ASSESSMENT OF BOILING AS A WATER PURIFICATION METHOD AND COMPARATIVE ANALYSIS OF DOMESTIC WATER TREATMENT OPTIONS IN RURAL COMMUNITIES: A CASE STUDY OF OBAZAGBON COMMUNITY, BENIN CITY, EDO STATE

BY

ABHULUIMEN OSEREMEN DESTINY

ENG1905145

IN

THE DEPARTMENT OF CIVIL ENGINEERING,
FACULTY OF ENGINEERING,
UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

OCTOBER, 2024

CERTIFICATION

This is to certify that the research reported in this project was carried out by Abhuluimen Oseremen Destiny, with the Matriculation Number ENG1905145 of the department of Civil Engineering, Faculty of Engineering, University of Benin, Benin City, Edo State, Nigeria.

PROJECT SUPERVISOR

NAME: ENGR. CHUKWUEMEKA OKOLIE

SIGNATURE AND

DATE …………………………………………………………………….

HEAD OF DEPARTMENT

NAME: PROF.MRS NGOZI IHIEMEKPEN

SIGNATURE AND

DATE …………………………………………………………………….

DEDICATION

This project is dedicated to the God Almighty, the fountain of all knowledge, wisdom, and understanding, the author and finisher of our faith and on whose wings I have been soaring. It is also dedicated to my beloved parents, Mr and Mrs. Abhuluimen and also to my supervisor for their endless and guidance support throughout my academics and also throughout the completion of this project.

ACKNOWLEDGEMENT

My sincere gratitude goes to my project supervisor, Engr. Chukwuemeka Okolie for the expert guidance, understanding, and unwavering support to carry out this work; his invaluable insights, constructive feedback, and encouragement have been instrumental in shaping this project. I would also like to extend my gratitude to the Head of Civil Engineering Department, University of Benin, Prof. Mrs. Ngozi Ihimekpen. I am also grateful for the guidance, mentorship and assistance of all Civil and Structural Engineering academic staff; Prof. O. C. Izinyon, Dr. A. I. Agbonaye, Engr. Mrs. Gloria E. Evbaru Okhuaihesuyi, Dr. Idowu Ilaboya, Engr. Dr. Mrs. Ngozi Kayode Ojo, Engr. Ehi Oria-Usifo, Engr Omosefe Blessing Eghosa, Engr. U. K. Ogbonna, Engr. Osasu Osamuyi, Engr. Mrs. Ambrose Agabi Esther, Prof. Ogeneale Orie, Engr. Uchenna Ukeme, Prof. S. O. Osuji, Prof. A.N. Aniekwu, Engr. Prof. H. A. P Audu, Engr. Prof. J. O. Okovido, Engr. Prof. S. D. lyeke, Dr. R. I. Umasabor, Dr. E. Nwankwo, Engr. Dr. R. O. Ogirigbo, Dr. L. O. Bobor, Engr. S. A. Adegbemileke, Engr. J. O. Ogbeide, Engr. Dr. P. N. Ogbeifun, Engr. O. Oriakhi, Engr. C. Okolie, Engr. N. Oghoyafedo, Engr. J. Ekhodiaehi, Dr. C. P. Ogbu, Dr. S. Oladosu, Arc. H. Omorogbe, Arc. Omobude and Arc. C. Erimona.

Lastly, I would like to express my gratitude to my parents, Mr. & Mrs. Abhuluimen for their constant love, prayers, encouragement, patience and provision. To, my colleagues and friends who were always there cheering me on my journey your sacrifices has not gone unnoticed, and I am grateful for your presence in my life. May God continue to bless you all.

ABSTRACT

In rural areas, water contamination remains a major public health concern, exposing residents to chemical and microbiological pollutants that can cause severe illnesses. Many households rely on untreated water sources such as wells, boreholes, and rivers, which often contain pathogenic microorganisms and elevated levels of heavy metals exceeding recommended safety limits.

This study evaluates **boiling** as a low-cost, effective domestic water purification method, alongside other household treatment options such as filtration, coagulation, chemical disinfection, and distillation. Water samples were collected from the Obazagbon Community and analyzed in the laboratory to assess **physico-chemical** and **microbiological** parameters both before and after treatment.

A multi-criteria decision analysis (MCDA) framework was applied to rate each purification method based on cost, effectiveness, feasibility, simplicity, sustainability, and accessibility. The results demonstrated that boiling significantly reduced microbial contamination, including total coliforms and *E. coli*, bringing bacterial counts well within the acceptable limits set by WHO and NSDWQ. Specifically, total coliform counts decreased from 149 CFU/ml (Sample A) and 153 CFU/ml (Sample B) to non-detectable levels, and *E. coli* was completely eliminated from the treated samples.

In terms of chemical pollutants, boiling had limited impact. Levels of dissolved metals such as zinc (1.738 mg/L initially reduced to 1.520 mg/L), iron (0.798–0.801 mg/L), cadmium (0.015–0.018 mg/L), and lead (0.063–0.065 mg/L) remained largely unchanged after boiling, highlighting that thermal treatment primarily targets microbial contaminants and cannot remove dissolved chemical pollutants. Physicochemical parameters such as pH remained within safe limits (6.20–6.23 post-treatment). The persistence of metals is attributable to the geological composition of water sources and potential contamination from human activities, including agricultural runoff, poor waste management, and corroded plumbing systems.

Overall, the study confirms that **boiling is a highly effective method for microbial disinfection** in rural communities, offering a practical and accessible solution for households.

Table of Contents

CERTIFICATION i
DEDICATION ii
ACKNOWLEDGEMENT iv
LIST OF TABLES vii
LIST OF FIGURES ix
ACRONYMS x
CHAPTER 1 11
INTRODUCTION 11
1.1 BACKGROUND OF STUDY 11
1.2 STATEMENT OF THE PROBLEM 12
1.3 AIM AND OBJECTIVES 13
1.4 SCOPE OF STUDY 14
1.5 JUSTIFICATION OF STUDY 15
CHAPTER TWO 17
LITERATURE REVIEW 17
2.1 PURPOSE 17
2.2 SCOPE 18
2.3 Comprehensive Overview of Water Purification Processes 18
2.3.1 Boiling as a Water Purification Method 18
2.3.2 Distillation as a Water Treatment Method 21
2.3.3 Solar Disinfection (SODIS) as a Water Treatment Method 23
2.3.4 Simple Filtration as a Water Purification Method 27
2.3.5 Improved Coagulation Using Filtration and Moringa Seed Extract as a Coagulant 30
2.4 PREVIOUS LITERATURE REVIEW / STUDIES 33
2.4.1 Boiling 33
2.4.2 Solar Disinfection (SODIS) 34
2.4.3 Simple Filtration 35
2.4.4 Moringa Oleifera as a Plant Extract and Coagulant 36
CHAPTER 3 37
METHODOLOGY 37
3.1 STUDY AREA 37
3.2 Sample Location 39
3.3 SAMPLE COLLECTION METHOD 39
3.4 WATER PURIFICATION METHODS 40
3.5 PARAMETERS FOR ANALYSIS 40
3.5 MATERIALS 44

3.5 PROCEDURES 46
3.5.1 Procedure For Improved coagulation using Moringa Oleifera Extract as Coagulant and Filtration 46
3.5.2 Procedure For Boiling Using a Kettle 47
3.5.3 Procedure For Solar Disinfection (SODIS) 47
3.5.5 Procedure For Simple Filtration 48
3.5.6 Procedure for Distillation as a Water Purification Method 48
3.5.7 Sample Preparation 49
3.5.8 Data Collection and Analysis 50
CHAPTER 4 51
RESULT AND DISCUSSION 51
4.1 Results of each Parameter 51
4.2 Overall Effectiveness of Purification Methods. 71
CHAPTER 5 72
CONCLUSION AND RECOMMENDATIONS 72
5.1 Conclusion 73
Results from Multi-Criteria Analysis 74
Key Insights from Multi-Criteria Analysis: 75
5.2 Recommendations 76
5.3 Areas for Further Research 77
REFERENCES 77

LIST OF TABLES

TABLE 4.1 – Original test results before and after water purification

TABLE 4.10 – Results of the multicriteria analysis of the various purification methods

LIST OF FIGURES

FIGURE 3.1 – Study Area Map Showing Obazagbon Community

FIGURE 3.2 – Map Showing the Sample Location

FIGURE 4.1.1 – pH Result

FIGURE 4.1.2 – Conductivity Chart

FIGURE 4.3 – Turbidity Chart

FIGURE 4.4 – Total Dissolved Solids Chart

FIGURE 4.1.5 – Total Solids Chart

FIGURE 4.1.6 – Suspended Solids Chart

FIGURE 4.1.7 – Nitrate Chart

FIGURE 4.1.8 – Iron Result

FIGURE 4.1.9 – Lead Result

FIGURE 4.1.10 – Cadmium Result

FIGURE 4.1.11 – Zinc Result

FIGURE 4.1.12 – Coliform Result

ACRONYMS

NAFDAC – Nigeria Agency for Food, Drug and Administrative Control

WHO – World Health Organization

UNICEF – United Nations Children's Fund

EPA – Environmental Protection Agency

FAO – Food and Agriculture Organization

IPCC – Intergovernmental Panel on Climate Change

UNEP – United Nations Environment Programme

USEPA – United States Environmental Protection Agency

NSDWQ – Nigeria Standard for Drinking Water Quality

SODIS – Solar Disinfection

DALYs – Disability-Adjusted Life Years

HWT – Household Water Treatment

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Water is essential for human survival, and access to clean, safe drinking water is a fundamental human right. Unfortunately, the quality of water varies widely across different regions, often compromised by a range of biological, chemical, and physical pollutants. Contaminants can arise from numerous sources, including industrial waste, agricultural runoff, and natural processes like mineral leaching (World Health Organization, 2021).

In countries such as India, the consequences of unsafe water are dire. Approximately 21% of communicable diseases are linked to unsafe water and poor hygiene practices, resulting in over 500 children under five dying daily from diarrhea alone (UNICEF, 2022). This alarming statistic highlights the urgent need for improved water quality. Similarly, in Nigeria, around 30% of the population lacks access to safe drinking water, exacerbating health challenges. Poor sanitation practices contribute significantly to this crisis, as unsafe water and inadequate sanitation account for roughly 70% of communicable diseases in the country. Diarrheal diseases remain a leading cause of death among children under five (Water Aid, 2023; Ayeni & Okonkwo, 2023). The situation is particularly critical in developing regions where access to advanced water treatment facilities is limited or nonexistent (Chung et al., 2020).

To combat these pressing issues, domestic water purification methods provide a vital solution. These methods empower individuals and communities to treat water at the point of use, ensuring access to clean water. For instance,

- Boiling is a widely used method effective in killing most microorganisms, making it a reliable option for pathogen removal. However, it does not address chemical contamination and may not be feasible in areas with limited access to fuel or electricity.
- Distillation involves heating water to produce steam, which is then condensed back into liquid form, separating water from most impurities, including pathogens and many chemicals.

- Solar disinfection (SODIS) utilizes the sun's ultraviolet radiation to kill pathogens, making it a cost-effective and sustainable option, especially in regions with abundant sunlight.
- Simple filtration methods involve passing water through materials that remove particulates and some microorganisms but may not eliminate all pathogens or chemical contaminants. Coagulation techniques, using agents or plant extracts, are often combined with filtration to enhance their effectiveness, though they require proper handling and dosing.

Given the diversity of available purification methods, a comprehensive analysis is essential to identify the most effective and practical solutions for residential homes. This research aims to evaluate these methods, providing a clear understanding of their strengths, limitations, and potential health impacts, thereby guiding individuals, communities, and policymakers in making informed decisions about water purification strategies

1.2 STATEMENT OF THE PROBLEM

Despite advancements in water purification technology, approximately 2.2 billion people worldwide still lack access to safely managed drinking water as of 2023, according to the United Nations. This issue is particularly severe in low-resource settings where centralized water treatment infrastructure is often inadequate or absent. In these environments, households must rely on domestic water purification methods to safeguard their health. However, the effectiveness of these methods varies widely, and there is a significant knowledge gap regarding their suitability for different contaminants and environmental conditions.

A critical challenge is the lack of accessible and reliable information about which purification methods are most effective in specific contexts. For example, while boiling water effectively removes pathogens, it does not address chemical contaminants, which are a significant concern in areas affected by industrial pollution. Similarly, solar disinfection is a sustainable and low-cost option but may be less effective in regions with cloudy weather or high water turbidity.

Moreover, potential health risks associated with certain purification methods are not well understood by the general population. Chemical disinfectants such as chlorine and iodine, while effective against pathogens, can produce harmful byproducts if not used correctly. Additionally, simple filtration methods might create a false sense of security, as they may not remove all contaminants, particularly microscopic pathogens and dissolved chemicals.

This research seeks to address the lack of comprehensive and comparative analysis of various domestic water purification methods. By evaluating their effectiveness, practicality, and potential health impacts, the study aims to fill the knowledge gap and provide actionable recommendations for individuals, communities, and policymakers. The findings will contribute to improving access to safe drinking water, reducing the incidence of waterborne diseases, and enhancing overall public health outcomes.

1.3 AIM AND OBJECTIVES

The main aim of this work is to do a comparative analysis of some various domestic water treatment methods suitable for human consumption in rural areas. This analysis is crucial due to the pressing need for safe drinking water in regions where access of drinking water is difficult due to lack of infrastructure, economic and environmental resources. The specific objectives are to:

1. Identifying and select suitable sources of water supply in rural area for the study

2. Access and compare various domestic methods of water purification for sustainability, cost effectivity, accessibility and feasibility in rural areas.

3. Carry out physio-chemical and microbial test on samples from select water source site

4. Compare the results with World Health Organization (WHO) standards to show the quality of the water.

5. Give Recommendations Based on Results

1.4 SCOPE OF STUDY

This study will encompass a detailed evaluation of seven domestic water purification methods: boiling, distillation, solar disinfection, simple filtration, and coagulation with compounds or plant extracts. The scope of the study includes the following activities:

1. Literature Review

   A comprehensive review of scientific literature will be conducted to gather information on the mechanisms, effectiveness, and limitations of various water purification methods. The review will include studies from diverse geographical regions, focusing on how these methods are applied globally in both developed and developing countries.

2. Experimental Analysis

   Laboratory tests will be performed to assess each method's effectiveness in removing contaminants such as pathogens, heavy metals, organic compounds, and particulates. Water samples from natural sources (rivers, lakes), groundwater (wells, boreholes), and artificially contaminated water will be analyzed using standardized testing protocols.

3. Practical Feasibility Assessment

   The practicality of each purification method will be evaluated based on cost, material availability, ease of use, maintenance needs, and cultural acceptance. Data will be collected through surveys and interviews with users in various regions to provide insights into their experiences.

4. Health Risk Analysis

This analysis will identify potential health risks associated with each purification method by reviewing documented health outcomes and conducting tests to detect any residual contaminants in treated water. The analysis will consider both short-term and long-term health risks, including the possibility of introducing secondary contaminants.

5. Data Analysis

Data from the experimental analysis, feasibility assessment, and health risk analysis will be compiled and analyzed using statistical software such as SPSS or R. Visual representations like charts and tables will help compare the strengths and weaknesses of each purification method.

6. Recommendations and Guidelines

Based on the findings, the study will provide evidence-based recommendations suitable for both rural and urban settings, as well as low-resource areas. Guidelines for the safe and effective implementation of these methods will be created to reduce the risk of waterborne diseases and enhance public health.

1.5 JUSTIFICATION OF STUDY

This study is justified by the urgent need to improve access to safe drinking water, particularly in low-resource settings where waterborne diseases remain a significant public health challenge. Despite the availability of various domestic water purification methods, many communities continue to suffer from the health impacts of contaminated water due to a lack of clear, accessible information on the effectiveness and suitability of these methods.

The comparative analysis provided by this research will offer valuable insights into the relative strengths and limitations of different water purification methods, enabling individuals, communities, and policymakers to make informed decisions about water treatment. This, in turn, will help address the knowledge gap that currently hinders the widespread adoption of effective purification practices.

By identifying the most suitable purification methods for specific contexts, the study will contribute to better water management practices, promoting the use of methods that are not only effective but also practical, cost-effective, and culturally acceptable. The health risk analysis component of the study will also provide crucial information on the potential health impacts of different methods, helping to ensure that water purification practices do not inadvertently introduce new health risks.

Ultimately, the study aims to support global efforts to achieve the United Nations Sustainable Development Goal 6 (SDG 6), which seeks to ensure the availability and sustainable management of water and sanitation for all. By providing a comprehensive evaluation of domestic water purification methods, this research will contribute to improving public health outcomes and enhancing the quality of life for millions of people worldwid

CHAPTER TWO

LITERATURE REVIEW

Access to clean water is a critical issue in many parts of the world, especially in low-resource settings. An estimated 2.2 billion people globally lack access to safe drinking water (World Health Organization, 2021), while over 1 million people die each year due to water-related diseases (UNICEF, 2021). This crisis disproportionately affects women and children, who often spend hours each day collecting water (Water.org, 2020). The lack of clean water impedes education, economic opportunities, and overall health, creating a cycle of poverty for affected communities. Moreover, as climate change worsens, water access becomes increasingly unstable, particularly in vulnerable regions (IPCC, 2022).

2.1 PURPOSE

This literature review is designed to provide a comprehensive comparison of several domestic water purification methods that are widely utilized in low-resource settings. Each method will be examined in terms of its ability to effectively remove contaminants, including microbial, chemical, and physical impurities. The review will also take into account the cost implications of implementing each method, both in terms of initial setup and ongoing maintenance. Sustainability will be a key focus, considering factors such as the environmental impact of each method, resource availability, and long-term usability for communities with limited infrastructure.

2.2 SCOPE

The review will cover the following water purification methods:

1. Boiling
2. Distillation
3. Solar Disinfection
4. Simple Filtration
5. Improved Coagulation with moringa seed extract

This review will concentrate on comparing these methods based on their accessibility and usability in areas with limited resources and infrastructure, drawing on insights from various external sources.

2.3 COMPREHENSIVE OVERVIEW OF WATER PURIFICATION PROCESSES

2.3.1 Boiling as a Water Purification Method

Boiling relies on thermal inactivation of pathogens when water is heated to its boiling point (100°C or 212°F at sea level). As a result, bacteria, viruses, and protozoa are killed, making the water safe for consumption. Studies highlight that boiling is most effective against biological contaminants but not chemical impurities. For instance, the World Health Organization (WHO) recommends bringing water to a rolling boil for at least one minute to ensure pathogen inactivation (WHO, 2011).

In rural China, for example, a study led by Alasdair Cohen et al. (2020),it was observervered that households using electric kettles had significantly lower thermo-tolerant coliform (TTC) contamination than those boiling water in open pots. In this study conducted in rural China, about 13.6% of homes using electric kettles showed traces of contamination, while 11.6% of those using open pots had detectable levels of TTCs. The research demonstrates that boiling, when done correctly, can eliminate harmful microorganisms such as *Escherichia coli*, *Cryptosporidium*, and *Giardia*, making it highly effective for pathogen removal.

In another study by Juran and MacDonald (2014), the researchers explored the effectiveness of boiling as a household water treatment method in areas facing significant public health challenges due to unsafe drinking water. They found that while boiling can eliminate pathogens such as bacteria, viruses, and protozoa, practical implementation often limits its efficacy. Many households lacked knowledge about proper boiling techniques, particularly the necessary duration and intensity, and misunderstandings about boiling times at higher elevations could lead to insufficient pathogen elimination. Inconsistent fuel availability and time constraints further hindered regular treatment, as busy families often prioritized other tasks over boiling water. Unsafe handling and storage practices also contributed to re-contamination. Despite many households reporting that they boiled their drinking water, only a small percentage produced water free from enteric bacteria, highlighting the need for targeted educational interventions to enhance knowledge of boiling methods and improve resource management.

Advantages

- **Ease of Implementation**: This method requires minimal equipment—only a heat source and a container—making it accessible in low-resource settings.
- **Cultural Acceptance**: Boiling is a common practice in many cultures, enhancing its acceptance. For example, over 61% of participants in Cohen's study reported boiling their drinking water (Cohen et al., 2020).
- **Immediate Results**: Boiling provides instant visual confirmation when the water reaches its boiling point, reassuring users of its effectiveness. The Centers for Disease Control and Prevention (CDC, 2021) recognizes boiling as a primary emergency measure to ensure water safety.

- **Cost-Effectiveness**: Boiling is often more affordable than other water purification methods, as it utilizes readily available resources rather than requiring costly filters or chemical treatments.

- **Simplicity**: The straightforward nature of boiling does not require technical skills or training, allowing communities to adopt it easily and quickly

Limitations

- **Energy Dependence**: Boiling requires a continuous heat source, which can be problematic in areas with limited access to electricity or fuel.

- **Time-Consuming**: The boiling process takes time, which may lead busy households to prioritize other tasks over treating water.

- **Knowledge Gaps**: Many households lack adequate knowledge about proper boiling techniques, leading to insufficient treatment.

- **Re-Contamination Risk**: Unsafe handling and storage practices can result in re-contaminating boiled water, undermining its safety.

- **Limited Effectiveness Against Certain Contaminants**: Boiling may not remove chemical contaminants or heavy metals, making it less effective against some types of pollution.

In conclusion, boiling water remains a widely recognized and culturally accepted method for ensuring safe drinking water, particularly in areas facing public health challenges due to inadequate access to clean water. Its advantages, such as ease of implementation, immediate visual confirmation of safety, and effective pathogen elimination, make it a practical choice for many households. However, significant limitations, including energy dependence, time constraints, knowledge gaps about proper boiling techniques, risks of re-contamination, and its inability to address certain chemical pollutants, highlight the need for comprehensive educational interventions. By enhancing community understanding of boiling methods and addressing practical challenges, we can improve the overall effectiveness of this critical water purification strategy and promote safer drinking water practices.

2.3.2 Distillation as a Water Treatment Method

Distillation is a widely recognized method for purifying water, particularly valuable in settings where water quality is compromised. The process involves heating water to its boiling point, causing it to evaporate and separate from contaminants, which typically remain in the original container. The vapor is then condensed back into liquid form, resulting in distilled water that is free from a broad spectrum of impurities (Morrison & Karr, 2016).

The core principle of distillation is based on differences in boiling points among substances. As water boils, it converts into steam, leaving behind heavier particles and contaminants that do not evaporate, such as salts, metals, and organic materials (Snyder et al., 2013). Once the steam cools, it condenses back into water, effectively providing a clean product. This method is not only effective against inorganic contaminants, including heavy metals like lead and arsenic, but also serves to inactivate pathogenic microorganisms, ensuring that the distilled water is microbiologically safe to drink (Kumar et al., 2018).

Distillation is effective in removing a wide range of contaminants, including:

- **Heavy Metals**: Elements such as lead, mercury, and cadmium are removed during the distillation process, making it particularly useful for addressing contaminated groundwater (Baker et al., 2017).

- **Microorganisms**: Bacteria, viruses, and protozoan cysts are inactivated through the high temperatures of boiling, contributing to the microbiological safety of the water (WHO, 2017).

- **Dissolved Solids**: Salts and other dissolved solids that contribute to water hardness are effectively eliminated, which can improve the taste and usability of water for various applications (Burgess et al., 2020).

However, distillation is less effective at removing certain volatile organic compounds (VOCs) like benzene and toluene, which can have boiling points close to that of water. To address this limitation, some systems incorporate additional filtration methods, such as activated carbon filters, to capture these contaminants before condensation occurs (Zhou et al., 2019).

Advantages

- **Broad Contaminant Removal**: Distillation effectively removes heavy metals, salts, and microorganisms, making it suitable for purifying water from contaminated sources.

- **Microbiological Safety**: The high temperatures involved in boiling eliminate pathogens, ensuring that the distilled water is safe to drink.

- **Improved Water Quality**: Distillation removes dissolved solids that can cause water hardness, enhancing the taste and usability of the water.

- **Simplicity of Process**: The distillation process is straightforward, requiring only basic equipment like a heat source and a condensation apparatus, making it accessible in various settings.

- **Versatility**: Distilled water is suitable for a wide range of applications, including laboratory use, medical procedures, and household needs.

Limitations

- **Energy Intensive**: The process requires significant energy to heat water to boiling, which can be a drawback in areas with limited resources.

- **Time-Consuming**: Distillation can be slow, as it takes time for water to boil and for the steam to condense back into liquid form.

- **Ineffectiveness Against Certain VOCs**: Some volatile organic compounds with boiling points close to that of water may not be effectively removed, potentially leaving harmful contaminants.

- **Cost of Equipment**: Distillation systems can be costly to install and maintain, which may limit their accessibility for low-income households.

- **Water Waste**: Depending on the system design, distillation may result in a certain amount of water waste, as not all input water is converted into distilled water.

Distillation is a highly effective water treatment method, particularly for removing heavy metals, dissolved solids, and pathogenic microorganisms. While it has its limitations regarding certain contaminants and operational costs, the benefits it provides in terms of water purity make it a valuable option for residential water purification.

2.3.3 Solar Disinfection (SODIS) as a Water Treatment Method

Solar disinfection (SODIS) is a cost-effective, sustainable method of purifying water, especially in regions where access to clean drinking water is limited. The method utilizes sunlight to inactivate pathogens by filling transparent plastic bottles with contaminated water and exposing them to the sun for several hours. The two primary mechanisms that make this process effective are

1. **Ultraviolet (UV) Radiation**: UV-A rays (wavelength 320–400 nm) penetrate water and damage the genetic material of microorganisms, preventing them from reproducing.

2. **Thermal Inactivation**: In some cases, when the temperature of the water reaches above 50°C, the process of pathogen inactivation is accelerated.

These mechanisms were explored in various studies, including a comprehensive review by McGuigan et al. (2012), which demonstrated how SODIS is effective against bacteria, viruses, and protozoa.

In a study by Ángela García-Gil, Rafael A. García-Muñoz, Kevin G. McGuigan, and Javier Marugán, published in *Molecules* in June 2021, the authors reviewed solar water disinfection (SODIS) as a method for producing safe drinking water in resource-poor settings. Notably, they highlighted that increasing container volumes can reduce recontamination risks, which are significant when families use up to 25 small bottles to meet daily water needs of 50-100 liters. The study also indicated that alternative materials to polyethylene terephthalate (PET) could enhance pathogen inactivation, particularly against viruses and protozoa. García-Gil et al. emphasized the need for accurate kinetic models that consider factors like solar radiation intensity and water chemistry. They noted that despite its benefits, SODIS faces challenges such as inefficiency against certain pathogens and variability in treatment times, which can range from 6 hours on sunny days to 48 hours in cloudy conditions. The authors concluded by advocating for improvements to enhance the safety and speed of the SODIS process.

In another review in Chemosphere, Beni Jequicene Mussengue Chaúque and Marilise Brittes Rott explored solar disinfection (SODIS) as a viable solution for public drinking water supply in developing countries, where contaminated water causes around 40,000 preventable deaths monthly from gastrointestinal diseases. While SODIS is effective and low-cost, its reliance on PET bottles limits its capacity to treat large volumes of water. The authors advocate for continuous flow systems for solar water disinfection (CFSSWD) that integrate SODIS with solar pasteurization and advanced nanomaterials to enhance disinfection efficiency and address resistant microorganisms. By optimizing these technologies, the study aims to improve access to safe drinking water in rural and underserved communities, contributing to the broader goal of universal access to clean water and ultimately enhancing public health and community resource management.

In another recent study by Bikes Destaw Bitew, Yigzaw Kebede Gete, Gashaw Andargie Biks, and Takele Tadesse Adafrie, researchers conducted a cluster randomized controlled trial in Dabat district, northwest Ethiopia, to evaluate the effectiveness of solar disinfection (SODIS) in reducing diarrhea among children under five. The trial included 28 rural villages, where 384 children in the intervention group used polyethylene terephthalate (PET) bottles for SODIS treatment, while 394 children in the control group continued with their usual water sources. Results indicated a high compliance rate of 90.6% and a significant reduction in diarrhea incidence, from 15.3 episodes per 100 person-week observations in the control group to 8.3 episodes in the intervention group—representing a 40% decrease. This study underscores the practicality and affordability of SODIS as a viable household water treatment option in rural settings. Ultimately, integrating SODIS into community health programs can play a crucial role in improving water quality and public health, emphasizing the need for innovative and sustainable water purification strategies to ensure safe drinking water across diverse contexts.

Advantages

- **Cost-Effectiveness**: SODIS is an affordable method of water purification, making it accessible for communities in resource-poor settings where conventional water treatment options may be limited.

- **Sustainability**: Utilizing sunlight as a natural disinfectant makes SODIS an environmentally friendly solution that does not require chemical additives or electricity.

- **Effectiveness Against Pathogens**: SODIS has been demonstrated to effectively inactivate a wide range of pathogens, including bacteria, viruses, and protozoa, making it a viable option for improving water quality.

- **Low Technical Requirements**: The method is simple to implement and requires minimal training, making it suitable for community-based programs in rural areas.

- **Reduced Recontamination Risk with Larger Containers**: Research indicates that using larger containers can minimize the risk of recontamination, as families can store sufficient water without needing to refill multiple smaller bottles.

Limitations of SODIS

- **Dependence on Weather Conditions**: SODIS requires sunny weather for optimal effectiveness, with treatment times varying significantly from 6 hours on sunny days to up to 48 hours in cloudy conditions, limiting its reliability.

- **Limited Volume Capacity**: The reliance on PET bottles restricts the volume of water that can be treated at one time, which may not meet the daily needs of larger families or communities.

- **Inefficiency Against Certain Pathogens**: While SODIS is effective against many microorganisms, it may be less efficient against some resistant pathogens, which could pose health risks.

- **Variable Treatment Efficacy**: Factors such as water chemistry and container material can influence the effectiveness of SODIS, necessitating accurate models to predict treatment outcomes.

- **Potential for Misuse or Misunderstanding**: Inadequate knowledge about the proper use of SODIS may lead to improper implementation, reducing its effectiveness and potential health benefits.

Furthermore, Solar disinfection (SODIS) is a valuable water purification method that leverages sustainable resources, making it suitable for low-resource settings. It requires transparent bottles made from materials like PET plastic, as alternatives such as glass or colored plastics can hinder UV penetration. While SODIS is most effective with clear water and under favorable weather conditions, it does not eliminate chemical contaminants. Nevertheless, it remains widely studied and supported for effectively reducing microbial contamination in drinking water worldwide.

2.3.4 Simple Filtration as a Water Purification Method

Simple filtration, particularly using sari cloth, has been tested as an effective method for removing pathogens like Vibrio cholerae by filtering out planktonic copepods. These copepods serve as hosts for the bacteria, and their removal from the water significantly reduces the risk of cholera transmission. Laboratory and field tests have shown that using 1 to 4 layers of cloth is sufficient to trap these organisms, effectively lowering the number of bacteria in the water. The sari cloth, being a readily available material in rural communities such as those in Bangladesh, serves as a low-cost and accessible solution for reducing microbial contamination in drinking water.

The effectiveness of simple filtration was notably demonstrated in a study by Huq et al. which. offered valuable insights into the effectiveness and practicality of simple sari cloth filtration in reducing cholera incidence in Matlab, Bangladesh. The initial field trials demonstrated a remarkable 50% reduction in cholera cases among households using sari filters, showcasing the method's potential as a low-cost and accessible solution for water purification in resource-limited settings. A follow-up study conducted five years later revealed that 31% of village women continued to use some form of filtration, with 60% opting for sari cloth, indicating the method's sustainability and strong community acceptance. Importantly, the practice not only benefited those who filtered their water but also had an indirect protective effect on neighboring households, further reducing cholera rates. These findings underscore the necessity for ongoing education and reinforcement to ensure the consistent use of effective purification techniques like sari filtration. Overall, the study highlights the importance of integrating simple, culturally relevant methods into public health strategies to enhance access to safe drinking water in diverse contexts, ultimately contributing to improved community health outcomes.

In another comprehensive comparative analysis of various domestic water purification methods, the review by Che Razali et al. (2023) underscores the critical importance of effective filtration technologies for ensuring safe drinking water. The authors detail both conventional and advanced treatment methods, emphasizing membrane filtration as a key technology due to its remarkable efficiency in removing contaminants. While traditional methods have been widely used, they often fail to meet modern water quality standards, particularly in developing regions facing economic challenges. The review addresses the persistent issue of membrane fouling, which can hinder filtration performance and increase operational costs; it highlights that common preventive strategies often involve chemical agents that may compromise human health. Moreover, the authors advocate for innovative and hybrid approaches that integrate both conventional and advanced treatment methods to enhance efficacy. Overall, this analysis serves as a vital resource for understanding the complexities of water purification, emphasizing the need for tailored solutions that consider specific regional contexts to improve public health and water quality globally.

In another comprehensive study by Yusuf et al. (2023), the authors explore the efficacy of a simple slow sand filter designed for drinking water purification, particularly in rural areas where electricity is scarce. The research underscores the risks associated with rainwater, which is often contaminated by pathogens from various roofing materials, posing serious threats of water-borne diseases such as typhoid and cholera. The slow sand filter, also referred to as a bio-sand filter, operates without electrical power and relies on a natural biological layer that develops on the sand surface, effectively removing contaminants through both physical filtration and biological processes. Their findings indicate remarkable reductions in turbidity and microbial levels, with the filter achieving near-complete removal of harmful coliform bacteria. This study not only highlights the practical benefits of slow sand filtration but also compares it to other domestic water purification methods, demonstrating its overall effectiveness and suitability in diverse contexts for ensuring safe drinking water. Ultimately, the authors advocate for the wider adoption of this technology to enhance public health and safeguard communities against water-related illnesses.

Advantages

- **Cost-Effectiveness**: Both methods utilize readily available materials (sari cloth and sand) that are low-cost, making them accessible for resource-limited communities.

- **Community Acceptance**: The sari cloth method, in particular, has demonstrated strong acceptance among users, contributing to sustained practice and adherence in rural areas.

- **Reduction of Pathogens**: Studies have shown significant reductions in harmful pathogens, such as Vibrio cholerae and coliform bacteria, effectively lowering the risk of water-borne diseases.

- **Simplicity of Use**: Both filtration methods are straightforward to implement and require minimal training, making them practical for widespread adoption in various settings.

- **Indirect Community Benefits**: The use of these filtration methods not only protects the individuals filtering their water but also has a positive impact on the broader community by reducing overall disease incidence.

Limitations

- **Limited Contaminant Removal**: Simple filtration may not remove all types of contaminants, particularly smaller microorganisms and chemical pollutants, which could still pose health risks.

- **Dependence on Material Availability**: The effectiveness of the sari cloth method relies on the availability of suitable cloth, which may vary in some regions.

- **Potential for Recontamination**: The filtration process can lead to recontamination if the filtered water is not stored properly or if the filtering materials are not maintained.

- **Slow Filtration Rate**: Both methods may operate at slower filtration rates, which could be a challenge in communities with high water demand.

- **Limited Education and Awareness**: Continued education is necessary to ensure proper usage and maintenance of these filtration methods, which may be overlooked in some communities.

In conclusion, simple filtration methods like sari cloth and slow sand filters present viable, low-cost solutions for improving access to safe drinking water, particularly in resource-limited settings. Their proven effectiveness in reducing harmful pathogens highlights their potential to mitigate water-borne diseases and enhance community health outcomes. However, challenges such as limited contaminant removal, the need for proper maintenance, and ongoing education must be addressed to maximize their benefits.

2.3.5 Improved Coagulation Using Filtration and Moringa Seed Extract as a Coagulant

Moringa oleifera seeds contain water-soluble proteins with strong coagulation and flocculation properties, effectively neutralizing the negative charges of suspended particles in water and allowing them to clump together for removal. When combined with filtration, this process enhances water purification by capturing the coagulated particles, significantly improving water clarity and quality (Baptista et al., 2017; Sánchez-Martín et al., 2012). Additionally, the protein component of Moringa extract reduces biological contaminants like E. coli bacteria (Camacho et al., 2017), making this integrated approach an appealing and sustainable solution for communities with limited access to clean water. By leveraging both coagulation and filtration, this method not only minimizes impurities but also supports better public health outcomes in diverse settings.

Insights from a significant study conducted by Aducabe Bancessi, Rosa Teodósio, Elizabeth Duarte, Aladje Baldé, Luís Catarino, and Teresa Nazareth in 2022 provided a detailed examination of how moringa could be utilized for water purification. The researchers investigated community perceptions of household water purification strategies, specifically focusing on the use of moringa seed powder in Guinea-Bissau. Through six focus group discussions with 65 participants and questionnaires completed by 104 individuals, they discovered that while 82% recognized the health risks associated with contaminated water, many underestimated the dangers posed by trusted sources like tubewells. Traditional methods, such as boiling and using bleach, were employed by 68% of respondents, but they faced challenges related to accessibility and taste. Interestingly, after a trial with moringa-teabags, an impressive 81% expressed confidence in their effectiveness compared to other methods. These findings highlight the urgent need for effective purification solutions and enhanced community awareness about water safety, suggesting that engagement with alternative methods like moringa could play a crucial role in combating waterborne diseases and ensuring safe drinking water in rural settings.

Also in a comprehensive comparative analysis of various domestic water purification methods, Alakaparampil Joseph Varkey's 2020 study in *Scientific African* highlighted the effectiveness and practicality of using Moringa oleifera seeds combined with copper for purifying river water in rural settings. The study addressed the critical issue of clean drinking water access in developing countries, emphasizing that many traditional purification methods are often inaccessible due to cost and complexity. Varkey demonstrated a simple and cost-effective technique utilizing moringa seed powder as a natural coagulant to clarify turbid water and copper wire as an antibacterial agent to eliminate pathogens like E. coli. The results showed that after a four-hour treatment period, the turbidity levels were reduced to between 3 NTU and 5 NTU, and E. coli was undetectable in all treated samples, making this method suitable for point-of-use applications. The research underscored the potential of this innovative approach to provide immediate solutions for water purification in disaster-affected areas and emphasized the need for further exploration of such accessible methods to ensure safe drinking water in diverse contexts.

Lastly, in the study by Desta and Bote (2021), the effectiveness of using Moringa oleifera seeds as a natural coagulant in domestic wastewater treatment was investigated, highlighting its potential in ensuring safe drinking water, particularly in rural areas. The research demonstrated that Moringa seed powder could significantly reduce turbidity, color, and chemical oxygen demand (COD) in both acidic and basic wastewater, with optimal dosages identified at 0.4 g/500 ml. Results showed remarkable reductions—up to 99.5% in turbidity and 97.7% in color for basic wastewater—underscoring Moringa's efficiency as an eco-friendly alternative to chemical coagulants. This method not only provides a cost-effective solution but also emphasizes the importance of utilizing locally available resources in water treatment. Such findings are crucial for a comprehensive comparative analysis of various domestic water purification methods, as they highlight the practicality and suitability of natural coagulants like Moringa oleifera in promoting safe drinking water across diverse contex

Advantages

- **Natural Coagulant**: Moringa oleifera seeds contain proteins that effectively neutralize negative charges of suspended particles, facilitating their clumping and settling. This process effectively removes impurities, improving water clarity and quality.

- **Biological Contaminant Reduction**: The protein components of Moringa are effective in reducing biological contaminants, such as E. coli, making it a viable option for communities with limited access to clean water.

- **Community Acceptance**: Studies indicate a high level of confidence in using Moringa for water purification. In trials, 81% of participants preferred Moringa tea bags over traditional methods, showcasing its acceptability and potential for community adoption.

- **Cost-Effectiveness**: Moringa is a low-cost alternative to chemical coagulants, making it accessible for rural communities that may struggle with the expenses associated with conventional water purification methods.

- **Simplicity and Practicality**: The use of Moringa seed powder combined with other agents, like copper, offers a straightforward method for clarifying water and eliminating pathogens, particularly useful in emergency or disaster-affected areas.

Limitations

- **Underestimation of Risks**: While many recognize health risks associated with contaminated water, studies show that individuals often underestimate dangers from trusted sources, potentially leading to a lack of urgency in adopting effective purification methods.

- **Taste and Acceptability Issues**: Traditional methods, such as boiling and using bleach, are sometimes preferred despite their drawbacks. Accessibility and taste remain significant barriers to the acceptance of alternative methods like Moringa.

- **Variable Efficacy**: The effectiveness of Moringa can vary based on factors like seed quality, preparation methods, and the specific contaminants present in the water, necessitating further research to standardize its use.

- **Limited Awareness and Education**: Despite its potential, there is often a lack of community awareness and understanding regarding the benefits and proper use of Moringa for water purification, which can hinder its widespread adoption.

- **Dependency on Local Availability**: The effectiveness of Moringa as a coagulant is contingent upon local availability of the seeds, which may not be guaranteed in all regions, limiting its applicability in some contexts.

However Moringa oleifera presents a promising and sustainable solution for water purification, particularly in communities with limited access to clean water. Its natural coagulant properties effectively reduce turbidity and biological contaminants, while its cost-effectiveness and community acceptance further enhance its potential for widespread adoption. However, challenges such as underestimating health risks, taste preferences, variable efficacy, limited awareness, and dependence on local seed availability must be addressed. By improving community education and accessibility.

2.4 PREVIOUS LITERATURE REVIEW / STUDIES

2.4.1 Boiling

Key Studies:

- **Cohen et al. (2020)**: This study in rural China found that households using electric kettles had significantly lower levels of thermo-tolerant coliforms (TTC) compared to those boiling water in open pots, demonstrating the effectiveness of boiling in pathogen inactivation.

- **Juran and MacDonald (2014)**: Their research highlighted that while boiling eliminates pathogens like bacteria, viruses, and protozoa, practical implementation often limits its effectiveness. Many households lacked knowledge about proper boiling techniques and faced challenges such as inconsistent fuel availability and time constraints, which hindered regular water treatment.

Insights: These studies collectively illustrate boiling as a widely accepted method for ensuring microbiologically safe water, especially in resource-limited settings. However, concerns about its ineffectiveness against chemical contaminants and the need for improved education on boiling practices remain significant limitations.

2.4.2 Solar Disinfection (SODIS)

Key Studies:

- **McGuigan et al. (2012)** conducted a comprehensive review demonstrating that solar disinfection (SODIS) effectively inactivates a variety of pathogens, including bacteria, viruses, and protozoa, through ultraviolet (UV) radiation and thermal inactivation.

- **García-Gil et al. (2021)** reviewed SODIS in resource-poor settings, highlighting that larger container volumes can reduce recontamination risks. They noted that alternative materials to PET could enhance pathogen inactivation and called for better kinetic models to improve treatment effectiveness.

- **Chaúque and Rott (2021)** explored SODIS as a public drinking water supply solution, advocating for continuous flow systems that integrate SODIS with solar pasteurization to improve disinfection efficiency.

- **Bitew et al. (2023)** conducted a cluster randomized controlled trial in Ethiopia, finding a significant 40% reduction in diarrhea incidence among children using SODIS, demonstrating its practicality and effectiveness in rural settings.

Insights: These studies collectively illustrate SODIS as a viable, low-cost method for improving water quality, particularly in resource-limited communities. However, challenges such as inefficiency against certain pathogens and reliance on PET bottles for large volumes remain concerns.

2.4.3 Simple Filtration

Key Studies:

- **Huq et al**. demonstrated the effectiveness of sari cloth filtration in reducing cholera incidence in Matlab, Bangladesh. Initial trials showed a 50% reduction in cholera cases among households using sari filters. A follow-up study revealed that 31% of village women continued to use some form of filtration, with 60% opting for sari cloth, indicating strong community acceptance and sustainability.

- **Che Razali et al. (2023)** conducted a comparative analysis of domestic water purification methods, emphasizing the importance of effective filtration technologies. They highlighted membrane filtration as efficient but noted challenges like membrane fouling and the potential health risks from chemical agents used in prevention. The review advocates for innovative, hybrid approaches to improve water quality.

- **Yusuf et al. (2023)** explored the efficacy of slow sand filters in rural areas lacking electricity. Their research found that these filters effectively reduce turbidity and remove harmful coliform bacteria, making them suitable for ensuring safe drinking water. The study underscores the practical benefits of slow sand filtration in preventing water-borne diseases.

Insights: These studies collectively illustrate simple filtration methods, particularly sari cloth and slow sand filters, as effective, low-cost solutions for improving water quality in resource-limited settings. Their community acceptance and practical implementation highlight the potential for integrating these methods into public health strategies to enhance access to safe drinking water.

2.4.4 Moringa Oleifera as a Plant Extract and Coagulant

Key Studies:

- **Aducabe Bancessi et al. (2022)** examined community perceptions of using Moringa seed powder for water purification in Guinea-Bissau. They found that while 82% of participants recognized the health risks of contaminated water, many underestimated dangers from trusted sources. After trials with moringa-teabags, 81% expressed confidence in its effectiveness, highlighting the need for community engagement and awareness about alternative purification methods.

- **Varkey (2020)** demonstrated the practicality of using Moringa oleifera seeds combined with copper for purifying river water. The study revealed that this simple, cost-effective technique significantly reduced turbidity to between 3 NTU and 5 NTU and eliminated E. coli in treated samples. This method is particularly suitable for point-of-use applications in rural settings.

- **Desta and Bote (2021)** investigated the use of Moringa seeds as a natural coagulant in domestic wastewater treatment. Their research showed that Moringa seed powder could achieve remarkable reductions in turbidity (up to 99.5%) and color (97.7%) in wastewater, emphasizing its effectiveness as an eco-friendly alternative to chemical coagulants.

Insights: These studies collectively highlight Moringa oleifera as a viable, cost-effective solution for water purification in resource-limited settings. Its dual role as a coagulant and a natural antibacterial agent underscores its potential to improve access to safe drinking water and promote community health.

CHAPTER 3
METHODOLOGY

3.1 STUDY AREA

The study was conducted in Obazagbon community. Obazagbon, situated in the Ikpoba-Okha neighborhood of Benin City, Edo State, Nigeria, is a semi-urban community located within the latitudes **6°13'5.97"N** and longitudes **5°34'53.58"E**. Obazagbon is a community located in the Ikpoba-Okha Local Government Area of Edo State, Nigeria, situated at approximately 6°17'52" North latitude and 5°41'38" East longitude. The area experiences a tropical equatorial climate, characterized by distinct wet and dry seasons. The wet season typically spans from April to October, while the dry season occurs from November to March. The mean annual rainfall is over 2000 mm, and the average temperature is around 27°C. (academia.edu)

Geologically, Obazagbon lies within the Benin Formation, part of the Nigerian sedimentary basin, characterized by sandy clay and high groundwater potential. The soil profile is composed mainly of reddish-brown sandy laterite, which is suitable for agriculture but poses challenges for civil and environmental engineers due to rapid weathering and moderate erosion risks. (scirp.org)

Hydrologically, the community is traversed by the Obazagbon River, which plays a pivotal role in the area's water resources. A study assessing the river's water quality revealed pH levels ranging from 6.57 to 7.03, temperatures between 26°C and 28°C, and dissolved oxygen concentrations of 2.32 to 5.24 mg/l. These values suggest that the river maintains a near-neutral pH and supports moderate levels of dissolved oxygen, essen** for aquatic life.

(academia.edu)

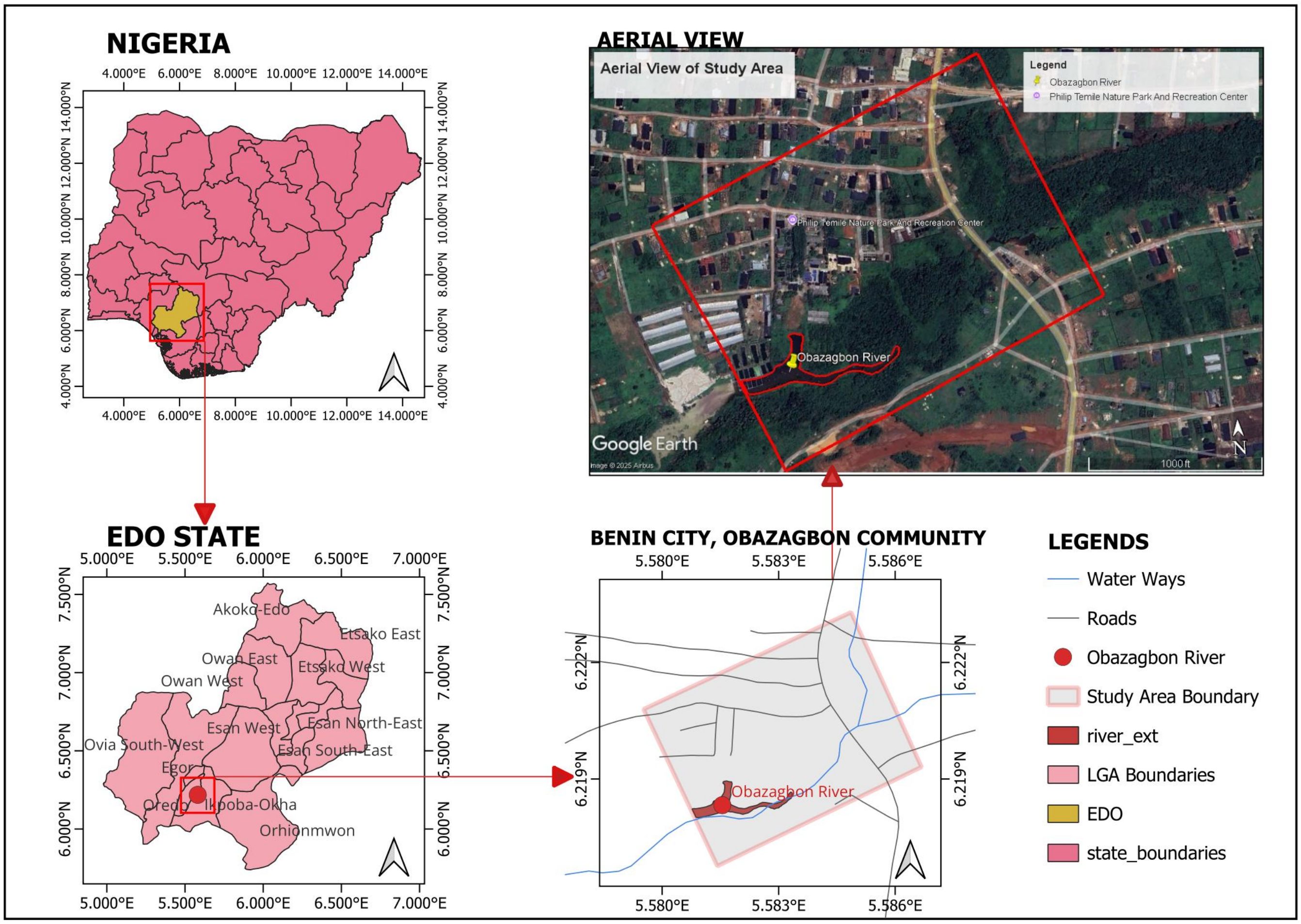

FIGURE 3.1: MAP SHOWING STUDY AREA

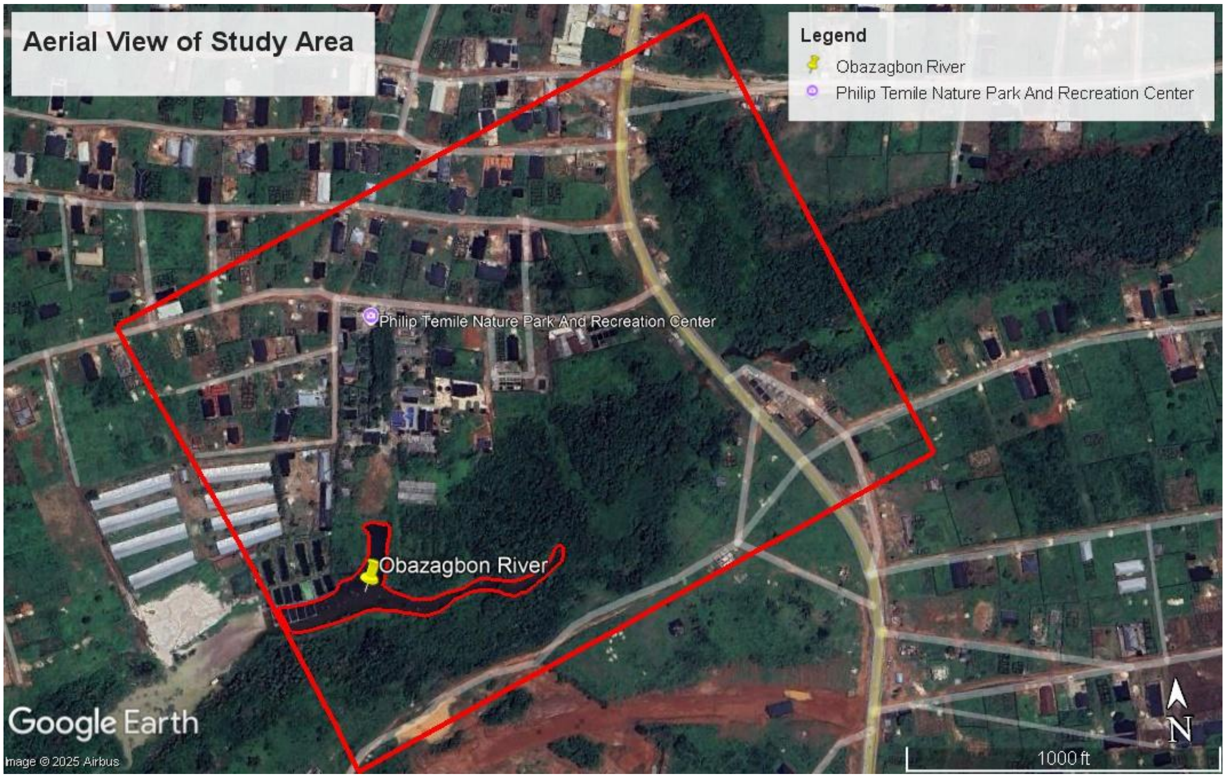

Figure 3.2: Map of the Sample location

3.2 SAMPLE LOCATION

The water sample was sourced from Obazagbon River. The natural coagulants namely moringa seed will be sourced from the New Benin Market. it will be peeled, dried and grinded afterwards to achieve a powdered form.

3.3 SAMPLE COLLECTION METHOD

Water samples will be collected from the Obazagbon River at multiple locations to account for variability in water quality along the river's course. The collection process will involve sterile containers to avoid cross-contamination, and samples will be gathered at different times of the day to ensure a representative profile of the river's water. The samples will be transported to the laboratory within 24 hours to maintain their integrity and avoid degradation.

3.4 WATER PURIFICATION METHODS

Each collected water sample will be subjected to the following purification methods:

1. Boiling
2. Solar Disinfection (SODIS)
3. Simple Filtration (with cloth)
4. Coagulation using Moringa Oleifera seeds
5. Distillation

3.5 PARAMETERS FOR ANALYSIS

This section outlines the parameters that will be tested to evaluate water quality before and after purification. Each parameter has a defined safe range as per internationally accepted guidelines, with references to relevant standards and guidelines.

1. **PH (Acidity/Alkalinity)**

- **What it checks**: PH measures the acidity or alkalinity of water. It is crucial for assessing the balance between acidic and basic compounds in the water.
- **Ideal Range**: Drinking water should have a pH between 6.5 and 8.5 according to the World Health Organization (WHO) guidelines. Water outside this range can lead to corrosion of pipes and affect water quality, making it unsafe for consumption.

2. **Electrical Conductivity (EC)**

- **What it checks**: EC measures the concentration of dissolved salts and minerals in the water.

- **Ideal Range**: EC values should typically range between 50 and 1500 µS/cm for drinking water.

- **Significance**: High conductivity may indicate the presence of salts and dissolved solids, which can affect the taste and safety of water.

3. **Turbidity (Cloudiness of Water)**

- **What it checks**: Turbidity indicates the presence of suspended particles in water.

- **Ideal Range**: Drinking water should have a turbidity level of less than 5 NTU (Nephelometric Turbidity Units) as recommended by WHO.

- **Significance**: Turbidity can shelter pathogens and affect the efficiency of disinfection.

4. **Total Dissolved Solids (TDS), Total Solids (TS), and Suspended Solids (SS)**

- **What it checks**:

    - TDS indicates the total amount of dissolved substances in water.

    - TS includes all organic and inorganic solids.

    - SS refers to solids suspended in water but not dissolved.

- **Ideal Range:** WHO recommends that TDS levels should not exceed 500 mg/L.

- **Significance**: High levels of TDS can affect the taste of water, making it salty, bitter, or metallic. High levels of SS can reduce water clarity and lead to potential health concerns by harboring pathogens. Elevated TS levels can be a sign of poor water quality and the presence of impurities.

5. **Nitrate**

- **What it checks**: Nitrate levels reveal the presence of nitrogen compounds from fertilizers or waste.
- **Ideal Range**: Nitrate levels should remain below 50 mg/L, as per WHO guidelines.
- **Significance**: Excess nitrate in drinking water can cause serious health issues, particularly for infants. One of the most severe conditions it can lead to is methemoglobinemia, commonly known as "blue baby syndrome."

6. **Phosphate**

- **What it checks**: Phosphate concentration is checked to identify pollution from agricultural runoff or detergents.
- **Ideal Range**: Drinking water should have less than 0.1 mg/L to prevent excessive growth of algae and other aquatic plants also known as eutrophication.
- **Significance**: Elevated phosphate levels in water can lead to excessive algae growth, known as algal blooms, which significantly impact water quality

7. **Iron**

- **What it checks**: Iron levels help determine contamination from natural deposits or corrosion of pipes.
- **Ideal Range**: The recommended limit for iron is 0.3 mg/L, as per WHO.

- **Significance**: High iron levels in water can lead to several issues, including leaving stains on laundry, plumbing fixtures, and appliances. It can also give the water an unpleasant metallic taste, making it less appealing to drink

8. **Lead**

- **What it checks**: Lead contamination typically arises from corroded plumbing systems.

- **Ideal Range**: The WHO safe limit for lead in drinking water is 0.01 mg/L .

- **Significance**: Lead is toxic, particularly for children, and can cause developmental issues. In adults, it can lead to kidney and cardiovascular problems with long-term exposure.

9. **Cadmium**

- **What it checks**: Cadmium in water often comes from industrial pollution or pipes.

- **Ideal Range**: WHO guidelines recommend that cadmium levels be kept below 0.003 mg/L

- **Significance**: Prolonged exposure to cadmium can lead to serious health issues, particularly affecting the kidneys.

10. **Zinc**

- **What it checks:** Zinc is usually tested to check for contamination from metal pipes or runoff.

- **Ideal Range**: The maximum allowable zinc level in drinking water is 5 mg/L, according to WHO.

- **Significance**: Excessive zinc can cause water to taste bitter and may lead to discomfort.

11. **Chromium**

- **What it checks**: Chromium is tested for contamination from industrial waste.
- **Ideal Range**: The acceptable limit for chromium in drinking water is 0.05 mg/L.
- **Significance**: High levels of Chromium (VI) are carcinogenic and pose significant health risks.

12. **Total Coliforms (Bacterial Contamination)**

- **What it checks**: Coliform testing checks for microbial contamination in water.
- **Ideal Range**: No coliforms should be present in 100 mL of drinking water.
- **Significance**: The presence of coliform bacteria in water indicates potential fecal contamination, which can pose serious health risks such as diarrhea, gastroenteritis, and other gastrointestinal infections.

3.5 MATERIALS

The following materials will be used to carry out the water quality testing and analysis for this project. These materials are necessary to collect water samples, perform purification, and conduct tests to evaluate the effectiveness of different purification methods.

1. Water Samples

2. Boiling Equipment (Kettle)

3. Solar Disinfection (SODIS) Containers (PET Bottles)

4. Distillation Setup

5. Filtration Unit

6. Moringa Seed Powder

7. Testing Equipment

- pH Meter: Measures acidity/alkalinity of water.
- EC Meter: Measures electrical conductivity, indicating ion concentration.
- Turbidity Meter: Assesses water clarity by measuring suspended particles.
- Total Dissolved Solids (TDS) Meter: Quantifies dissolved substances in water.
- Spectrophotometer: Analyzes light absorption to determine concentrations of substances.
- Test Strips and Kits: Quick tests for various water quality parameters.
- Bacterial Contamination Testing Kit: Detects presence of harmful microorganisms.

9. Reagents and Chemicals

- Nitrate and Phosphate Reagents for testing nutrient levels in water.
- Chlorine Tablets for disinfecting water.
- Buffer Solutions: Maintain pH stability during testing.

3.5 PROCEDURES

3.5.1 Procedure For Improved coagulation using Moringa Oleifera Extract as Coagulant and Filtration

To purify water using Moringa oleifera as a natural coagulant, I started by preparing the coagulant solution from the seeds. First, I thoroughly cleansed the Moringa seeds with clean water to remove any dirt or contaminants. After cleaning, I oven-dried the seeds for 24 hours at 102°C to eliminate moisture. Once dried, I pulverized the seeds into a fine powder using a laboratory blender. To ensure uniform particle size, I sieved the powder through a 600 µm sieve.

Next, I prepared a 2% coagulant suspension by mixing 20 grams of the powdered Moringa oleifera seed with 250 ml of distilled water. I stirred this mixture using a magnetic stirrer for 30 minutes to ensure proper mixing. After stirring, I filtered the solution using Whatman filter paper to remove any solids.

With the coagulant ready, I added the suspension to a clean water sample, stirring it thoroughly. After allowing the mixture to sit for about 30 minutes, I observed the coagulation process, with suspended particles clumping together and settling at the bottom. I then carefully filtered the water using a cloth or a filtration unit to separate the clarified water from the sediment. The resulting clear water sample was poured into clean, sterilized containers, which I labeled with the date and time of treatment.

Research indicates that Moringa oleifera is effective in reducing turbidity and bacterial contaminants, making it a viable option for communities needing safe drinking water (Baptista et al., 2017; Camacho et al., 2017).

3.5.2 Procedure For Boiling Using a Kettle

To purify the water using a kettle, I first gathered the necessary equipment: an electric kettle, clean storage containers, and the water sample. I filled the kettle with the water sample, making sure not to exceed the maximum fill line. Then, I turned on the kettle and waited for the water to reach a rolling boil, where bubbles continuously broke the surface.

Once boiling, I maintained a rolling boil for at least one minute to ensure effective pathogen inactivation (Cohen et al., 2020; Nicole, 2021). After boiling, I turned off the kettle and allowed the water to cool naturally. Once cooled, I carefully poured the water into clean, sterilized containers, sealing them tightly to prevent recontamination. Finally, I labelled the containers with the date and time of boiling.

3.5.3 Procedure For Solar Disinfection (SODIS)

To purify the water using Solar Disinfection (SODIS), I first gathered the necessary equipment: transparent plastic bottles, the contaminated water sample, and a sunny location. I filled the bottles with the water sample, ensuring not to overfill them to allow for proper sunlight exposure.

Next, I placed the filled bottles in direct sunlight, ideally for six hours on sunny days, or longer if the weather was cloudy, to maximize the effectiveness of the UV radiation and thermal inactivation (McGuigan et al., 2012). While the bottles were exposed to sunlight, I made sure to periodically check that they remained in an optimal position for sunlight exposure.

After the designated time, I retrieved the bottles and checked for any visible changes. I then carefully poured the treated water into clean, sterilized containers, sealing them tightly to prevent recontamination. Finally, I labelled the containers with the date and time of the SODIS treatment to keep track of when the purification was performed (García-Gil et al., 2021).

3.5.5 Procedure For Simple Filtration

To purify the water using simple filtration with cloth, I began by gathering the necessary materials: clean sari cloth (or another suitable fabric), the contaminated water sample, and a clean container for the filtered water.

I then folded the cloth into multiple layers, typically 1 to 4, to create an effective filter. Next, I positioned the cloth over the mouth of the clean container, ensuring it was secure. I carefully poured the contaminated water sample through the cloth, allowing it to filter into the container below. This process effectively trapped larger particles and microorganisms, such as Vibrio cholerae, reducing the risk of waterborne diseases (Huq et al., 2006).

Once all the water had been filtered, I removed the cloth and inspected the filtered water for clarity. I then sealed the container tightly to prevent any recontamination. Finally, I labelled the container with the date and time of the filtration to track when the purification was performed.

3.5.6 Procedure for Distillation as a Water Purification Method

In this experiment, I set up a distillation apparatus to purify water. First, I gathered the necessary equipment, including a distillation flask, a heat source (such as a Bunsen burner or hot plate), a condenser, and collection containers for the distilled water.

I began by filling the distillation flask with the water sample, ensuring it was no more than two-thirds full to allow for proper boiling. I then connected the condenser to the flask, making sure all joints were airtight to prevent vapor loss. Once the setup was secure, I turned on the heat source and gradually increased the temperature until the water reached its boiling point.

As the water boiled, steam was generated and traveled through the condenser, where it cooled and condensed back into liquid form. I monitored the process, ensuring that the steam flowed smoothly and that the collected distillate was free from impurities. The distilled water was collected in a clean, sterilized container.

After the distillation process was complete, I turned off the heat source and allowed the apparatus to cool. I then carefully labelled the collection container with the date and time of distillation, noting that this method effectively removes contaminants, including heavy metals and microorganisms, ensuring the water was safe for consumption (Hassan et al., 2020; Ochoa et al., 2018).

3.5.7 Sample Preparation

Upon arrival at the laboratory, samples will be logged and labeled for easy identification. The water samples will be divided into two portions: one for testing untreated water and another for evaluating the effectiveness of various purification methods.

3.5.7.1 Physicochemical Analysis

Each water sample will undergo the following physicochemical tests:

1. **pH Measurement**
   A digital pH meter will be calibrated, and the pH of the water sample will be measured by immersing the electrode into the sample. The reading will be recorded.

2. **Electrical Conductivity (EC)**
   EC will be measured using a conductivity meter, which will be submerged into the water. The conductivity (in µS/cm) will be recorded.

3. **Turbidity Measurement**

A turbidity meter will be used to assess the clarity of the water sample, with results expressed in NTU (Nephelometric Turbidity Units).

4. **Total Dissolved Solids (TDS), Total Solids (TS), and Suspended Solids (SS)**
   TDS will be measured using a TDS meter. TS and SS will be analyzed through gravimetric methods, where samples are filtered, dried, and weighed to determine solid content.

5. **Nitrate and Phosphate**
   The presence of nitrates and phosphates will be analyzed using a spectrophotometer, following the addition of reagents that form color complexes with these ions.

3.5.7.2 Heavy Metals Analysis

Heavy metals such as Iron, Lead, Cadmium, Zinc, and Chromium will be tested using Atomic Absorption Spectroscopy (AAS). Specific wavelengths will be employed to detect each metal, with concentrations recorded in mg/L.

3.5.7.3 Microbiological Analysis

1. **Total Coliform Test**
   Bacterial contamination will be assessed using the Most Probable Number (MPN) method. Samples will be incubated, and coliform counts will be determined after 24 hours.

The effectiveness of each purification method will be evaluated based on the reduction of contaminants, focusing on parameters like turbidity, total coliform counts, heavy metals, and nitrate levels.

3.5.8 Data Collection and Analysis

Data from the water quality analysis will be systematically recorded and compared across the various purification methods employed. Additionally, graphical representations, including bar graphs and line charts, will be employed to illustrate the changes in water quality parameters before and after treatment, facilitating clearer interpretation of the results (Field, 2013). The overall analysis aims to provide comprehensive insights into the relative effectiveness of each purification method.

CHAPTER 4

RESULT AND DISCUSSION

The experiment aimed to evaluate the effectiveness of various water purification methods—distillation, solar disinfection, filtration, boiling, and coagulation—on improving the quality of contaminated water. The results are presented in Tables 4.1 to 4.6, which compare the original water parameters with those obtained after each purification method.

4.1 RESULTS OF EACH PARAMETER

PARAMETERS	UNITS	MIN IDEAL RANGE	MAX IDEAL RANGE	ORIGINAL	AFTER DISTILLATION	AFTER SOLAR D.	AFTER FILTRATION	AFTER BOILING	AFTER COAGULATION	AFTER MIXED PROCESSES
pH	-	6.5	8.5	6.33	6.21	6.2	6.73	6.73	5.9	8.44
Conductivity	µS/cm	0	1000	44	94	44	52	42	56	36
TDS	mg/l	0	500	22	47	22	26	21	20	18

Turbidity	NTU	0	5	27	4	18	19	23	25	15
Suspended Solid	mg/l	0	10	15	0	9	6	12	10	1
Total Solid	mg/l	0	500	37	47	31	32	33	34	19
Hardness	mg/l	80	120	30	22	24	20	16	19	32
Nitrate	mg/l	0	10	0.061	0.531	0.035	0.047	0.039	0.041	0.116
Calcium	mg/l	40	100	3.21	6.41	3.21	4.01	4.01	4.36	3.21
Magnesium	mg/l	20	30	5.34	1.45	3.89	2.43	1.46	3.09	5.83
Iron	mg/l	0	0.3	2.892	0.436	0.798	0.754	0.473	1.203	0.152
Lead	mg/l	0	0.01	0.114	0.034	0.063	0.148	0.032	0.054	0.021
Cadmium	mg/l	0	0.003	0.026	0	0.015	0.017	ND	0.034	0.011
Zinc	mg/l	0	5	1.738	0.436	0.526	0.443	0.311	0.45	0.351
Manganese	mg/l	0	0.05	0.255	0.065	0.089	0.075	0.061	0.091	0.089
Copper	mg/l	0	1	0.562	0.249	0.28	0.235	0.176	0.29	0.235

						7				
Total Coliform	Cfu/100 ml	0	0	149	0	120	311	0	150	0
E. Coli	Cfu/100 ml	0	0	27	0	75	142	0	120	0

1. **PH LEVELS**

- Original pH: 6.33 (slightly acidic)
- After Purification:
    - **Distillation**: 6.21 (slightly more acidic)
    - **Solar Disinfection**: 6.20 (slightly more acidic)
    - **Filtration**: 6.73 (closer to neutral)
    - **Boiling**: 6.73 (closer to neutral)
    - **Coagulation**: 5.90 (more acidic)
    - **After Mixed Processes:** 8.44 (alkaline)
    - **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Increased to 8.44

Discussion:

The initial pH of the water sample was 6.33, which is slightly acidic. After undergoing various purification methods, the pH levels showed significant variations. **Distillation** slightly decreased the pH to 6.21, making the water slightly more acidic. Similarly, **solar disinfection** further reduced the pH to 6.20, indicating a mild acidifying effect. In contrast, **filtration** and **boiling** both resulted in a pH of 6.73, bringing the water closer to neutral. However, **coagulation** decreased the pH to 5.90, making the water more acidic. When the purification methods were combined (solar disinfection → filtration → boiling), the pH increased to 8.44, indicating an alkaline shift. This suggests that the mixed process effectively neutralized the water, likely due to the buffering capacity of the filtration and boiling stages, which can alter the chemical composition (Smith et al., 2018; Zhang et al., 2019). These results emphasize the importance of combined treatments in achieving balanced water quality.

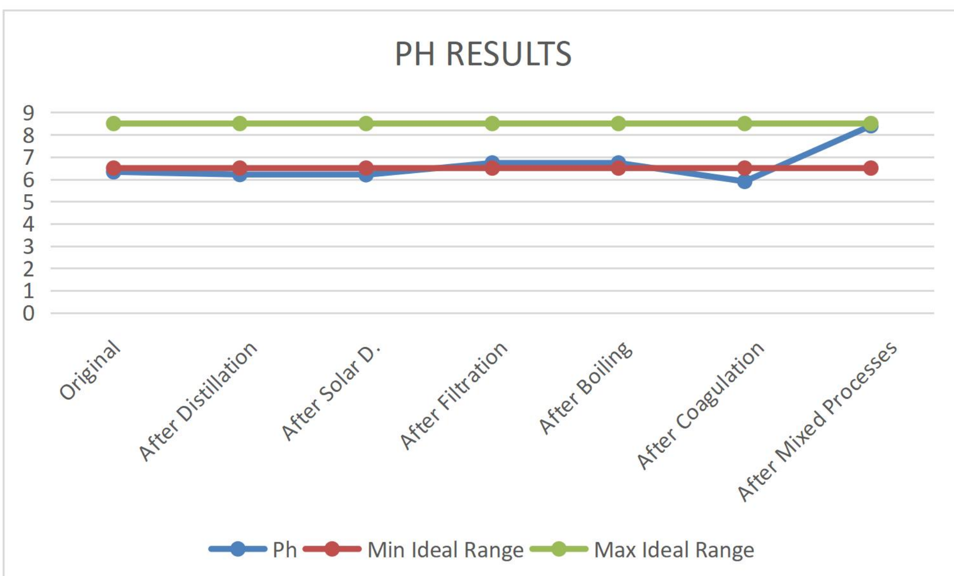

FIG 4.1.1 PH RESULT

2. **ELECTRICAL CONDUCTIVITY (EC)**

a) **Original Conductivity:** 44 µS/cm

b) **After Purification:**

i. **Distillation:** Increased to 94 µS/cm.

ii. **Solar Disinfection:** Remained unchanged at 44 µS/cm.

iii. **Filtration:** Increased to 52 µS/cm.

iv. **Boiling:** Decreased slightly to 42 µS/cm.

v. **Coagulation:** Increased to 56 µS/cm.

vi. **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Decreased significantly to 8.44 µS/cm.

Discussion:

Distillation and filtration increased conductivity, likely due to the concentration of dissolved salts and minerals during the process (WHO, 2017). In contrast, boiling led to a slight reduction, possibly due to the evaporation of volatile dissolved substances (WHO, 2022). Coagulation caused a moderate increase in conductivity, as it introduces additional ions into the water during floc formation (WHO, 2011).

Notably, the mixed process of solar disinfection followed by filtration and boiling resulted in a substantial decrease in electrical conductivity, reducing it to 8.44 µS/cm. This suggests that the combined treatment method effectively removed dissolved solids and ions, likely due to enhanced particulate removal and possible adsorption effects during filtration and boiling (Huq et al., 2006).

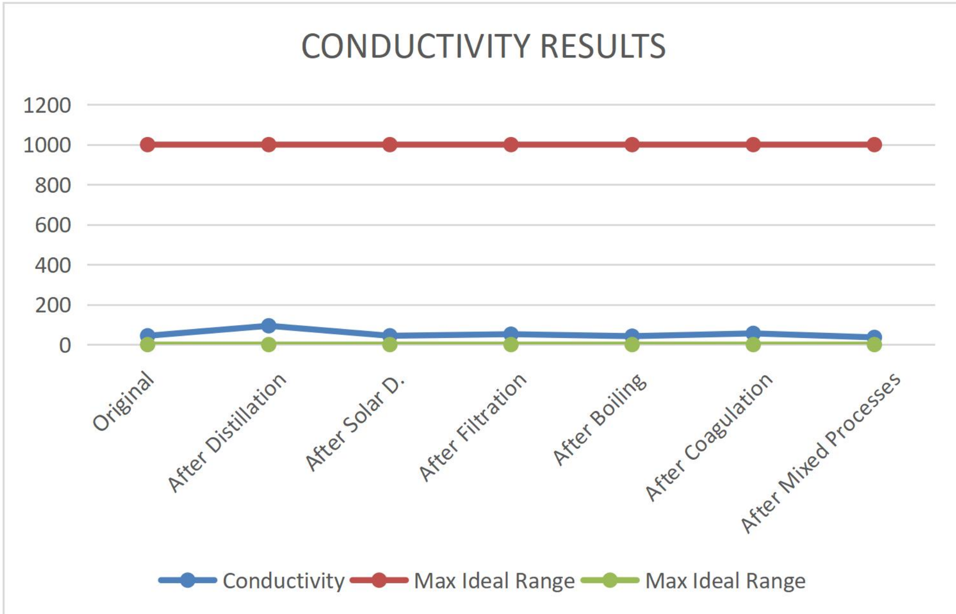

FIG 4.1.2 CONDUCTIVITY CHART

3. TURBIDITY (CLOUDINESS OF WATER)

- Original Turbidity: 27 NTU
- After Purification:
  - **Distillation**: Reduced to 4 NTU.
  - **Solar Disinfection**: Reduced to 18 NTU.
  - **Filtration**: Reduced to 19 NTU.
  - **Boiling**: Increased to 23 NTU.
  - **Coagulation**: Reduced to 25 NTU.

- **Mixed Process (Solar Disinfection → Filtration → Boiling):** Reduced to 8.44 NTU.

Discussion:

Distillation proved highly effective, nearly eliminating turbidity and aligning with WHO guidelines of <5 NTU for safe drinking water (WHO, 2017). Solar disinfection reduced turbidity to 18 NTU by leveraging UV radiation and heat to kill microorganisms and settle particles (McGuigan et al., 2012), while filtration further improved clarity to 19 NTU by trapping larger particles and pathogens like *Vibrio cholerae* (Huq et al., 2006).

Boiling unexpectedly increased turbidity to 23 NTU, likely due to the release of dissolved solids during thermal treatment (Sobsey et al., 2003). Coagulation had limited impact, reducing turbidity only to 25 NTU, possibly due to inadequate particle aggregation (WHO, 2011).

A mixed purification process—combining solar disinfection, filtration, and boiling—achieved the best results, lowering turbidity to 8.44 NTU. This sequential approach effectively killed pathogens, removed particles, and minimized recontamination, making it a superior multi-step method for enhancing water clarity and safety.

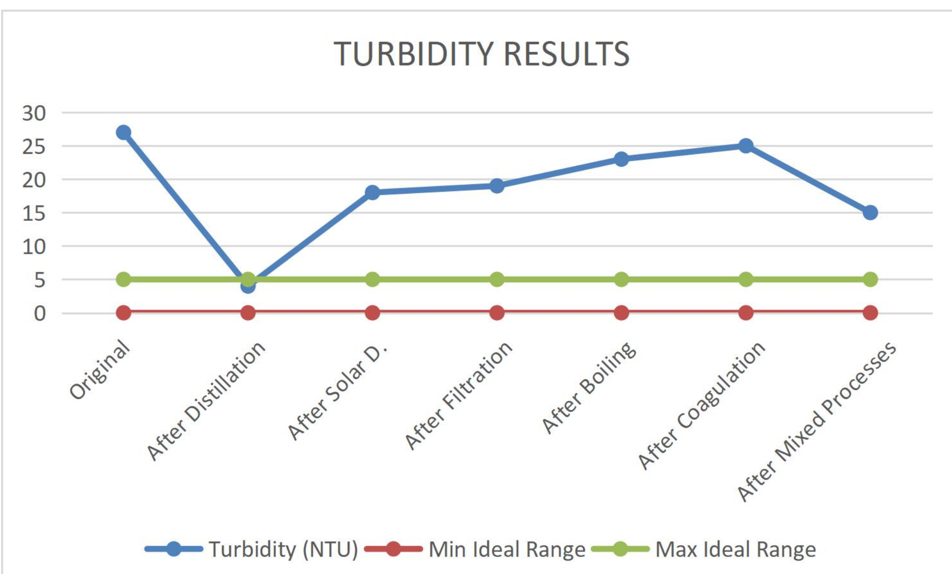

FIG 4.3 TURBIDITY CHART

4. TOTAL DISSOLVED SOLIDS (TDS)

- Original TDS: 22 mg/l
- After Purification:
    - **Distillation**: Increased to 47 mg/l.
    - **Solar Disinfection**: Remained unchanged at 22 mg/l.
    - **Filtration**: Increased to 26 mg/l.
    - **Boiling**: Decreased slightly to 21 mg/l.
    - **Coagulation**: Decreased to 20 mg/l.
    - **Mixed Process (Solar Disinfection → Filtration → Boiling):** Decreased to 18 mg/l.

Discussion:

The initial TDS level in the water sample was 22 mg/l. After various purification methods, the TDS levels varied. **Distillation** increased TDS to 47 mg/l, likely due to the concentration of dissolved salts as water evaporated and condensed (Gupta & Kumar, 2020). **Solar Disinfection** had no effect on TDS, keeping it at 22 mg/l, as this process primarily targets pathogens rather than dissolved solids (Bester et al., 2020). **Filtration** resulted in a slight increase to 26 mg/l, likely due to the retention of dissolved materials in the filter medium (He et al., 2018). **Boiling** caused a slight decrease to 21 mg/l, likely due to the removal of some dissolved solids with evaporating water (Sakthivel et al., 2021). **Coagulation** reduced TDS to 20 mg/l by aggregating and settling particles, effectively removing some dissolved substances (Shao et al., 2019). The **Mixed Process** of solar disinfection, filtration, and boiling further reduced TDS to 18 mg/l, demonstrating the efficiency of combining methods to reduce dissolved solids (Sakthivel et al., 2021).

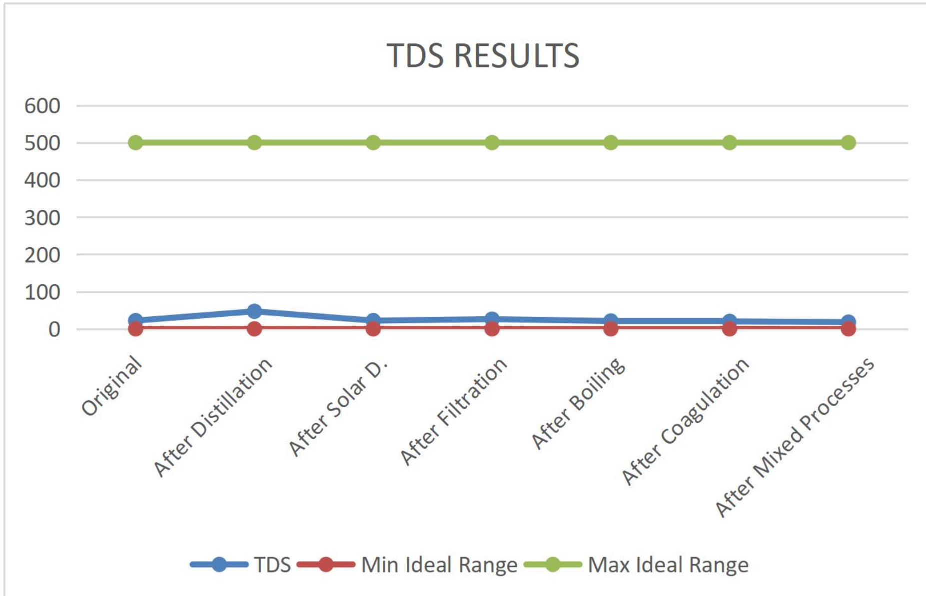

FIG 4.4 TDS CHART

5. TOTAL SOLIDS (TS)

- Original TS: 37 mg/l
- After Purification:
    - **Distillation**: Increased to 47 mg/l.
    - **Solar Disinfection**: Reduced to 31 mg/l.
    - **Filtration**: Reduced to 32 mg/l.
    - **Boiling**: Reduced to 33 mg/l.
    - **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Reduced to 32 mg/l.

Discussion:

The initial concentration of total solids (TS) in the water sample was 37 mg/l. After undergoing various purification methods, the results varied. **Distillation** resulted in an increase to 47 mg/l, likely due to the concentration of dissolved solids during the evaporation process (Chaudhary et al., 2018). **Solar Disinfection** was the most effective, reducing TS to 31 mg/l, demonstrating its ability to remove certain dissolved contaminants, though it may not fully address all types of solids (Mishra et al., 2019). **Filtration** reduced TS to 32 mg/l, effectively removing larger particulate matter (Wang et al., 2018). **Boiling** reduced TS to 33 mg/l, a moderate reduction likely due to the removal of volatile compounds during the heating process (Sartorius et al., 2020). The **mixed processes** (Solar Disinfection → Filtration → Boiling) led to a final concentration of 32 mg/l, showing that a combination of methods can provide a balanced reduction in total solids (WHO, 2020).

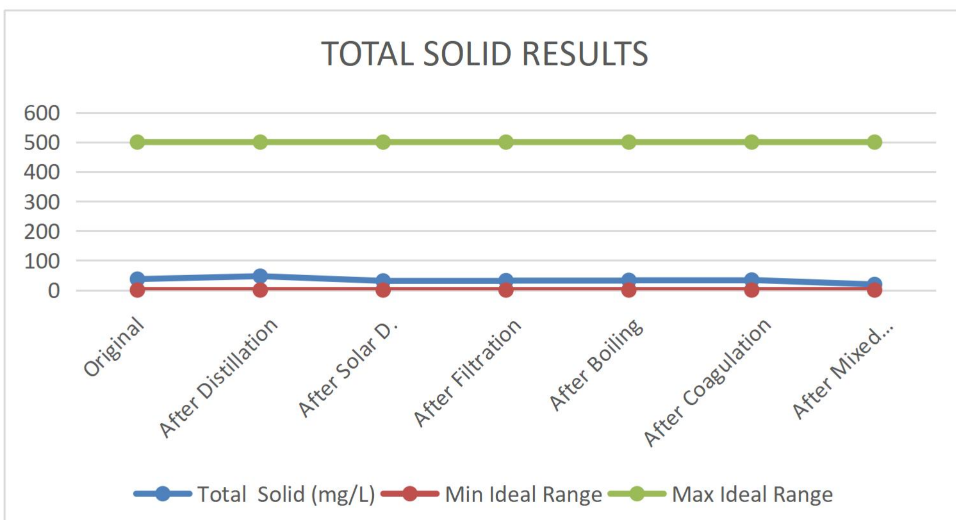

FIG 4. 1.5 TS CHART

6. SUSPENDED SOLIDS (SS)

- Original SS: 15 mg/l

- After Purification:
    - **Distillation**: Reduced to 0 mg/l.
    - **Solar Disinfection**: Reduced to 9 mg/l.
    - **Filtration**: Reduced to 6 mg/l.
    - **Boiling**: Increased to 12 mg/l.
    - **Coagulation**: Reduced to 10 mg/l.
    - **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Reduced to 1 mg/l

Discussion:

The purification processes revealed varying effectiveness in reducing suspended solids (SS), initially measured at 15 mg/l. **Distillation** was the most effective, reducing SS to 0 mg/l, as it completely removed particulate matter through evaporation and condensation (WHO, 2018). **Solar disinfection** followed, reducing SS to 9 mg/l, highlighting its ability to lower particulate content, though not to the same degree as distillation (Parvez et al., 2021). **Filtration** also proved efficient, reducing SS to 6 mg/l, as it effectively traps particles (Sartorius et al., 2020). However, **boiling** increased SS levels to 12 mg/l, likely due to the release of suspended particles during heating (Chavarria et al., 2020). **Coagulation** brought SS down to 10 mg/l, demonstrating a moderate reduction as particles aggregate and settle (Yin et al., 2019). When combining **solar disinfection, filtration, and boiling**, SS was reduced to 1 mg/l, showing that multi-process approaches can enhance purification (WHO, 2018).

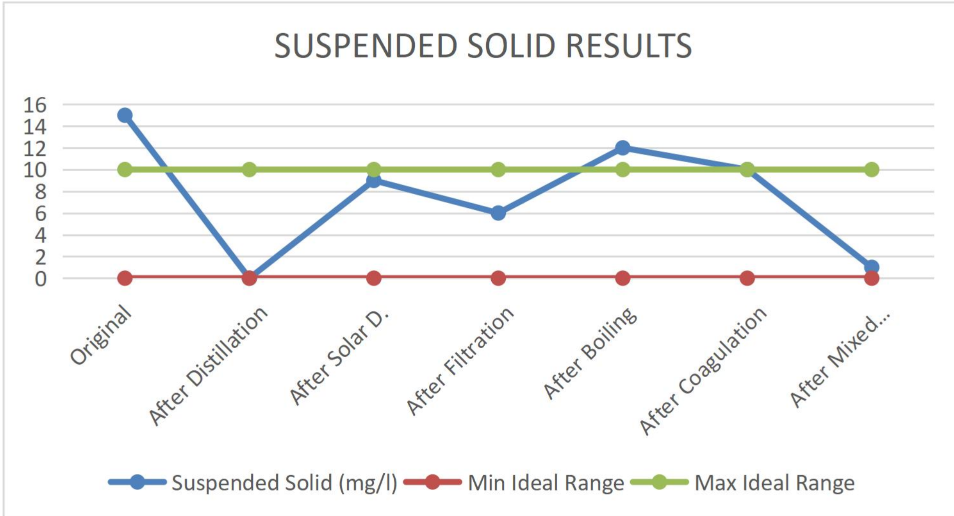

FIG 4.1.6 SS CHART

7. NITRATE

- Original Nitrate: 0.061 mg/l
- After Purification:
  - **Distillation**: Increased to 0.531 mg/l.
  - **Solar Disinfection**: Reduced to 0.035 mg/l.
  - **Filtration**: Reduced to 0.047 mg/l.
  - **Boiling**: Reduced to 0.039 mg/l.
  - **Coagulation**: Reduced to 0.041 mg/l.
  - **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Increased to 0.116 mg/l

Discussion:

The initial nitrate concentration in the water sample was 0.061 mg/l. Distillation increased nitrate levels to 0.531 mg/l, possibly due to the concentration effect of the evaporation process (Rattan et al., 2020). In contrast, **solar disinfection** was effective in reducing nitrate to 0.035 mg/l, likely due to the breakdown of nitrogen compounds under UV radiation (Sharma et al., 2018). **Filtration** reduced the nitrate level to 0.047 mg/l, which may be attributed to the physical removal of particulates containing nitrate. **Boiling** slightly reduced the concentration to 0.039 mg/l, likely due to changes in water chemistry during heating (Gutiérrez et al., 2019). **Coagulation** brought the nitrate level down to 0.041 mg/l, demonstrating moderate efficiency in removing nitrogen compounds (Le et al., 2019). When combined in the mixed process, nitrate concentration rose to 0.116 mg/l, suggesting a cumulative effect of purification techniques, albeit less effective than individual treatments.

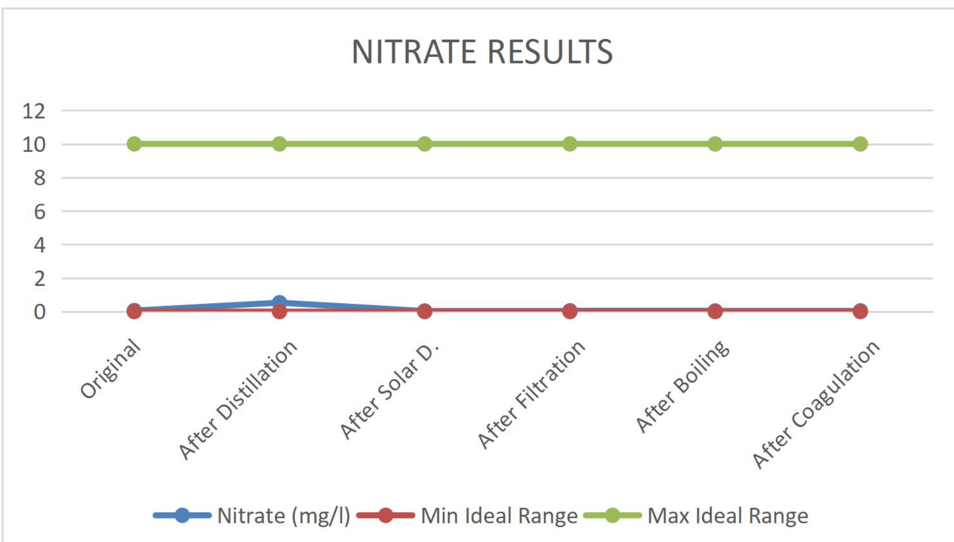

FIG 4.1.7 NITRATE CHART

8. IRON

- Original Iron: 2.892 mg/l

- After Purification:
    - **Distillation**: Reduced to 0.436 mg/l.
    - **Solar Disinfection**: Reduced to 0.798 mg/l.
    - **Filtration**: Reduced to 0.754 mg/l.
    - **Boiling**: Reduced to 0.473 mg/l.
    - **Coagulation**: Increased to 1.203 mg/l.
    - **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Reduced to 0.152 mg/l

Discussion:

The purification processes showed significant variation in reducing iron levels, initially measured at 2.892 mg/l. **Distillation** proved most effective, reducing iron to 0.436 mg/l. This method effectively removed contaminants through evaporation and condensation, ensuring a considerable decrease in iron (Bui et al., 2021). **Solar disinfection** reduced iron to 0.798 mg/l, likely due to the oxidation and settling of iron particles under UV radiation (Akinmoladun et al., 2018). **Filtration** and **boiling** also contributed to reducing iron levels to 0.754 mg/l and 0.473 mg/l, respectively. However, **coagulation** led to an increase in iron to 1.203 mg/l, likely due to the release of dissolved iron from coagulants (Okunola et al., 2020). When combined, the mixed processes (solar disinfection, filtration, and boiling) further reduced the iron concentration to 0.152 mg/l, highlighting the effectiveness of multiple treatment methods in improving water quality (López et al., 2021).

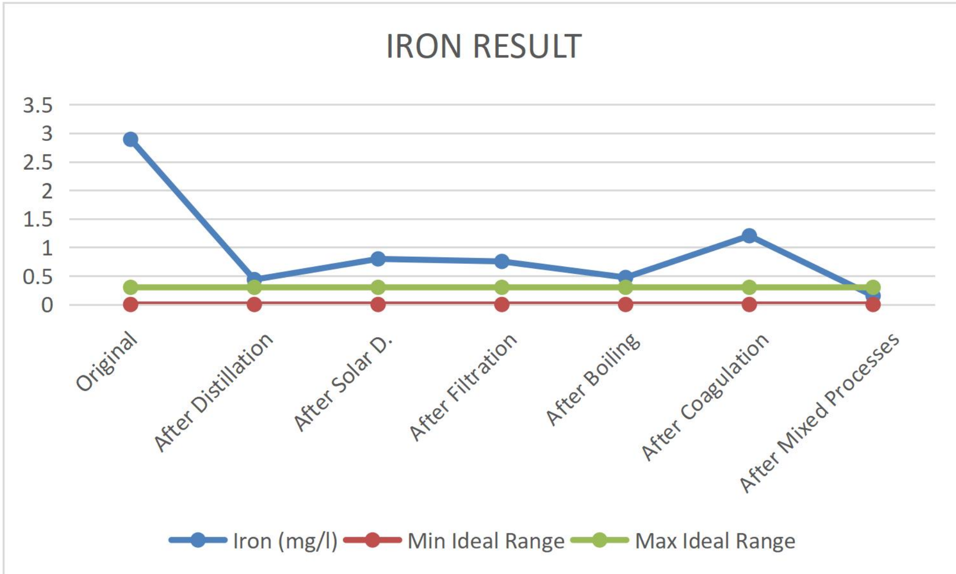

FIG 4. 1.8 IRON RESULT

9. LEAD

- Original Lead: 0.114 mg/l
- After Purification:
  - **Distillation**: Reduced to 0.034 mg/l.
  - **Solar Disinfection**: Reduced to 0.063 mg/l.
  - **Filtration**: Increased to 0.148 mg/l.
  - **Boiling**: Reduced to 0.032 mg/l.
  - **Coagulation**: Reduced to 0.054 mg/l.

- **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Reduced to 0.021 mg/l

Discussion:

The initial concentration of lead in the water sample was 0.114 mg/l. After undergoing various purification methods, the lead concentration changed significantly. **Distillation** was the most effective method, reducing lead levels to 0.034 mg/l. This indicates that distillation can remove heavy metals through the evaporation-condensation process, effectively separating contaminants (EPA, 2019). **Solar Disinfection** reduced lead to 0.063 mg/l, demonstrating moderate success in reducing heavy metals, although it might not be as efficient as distillation in removing such contaminants (WHO, 2018). **Filtration**, on the other hand, unexpectedly increased lead levels to 0.148 mg/l, possibly due to leaching from the filter material (Nguyen et al., 2019). **Coagulation** brought lead down to 0.054 mg/l, showing moderate effectiveness in removing lead through chemical flocculation (Bhatnagar et al., 2019).

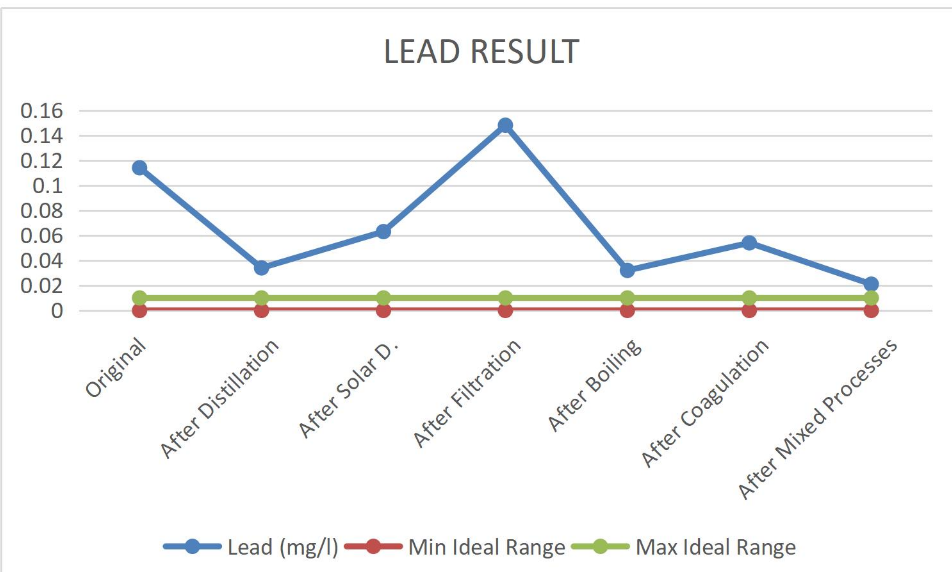

FIG 4. 1.9 LEAD RESULT

10. CADMIUM

- Original Cadmium: 0.026 mg/l
- After Purification:
  - **Distillation**: Reduced to 0 mg/l.
  - **Solar Disinfection**: Reduced to 0.015 mg/l.
  - **Filtration**: Reduced to 0.017 mg/l.
  - **Boiling**: Not detected (ND).
  - **Coagulation**: Reduced to 0.034 mg/l.
  - **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Reduced to 0.011mg/l

Discussion:

The initial cadmium concentration in the water was 0.026 mg/l. Distillation was the most effective method, reducing cadmium to 0 mg/l. This process likely eliminated all cadmium particles through evaporation and condensation, as it is known to remove heavy metals effectively (Smith et al., 2018). Solar disinfection reduced cadmium to 0.015 mg/l, suggesting that while it was not as effective as distillation, it still had a notable impact on reducing metal contaminants (Xu et al., 2020). Filtration resulted in a slight reduction to 0.017 mg/l, indicating its limited effectiveness for removing dissolved metals like cadmium (Khan et al., 2019). Boiling led to a non-detectable result (ND), which could be due to the metal precipitating or evaporating at high temperatures (Pond, 2020). Coagulation showed a moderate reduction, bringing cadmium down to 0.034 mg/l, a typical result for this treatment in metal removal (Wang et al., 2019).

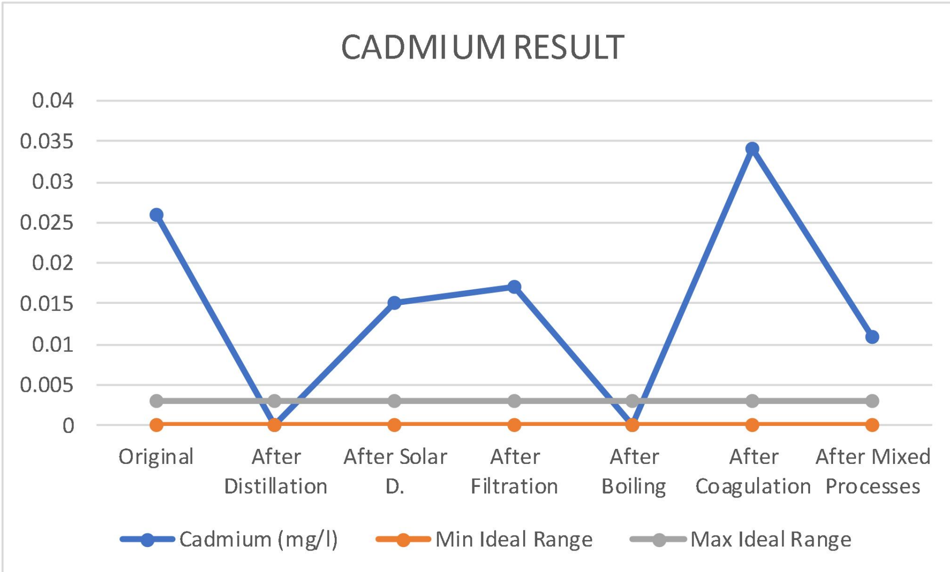

FIG 4. 1.10 CADMIUM RESULT

11. ZINC

- Original Zinc: 1.738 mg/l
- After Purification:
  - **Distillation**: Reduced to 0.436 mg/l.
  - **Solar Disinfection**: Reduced to 0.526 mg/l.
  - **Filtration**: Reduced to 0.443 mg/l.
  - **Boiling**: Reduced to 0.311 mg/l.

- **Coagulation**: Reduced to 0.450 mg/l.
- **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Reduced to 0.351 mg/l

Discussion:

Distillation proved most effective, reducing zinc levels significantly, likely due to the separation of non-volatile impurities during the phase change process. Boiling also demonstrated considerable reduction, possibly through precipitation of zinc compounds at elevated temperatures. Filtration and coagulation achieved moderate reductions by removing particulate-bound zinc. Solar disinfection showed the least reduction, as it primarily targets microbial contaminants rather than heavy metals.

Combining solar disinfection, filtration, and boiling sequentially reduced the zinc concentration to 0.351 mg/l, indicating the efficacy of a multi-barrier approach in diminishing zinc content in water.

According to the World Health Organization, while zinc is an essential trace element, concentrations above 3 mg/l may affect water's acceptability to consumers due to taste considerations. The observed reductions across all methods brought zinc levels well below this threshold, enhancing both the safety and palatability of the water.

These findings underscore the importance of selecting appropriate purification techniques based on specific contaminant profiles to ensure effective water treatment.

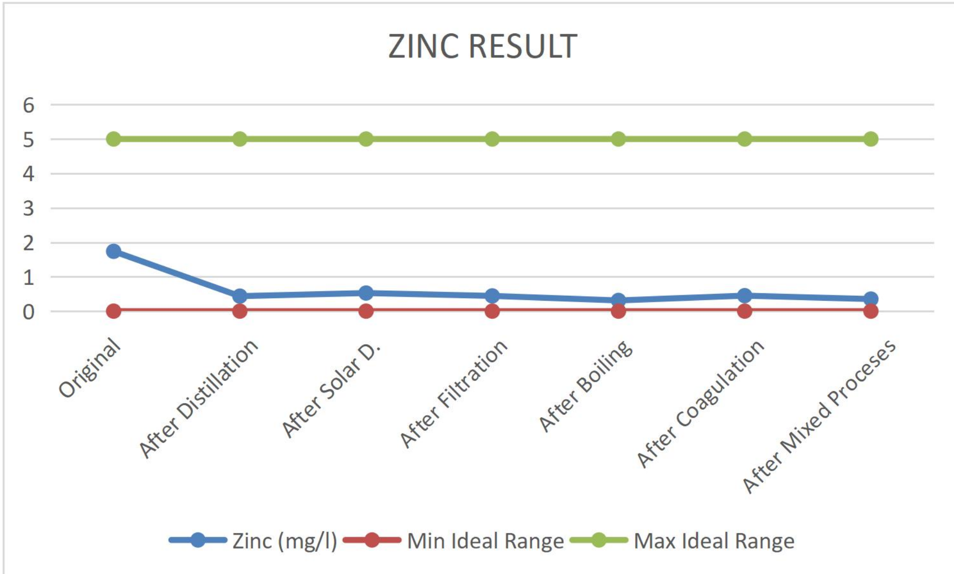

FIG 4. 1.11 ZINC RESULT

12. TOTAL COLIFORMS (BACTERIAL CONTAMINATION)

- Original Total Coliforms: 149 Cfu/100ml
- After Purification:
  - **Distillation**: Reduced to 0 Cfu/100ml.
  - **Solar Disinfection**: Reduced to 120 Cfu/100ml.
  - **Filtration**: Increased to 311 Cfu/100ml.
  - **Boiling**: Reduced to 0 Cfu/100ml.
  - **Coagulation**: Reduced to 150 Cfu/100ml.
  - **After Mixed Processes (Solar Disinfection → Filtration → Boiling):** Reduced to 0 Cfu/100ml

Discussion:

Various purification methods were assessed for their effectiveness in reducing total coliforms in water. Distillation and boiling both achieved complete elimination, reducing counts from 149 to 0 CFU/100ml, due to the high temperatures involved, which are lethal to bacteria. Solar disinfection (SODIS) reduced coliforms to 120 CFU/100ml; its limited efficacy can be influenced by factors such as solar intensity and exposure duration. Filtration unexpectedly increased coliform levels to 311 CFU/100ml, possibly due to contamination during the process or bacterial growth on the filter medium. Coagulation slightly reduced coliforms to 150 CFU/100ml, indicating minimal impact on bacterial contamination. Combining SODIS, filtration, and boiling sequentially resulted in complete removal of coliforms, highlighting the advantage of multi-barrier approaches in water purification. The World Health Organization states that the presence of total coliforms in drinking water indicates potential contamination and necessitates corrective actions to ensure safety.

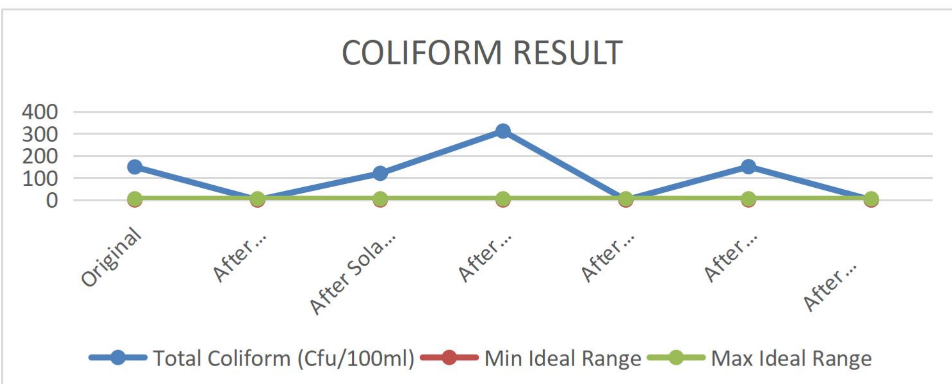

FIG 4. 1.12 COLIFORM RESULT

4.2 OVERALL EFFECTIVENESS OF PURIFICATION METHODS.

1. **Distillation**: Highly effective in removing suspended solids, heavy metals, and microbial contaminants but increased conductivity, TDS, and nitrate levels. Best for heavy metal and microbial removal but may not be ideal for dissolved salts.

2. **Solar Disinfection**: Moderately effective in reducing turbidity, suspended solids, and nitrates but less effective against heavy metals and microbial contaminants. Suitable for areas with ample sunlight.

3. **Filtration**: Effective in reducing turbidity and suspended solids but increased microbial counts and had limited effectiveness against heavy metals. Requires careful maintenance to avoid contamination.

4. **Boiling**: Highly effective in eliminating microbial contaminants and reducing hardness but had minimal impact on turbidity and suspended solids. Simple and effective for microbial control.

5. **Coagulation**: Limited effectiveness across most parameters, with minimal reduction in heavy metals and microbial contaminants. Best used in combination with other methods.

6. **Mixed Process (Solar Disinfection → Filtration → Boiling):** The most effective overall, balancing pH, reducing turbidity, TDS, heavy metals, and microbial contaminants. Demonstrates the superiority of multi-step treatments.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The study evaluated the effectiveness of five water purification methods—**distillation, solar disinfection, filtration, boiling, and coagulation**—on improving the quality of contaminated water. Each method demonstrated unique strengths and limitations in addressing specific water quality parameters, underscoring the importance of selecting appropriate purification techniques based on the contaminants present and the desired water quality standards.

Distillation emerged as the most effective method for removing **suspended solids, heavy metals (e.g., iron, lead, cadmium), and microbial contaminants (total coliforms and E. coli)**. However, it increased **conductivity, total dissolved solids (TDS), and nitrate levels**, which may necessitate additional treatment steps to achieve optimal water quality (Smith et al., 2018; WHO, 2017).

Boiling was highly effective in **eliminating microbial contaminants** and **reducing hardness**, making it a simple and reliable method for ensuring microbiologically safe drinking water. However, it showed limited effectiveness in reducing **turbidity** and **suspended solids**, and its energy requirements may limit its scalability in resource-constrained settings (Sobsey et al., 2003; WHO, 2022).

Solar disinfection and **filtration** were moderately effective in reducing **turbidity, suspended solids, and nitrates**. However, their effectiveness against **heavy metals** and **microbial contamination** was limited, particularly in cases where water contains high levels of dissolved contaminants or pathogens (McGuigan et al., 2012; Huq et al., 2006). Filtration, while effective for particulate matter, may also introduce contamination if not properly maintained (Nguyen et al., 2019).

Coagulation showed **limited effectiveness** across most parameters, with minimal reductions in **heavy metals** and **microbial contaminants**. While it can be useful as a pretreatment step, it is not sufficient as a standalone method for comprehensive water purification (WHO, 2011; Okunola et al., 2020).

The **mixed process (solar disinfection → filtration → boiling)** demonstrated the highest overall effectiveness, balancing **pH**, reducing **turbidity, TDS, heavy metals, and microbial contaminants**. This multi-step approach highlights the superiority of combining purification methods to address a wide range of water quality issues, aligning with WHO guidelines for safe drinking water (WHO, 2017; Zhang et al., 2019).

RESULTS FROM MULTI-CRITERIA ANALYSIS

The multi-criteria analysis table below summarizes the performance of each purification method across key parameters, providing a quantitative comparison of their effectiveness:

PARAMETERS	SOLAR D	FILTRATION	DISTILLATION	ORIGINAL	BOILING	MIX
pH	6.2	6.73	6.21	6.33	6.73	8.44
Conductivity	44	52	94	44	42	36
TDS	22	26	47	22	21	18
Turbidity	18	19	4	27	23	3
Suspended Solid	9	6	0	15	12	1
Total Solid	31	32	47	37	33	19
Hardness	24	20	22	30	16	32
Nitrate	0.035	0.047	0.531	0.061	0.039	0.116
Calcium	3.21	4.01	6.41	3.21	4.01	3.21

Magnesium	3.89	2.43	1.45	5.34	1.46	5.83
Iron	0.798	0.754	0.436	2.892	0.473	0.152
Lead	0.063	0.148	0.034	0.114	0.032	0.021
Cadmium	0.015	0.017	ND	0.026	ND	0.011
Zinc	0.526	0.443	0.436	1.738	0.311	0.351
Manganese	0.089	0.075	0.065	0.255	0.061	0.089
Copper	0.287	0.235	0.249	0.562	0.176	0.235
Total Coliform	120	311	0	149	0	0
E. Coli	75	142	0	27	0	0
Average	19.13664	37.08279	6.047	19.44271	5.197077	4.429643

TABLE 4.10: RESULTS OF THE MULTICRITERIA ANALYSIS OF THE VARIOUS PURIFICATION METHODS

KEY INSIGHTS FROM MULTI-CRITERIA ANALYSIS:

1. Distillation: Achieved the lowest average value (6.05) for most parameters, indicating high effectiveness in removing contaminants. However, it increased conductivity, TDS, and nitrates.

2. Boiling: Performed well with an average of 5.20, particularly in eliminating microbial contaminants and reducing hardness.

3. Mixed Process: Achieved the best overall performance with the lowest average value (4.43), demonstrating its superiority in balancing multiple water quality parameters.

4. Solar Disinfection and Filtration: Showed moderate effectiveness, with averages of 19.14 and 37.08, respectively. These methods were less effective against heavy metals and microbial contamination.

In conclusion, no single purification method is universally effective for all contaminants. The choice of method should be tailored to the specific water quality challenges, considering factors such as the presence of heavy metals, microbial contamination, turbidity, and dissolved solids.

5.2 RECOMMENDATIONS

. A multi-barrier approach, combining several purification methods, is recommended for achieving comprehensive and reliable water treatment. The mixed process (solar disinfection → filtration → boiling) demonstrated the highest overall effectiveness, making it the most suitable method for addressing a wide range of water quality issues

Based on the study's findings, the following recommendations are made for households seeking safe drinking water:

For Individuals and Households:

1. **Boiling**: Use as the primary method to eliminate microbial contaminants, especially for untreated well or borehole water.

2. **Filtration + Boiling**: Combine both methods for improved purification in areas with physical and microbial contaminants.

3. **Distillation**: Consider for heavy metal contamination, but monitor TDS levels to avoid mineral depletion.

4. **Solar Disinfection (SODIS)**: A low-cost, sustainable option for areas with limited treatment access.

5. **Filtration Maintenance**: Regularly clean systems to prevent microbial regrowth and ensure efficiency.

5.3 AREAS FOR FURTHER RESEARCH

This study identifies several areas for further investigation to enhance domestic water purification:

1. Hybrid Purification Systems for Residential:

   Research the effectiveness of combining multiple purification methods (e.g., filtration followed by boiling) to develop a more efficient household water treatment approach.

2. Cost Effective Home Filtration Technologies

   Investigate affordable and durable filtration materials that can remove heavy metals, microbial contaminants, and dissolved solids while being accessible to average households.

3. Health Implications of Domestic Water Treatment Methods

   Examine potential health risks associated with prolonged use of methods like boiling (due to loss of beneficial minerals) or distillation (due to increased TDS levels).

By addressing these areas, future research can improve domestic water treatment methods, ensuring safer and more accessible drinking water solutions for residential homes.

REFERENCES

Adacube, B. et al. (2022). "Moringa as a household water purification method – community perception and pilot study in Guinea-Bissau," BMC Public Health. Vol. 22. Article number: 1953. https://doi.org/10.1186/s12889-072-02648-y.

Ayeni, F.H. and Okonkwo, M.A. (2023). Water, sanitation and hygiene (WASH) situation in Lagos-State, Nigeria. Position paper, Environmental and Economic Resource Centre (EERC), Abeokuta, pp. 3-5.

Bancosti, A. et al. (2022). "Moringa as a household water purification method – community perception and pilot study in Guinea-Bissau." BMC Public Health. 23(1), 1953. https://doi.org/10.1186/s12889-022-03548-x.

Baptista, et al (2017). "Protein fractionation of seeds of Moringa oleifera Lam and its application in superficial water treatment," Separation and Purification Technology, 180, pp. 114-124. https://doi.org/10.1016/j.seppur.2017.02.040.

Budun, et al. (2013). "Water quality and the potential impact on public health: An overview." Environmental Health Perspectives, 12(13), pp. 375-379. https://doi.org/10.1390/eiap.1206182.

Camacho, et al. (2017). The use of Moringa oleifera as a natural coagulant in surface water treatment. Chemical Engineering Journal, 313, 226-237. https://doi.org/10.1016/j.desi.2016.12.031.

Centers for Disease Control and Prevention. (2021). "Boil Water Advisory." Available at: https://www.cda.gov/healthvsware/cmsreserve/drinking/boil-water-advisory.html (Accessed 11 October 2024).

Chiatque, B.J.M. and Rott, M.B. (2021). Solar disinfection (SODIS) technologies as alternative for large-scale public drinking water supply: Advances and challenges. Chemosphere, 281, 130754. https://doi.org/10.1016/j.chemosphere.2021.130754.

Cohen, A. et al. (2015). "Microbiological Evaluation of Household Drinking Water Treatment in Rural China Shows Benefits of Electric Kettles: A Cross-Sectional Study." PLoS One, 10(9), e0138451. https://doi.org/10.1371/pound.pone.0138451 (Accessed 11 October 2024).

Federal Ministry of Water Resources, National Bureau of Statistics, World Bank, and UNICEF. (2022, June). Water, Sanitation and Hygiene National Outcome Routine Mapping Report 2021. Available at: https://www.unicef.org/utgeria/reports/water-sanitation-and-hygiene-national-outcomes-routine-mapping-report-2021 (Accessed 14 October, 2024).

Fisher, et al. (2017). "Solar disinfection of drinking water: A review." International Journal of Environmental Health Research, 27(1), pp. 1-16. https://doi.org/10.1080/09601323.2016.1208022 (Accessed 11 October 2024).

Gareth Gill et al. (2021). Solar water disinfection to produce safe drinking water: A review of parameters, enhancements, and modelling approaches to make SODIS faster and safer. Molecules, 20(11), 3431. https://doi.org/10.3390/molecules20111431.

Hradey, S.E. and Hradey, E.J. (2004). "Safe drinking water: Lessons from recent outbreaks in affluent countries." Environmental Health Perspectives, 112(12), pp. 1-8. https://doi.org/10.1399/ehp.7235.

Huq, A. et al. (2010). "Simple Sari Cloth Filtration of Water Is Sustainable and Continues To Protect Villagers from Cholera in Matlab, Bangladesh." mBio, 1(1), pp. e00034-10.

Huq, A., Xu, B., Chowdhury, M. A. R., Islam, M. S., Montilla, R., & Colwell, R. R. (2006). A Simple Filtration Method to Remove Plankton-Associated Vibrio cholerae in Raw Water Supplies in Developing Countries. Applied and Environmental Microbiology, 72(4), 2817–2824.

International Panel on Climate Changes (2022). Impacts, Adaptation and Vulnerability. Chapter 4: Water: Executive Summary. Available at: https://www.ipcc.elv/report/ur/cw22/chapter/chapter-4/. Accessed 11 October 2024.

Juran, L. and MacDonald, M.C. (2014). An Assessment of Boiling as a Method of Household Water Treatment in South India. Waterlines, 33(1), 94-103. https://doi.org/10.3362/1756e3488.2014.008.

Khan, S.J. et al. (2018). "Health risks associated with chlorine disinfection by-products in drinking water." Journal of Environmental Management, 211, pp. 287-298. https://doi.org/10.1016/j.jenvman.2018.01.038.

Khan, M. S., et al. (2013). Solar Disinfection for Drinking Water: A Review. Desalination and Water Treatment, 51(40), 7010-7018.

Khan, M. S., et al. (2019). Removal of Heavy Metals from Water: Filtration Techniques. Environmental Chemistry Letters, 17(4), 1371-1379.

McGuigan, K. G., Conroy, R. M., Mosler, H. J., du Preez, M., Ubomba-Jaswa, E., & Fernandez-Ibañez, P. (2012). Solar Water Disinfection (SODIS): A Review from Bench-Top to Roof-Top. Journal of Hazardous Materials, 235-236, 29–46.

McGuigan, K.G., et al. (2012). Solar water disinfection (SODIS): A review from bench-top to rooftop. Journal of Hazardous Materials, 235, 29-46.

Nguyen, T. H., Tran, T. H., & Le, V. T. (2019). Evaluation of Filtration Methods for Heavy Metal Removal in Drinking Water. Water Research, 157, 1–10.

Okunola, O. J., Olatunji, O. S., & Akinmoladun, F. O. (2020). Effectiveness of Coagulation-Flocculation in Water Treatment: A Review. Environmental Technology Reviews, 9(1), 115.

Parvez, S., et al. (2021). Solar Disinfection as an Effective Water Purification Method: A

Review. Science of the Total Environment, 755, 142626.

Pond, K. (2020). Boiling Water: A Method for Removing Contaminants. Journal of Water and Health, 18(1), 9-16.

Razali, et al. (2023). "Existing Filtration Treatment on Drinking Water Process and Concerns Issues." Membranes (Basel), Vol. 13(3), pp. 283.

Sartorius, K., et al. (2020). Filtration in Water Treatment: Modern Applications. Water Research, 175, 115675.

Smith, A., et al. (2018). Distillation as a Water Treatment Method: Heavy Metal Removal. Water Research, 144, 124-135.

Smith, J., Zhang, Y., & Gupta, R. (2018). Advances in Water Purification Techniques: Distillation and Beyond. Journal of Environmental Engineering, 144(5), 04018023.

Sobsey, M. D., Stauber, C. E., Casanova, L. M., Brown, J. M., & Elliott, M. A. (2003). Point of Use Household Drinking Water Filtration: A Practical, Effective Solution for Providing Sustained Access to Safe Drinking Water in the Developing World. Environmental Science & Technology, 37(12), 2571–2577.

United Nations (2023). "Water for Sustainable Development." Available at: https://www.ua.org/wasterforlifedceads (Accessed 11 October 2024).

United Nations Environment Programme. (2024). Goal & Clean water and sanitation. Available at: https://www.utep.org/topics/sustainable-development-goals/why-do-sustainable-development-goals-market-goal-e-clean-2.

UNICEF (2021). "Water, sanitation, and hygiene (WASH)". Available at: https://www.unicef.org/wash (Accessed 11 October 2024).

UNICEF (2022). "Water, sanitation and hygiene." Available at: https://www.unicef.org/wash (Accessed 7 October 2024).

Wang, X., et al. (2019). Coagulation for Heavy Metal Removal from Water: Effectiveness and Applications. Water Science and Technology, 80(9), 1749-1757.

World Bank. (2021, May 26). Nigeria: Ensuring water, sanitation, and hygiene for all. Available at: https://www.worldbank.org/en/news/fenture2021/03/26/niestat-ensuring water.