloramines to the third filter, it also attracts and interacts with positively charged ions. The reverse osmosis membrane is then used to remove molecules heavier than water, such as salt, excessive lead, dissolved minerals, and fluoride. The post-carbon filter is what ultimately cleans the water (Quench 2019).

It is vital to comprehend that a RO system uses cross-filtration rather than conventional filtration, which catches pollutants within the filter material. When a solution flows through or crosses a filter having two outlets—one for filtered water and one for polluted water—cross-filtration takes place. Crossflow filtration enables water to remove pollutant build-up while simultaneously generating sufficient turbulence to maintain a clean membrane surface (PureTec 2022).

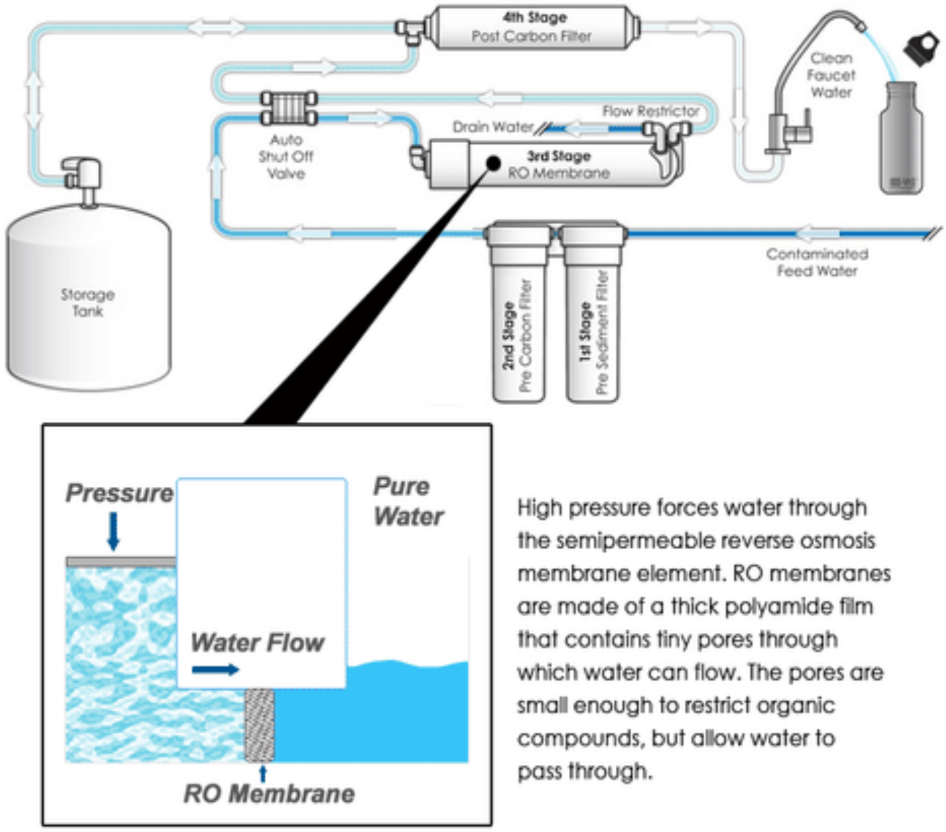

Figure 21 Stages of RO Systems

Source: (John Woodward 2022)

4.3.4.2 Contaminants that Reverse Osmosis Remove

A reverse osmosis system removes dissolved solids like fluoride and arsenic through the RO membrane. A RO system additionally has sediment and carbon filtering for additional savings. Carbon filters in a RO system remove chlorine as well as unfavourable tastes and odours and get rid of dirt and other particles. Salt, pesticides, and herbicides are only a few of the contaminants that are removed (John Woodward, 2022).

Although a reverse osmosis system should not be relied upon to eradicate bacteria and viruses, it removes up to 99 % or more of the dissolved salts (ions), particles, colloids, organics, bacteria, and pyrogens from the water supply. Based on their size and charge, pollutants are rejected by a RO membrane. An efficient RO system is likely to leave any impurity with a molecular weight greater than 200. The higher the ionic charge of a pollutant, the more likely it is that it won't be able to pass through the RO membrane. Sodium ions, which are monovalent and have only one charge, are not rejected by the RO membrane, in contrast to calcium, which has two leaders. Similarly to this, gases like

CO_2 are not effectively removed by a RO system because they are not significantly ionized (charged) while in solution and have a very low molecular weight. Because a RO system does not remove gases, the amount of CO_2 in the input water during the process of CO_2 being converted to carbonic acid may result in the pH level of the permeate water is somewhat lower than expected (PureTec 2022). Brackish, surface, and groundwater can all be successfully treated with reverse osmosis in both large and small flow applications.

4.3.5 Technology SWOT Analysis

SWOT analysis is being used to show which technology is best for the Asuogya region based on the findings. The SWOT analysis is a starting point for considering the area's remoteness, access to electricity, the country's existing economic potential, and the efficiency and efficacy of the technology over the area's toxins. Based on the SWOT analysis, distillation will be highly successful and efficient in the Asuogya region and its environs, even if reverse osmosis is the most effective for the mitigation of pollutants.

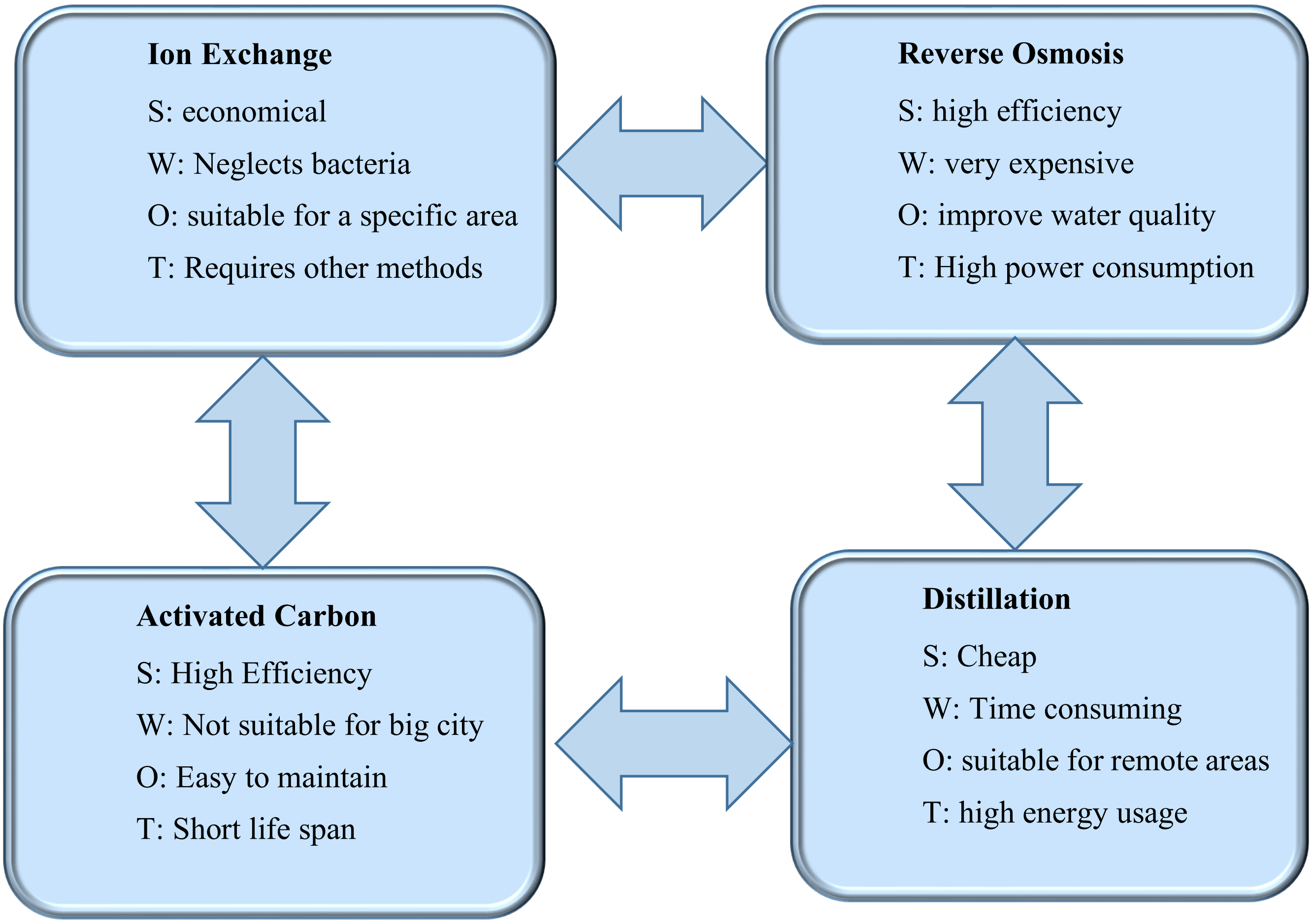

Figure 22 SWOT analysis of proposed technology

Source: (Author 2023)

Notes: Before accessing data on the costs and implementation capability of the technology, a simple SWOT analysis was chosen as a guideline for this project. In this situation, cheap refers to lesser prices as compared to other technologies, whereas highly expensive refers to the amount of capital needed to deploy the technology on the ground, considering raw materials, supply, and upkeep.

5 Discussion

Figure 23: Women fetching from a dirty water

Source: (Dzokpo 2019)

A large majority of people in Ghana still have very little access to clean, safe drinking water, especially in rural regions as shown in Figure 23 where women are seen fetching dirty water. In Ghana, one in ten people may take longer than 30 minutes to find better drinking water, according to UNICEF. Families in Ghana face the risk of consuming water contaminated with faeces in 76 % of cases. Although Ghana is known for its abundance of water bodies, marine life, and coastal resources, the nation still struggles to provide access to safe drinking water, especially in rural areas. Mining, farming, and urbanization have significantly contaminated the nation's freshwater supplies. Consuming contaminated water exposes people to illnesses like cholera, diarrhoea, and skin conditions. Children in Ghana, especially those from low-income households living in remote areas, experience morbidity as a result of contaminated drinking water. The development of the nation depends on everyone having access to clean, drinkable water. This study can help Asuogya's water quality and serve as a blueprint for rural development, namely by boosting rural community livelihood and environmental sustainability.

The results of the test samples revealed that the three water sources that were chosen in Asuogya and its surroundings had residues of heavy metals, making them unfit for human consumption. The water samples from the Asuogya Stream and Ahanyaso River had significant amounts of Fe, as seen in Table 4. The part of Fe in the Asuogya stream was 0.52 mg/l, and in the Ahanyaso River was 1.26 mg/l, both of which are higher than the 0.3 mg/l Ghanaian water standards. Large quantities of iron in water bodies are most likely caused by mining operations, according to Ghana's National Drinking Water Quality Management Framework. Acid mining wastes from pyrite tailings can release and transport heavy metals like iron, aluminium, and manganese (Ministry of Water Resource Works and Housing 2015). For humans, iron is a crucial nutrient. Iron in water is typically not harmful to one's health. Iron is required by the organism for the blood to carry oxygen. When drunk, water with a high iron content may taste metallic (MN Dept. of Health 2022). Significant amounts of iron that are absorbed are deposited in the liver, lungs, and heart, where they may cause harm to these crucial organs. The adverse effects of iron alone might not be as significant as those of its compounds. Lung disease may be brought on by iron dust (Lenntech B.V 2010). Due to the municipal waste dumpsite's location, a similar study carried out at Sunyani Municipal revealed a significant percentage of iron and other heavy metals in water bodies in the municipal. It demonstrated that sedimentation as a result of surface runoff following a wet season might be the cause of the elevated concentration of iron in the water bodies (Miwornunyuie & Akpoti 2016).

In most metropolitan areas, untreated sewage discharges from municipal waste have significantly contaminated the water supply. Release of untreated municipal waste from home and industrial wastewater, which produces odour and nutrient enrichment, culminating in an algal bloom, is progressively killing the lagoons and rivers around industrial districts. The quality of Ghana's surface and groundwater resources is declining as a result of the uncontrollable pollution levels brought on by "galamsey" (illegal mining), waste, leachate from chemical fertilizers and pesticides used in agriculture, chemicals for mining, and fishing. Solving these issues cannot be met using the current water management techniques. Water resources per person in Ghana have been getting scarcer for the past six years and counting (Yeleliere et al., 2018). This has motivated the investigation of practical and economical solutions that may be used to provide Asuogya and the communities around it with access to sustainable and safe water.

The three water bodies provided samples from each of which had significant amounts of chlorine. Kwasikorankurom Borehole reading was 50.037 mg/l, but the Asuogya stream was 49.581 mg/l and the Ahanyaso River's was 43.746 mg/l. These bodies of water have more chlorine than the WHO's recommended level of 5 mg/l. Chlorine (Cl) is produced in large quantities and is used extensively as a disinfectant in both commercial and residential settings (Herschy 2012). Despite having a helpful function, chlorine may nonetheless be harmful to humans. You could have nausea, diarrhoea, and stomach aches if you consume too much chlorine. Additionally, it could lead to dry and irritated skin. Trihalomethanes (THMs), produced when chlorine reacts with water, have been linked to heart disease, eczema, cancer, and a variety of other conditions (Hanson 2018). Due to these factors, it's imperative to routinely keep the amounts of chlorine in drinking water sources within a safe range.

Those numbers were 0.14, 17.6, and 18 NTU for turbidity. The turbidity standard set by the WHO and Ghana Water is 5 NTU. The fact that the Asuogya Stream and Ahanyaso River are surface waters, which are known to have higher turbidity than groundwater, causes an increased risk for turbidity. Particle size and shape, chemistry, and dissolved and suspended particles all have an impact on the turbidity of water. A few of the water quality indicators that can be used to describe turbidity are total suspended solids, volatile suspended solids, total dissolved solids, suspended sediment concentration, chlorophyll concentration, and particle size analysis. Additional factors, including flow, sediment source and composition, algae species, and sediment transport characteristics, can also provide important information on the turbidity in the water (Peterson & Gunderson 2008). High turbidity can be detrimental to aquatic life, raise the cost of water treatment for drinking and food processing, and drastically reduce the aesthetic value of lakes and streams (Peterson & Gunderson 2008). Leisure time activities and tourism are impacted by these factors.

Manganese concentrations of 0.1 mg/l, 0.3 mg/l, and 0.4 mg/l were discovered in the Kwasikorankurom borehole, Asuogya stream, and Ahanyaso River, respectively. Even though they did not exceed Ghana's water standards or the WHO's Mn threshold, manganese concentrations of greater than 0.1 mg/l in water supplies can stain clothing and give water an unpleasant taste. The permissible limit of 0.1 mg/l is exceeded by the WHO standard of 0.5 mg/l and the recommended health-based value of 0.4 mg/l in

Ghanaian water standards because concentrations of 0.2 mg/l frequently result in a coating on pipes that may flake off as a black precipitate (Herschy 2012). These findings correspond to Gyawu-Asante et al. (2017) that looked at the effects of surface gold mining in Bibiani, Ghana, on water bodies below the surface and the earth. They discovered that manganese levels were below and within WHO and Ghanaian water quality requirements. Our bodies require trace levels of manganese; thus, we must consume it. It facilitates the digestion of proteins, lipids, and carbohydrates by the body's enzymes (Harvard 2019). Although our bodies need manganese to function properly, too much of it can be harmful. Children and adults may experience memory, attention, and motor function problems after consuming manganese-rich water over an extended period. If a newborn is under a year old, drinking water with a high manganese content can impact their learning and behaviour (Minnesota Department of Health 2016).

Reverse osmosis technology is the most suitable and practical water treatment method for the Asuogya community and its environs because it is not a heavy industrial sector. Reverse osmosis is a highly effective and efficient way of treating water, but it is also quite expensive and energy intensive. It will be a suitable technology that can be employed as the society and economy develop. Since distillation is more suitable for small communities with sparse populations, it should be utilized to treat water in the Asuogya community in the interim. The removal of heavy metals, organic and inorganic contaminants, pesticides, and other pollutants from water is more effective and efficient through distillation

The results of the study demonstrated that there is evidence of polluted water by contaminants in Asuogya and its surroundings. In terms of water quality, diarrhoea is the most prevalent disease affecting the residents of Asuogya. In addition to access to safe and potable water, these water pollution issues affect most ignorant villagers and city dwellers on the fringes of Sunyani West Municipality. Consuming untreated water, failing to boil water properly, or utilizing the incorrect filtration technique may be the source of the difficulties. Even though the raw untreated water is contaminated, the GWCL works effectively to deliver clean water to households through the distribution network. However, this clean water does not reach the villages and outskirts of the city.

6 Conclusion

Based on the findings, it can be revealed that there are unavoidable pollutants in the water bodies in Asuogya and its surroundings in the Sunyani West Municipal. The contaminants from untreated water can be classified into physical, biological, and chemical. The primary physical pollution is from turbidity and total dissolved solids. The natural contaminations are mainly total coliforms and faecal coliforms. At the same time, the chemical pollutants consist of heavy metal compounds.

The investigation's target water bodies turned out to have high levels of turbidity, Fe, and Cl. Other trace elements such as Cl, NO2-, NO3-, SO42-, F-, Cr, Ca, As, and Al were relatively low and within standards compared to the Ghana Water Quality and WHO recommendations. As a result, the study suggests using technologies including distillation, ion exchange, activated carbon treatment, and reverse osmosis to purify water sources in Asuogya and its surroundings so that people may obtain safe and usable water.

Considering the findings, the water management in Sunyani West Municipality will need to be improved by expanding the water delivery to the small villages and district's Asuogya. Diverse water management and harvesting techniques could help the region, relieving water stress and promoting a healthy aquatic environment. An adaptation to the use of groundwater reserves may be put into action, which would be beneficial for the Asuogya community. The community might use groundwater to provide access to clean drinking water effectively. For water treatment technology to operate to its full potential and capacity, it should be used in conjunction with local water quality. Based on my findings, distillation would be a more suitable technology. Since distillation is more ideal for small communities with sparse populations, it should be utilized to treat water in the Asuogya community in the interim. The removal of heavy metals, organic and inorganic contaminants, pesticides, and other pollutants from water is more effective and efficient through distillation. The study also suggests that the government get involved and educate residents of rural and suburban areas—especially the less educated ones—about the safety of their drinking water.

The government should also construct cutting-edge water treatment equipment to guarantee that everyone has access to safe drinking water, especially in remote areas. The most crucial element in a country's development is clean, safe drinking water; hence the government should place more emphasis on it than other things. Before controlling natural water supplies, the government must step in to protect the environment from solid and profit-driven corporations.

Additionally, it must ensure that GWCL has the tools necessary to hold companies accountable for how they use water resources, both during and after operations, in terms of environmental reclamation, water recycling, and secure disposal. The report also advises that communities should be protected and that rural district councils should receive training in the monitoring, managing, technology transfer, and reallocation of clean water skills for natural water surfaces of either local or foreign firms. This recommendation corresponds to the Asuogya community.

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8 Appendix

List of the Appendix:

1. Certificate of Analysis, Ghana Water Company Limited.

Appendix 1: Certificate of Analysis, Ghana Water Company Limited

GHANA WATER COMPANY LIMITED

Main Bankers: GCB Bank Limited
Societe Generale Ghana
National Investment Bank

My Ref. No.:...

Your Ref. No.:.......................................

Brong Ahafo Region
Post Office Box 88
Sunyani – Ghana
West Africa
BS-0492-1921

30th JANUARY,2023

Attn. YAA ADU POKUA

CERTIFICATE OF ANALYSIS

SAMPLE DESCRIPTION: BOREHOLE, STREAM, RIVER	DATE OF ANALYSES: 14/12/2022
SAMPLE TAKEN BY: CLIENT	ANALYSED BY: SANDRA SARFOWAA SARPOMAA
SAMPLE RECEIVED BY: PEPERTUAL PEPRAH	VERIFIED BY: LYDIA AGYEIWAA (W.Q.A SUPERVISOR)
LOCATION: KWASIKORANKUROM (BOREHOLE), ASUOGYA (STREAM), AHANYASO (RIVER)	

TEST RESULTS

PHYSICO-CHEMICAL ANALYSIS: DATE OF ANALYSIS: 13/01/2023

PARAMETER	TEST METHOD	UNITS	GHANA STANDARD SPECIFICATION	RESULTS		
				BOREHOLE	STREAM	RIVER
Temperature		°C	-	27.80	28.10	25.00
pH	Electrometric	-	6.5-8.5	7.20	7.70	8.20
Turbidity	Nephelometric	NTU	5	0.14	17.60	18.00
Conductivity	Electrometric	μs/cm	-	708.00	312.00	219.00
Total Dissolved Solids	Electrometric	mg/l	1000	354.00	156.00	110.00
Alkalinity	Titrimetric	mg/l	-	590.00	222.00	144.00
Calcium	Titrimetric	mg/l	-	40.80	25.60	24.00
Magnessium	Titrimetric	mg/l	-	56.86	13.12	5.35
Chloride	Argentometric titration	mg/l	250	96.00	84.00	56.00
Nitrite	HACH 10019	mg/l	3.0	0.00	0.00	0.01
Nitrate	HACH 8039	mg/l	50	4.00	2.20	1.70
Sulphate	HACH 8051	mg/l	250	7.00	1.00	2.00
Fluoride	HACH 8029	mg/l	1.5	0.10	0.27	0.14

Registered Office: 28th February Road, (Near Independence Square)
Telephone: 233-508-300-537
Website: www.gwcl.com.gh E-mail: info@gwcl.com.gh

Iron	HACH 8008	mg/l	0.3	0.01	0.52	1.26
Manganese	HACH 8034	mg/l	0.4	0.1	0.30	0.40
Chromium	HACH 10218	mg/l	-	0.05	0.00	0.00
Aluminium	HACH 8012	mg/l	0.2	0.08	0.04	0.06
Arsenic	2822800(EZ arsenic)	mg/l	0.01	0.00	0.00	0.00

Note: These results are only applicable to the sample(s) submitted to the laboratory.

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Andrew N. Sadique
(Asst. WQA Officer)