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Impacts of water quality on the Compressive Strength of Concrete: Case of Banteyiketu, Betel, Bulbula and Mekanisa rivers in Addis Ababa

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DECLARATION

I declare that, this thesis prepared for the partial fulfillment of the requirements for the degree Of Master of Science in Construction Management entitled 'Impacts of Water Quality on the Compressive Strength of Concrete: Case of Addis Ababa Rivers' is my original research work and has not been presented in any university.

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CONFIRMATION

The research completed by Aklesia Dereje Negash titled 'Impacts of Water Quality on the Compressive Strength of Concrete: Case of Addis Ababa Rivers' was conducted under my Supervision and submitted to the examination in partial fulfillment of the requirements for The Master's degree in Infrastructure Planning and Management

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CERTIFICATION

The undersigned have examined the thesis entitled ‘Impacts of Water Quality on the Compressive Strength of Concrete: Case of Addis Ababa Rivers’ presented by Aklesia Dereje Negash, a candidate for the degree of Masters of Science, and hereby certify that it is worthy of acceptance.

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ABSTRACT

Addis Ababa is a water stressed city and it does not meet the demand of domestic water. On the other hand, there are aggressive constructions all over the city that need abundant water. In most of the areas, the construction has used piped water supply which adds an additional burden to the city's water distribution system. So, it is very important to consider alternative water supply for the construction industry. So, one of the possible sources is river water. In Addis Ababa, about 10 rivers flow through the city at various locations. The rivers have different capacities and quality levels. This research investigates the impact of using water from various rivers in Addis Ababa on the comprehensive strength of concrete. The study aims to identify key water quality parameters that influence concrete performance and assess the suitability of Addis Ababa river water for construction purposes. Water samples were collected from four distinct locations namely Bantiketu, Betel, Bulbula and Mekanisa taking into consider the river flow rates. Laboratory tests were conducted to evaluate parameters including pH levels, suspended and dissolved solids, and chemical composition. The results were compared with a control sample using potable water and analyzed against ASTM and ACI standards. The findings reveal that river water quality varies across sampling points, with Banteyiketu and Mekanisa exhibiting the cleanest water suitable for concrete mixing. Although Betel (P3) showed higher acidity and nitrate levels, requiring caution and potential treatment, all samples generally fell within permissible limits for concrete use. The Bulbula sample demonstrated the highest compressive strength, while the other samples also showed acceptable performance by the 28th day. This research concludes that with proper quality control, river water can serve as a viable alternative source of water for concrete production in Addis Ababa, addressing local water scarcity challenges. Building a three-story structure consumes water equivalent to the daily needs of 442–883 people or residents in 3–6 condominium blocks. This emphasizes the need for sustainable water management in urban construction.

Key words: Construction, compressive strength, water quality, Addis Ababa Rivers,

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ABBREVATIONS AND NOTATION

ACI	American Concrete Institute
AAWSA	Addis Ababa Water & Sewerage Authority
ASTM	American Society for testing and material
EN	European norm
g/l	Gram per Liter
IS	Indian standard
Km	Kilo Meter
LPCD	Liters per capita per day
m^3/day	Cubic meter per day
mg/l	Milligram per liter
N/MM^2	Newton per square millimeter
NRMCA	National Ready Mixed Concrete Association
PCA	Portland cement Association
PH	Power of hydrogen
UN	United Nation

CHAPTER ONE: INTRODUCTION

1.1 Background

Addis Ababa, the capital city of Ethiopia and the headquarter of African Union has many rivers which are the tributary of main Akaki river (Teleku / Big and Tinishu / Little). The tributaries of the Akaki River includes Kebena, Bantiyketu, Kortame, Bulbula, Lequ Soramba and kotebe rivers are the mains. All rivers at the end joins to Akaki river that consists of two main branches, meet at the confluence of Aba-Samuel reservoir. Little Akaki flows through the western part of the city, rises north-west of Addis Ababa on the flanks of Wechacha Mountain and has a length of 40 km before it reaches Aba Samuel reservoir.

The Big Akaki river located in the eastern part of the city which rises from north-east part of Addis Ababa (Entoto Kidane Miheret) area and flows into Aba-Samuel reservoir after about 53 km.

Along the rivers course, there are about four reservoirs; upstream and downstream of Addis Ababa constructed for various purposes. With the exception of Aba Samuel, all reservoirs supply water to Addis Ababa. Whereas, Aba Samuel is the first hydropower dam in Ethiopia constructed in the late 1930s for power generation. The municipal and industrial effluents that discharged into this rivers have significant challenges to the quality water which makes difficult for treatment and live of the biodiversity (Elias, 2017).

Addis Ababa city water demand has been increasing over time as a result of urban expansion and the increase in population, as well as rural-urban migration. Addis Ababa Water and Sewerage Authority (AAWSA) has mandated to supply water to the city. The authority is only supplier of water for the public and domestic demand. Various studies showed that the amount of water supplied to the city is much below to the demand. AAWSA report indicated that the city supplied water about 50 to 60% of the demand (Behailu B. et al, 2022). There is a severe shortages of water in the city.

In the meantime, there are enormous construction in the city that requires water for concreting. The construction industry also utilized from the AAWSA water supply. It adds additional demand and aggravates the city water supply system. Hence, it to explore alternative sources for concrete work. River water can be used as an alternative for non-drinking purposes like concrete mixing and irrigation. In construction, it helps reduce reliance on municipal water if it meets quality standards. Farmers also use river water for irrigating crops around the city. This eases the demand on Addis Ababa's limited treated water supply.

Among the potential alternative water sources for construction, untreated river water stands out as the most accessible. The presence of several rivers in Addis Ababa presents an opportunity to ease the growing demand for water in the construction sector. However, the effect of water quality from these rivers on the compressive strength of concrete remains insufficiently studied. Poor water quality can significantly reduce concrete strength, ultimately affecting the safety and durability of structures. Therefore, this research evaluated the suitability of river water in Addis Ababa for concrete mixing by comparing its impact on compressive strength with that of piped water supplied by AAWSA.

1.2 Problem statement

Water supply is an important segment for the development and sustainable life. However, in Addis Ababa, Ethiopia, the availability, adequacy and the quality of water supply does not meet the demand mainly due to the limitation of the capacity of water sources. On the other hand, Addis Ababa city population is increasing alarmingly due to internal migration and high population growth rate. Furthermore, the city is under rapid development and there are enormous construction activities along with rapid urbanization, and high expansion of industrialization around the city (i.e. small-scale and large-scale industries) (Dioha, 2020). Construction authorities contribute significantly to the pressure on Addis Ababa's already strained water supply by relying heavily on treated municipal water for concrete mixing and other construction activities. This added demand from large-scale construction projects exacerbates existing shortages and competes with domestic and public needs, leading to reduced water availability for residents (Birhanu, 2022)

Studies in developing countries indicate that while 20 liters per Person per day is considered adequate for domestic use (UN, 2001). In Ethiopia, the average per person water consumption varies between 10 and 20 liters per person per day in some urban areas and 3 to 4 liters per person per day in rural areas. (Woldemariam & Berhanu, 2009). It is obvious the per capita consumption varies with time. For example, the country ten years' development plan (2021 – 2030) indicated that for urban residents with access to 100 litters of tap water per person per day for grade one cities. According to the classifications, Addis Ababa is grade one city.

Over the recent years Addis Ababa's population has increased by more than 4% per year with the current estimated city's population standing at about 5.2 million (Addis Ababa, Ethiopia Metro Area Population, 2025). This rate of growth is expected to aggravate the gap in supply and demand for water, a problem expected to linger for the foreseeable future unless significant intervention can be conducted.

It requires an estimated supply of about 1.2 million m^3/day to meet the current demand of water. However, from various sources the actual supply is about 600 thousand liters per day. This inconsistency is in stark contrast with the current water production rates from both surface water and groundwater. It showed that the city covered only about 50% of the daily requirement (Moreda, 2023). Residents in Addis Ababa are suffering from acute shortage of water and are often hardest hit by the disruption, and thus get water supply just once a week and sometimes once in 2 weeks (Dioha, 2020).

The existing situation indicated that the majority of the construction industry utilized piped water for mixing a concrete and for curing purpose. This is also another burden to the city water distributions. There are many researches done on the water contents and pollution causes of the rivers in Addis Ababa, but there is a research gap on how much the Addis Ababa construction is sector is taking part from the water consumption of the country. The experience of other countries like in Hebei in 2015, the construction sector takes 24 to 33 % of the total water consumptions, which is about one-third of the required domestic demand. It creates another challenge for the water distribution to the city population. The Ethiopian constitution, Article 90 stated that citizens have a right to access potable water. In the case of Addis Ababa, the constitutional law was not respected.

Even though for the preparation of concrete requires good quality of water, Addis Ababa rivers water quality for the purpose of construction requirements specially for concreting should be checked against the standard. Therefore, the research attempts to identify the suitability of water found in the city's rivers that can be used in construction to make concrete. The research sought to address the management of costs and quality of the construction works.

1.3 General Objective

The general objective of the research is to analyze the water quality of Addis Ababa Rivers for concrete works and to find an alternative source of water for concrete production.

1.4 Specific Objective

- to evaluate the water quality and characteristics of main rivers in Addis Ababa.
- to compare the compressive strength of concrete made using river water and piped water
- to develop strategies to use the river water in Addis Ababa for concrete making.

1.5 Research question

- What is the current water quality of rivers flowing across Addis Ababa?
- Is it possible to use the Addis Ababa river water for concreting?
- What is the difference in compressive strength between concrete mixed with river water and that mixed with piped water?
- What are the main pollutants that inhibits the water from being used as construction input?

1.6 Significance of the study

This was conducted to search to construction industry in Addis Ababa an alternative water source to be used for the construction industry since the piped water currently supplied even could not meet the domestic demand. It can also have tried to identify which rivers can be used as they are and which ones cannot, as well as how far are they from being used as an input for construction. It can also be the basis study in this area and a baseline for the construction sector to consider river waters to be used in construction to optimize the utilization of available water resources. It will also give a new insight for the new riverside development projects that are planned to be built along the rivers of Addis Ababa.

1.7 Scope of the study

This research is both thematic, as it focuses on water quality and concrete production, and spatial, since it is centered on the rivers in Addis Ababa. It conducted in Addis Ababa and the results represented only the case of Banteyektu, Bulbula, Betel and Mekanisa**.** The research identified four sites for sampling based on its accessibility, budget and time limitations. The focus of the research is not to identify the source of pollution of the rivers. It does not address and recommend the treatment options to make use of rivers for construction purpose and does not cover implementation plan for the treatment options.

1.8 Limitations of the study

This research has encountered different kinds of limitations during collection of samples and analysis of the water samples. There was a logistical constraint and access to the sampling sites. Despite the efforts made to analyze all the chemical compositions in the samples, the availability of facilities was limited in the laboratory able to access. There is also lack of comprehensive data on the amount of water being consumed by the construction specifically in Addis Ababa. Hence, trends of India were taken. India and Ethiopia both face water scarcity worsened by rapid urbanization and booming construction. Construction activities in both countries often rely on treated municipal water, straining supplies meant for domestic use. Alternative sources like river or recycled water are underused due to quality concerns and lack of research in the area.

1.9 Organization of the document

First chapter provides an overview of the Research background, outlines Problem statement and research questions, as well as the Researches General and specific objectives, significance, scope, and limitations of the study.

The second chapter is the literature review part gives an overview of basic terms and definitions, about construction and water demand. Identifies the water scarcity of Addis Ababa. Assess the main chemical composition and limitations for the water to be used to mix concrete and its effect on the strength of concrete.

The chapter is the Methodology which outlines the research approach, techniques, and design employed to define the methods used in the study. It also details the procedures for data analysis and validation applied throughout the research process.

The fourth chapter is the research and discussion which presents the experiments and the results. In general, it presented the investigation of the suitability of the rivers water across Addis Ababa in terms of concrete comprehensive strength parameter. It discussed in detail on each experiments and the results from those experiments and tests.

The last chapter summarizes the research emphasizing the effects of water quality tests done on the quality of concrete. It also recommends some possible solutions for concerning bodies and upcoming researchers who are interested on this area of study.

1.10 Research gap

There is a research gap in understanding the construction sector's contribution to water consumption in Addis Ababa. While river pollution has been studied, little attention has been given to assessing the suitability of river water for concrete production. This study aims to explore that potential and reduce the construction sector's reliance on treated municipal water.

CHAPTER TWO: LITRATURE REVIEW

2.1 Introduction

Water is the basis of life and is a driving force for economic and social development and for poverty reduction. Water plays a, major role in everyday life of each individual starting from drinking to hydrate one's body to sanitation, industry and agriculture.

People working in different fields need water for different purposes such as farmers need water to grow crops, gardeners to water plants, industrialists for input in production, to generate power, etc. So, it is mandatory to save clean water for the wellness of our future generations and healthy life of water and wildlife. People at many places of the world are suffering from water scarcity or completely lack of water in their regions. (Asamoah, 2018)

Water is very important part in everyday life of people. It is also a scarce resource around the world as well as Ethiopia. In Addis Ababa the problem is more suffered with the shortage of clean water for daily consumption. Managing scarce water resource is the concern of every nation and need to optimize the available resources effectively. (Dioha, 2020)

Not only the quantity but also the impact of water quality on concrete comprehensive strength using water from various sources in Addis Ababa requires an attention. It clear that the quality of water affects the compressive strength of concrete. Various research findings provided insights on relationship between water quality and concrete properties. Water exposes to impurities due to natural and /or human interactions. (Birhanu, 2022)

The research reviewed different researches and case studies conducted on the impact of water source for concreting. It also assessed the main impurities that inhibit the quality of concrete in the construction sector.

2.2 Water Scarcity

2.2.1 Global Water Scarcity

Water is a scarce resource around the world. Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of water scarcity. Another 1.6 billion people around the world, or almost one quarter of the world's population, face economic water shortage (where countries lack the necessary infrastructure to take water from rivers and aquifers). Two thirds of the world's population currently live in areas that experience water scarcity for at least one month a year. (Nations, 2018)

By 2025, 1.8 billion people are expected to be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under water stress conditions. With the existing climate change scenario, by 2030, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people, respectively. A third of the world's biggest groundwater systems are already in distress. Nearly half the global population are already living in potential water scarce areas at least one month per year and this could increase to some 4.8–5.7 billion in 2050. About 73% of the affected people live in Asia (69% by 2050). (Nations, 2018)

2.2.2 Water Scarcity in Ethiopia

Ethiopian water resources are unevenly distributed. The River Basins in the western part of the country account for approximately 70% of its water resources. Conversely, substantial volume of the water demand, particularly for irrigation, exists in the eastern portion, indicating a heavy imbalance that leads to severe water stress — which poses serious threats to human lives, livelihoods and economic stability. (Adane, Swedenborg, & Yohannes, 2021)

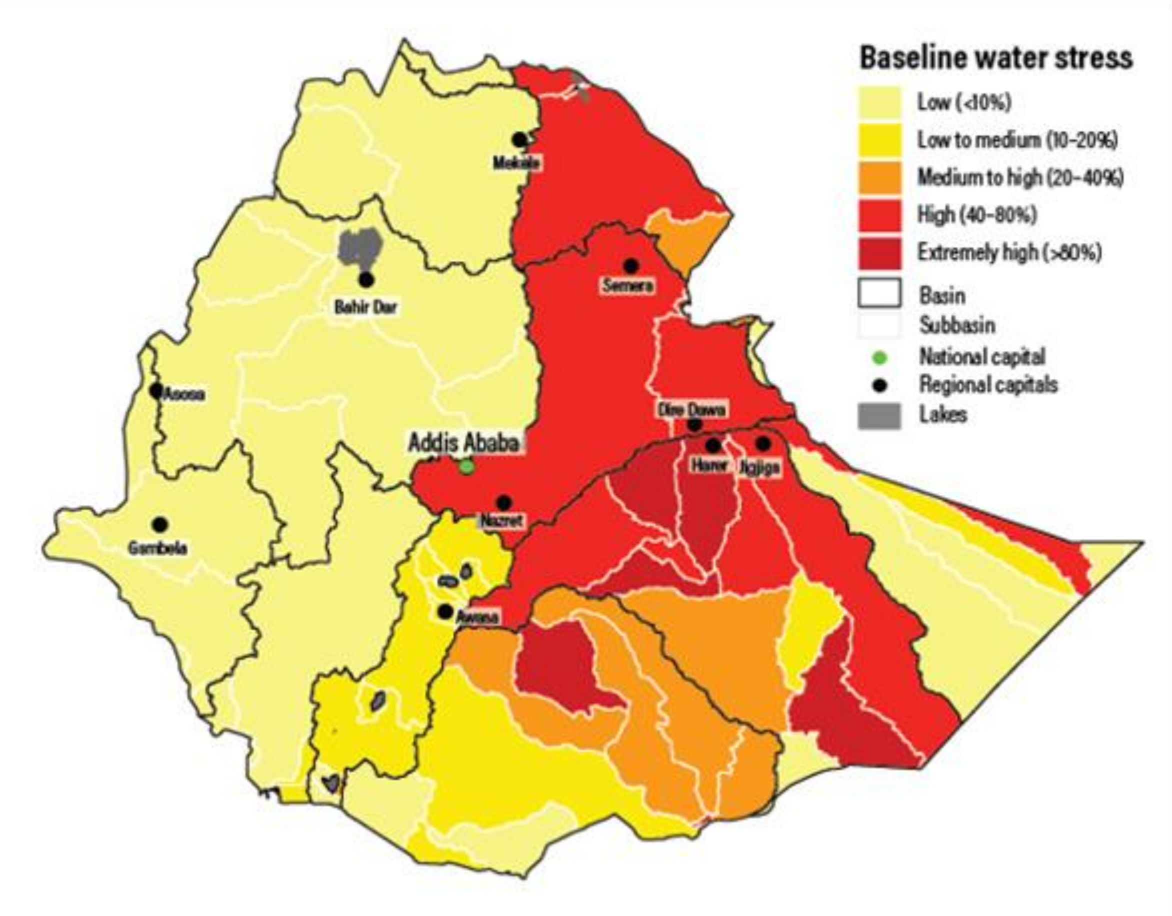


Figure 2.1 Baseline water stress of Ethiopia at sub basin level, 2015 (Zablon Adane, 2021)

2.3 Water conditions of Addis Ababa City

2.3.1 Main Water Sources for Addis Ababa

Addis Ababa's main water sources are groundwater (deep wells), surface water (Awash River), and to a lesser extent, springs and shallow wells. The growing reliance on groundwater and the increase in private wells are putting significant pressure on the city's water resources (Moreda, 2023)

2.3.2 Water Supply for Addis Ababa

A study on Addis Ababa water supply condition states that about 542,000 m3/day was distributed, about 204,000 m3/day form the reservoirs and the remaining about 338,000 m3/day from groundwater sources. (Dioha, 2020) Legedadi, Gefersa, and Dire reservoirs are the primary surface water sources, while the Akaki and Legedadi wellfields serve as the primary groundwater sources supplying Addis Ababa. Using the baseline water supply condition, the water supply coverage in Addis Ababa is around 50%. Current low coverage indicates there will be increasingly severe water shortages in the future if the population growth rate increases with such trends and there are no water supply improvements or new infrastructure projects come into operation. This limited water supply coverage could trigger multifarious effects on sanitation, food, health, and aesthetic services of the community. (Tefera, Taddele, Srinivasan, Baker, & Ray, 2023). Moreover, it hampers the construction industry in terms of quality and cost.

Table 2.1 Addis Ababa water supply sources, estimated production and cover rate (Dioha, 2020)

AAWSA water sources	Estimated production (m^3/day)	Cover rate (%)
Surface water sources		
Legedadi & Dire dam reservoir (combined)	174,000	32.10%
Geferssa reservoir	30,000	5.54%
Groundwater sources		
Legedadi deep well	40,000	7.38%
Akaki old well field	8,000	1.48%
Akaki Phase II	66,000	12.18%
Akaki Phase 3A	36,000	6.64%
Akaki Phase 3B	68,000	12.55%
Akaki Koye Feche	30,000	5.54%
Pocket area wells	90,000	16.61%
Total	542,000	100%

A significant imbalance between demand and supply is recognized by the Addis Ababa Water and Sewage Authority (AAWSA), the city's major water and wastewater service provider. As such a water rationing delivery plan has been put in place for some time. Large parts of the city supply water rationed two to three days per week in most areas. In addition, there is a considerable amount of pent-up demand from new building construction throughout the suburbs and surrounding areas. This new demand has yet to be accounted for and the systems need to be connected to the AAWSA distribution network. (Moreda, 2023)

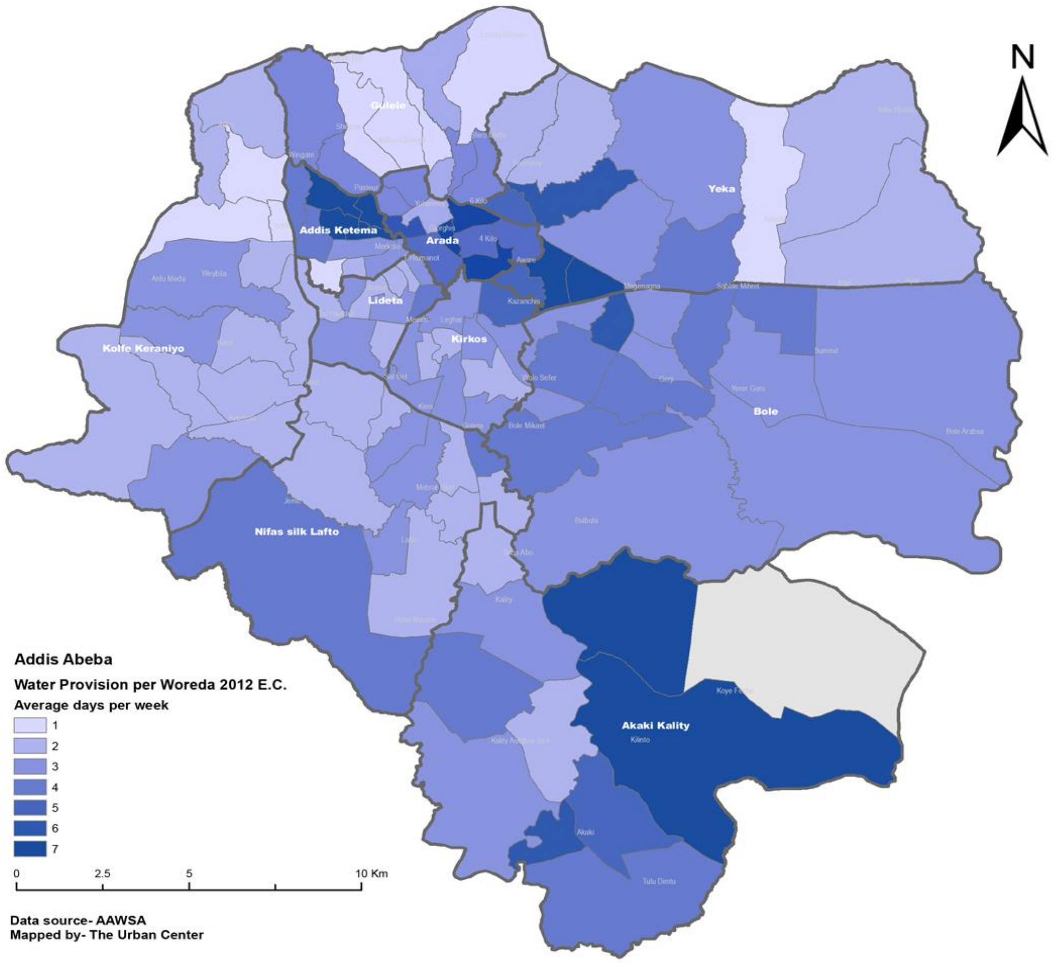


Figure 2.2 Regional water rationing schedule developed by AAWSA

2.3.3 Water Consumption in Addis Ababa

On average 32% of households were found to use water less than 10 lpcs, 44% of households are between 10 to 20 lpcd. 17% of households are used about 20 to30 lpcd while the remaining, 7% of the households, used 30 to40 lpcd of water. The mean value of the per capita water use for total 105 households is about 17.1 lpcd. The average per capita water consumption of more than 75% of the sample households was less than 20 lpcd. This is low as compared to WHO recommendation which is 20 lpcd for basic access to water supply. Hence it can be concluded that most of the respondent households to haven't access to improved water supply. These results were in lined with to AAWSA's report on water consumption which was 15 to 30 lpcd for households using taps connections (Sharma & Bereket, 2008)

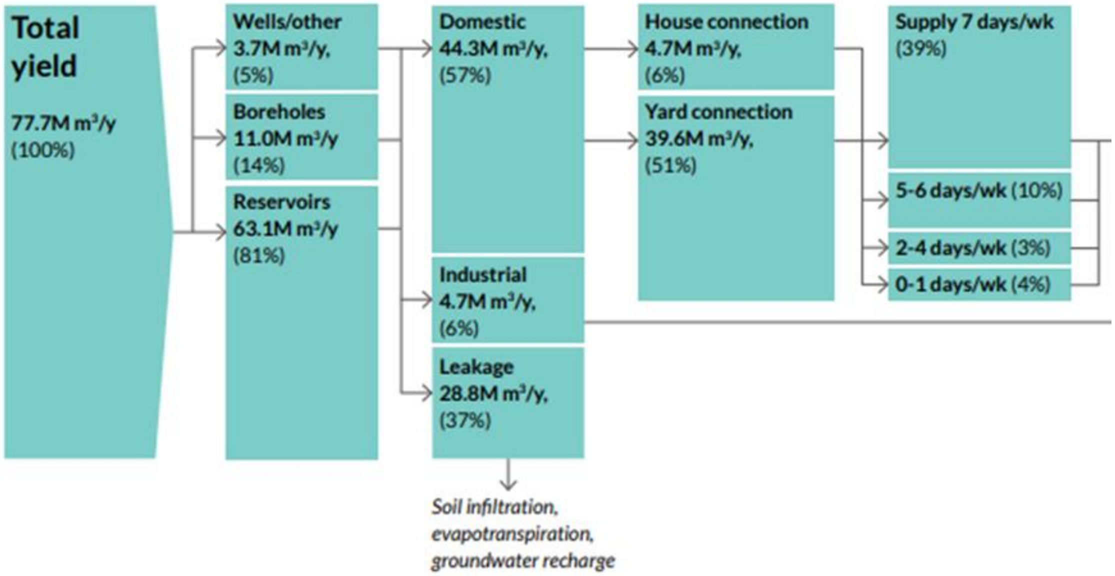


Figure 2.3 Regional water rationing

2.4 Construction in Addis Ababa

The construction industry in Addis Ababa, Ethiopia, is a significant sector that encompasses various areas such as housing, road construction, energy projects, real estate, riverside development and industrial parks. Both local and foreign companies involved in the industry, with Chinese companies playing a dominant role in undertaking mega projects. The industry is projected to experience substantial growth, with an annual average growth rate of more than 8%. (Report, Research, & Market, 2022). The construction market size in Ethiopia was reported to be $54.8 billion in 2022, and the size increased with time.

The construction industry in Ethiopia was grew by 5.6% in 2023, and expected to register an average annual growth of 8.9% from 2024 to 2027. The industry's growth over the forecast period will be supported by rising foreign direct investment (FDI) in the country, coupled with the re-start of halted development projects. In August 2023, the Ethiopian Investment Commission (EIC) announced that the country attracted ETB 213 billion ($3.4 billion) in Foreign Direct Investment (FDI) by registering 269 investment projects. As compared with the 2021/22 FDI, the country attracted ETB194.2 billion ($3.1 billion) in FDI which shows the industry grew by 9.7%. (Markets, Dec 2023). Most investments are concentrated in the construction industry.

2.5 Concrete in Construction Industry

Concrete is one of the oldest and most common construction materials in the world, mainly due to its low cost, availability, its long durability, and ability to sustain extreme weather environments. (Tantaw & Hasan, 2015).

It is the most common building material for many years. It is expected to remain so in the coming decades unless replacement materials come into place. Much of the developed world infrastructures have built with various forms of concrete. Mass concrete for dams’ construction, reinforced concrete for buildings, pre-stressed concrete for bridges, and precast concrete components are some of the typical application areas. It is anticipated that the rest of the developing world uses these forms of construction in the development of infrastructures (Tam, 2003)

The constituents of modern concrete have increased from the basic four (Portland cement, water, aggregate, and sand) to include both chemical and mineral admixtures. It forms a uniform plastic material which gradually sets after a period of one of one to three hours which increases in strength, particularly over the first month of its life. (Leigh & McCarthy, 2010)

2.5.1 Cement

Cement is a basic ingredient of concrete and mortar. The most common type of hydraulic cement, Portland cement, consists of a mixture of oxides of calcium, silicon and aluminum. It is manufactured primarily from limestone, clay minerals and gypsum in a high temperature process that drives off carbon dioxide and chemically combine the primary ingredients into new compounds. Hydraulic cement hardens and set after the addition of water as a result of chemical reaction with the mixing water and after hardening, retain strength and stability even under water.

Cement and water form a paste coating each particle of stone and sand. The hydration reaction causes cement paste to harden and gain strength. This reaction is vital for properties attained in the final concrete mix, and as such, the characteristics of the concrete are determined by the quality of the paste. The strength of the paste in turn, depends on the ratio of water to cement. High-quality concrete is produced by lowering the water cement ratio as much as possible but always trying to retain enough water to ensure the workability of fresh concrete. A higher quality concrete is produced of less water is used, provided the concrete is properly placed, consolidated, and cured. Concrete requires time to fully hydrate before it acquires strength and hardness, thus concrete must be cured once it has been placed. Curing is the process of keeping concrete under specific environmental condition until hydration is relatively complete. (Leigh & McCarthy, 2010)

2.5.2 Water

Water is also another important ingredient of concrete. Part of mixing water is utilized in the hydration of cement and the balanced water is required for imparting the workability of concrete. Thus the quantity and quality of water is required to be looked into very carefully. The strength and durability of concrete is reduced due to the presence of chemical impurities in water. Most of the specifications recommended the use of potable water for making concrete. A practical solution would be tests for time of set and strength of concrete between the water under consideration and the water of proven quality.

The water is used to wet the surface of aggregates to develop adhesion because the cement pastes adheres quickly and satisfactory to the wet surface of the aggregates than to a dry surface. It helps to prepare a plastic mixture of the various ingredients and to impart the workability of concrete to facilitate placing in the desired position. Water is also needed for the hydration of the cementing materials to set and harden during the period of curing. (Nikhil & sushma, 2011). Curing also requires sufficient quantity and quality of water to achieve the desired concrete strength.

2.6 Water Consumption of Construction Projects

In worldwide, the utilization of water is rapidly growing due to an increasing number of residential, commercial, industrial, and agricultural water consumers. The global water demand is increased by 55%, and currently, around 25% of large cities are experiencing some levels of water stress. (Salehi & Mariyam, 2021)

The water demand of the construction industry also increasing along with the increments of investment in the sector. Water is a resource that comprises several activities in a construction site. Its form of use varies according to the operations performed throughout along the construction stages. However, water is not seen or treated as a key material of civil construction. This situation, according to Neto (2013), observed that in compositions of engineering cost estimate water didn't value as an input. Whereas, the role of water for compaction, manufacturing of concrete, mortar, curing of concrete, testing for waterproofing, latex painting and cleaning, etc. has significant contributions. (Camilla, Simon, & Cerqueira, 2015).

The civil construction industry contributes significantly to the depletion of natural resources, especially water. These construction industries consume water in massive quantities, either directly or indirectly. The virtual water consumption of residential building construction is 20.8M^3/SQM, (20,800.00 L/SQM). (Gholamreza Heravi, 2019) According to the research conducted in India, the daily water consumption of building construction in India is almost equivalent to the water requirement of 25 families/day (Bardhan, 2011).The indirect water consumption includes water usage during the manufacture of construction materials, daily water spent on site for cleaning, and daily water consumption of laborers on site. Whereas, direct water consumption activities include curing, mixing of concrete/mortar, and testing of materials. Heravi et al. (2019) reported that indirect water consumption (85%) is higher than the direct water consumption (15%) in building construction. (AR. Mohamed Rameez, Rameez, Taskeen, & Indrapriya, 2022)

2.6.1 Average Water Consumption of a construction project

Water consumption can range from 1 to 14 liters per square meter per day depending on the construction activities involved. For instance, a study indicated that water consumption could be as high as 13.67 kL/sqm in certain projects, while other estimates suggest 8.87 kL/sqm and 9.50 kL/sqm for different sites in India. (Kate & Pawar, 2021)

The water consumption for building construction in Addis Ababa can vary significantly based on several factors, including the size and type of the project, the materials used, and the construction methods employed. While specific figures for Addis Ababa are not readily available in the search results, we can draw insights from general construction practices and studies. And we take the case of the above study for estimation.

In Ethiopia, the average per person water consumption varies between 10 and 20 liters per person per day in some urban areas and 3 to 4 liters per person per day in rural areas. (Woldemariam & Berhanu, 2009).

2.7 Variation in Water Quality among Sources

The rapidly declining freshwater resources and aging water infrastructure in numerous urban and rural regions created hardship for many water utilities addressing the regular water demand. The solutions employed by the water utilities to cope with the water shortage are mainly focusing on providing alternative source of water. (Salehi & Mariyam, 2021)..

A research done on the quality of mixing water and how it affects the setting, hardening, and strength of concrete showed the effect of water quality on split tensile and compressive strength, which is to know the effect of chemical impurities in mixing water on different properties of concrete. This work was carried out for a mix of M 20 (C 20) grade concrete with to study effect of use of potable, ground and sewage water on the strength development of concrete at 7, 14 and 28 days. The results indicated that potable water results in good strength properties in concrete and there is increase of 33.34% in compressive strength when compared to sewage water. (Placeholder1)

There is another research conducted which investigates the effect of water sources on concrete properties and assessing qualities of different sources of water for mixing concrete. Water from the stream, the hand-dug well and the borehole were used for the experiments with pipe water serving as the control. Cubes and beams were casted and tested for compression and flexural strengths at 7-day and 28- day curing ages. Chemical and physical properties of the water samples were also tested. The results indicated that the chemical impurities of all the water types were within the limits given in GS 175-1:2009, EN 1008, ASTM C94 and AS 1379. The physical specifications were all satisfactory, except for the stream water. The water sources had no significant effect on the workability of concrete. Effects of efflorescence were not observed on hardened concrete specimens obtained from any of the water sources. Concrete specimens mixed with water from the hand-dug well had provided the highest compressive strength. (Peter, Kennedy, & wisdom, 2019)

Another study also investigated the effect of different kinds of water on compressive strength of concrete which mainly concentrates on the effect of different qualities of water on concrete compressive strength. The concrete mix of M20 grade with water cement ratio of 0.5 was used. Water samples, such as tap water, sewage treated water, bore well water, treated dairy wastewater were collected from Hassan city and were used to cast 150mm concrete cubes. The cured cubes were cured for 7, 14 & 28 days for compressive strength assessment. The outcome result of the study exhibited that the compressive strength of the concrete cubes prepared with tap water, bore well water, dairy treated wastewater(DTWW), sewage water(STWW) improved with days & not having much deviation in their Compressive strength. (Manasa, Lamani, & Mohan, 2020)

Another study conducted on effects of different sources of water on the properties of concrete evaluated the characteristics of concrete produced with river water, well water, and potable tap water. Compressive strength and density parameters were used to evaluate the characteristics of concrete specimens of mix ratios 1:2:4 and 1:11/2:3 produced with water from the different sources. The results showed that concrete specimens produced with tap water had the highest mean compressive strength at 28 days. While well water had the lowest compressive strength, it was concluded that well water was not suitable for concrete works even though it is already being used on some sites that can't access tap water. (Ignatius & Adedeji, 2019)

Abrams cast concrete cylinders using a large number of waters, many of which were unpotable and tested them in compression at ages up to twenty-eight months and found that in spite of the wide variation in the quality of water used, most of the samples gave good results. Abrams quoted that seawater with a total salinity of about 3.5 percent produces a slightly higher early strength but a lower long terms strength, the loss of strength is usually no more than 15% and can therefore often be tolerated. Thomas and Lisk (Lisk, 1970) suggested that the sea water slightly accelerates the setting time of cement. Lea (Neville, 1995) reported that water containing large quantities of chlorides e.g. sea water tends to cause persistent dampness and surface efflorescence. Mc Coy reported that water with pH of 6.0 to 8.0, which does not taste saline or brackish, is suitable for use. (McCoy, 1978) Steinour described that impurities in water may interfere with the setting of the cement, adversely affect the strength of the concrete or cause staining of its surface, and also lead to corrosion of the reinforcement. Addition of 2 percent sodium benzoate reduces the compressive strength of concrete. P. Ghosh et.al reported that presence of micro-organism in mixing water increases the compressive and tensile strength of concrete. (Ghosh, 2005) G.Reddy Babu reported that samples prepared with treated wastewater of electroplating industry did not show loss of strength, though their setting time had increased. In high concentration of metal ions, the compressive and flexural strength marginally increased. (Placeholder1)

According to the global agencies of world health organization, world metrological organization and UNICEF, the utilization of fresh water goes on enlarging from twenty centuries due to overpopulation and frequent implementation of safe accessible water in relative fields, diminishing the quantity and quality available which ultimately causes gap between ecology and environment for livable water. In the construction industry, water can be saved to a large extent by just interchanging this water by various water available viz. seawater, waste water, sewage water and waste wash water based on literature data and studies which show normal and insignificant changes in the strength of cement hardened concrete. (Nakul, Ashish, Ankur, Rajeshl, & Vikram, 2020)

2.8 Standard Guidelines and Specifications for Water Quality on Concrete Mixing

2.8.1 International standards for water quality in concrete mixing

International standards that guides about the water quality specifications and guidelines to use when mixing concrete are showed in Table 2.2

Table 2.2 water quality specifications and guidelines for concrete mixing

Standard set by	Water quality requirement
American Concrete Institute (ACI):	ACI is a leading organization in the concrete industry. It is not specifically focus on water quality, their publications, such as the "Manual of Concrete Practice," contain information on concrete mixing practices.
D4130-15	Standard Test Method for Sulfate Ion in Brackish Water, Seawater, and Brines

American Society for Testing and Materials (ASTM):	ASTM has standards related to concrete and aggregates. ASTM C94, titled "Standard Specification for Ready-Mixed Concrete," provide some insights into water quality considerations.
National Ready Mixed Concrete Association (NRMCA):	NRMCA is an industry organization that provides resources and guidance on concrete production. Check their publications and guidelines for information on water quality considerations.
Portland Cement Association (PCA):	PCA is a trade association that offers information on cement and concrete. They may have publications or guidelines related to water quality in concrete mixing.
Water Quality Guidelines by Regulatory Agencies	Check water quality guidelines provided by environmental agencies in a region or country. These guidelines may have recommendations on water quality parameters to ensure environmental compliance when using water in concrete mixing.
Research Papers and Technical Journals:	Explores academic and technical journals that focus on concrete technology and construction materials. Research papers in these journals may discuss the impact of water quality on concrete properties.

2.8.2 Local Specifications in Addis Ababa

In 1995, Ministry of Works and Urban Development prepared Building code standards of general application. The purpose of these standards to serve as a nationally recognized documents, the application of which is deemed to ensure compliance of buildings with the minimum requirements for design, construction and quality of materials set down by the “National Building Code”. The major benefits to be gained in applying these standards are harmonization of professional practice and ensuring of appropriate levels of safety, health and economy with due consideration of the objective conditions and needs of the country. (Bekele, 1993)

Water used for concrete mixing must be clean and free from harmful impurities such as oils, acids, alkalis, salts, organic matter, or other substances that could adversely affect the strength, durability, or setting time of the concrete. (EBCS-2, 1995)

2.8.3 Different Codal values and provisions for the assessment of water in concrete

Table 2.3 Requirements and test procedures for preliminary inspection of mixing water (standard, 2002)

	Impurities	Standard	Requirement
1	Oils and fats	EN 1008:2002 (E)	Not more than visible traces
2	Detergents	EN 1008:2002 (E)	Any foam should disappear within 2 minutes.
3	Color	EN 1008:2002 (E)	The color shall be assessed qualitatively as pale yellow or paler
4	Suspended matter	EN 1008:2002 (E)	Maximum 4 ml. sediment
5	odor	EN 1008:2002 (E)	No smell, except the odor allowed for potable water. No smell of hydrogen sulphide after addition of hydrochloric acid.
6	Humic matter	EN 1008:2002 (E)	The color shall be assessed qualitatively as yellowish brown or paler, after addition of NaOH.

Table 2.4 Limits of permissible impurities (standard, 2002)

	Type of impurities	Standards	Permissible limit
1	Organic solid		0.02 or 2000mg/l
2	Inorganic solid		0.3 g/l
3	Sulfates (SO_3)		0.04 g/l
4	Alkali Chlorides (as Cl_2) (a) Plain concrete (b) Reinforced concrete		 0.20 g/l 0.05 g/l
5	Suspended particles		0.02 g/l
6	Cl^- content	IS 3025 -Part 32[5]	0.02 g/l

		IS 456[6] ,	
7	Nitrates; expressed as NO3	EN 1008:2002 (E)	500 mg/l
8	PH	IS 456-2000	6.5 - 8.5
9	Alkalinity	B. R. D, "Understanding ASTM C 94." [50] H. H. Steinour, "Hou impure it can be." Portland Cement Association	600 mg/l
10	Calcium	EN 1008	0.2 g/l
11	Magnesium	EN 1008	0.1 g/l
12	Potassium	EN 1008	0.1 g/l
13	Total solids	IS 3025 -Part 32[5] IS 456[6] ,	2 g/l
14	Suspended solid		2 g/l
15	Dissolved solid		0.5 g/l
16	Organic solid		0.2 g/l
17	Inorganic solid		3 g/l

2.9 Compressive Strength of Concrete

The design of concrete mixtures considers to acquire a high range of mechanical and durability properties and to meet the design requirements of a concrete structure. The compressive strength of concrete is the most commonly used property for the design of civil structures to check and approve the structure acceptance. It is often necessary to test concrete structures after the concrete has hardened and in this case to determine if the structure is suitable for its purpose. Ideally such testing should be done without damaging the concrete. The tests available for testing hardened concrete range between the completely nondestructive, where there is no damage to the concrete, through those were the concrete surface is slightly damaged, to partially destructive tests, where the concrete surface had to be repaired after testing. The range of properties that can be assessed using nondestructive tests is quite large and includes such fundamental parameter as density, modulus of elasticity, compressive strength, surface hardness and absorption as well as reinforcement size and location. (Naser Kabashi, December 2015)

The compressive strength is the capacity of a material or structure to withstand loads and the ultimate compressive strength of a material is that value of uniaxial compressive stress reached. (Koncar, 2019). When the material fails completely. The compressive strength is usually obtained experimentally by means of a compressive test where uniaxial compressive load is applied till its failure. (Mehmet Serkan Kırgız, 2019)

Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during the production of concrete, etc.

Test for compressive strength is carried out either on a cube or cylinder. Various standard codes recommend a concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard Test Method. For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical molds of size 15cm x 15cm x 15cm are commonly used.

The concrete is poured in the mold and appropriately tempered so as to reduce the void part. After 24 hours, the mold is removed, and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by placing cement paste and spreading smoothly on the whole area of the specimen.

These specimens are tested by compression testing machine after seven days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete. (ishra, 2021)

Table 2. 5 Compressive strength and permissible limit (Kucche, 2015)

Parameter	**Standards**	**Limits**	**Provision / Remarks**
Compressive strength	IS 456-2000	≥85% of the mean compressive strength of control specimen shall be taken.	The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ±15 percent of the average. If more, the test results of the sample are Invalid.
	AS 1379	≥90% of the mean strength of the control samples prepared with water From a stable drinking water supply.	7day and 28day compressive strength of concrete made with water from a source with no service record. Test procedure accordance with AS1012.9
	ASTM C94	≥90% of the mean strength of the control samples prepared with distilled or Potable water.	The mean 7day compressive strength of the mortar or concrete samples prepared with the water which must be controlled sample. Test procedure accordance with C109[A].
	EN 1008	≥90% of the mean strength of the Control samples prepared with distilled or de-ionized water.	The mean 7day and 28day compressive strength of the mortar or concrete samples Prepared with wash water.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Materials

The materials used for the concrete preparation are Cement, sand, and coarse aggregate formed the core components of the concrete mix, with all materials measured by weight to ensure precision in each batch. Both potable water and river water samples were used in separate batches, but the mixing ratio remained consistent across all samples to maintain comparability in the results. This approach helped to eliminate variations that might arise from inconsistent proportions, ensuring that the differences observed in the outcomes were attributed solely to the type of water used.

The sand and aggregate were thoroughly inspected and cleaned to remove any dust, debris, or organic matter that could potentially affect the concrete's strength or setting behavior. Although no laboratory tests were performed on the sand and aggregate, standard quality assurance practices were followed to select clean and well-graded materials. These steps were critical in producing reliable and reproducible concrete samples suitable for testing and comparison.

The mixing process was also carefully controlled. Before each batch, the interior of the concrete mixer was cleaned and slightly moistened to prevent material loss and ensure uniform mixing. The materials were added systematically, and mixing was conducted thoroughly to avoid segregation and achieve a consistent texture. This ensured that the concrete produced was of uniform quality and suitable for testing various mechanical and durability properties.

The equipment utilized in this research ensured precision and consistency during the concrete preparation process. A mechanical concrete mixer was used to achieve uniform blending of the constituent materials and prevent segregation. Weighing scales facilitated the accurate measurement of cement, sand, and aggregate in accordance with the designated mix ratio. Standard tools, including shovels and buckets, were employed for the manual handling and transfer of materials. Clean water containers were used for the storage and controlled addition of mixing water. Concrete molds and a curing tank were used for sample casting and to maintain appropriate curing conditions.

3.2 Methods

3.2.1 Study Area

The study was conducted in Addis Ababa City. It is the capital and largest city of Ethiopia located in the central part of the country having an average altitude of around 2,355 meters above sea level. The city is one of the fastest growing in Ethiopia and numerous constructions are undergoing.

The geographical coordinates of Addis Ababa are approximately 9°02'N latitude and 38°45'E longitude. The city is situated in the foothills of the Entoto Mountains, with the Akaki River running to the southern part of the city. (LatLong.net, 2021)

The city holds around 527 square kilometers of area. The population density is estimated to be nearly 5,165 per square kilometer. (World population Review, 2024)

3.2.2 Research Design

Samples were collected from four rivers found at various locations of Addis Ababa. The sites were selected purposively taking into account accessibility, the rivers flow properties, and the reach of the rivers. More emphasis was given to upper and middle reach of the rivers since the quality more deteriorates in the downstream with the interventions of the human activities.

The water samples were collected using 20-liter jar and took at the center of the river flow using wadding technique. A part of the sample sent to the AAU-AAiT water quality laboratory for test and the remaining part used to mix concrete specimens and curing purposes. List of tests were prepared and labelled considering the concrete quality requirements. Tests were conducted following the laboratory procedures. The maximum time between the sampling and testing was 8 hrs.

The research used experiment to identify the parameters. The portion of the mixture which is the amount of cement, aggregate and water is kept constant through all the mixes. The mixture is designed as C-25 concrete. It was chosen due to its common use in general construction, making the results more applicable to practical building conditions. The sources of water used for the mixture was water taken from the four sampling locations chosen (namely Banteyiketu, Bulbula, Betel, amd Mekanisa) and were compared to reference concrete specimen which was mixed with potable water to serve as a control sample. A total of 45 cubes were casted. The comprehensive strength of cubes was tested on 7^{th}, 14^{th} and 28^{th} days at EiABC material laboratory. During the period, the cubes were cured with similar source of water.

3.2.3 Study Variables

The variables studied are divided into three groups: independent, dependent and controlled variables. Independent variables are those variables that are not influenced by others; the properties of dependent variables, on the other hand, are influenced by other variables. Controlled variables are used as a benchmark to evaluate the properties of other variables. Water quality parameters collected from four different sites were taken as independent parameters; however, the comprehensive strength tested at 7^{th}, 14^{th}, and 28^{th} days taken as dependent variables which mainly depends on the water quality. Controlled variables are those materials commonly used for sample preparation such as sand, aggregate, and cement. In addition, potable water used to mix concrete as reference taken as controlled variables.

3.2.4 Data Source

A. Primary data sources

Primary data for this research are mainly includes.

- Test results of water quality at four sampling sites
- Compressive strength test of the cubes at 7^{th}, 14^{th}, and 28^{th} days.

B. Secondary data sources

Secondary data for this research is the data and findings that are already collected by someone else and found to be useful. It includes.

- specifications and guidelines from different standard books
- Researches and data collected about the locations and content of the rivers found in Addis Ababa.
- previous research findings on the effect of different water sources on concrete which were performed on other countries

- Historical data on local water quality parameters of local potable water provided by AAWSA.

3.3 Population and Sampling Method

3.3.1 Study Population

The study attempted to identify alternative water sources for concrete mixing by assessing rivers in Addis Ababa. In Addis Ababa, there are about ten major rivers crossing the city having different flow rates. Hence, all rivers found in Addis Ababa are the study population.

3.3.2. Sampling

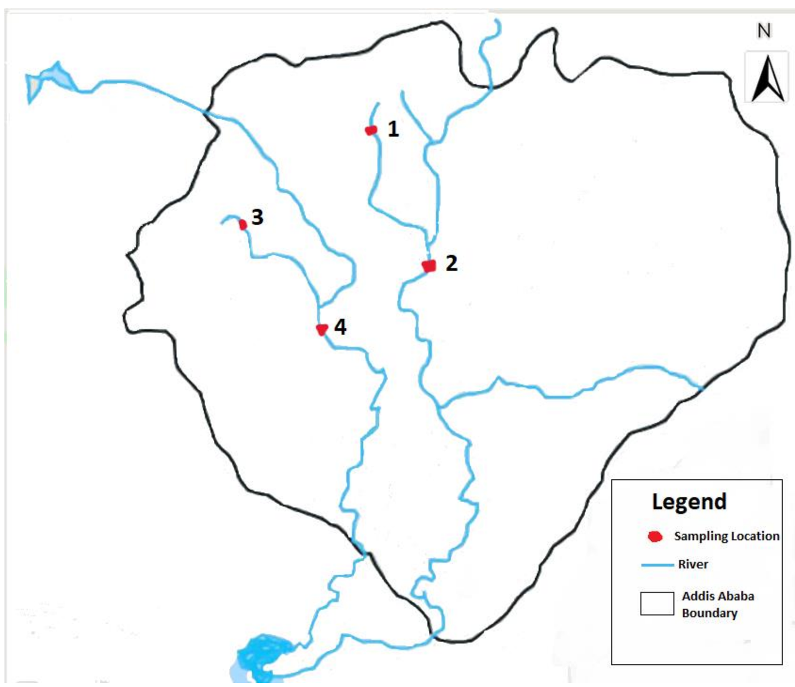


Figure 3.1 Sampling Locations

Rivers in Addis Ababa run through the different parts of the city. The main is Akaki River. Akaki River System is one of the 21 sub-basins of Awash River. It stretches from Mount Entoto in the North to the Southwest direction towards Aba Samuel reservoir which is the final stopover of the river. The Akaki River system crosses all the 11 sub-cities and about 116 Woredas. It covers the western part of the city, the tributary namely Small Akaki (Tinishu) rises northwest of Addis Ababa on the flanks of Wechacha Mountain and flows for 40 km before it reaches the Aba-Samuel Reservoir. The eastern tributary of the river (Tiliku Akaki) rises North of Addis Ababa (Mount Entoto) flows about 53 km and tumbles into the Aba-Samuel Reservoir. Before the first confluence point of the Tinishu and Tilku Akaki, the rivers provide myriads of economic, socio-cultural, and environmental services and water values. (Amare Haileslassie, March 2024).

Among the ten rivers found in Addis Ababa, the study took four rive locations for analysis considering its accessibility, budget and time constraints of the research. The sample size consisted of five different water sources: potable water was used as a control group, and four river samples were gathered from various locations.

This sample was selected to enable a comparative analysis of the effect of different kinds of river water sources on concrete strength while ensuring practical feasibility and by taking into considerations of research constraints.

A. Small Akaki (Tinishu)

The Small Akaki (Small) River, also known as the Little Akaki River, flows from the Entoto Hills north of Addis Ababa, Ethiopia. The river flows south through Addis Ababa's densely inhabited and industrialized areas, including the suburbs of Kolfe Keranio, Nifas Silk-Lafto, and Akaki Kality. As it travels through the city, the river collects a huge amount of urban runoff and industrial garbage, which degrades its water quality. The Small Akaki (Small)) River eventually merges with the Big Akaki (Tiliku) River, also known as the Great Akaki River, on the southern suburbs of Addis Ababa. They continue their journey towards the Awash River Basin, adding to the hydrological network that supports both agricultural and natural systems in the region. (Samuel Melakua, November 2005)

B. Big Akaki (Tiliku)

The Big Akaki (Tiliku) River begins its journey in the Entoto Hills, situated to the north of Addis Ababa, Ethiopia. From its source, the river flows southward through the city, weaving its way through various urban districts including Gullele, Addis Ketema, and Lideta. As it courses through the capital, it traverses both residential neighborhoods and industrial zones, collecting runoff and, unfortunately, a considerable amount of pollutants. The river's path takes it past landmarks and infrastructure, where it serves as an essential water source despite the challenges posed by contamination. (Samuel Melakua, November 2005)

After passing through Addis Ababa, the Big Akaki (Tiliku) River continues its journey southward, flowing through the towns of Akaki and Kaliti. As it exits the urban stretch, it passes through several Peri-urban and rural areas. Eventually, the Big Akaki (Tiliku) merges with the Small Akaki (Small)) River, combining their flows and continuing their journey together towards the south. The confluence of these rivers marks a significant juncture as they leave the urban environment and travel into rural areas outside Addis Ababa, eventually contributing to bigger water systems throughout the region. This tour emphasizes the river's importance to both urban and rural people, as well as the continued need for sustainable water management measures.

3.3.3 Sampling Locations

The river samples were gathered from distinct points along its course tracing its journey from inception to culmination. Sampling locations from the river are taken from four different sites. The points are chosen on the basis of the flow rate, accessibility, and expected quality parameters (it is true upstream of the river has relatively better quality). It is expected the water quality varies along the river from upstream to downstream. The factors mainly depend on the settlement, availability of factories near to the riverside and management factors such as river protection works, existing escalating activities.

The samples were collected from four location mainly along four rivers. As shown in Figure 3.1 two samples were taken in the upstream parts of the river expecting better quality of the river since the contamination level is relatively low. The other two samples (sample 2 and 4) were collected at the locations of where the two streams joined together (confluence of Small) and Big Akaki (Tiliku) and banteyiketu and bulbula rivers). This sampling techniques was applied to capture the rivers characteristics at various stages of the flow. It gives a throughout understanding and holistic view of the river water quality.

Sampling Location 1 (Banteyiketu River)

The first sample (sample point 1) was collected from the upstream of the Banteyiketu River. The area is characterized by minimal human activity and very few settlements during the study period, which significantly reduces the potential for contamination. The surrounding environment is notably less interference on water quality having a natural vegetation, industrial and agricultural pollutants. The water at this point is visibly clear and free from debris, reflecting the low level of human interference. This section of the Banteyiketu River provides a valuable baseline for understanding the river's natural state before it encounters more populated and industrial areas downstream.

Sampling Location 2 (Bulbula River)

The second sample was collected from a point where the Banteyiketu River converges with the Bulbula River, located in the active middle part of the city. This area is heavily influenced by urban activities, with the river flowing through zones characterized by dense commercial operations and residential areas. The water here exhibits a noticeable change in color, indicating the presence of some pollutants. The surrounding environment, marked by intensive human activity, expected that it is significantly impacts the river's water quality as there was a trend towards discharging wastewater into the rivers,

Sampling Location 3 (Betel River)

The third sample was collected from the upstream section of the Big Akaki (Tiliku) River, where the surrounding areas are characterized by moderate settlements. This area is also characterized by a mix of residential zones and agricultural fields, which exert some influence on the river's water quality. It was observed that the river water at the location somewhat low quality. There is a slight odor present, likely resulted from the runoff from nearby farms and settlements. Despite these factors, the river water at the location was relatively free from significant litter or debris, it observed that the area was not as severely affected.

Sampling Location 4 (Mekanisa River)

The fourth sample was collected from the confluence of the Small Akaki (Small)) and Big Akaki (Tiliku) rivers, a location where the combined product of both waterways become evident. The water here is notably turbid, with a moderate color and a discernible odor, expected relatively a higher level of contamination. This area is surrounded by nearby settlements and is heavily impacted by extensive farming activities along the riverbanks, contributing to the river's compromised quality. The agricultural runoff and human activities in the vicinity have led to decrease the water quality, making this section of the river more affected compared to the upstream area.

Table 3.1 sampling location coordinates

Destination of sample site	Specific name	Coordinate		
		x	y	altitude
1	Banteyiketu River	38°45'25.6" E	9°03'17.9" N	2,350 m
2	Bulbula River	38°46’39.3” E	8°59’29.7” N	2,350 m
3	Betel River	38°42’39.8” E	9°00’36.6” N	2,350 m
4	Mekanisa River	38°43’59.7” E	8°58’25.8” N	2,355 m

3.3.4 Sample Size

Five different sources of water were used in the study's, including potable water that serves as a control and four river water samples that were taken from four locations. The sample size also includes the number of concrete cube samples that were casted for compressive strength testing at different durations (7, 14, and 28 days). The strategy preserved a practical feasibility within the confines of the research while assuring a systematic examination of the impact of various water sources on concrete strength.

Table 3.2 Sample size for concrete mixing and curing water

Water source	Number of concrete cube samples (15cm by 15cm by 15cm) per testing days		
	7th day	14th day	28th day
Potable water (from EiABC water supply line)	3	3	3
Sample 1 (Banteyiketu river)	3	3	3
Sample 2 (Bulbula River)	3	3	3
Sample 3 (Betel River)	3	3	3
Sample 4 (Mekanisa River)	3	3	3
Number of samples per testing days	15	15	15
Total	45 cubes		

3.4 Sample Collection Procedure

Water samples were collected using wadding techniques from four different locations along rivers in Addis Ababa to ensure a representative sampling of the water quality across the city. Discrete samples were collected using 40 liters (two jerican) and a 5 liters jerican at the same location and time. After Marking and labeling the samples, the 5 liters jerican samples were sent to Addis Ababa University Institutes of Technology water quality laboratory to determine the quality, focusing on parameters that significantly affect the concrete comprehensive strength, such as pH, dissolved solids, PH, Acidity test, Alkalinity test, Chloride, Sulphate, Nitrate, Calcium, Magnesium, and Potassium. The other 40 litres samples from each location were took to EiABC material laboratory for concrete mixing and curing purposes.

The concrete samples went through compressive strength testing at three different curing periods which is the 7th, 14th, and 28th days. This process allowed for a detailed evaluation of the impact of the river water on the concrete's strength over time, providing critical data to assess the feasibility of using river water as an alternative source for concrete mixing.

3.4.1 Experimental Procedures

The laboratory experiments were conducted, starting with the preparation and testing of concrete-making materials. Based on these test results, concrete-making materials are proportioned, and a mix-design was formulated for C-25 grade concrete. Concrete samples are then prepared to match specified characteristics. Subsequently, fresh concrete samples undergo testing using water collected from the four different areas chosen along the course of the river. Sources, with concrete cubes cast to assess properties for compressive strength test. Lastly, the curing process is monitored to evaluate its impact on concrete performance. This structured methodology ensures a comprehensive investigation into the effects of water source on concrete properties, enabling informed conclusions and recommendations.

Similarly, the water quality laboratory tested pH levels, suspended and dissolved solids, and chemical composition parameters. The samples were carefully handled to maintain the quality. The maximum hours between the sample collection and test operation was 8 hrs. This makes the sample not changing its properties with time. In addition, the sample jericans were carefully cleaned with distilled water and make it free from previous contaminates. Figure 3.2 shows the general procedures applied to test the water quality. For the preparation of concrete, the materials used followed a specific mix ratio, which was consistent for both potable water and the collected river water samples. The mix ratio was 1:1.87:2.58 for cement, sand, and aggregate, respectively. For each batch, 15.5 kg of cement, 29 kg of sand, 40 kg of aggregate, and 7 liters of water were used. The same ratio was applied across all water samples to maintain consistency in the comparison. The materials were measured by weight to ensure precision. In terms of preconditions, the aggregate and sand were thoroughly inspected and cleaned to remove any dust or organic matter before use. No specific tests on aggregate and sand were conducted for this experiment, but their quality was ensured by adhering to standard practices. The interior of the mixer was cleaned and moistened before mixing, and the concrete was mixed uniformly to avoid segregation. The laboratory methods followed established standards, including ACI 211.1 for mix design, ASTM C1602 for water quality, and ASTM C192/BS EN 12390 for specimen preparation and testing. Water sampling followed APHA guidelines to ensure accuracy and prevent contamination.

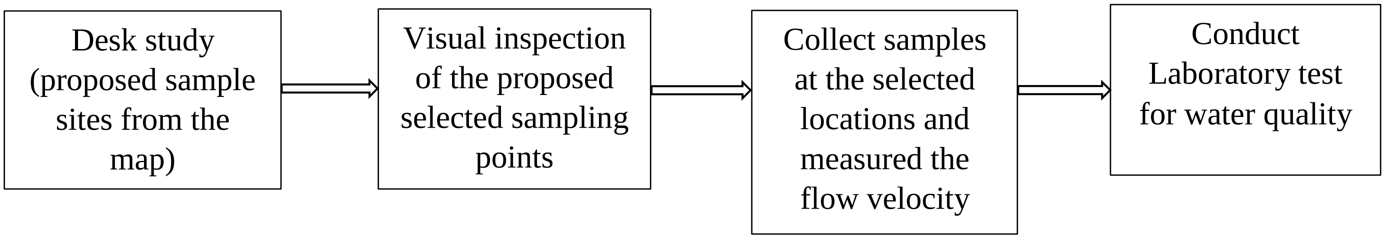


Figure 3.2 Laboratory test for water quality flow chart

3.4.2 Mixing of Concrete

Concrete materials were prepared using water from the identified sources through a carefully controlled mixing process. The ingredients were accurately measured by weight to ensure proper proportions. Before mixing, the interior of the mixer was cleaned and moistened. The process began with adding coarse aggregate and some water, followed by the gradual incorporation of fine aggregate, cement, and the remaining water while the mixer was in operation. After mixing, the concrete was transferred to a clean, damp mixing pan and remixed with a shovel to achieve a uniform texture.

3.4.3 Mix Design and Proportioning

Ordinary Portland cement (OPC) meeting the requirement of BS EN 197-1(2001) was used in the preparation of 150 mm cube specimens. The materials used is Habesha PPC, sand and aggregate used uniformly throughout each samples.

Table 3.3 Mix Design and Proportioning

NO	Water type	Material	Unit	Quantity	Ratio
1	Potable water (from EiABC water Supply pipe line)	Cement	Kg	15.5	1
		Sand	Kg	29	1.87
		Aggregate	Kg	40	2.58
		Water	Liter	7	0.45
2	All collected samples	Cement	Kg	15.5	1
		Sand	Kg	29	1.87
		Aggregate	Kg	40	2.58
		Water	Liter	7	0.45

3.4.4 Casting of the Concrete

Rectangular molds were cleaned and lubricated before casting to make it easier to remove the concrete specimens. Three layers of the concrete mixes were poured into the molds, and each layer was compressed using a steel tamping rod that measured 16 mm in diameter and 600 mm in length. Each layer was applied 25 times. The molds were then gently tapped with a hammer to seal any gaps that remained and expel any trapped air bubbles after the tamping process. The concrete cubes measuring 150 mm were ready for tests on their compressive strengths. Various sources of water were used in the studies. After a day, the concrete samples were demolded, and 45 specimens in total were ready for testing at days 7^{th}, 14^{th} and 28^{th} and placed at distinct locations by labelling.

3.4.5 Curing of concrete

Forty five concrete cubes were prepared for the compressive strength tests in this study, and the tests were set for the 7^{th}, 14^{th}, and 28^{th} days. To provide uniform and regulated cement hydration, the cubes were cured in water from their respective sources. Because the curing process allowed the concrete to retain enough moisture to promote the chemical reactions required for effective hardening, it was essential for the development of the concrete's strength and endurance. Up until the specified testing days, the cubes were kept submerged in the water, guaranteeing ideal and uniform curing conditions for every sample with the respective water sources. This technique assisted in avoiding any early drying that would have impacted the compressive strength findings.

3.5 Compressive Strength Test

In this research, Forty five concrete cubes were meticulously prepared to assess their compressive strength, with testing scheduled at 7, 14, and 28 days. The cubes were cast using a mix that incorporated samples collected from various parts of a river. Alongside these, a control group of cubes was prepared using potable water to establish a baseline for comparison. This experimental design allowed for a comprehensive evaluation of how different water sources might influence the concrete's compressive strength.

The compressive strength was tested for all samples by using a compression testing machine. Specimens were loaded to failure at 7, 14, and 28 days. The maximum load sustained by the specimen was recorded and the compressive strength. The primary focus was on the compressive strength testing of these cubes, comparing those made with river water to those made with potable water. By analyzing the strength of the river-sourced samples against the control sample, the study aimed to determine the impact of the river water’s composition on concrete performance. The results from these tests are crucial for understanding how variations in water quality affect the strength and durability of concrete.

3.6 Data Analysis

The research detailed analyzed pH levels, dissolved oxygen concentrations, and pollutants measured in the water samples. It also showed trends and connections between different variables, making complex information more digestible. Excel spreadsheet was used to analyze the relationship between water quality parameters and how different materials performed under various conditions during the compressive strength tests. Figure 3.3 shows the flowchart of the data analysis.

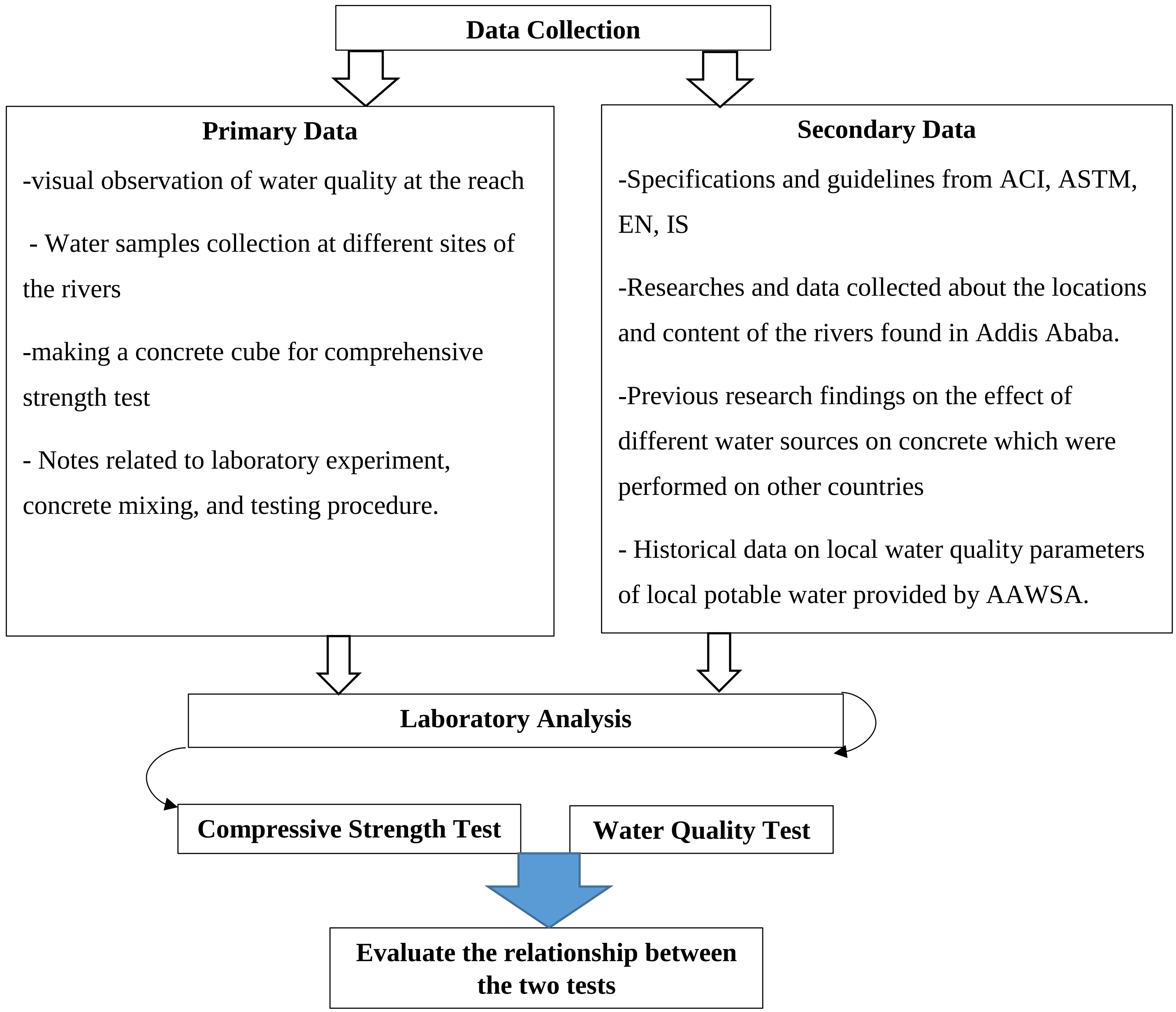


Figure 3.3 Data Analysis Flow chart

Estimating the equivalent population's daily water use provides a relatable measure of the construction project's water demand. This helps contextualize resource consumption, highlights the importance of efficient water management, and informs decisions to minimize impacts on local water resources.

To estimate the equivalent population's daily water use based on the construction's daily water consumption, the following formula was used:

To calculate the number of people whose daily water consumption matches the construction's daily water use:

Population Equivalent = $\frac{Construction\ Daily\ Water\ Use}{Daily\ Water\ Use\ Per\ Person}$ ---------Equation 3.1 Population Equivalent

Where:

- Construction Daily Water Use is the average daily water consumption for the construction, calculated by dividing the total water use by the duration of the project.
- Daily Water Use per Person is assumed to range between 10 and 20 liters/day, based on data from Woldemariam (2009).

CHAPTER FOUR: RESULT AND DISCUSION

4.1 Laboratory Test Results

This research involved testing concrete samples mixed with potable and river water from four locations to assess the impact of water quality on strength and durability. The results provided key data on the suitability of these water sources for concrete production. Based on the research results, several observations can be made regarding the water quality from the four sampling points: Banteyiketu (P1), Bulbula (P2), Betel (P3), and Mekanisa (P4). The water quality parameters have been compared with standards permissible by the American Concrete Institute (ACI) and other relevant guidelines.

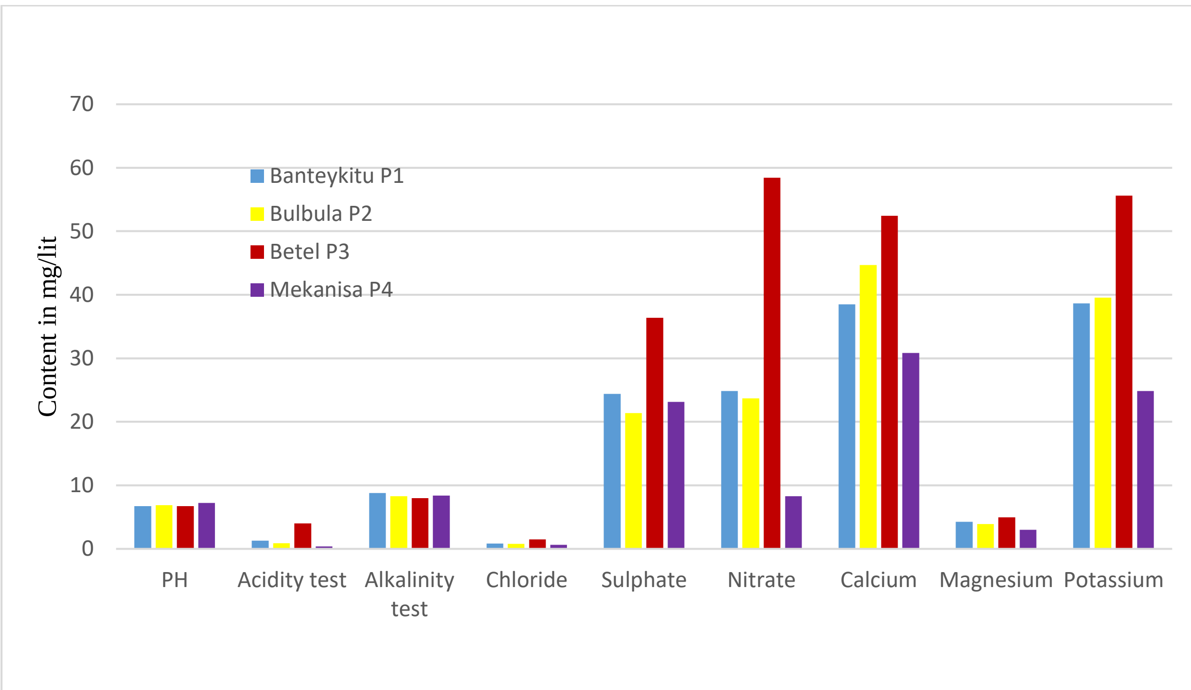


Figure 4.1 water Content comparison analysis

The test result of PH in the four location indicated its values ranging from 6.72 to 7.24, which indicates a slightly acidic to neutral ph. As per the ACI 318-19 guidelines, the ideal pH range for mixing water is between 6.0 to 8.0. All four sampling points fall within this permissible range, making them suitable for concrete mixing in terms of ph.

Acidity levels vary significantly, with Betel (P3) having the highest acidity at 4.00 mg/L and Mekanisa (P4) the lowest at 0.40 mg/L. High acidity can affect the durability of concrete. The permissible limit for acidity in mixing water is generally less than 1.00 mg/L. Betel (P3) exceeds this limit, which could potentially lead to problems such as decreased concrete strength and durability. According to acidity test result, water found in Bulbula and Mekanisa can be used for concrete work.

Alkalinity levels are relatively consistent, ranging from 8.00 to 8.80 mg/L. Alkalinity helps in neutralizing acidity and provides a buffer capacity. The permissible limit for alkalinity is not strictly defined but should be sufficient to counter balance the acidity according to general guidelines (ACI 318-19). All samples fall within a safe range that can effectively neutralize their respective acidity levels.

The sample taken at Betel (P3) has the greatest chloride level, 1.50 mg/L, whereas values are low at all other locations. For reinforced concrete, the ACI states that the chloride content should be less than 500 mg/L. All sampling points are well within this limit, making them safe in terms of chloride content. High chloride content can lead to corrosion of reinforcement in concrete, but the levels here are negligible.

Sulphate levels showed that highest at Betel (P3) with 36.37 mg/L, while other points range between 21.40 and 24.40 mg/L. The ACI recommends that the sulphate content should not exceed 1,000 mg/L. All the samples fall well within this permissible limit, thus minimizing the risk of sulphate attack, which can cause expansion and cracking in concrete. Whereas, the nitrate content at Betel (P3) has a significantly high level, 58.43 mg/L, which might indicate contamination. Other points have nitrate levels between 8.30 and 24.87 mg/L. While there are no specific guidelines for nitrate content in concrete mixing water, high nitrate levels can indicate pollution and may affect the setting time and strength of concrete.

Calcium content is highest at Betel (P3) with 52.44 mg/L, indicating higher hardness of water. Other points range from 30.87 to 44.67 mg/L. Calcium levels in mixing water do not have a strict permissible limit but can contribute to the overall hardness of water, which can influence the concrete setting process. Higher calcium levels can benefit the concrete by contributing to strength development.

Magnesium levels are fairly low, with Betel (P3) having the highest at 4.99 mg/L. The permissible limit for magnesium in mixing water is generally less than 50 mg/L. All sampling points fall well within this limit. High magnesium content can contribute to scaling and deterioration of concrete, but the levels here are safe. Moreover, the potassium levels are highest at Betel (P3) with 55.63 mg/L. Potassium does not have a significant impact on concrete properties and there are no specific permissible limits for potassium content in mixing water.

4.2 Comparison Analysis

Banteyiketu (P1) and Bulbula (P2) generally exhibit similar water quality characteristics, with minor variations in pH, acidity, and other parameters. Both are within safe limits for all tested parameters, making them suitable for concrete mixing. Betel (P3) stands out with higher levels of several parameters such as acidity, sulphate, nitrate, calcium, and potassium. This indicates potential contamination or different water source characteristics, making it less suitable without treatment or dilution. However, Mekanisa (P4) shows the lowest acidity and nitrate levels, with other parameters falling within permissible limits, making it a safe option for concrete mixing.

In conclusion, while most sampling points fall within permissible limits for the various parameters, Betel (P3) requires caution due to its higher acidity and nitrate levels. The overall water quality varies across the sampling points, which could impact the performance and durability of concrete differently. Using water from Betel (P3) for concrete mixing may require additional treatment to ensure it meets the necessary standards for construction use.

4.3 Total solids result

The Total Solids (TS) test is an essential procedure in assessing the suitability of water for concrete mixing, particularly when using water from natural sources such as rivers. Total solids in water include both suspended and dissolved particles, which can influence the quality and performance of concrete. High levels of total solids may introduce impurities, affect the hydration process, and ultimately impact the strength and durability of the concrete. In this research, water samples were collected from various points to measure the total solids content. These measurements provide critical data on the water quality and its potential effects on concrete properties, ensuring that the water used in mixing meets the necessary standards for optimal concrete performance.

The total solid concentrations in all four locations are significantly below the permissible limit of 50 mg/L, making the water from all sampling points suitable for concrete mixing based on this parameter. Specifically, Banteyiketu P1 has a total solid concentration of 0.0103 mg/L, Bulbula P2 has 0.0274 mg/L, Betel P3 has 0.0312 mg/L, and Mekanisa P4 has 0.0259 mg/L. These values indicate that the total solid content in the water is minimal and should not affect the concrete's quality.

When considering inorganic solids, the concentrations are also very low and well within safe limits for concrete mixing. Banteyiketu P1 has an inorganic solid concentration of 0.0043 g/L, Bulbula P2 has 0.0204 mg/L, Betel P3 has 0.0208 mg/L, and Mekanisa P4 has 0.0235 g/L. These low values suggest that the presence of inorganic matter in the water is negligible, which is favorable for maintaining the integrity of the concrete mix.

The concentrations of organic solids in the samples are similarly low and suitable for concrete mixing. The organic solid concentration is 0.006 g/L for Banteyiketu P1, 0.007 mg/L for Bulbula P2, 0.0104 mg/L for Betel P3, and 0.0024 mg/L for Mekanisa P4. These figures indicate that organic contaminants are present at very low levels, ensuring that the water quality meets the necessary standards for concrete mixing.

In comparing the different sampling points, Banteyiketu P1 stands out with the lowest total solid concentration, making it the cleanest water source among the four. Its inorganic and organic solid concentrations are also very low, enhancing its suitability for concrete mixing. Bulbula P2, while having the highest total solid concentration, remains well within acceptable limits and is thus also suitable for use. Betel P3, with a slightly higher total solid concentration compared to Mekanisa P4, remains within safe limits, and its inorganic and organic solid concentrations are comparable to the other sources. Mekanisa P4, despite having a slightly higher inorganic solid concentration than the other sources, is still well within the permissible limit for concrete mixing water.

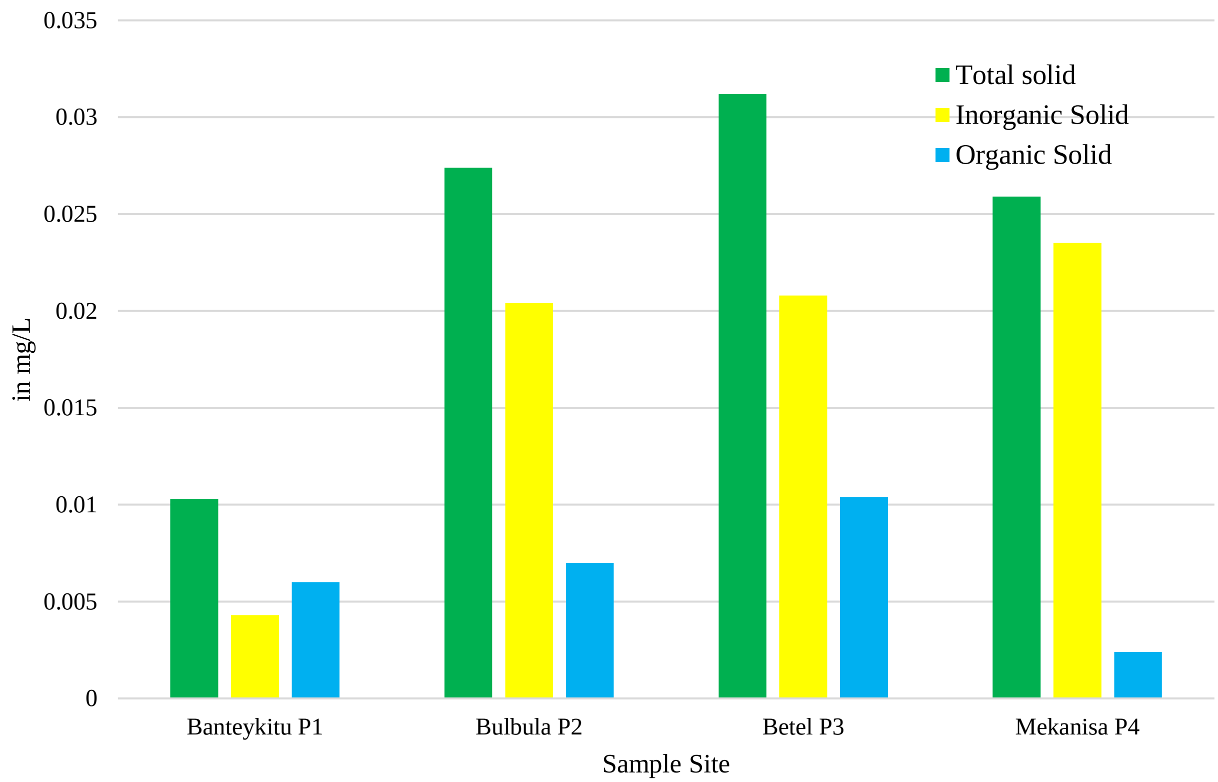


Figure 4.2 total solid comparison analysis

Generally, all four water samples from different locations in Addis Ababa are suitable for use in concrete mixing as per ASTM C1602/C1602M standards. Banteyiketu P1 and Mekanisa P4 have the cleanest water quality, with the lowest concentrations of total, inorganic, and organic solids. However, Betel source has higher acidity level and need to reclaimed. These findings suggest that water from these sources can be effectively used in concrete mixing without compromising the quality of the concrete. This analysis highlights the importance of ensuring water quality in construction to achieve the desired properties and durability of concrete structures.

4.4 Analysis of Water Quality Parameters across Four Rivers

The difference in the pH levels among all the river samples can be attributed to several factors that affect water quality as the rivers flow through different areas and are subjected to varying environmental and human influences. Human activities such as industrial effluents, urban runoff, and agricultural activities can introduce acidic or alkaline substances into the river, affecting pH levels. For example, Bulbula P2 and Mekanisa P4 likely experience industrial and urban pollution, leading to fluctuations in pH. Also agricultural activities: using fertilizer which often contains ammonia and nitrates, can lower the pH in rivers like Betel P3.

The differences in acidity levels among the four rivers can be attributed to various environmental, chemical, and human factors influencing the rivers' water quality. Acidity is often measured by the pH scale, but additional factors like dissolved acid compounds can also influence results. Industrial discharges, urban sewage, and agricultural runoff often introduce acidic substances like sulfuric and nitric acids into rivers. Bulbula (P2) and Mekanisa River (P4) are likely affected by these sources. Moreover, runoff from agricultural land with the presence of nitrogen compounds like ammonia and nitrates can lower pH, particularly in Betel River (P3).

The variation in chloride levels among the rivers is likely due to urban runoff and agricultural inputs. Higher concentrations in Bulbula (P2) and Mekanisa (P4) can be attributed to urban sources like sewage and cleaning agents, while elevated levels in Betel (P3) are likely due to fertilizer and animal waste from nearby agricultural activities.

4.4.1 Analysis of river water content across the rivers

The analysis of water quality across the four rivers Banteyiketu, Bulbula, Betel, and Mekanisa reveals variations. PH levels and acidity are shaped by urban runoff, industrial effluents, and agricultural activities, with Bulbula (P2) and Mekanisa (P4) exhibiting higher acidity due to urban pollution, while Banteyiketu (P1) maintains more neutral conditions. Chloride and sulfate concentrations are elevated in urban and agricultural zones, with Bulbula and Betel showing higher levels due to industrial discharge and fertilizer use. Similarly, nitrate concentrations are higher in Betel (P3) from agricultural runoff, while Mekanisa (P4) displays reduced levels due to higher flow rates and natural dilution processes.

Calcium and potassium concentrations also reflect agricultural and industrial impacts, with Betel (P3) showing elevated levels due to fertilizer use, while Mekanisa (P4) has lower concentrations because of faster flow and dilution. These findings highlight the dynamic interplay between natural and anthropogenic factors affecting water quality. They underscore the importance of tailored interventions to manage pollution and explore sustainable uses of river water, such as in concrete production, particularly in water-scarce environments like Addis Ababa.

4.4.2 The difference in inorganic solid composition between the four rivers

The difference in inorganic solid composition across the four rivers is influenced by several factors, such as geological conditions, human activities, and environmental conditions. Inorganic solids consist primarily of minerals, salts, and other non-organic materials like sand, silt, and clay. These solids can be sourced from erosion, industrial effluents, agricultural runoff, and atmospheric deposition.

4.5 Compressive Strength Test Result

The concrete's compressive strength was assessed on the 7, 14, and 28 days at three separate intervals. Separate water sources were used to make the concrete cubes, including river water obtained from four sampling locations and potable water used as a control. The objective of these tests was to assess how the quality of water, particularly rivers located in Addis Ababa, influences the compressive strength of concrete over time. The testing intervals provided insight into the early, middle, and late stages of the concrete's strength development.

The analysis indicated that with appropriate quality control and considering specific project requirements, river water from these sampling points in Addis Ababa can be used for concrete mixing, since the test result showed that almost similar comprehensive strength values with the potable water.

The compressive strength of concrete samples prepared with river water from four different sampling points in Addis Ababa was evaluated on the 7^{th}, 14^{th}, and 28^{th} days. These results were compared with a control sample prepared using potable water. The analysis and interpretation of results were conducted based on standards provided by authoritative references such as the American Concrete Institute (ACI) Manual of Concrete Practice and the British Standards (BS EN 12390-3).

4.5.1 7th Day Analysis

On the 7th day, the control sample exhibited a compressive strength of 11.40 N/mm². The Banteyketu sample (Sample 1) recorded an identical compressive strength of 11.40 N/mm², indicating 0% variation from the control. The Bulbula sample (Sample 2) achieved a compressive strength of 11.89 N/mm², representing a 4.30% increase relative to the control. The Betel sample (Sample 3) measured 11.61 N/mm², reflecting a 1.84% increase. In contrast, the Mekanisa sample (Sample 4) recorded a compressive strength of 11.01 N/mm², indicating a 3.42% reduction compared to the control.

According to the standards, concrete should achieve approximately 70% of its 28th day strength by the 7th day. Given the target 28th day strength of 17.00 N/mm², the expected strength on the 7th day should be around 11.90 N/mm². The Bulbula and Betel samples met this benchmark more closely, indicating their potential for acceptable early strength development.

Table 4.1 7th day compressive strength test results

7th day				
Sampling point	**Cube number**	**load at failure (KN)**	**Compressive strength(load/area)(N/MM2)**	**Average Compressive strength (N/MM2)**
Potable water (control sample)	P5PW 25/07	259	11.51	11.40
	P5PW 25/07	253	11.24	
	P5PW 25/07	257.6	11.45	
Sample 1 Banteyiketu	P5PW 26/07	258.6	11.49	11.40
	P5PW 26/07	252.2	11.21	
	P5PW 26/07	259	11.51	
Sample 2 Bulbula	P2BL 26/07	267.8	11.90	11.89
	P2BL 26/07	270.8	12.04	
	P2BL 26/07	264.2	11.74	
Sample 3 Betel	P3BT 25/07	265.2	11.79	11.61
	P3BT 25/07	253.2	11.25	

	P3BT 25/07	265	11.78	
Sample 4 Mekanisa	P4MK 25/07	245.2	10.90	11.01
	P4MK 25/07	249.6	11.09	
	P4MK 25/07	248.4	11.04	

4.5.2 14th Day Analysis

On the 14th day, the control sample reached a compressive strength of 14.25 N/mm². The Banteyketu sample (Sample 1) recorded 13.28 N/mm², representing a 6.79% decrease compared to the control. The Bulbula sample (Sample 2) achieved 14.97 N/mm², indicating a 5.05% increase. The Betel sample (Sample 3) measured 13.16 N/mm², reflecting a 7.65% reduction, while the Mekanisa sample (Sample 4) showed 13.50 N/mm², corresponding to a 5.26% decrease relative to the control.

Concrete is generally expected to achieve around 90% of its 28th day strength by the 14th day. This translates to an expected strength of about 15.30 N/mm². The Bulbula sample's performance was notable as it exceeded the control strength and approached the target 14th day strength, indicating a good rate of strength gain. Although the Banteyketu, Betel, and Mekanisa samples were below the expected 90% target, their results still indicate satisfactory progress in strength development.

Table 4.2 14th day compressive strength test result

14th day				
sampling point	**Cube number**	**load at failure (KN)**	**Compressive strength(load/area)(N/MM2)**	**Average Compressive strength (N/MM2)**
Potable water (control sample)	P5PW 25/07	323	14.36	14.25
	P5PW 25/07	321	14.27	
	P5PW 25/07	318	14.13	
Sample 1 Banteyiketu	P5PW 26/07	278.6	12.38	13.28
	P5PW 26/07	294.3	13.08	
	P5PW 26/07	323.7	14.39	

Sample 2 Bulbula	P2BL 26/07	343.35	15.26	14.97
	P2BL 26/07	343.35	15.26	
	P2BL 26/07	323.73	14.39	
Sample 3 Betel	P3BT 25/07	342	15.20	13.6
	P3BT 25/07	252	11.20	
	P3BT 25/07	294	13.07	
Sample 4 Mekanisa	P4MK 25/07	281.8	12.52	13.5
	P4MK 25/07	309.4	13.75	
	P4MK 25/07	320.2	14.23	

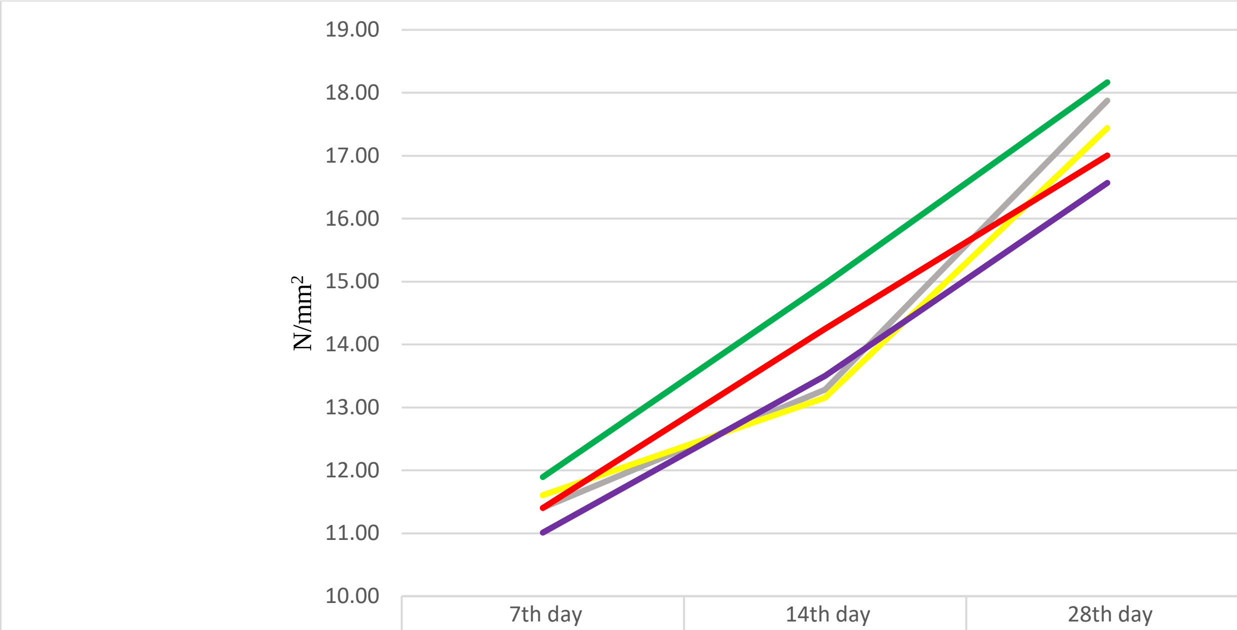
4.5.3 28th Day Analysis

On the 28th day, the control sample reached the target compressive strength of 17.00 N/mm². The Banteyketu sample (Sample 1) recorded 17.88 N/mm², indicating a 5.18% increase. The Bulbula sample (Sample 2) achieved the highest strength at 18.17 N/mm², showing a 6.88% increase. The Betel sample (Sample 3) reached 17.44 N/mm², reflecting a 2.59% increase. In contrast, the Mekanisa sample (Sample 4) recorded a compressive strength of 16.57 N/mm², representing a 2.53% decrease relative to the control.

The 28th day compressive strength is a critical indicator of the long-term performance and durability of concrete. According to the ACI and BS standards, the concrete samples from Banteyketu, Bulbula, and Betel not only met but exceeded the control sample's strength, indicating that river water from these points can produce concrete with satisfactory strength characteristics.

Table 4.3 28th day compressive strength test results

28th day				
Sampling point	**Cube number**	**load at failure (KN)**	**Compressive strength(load/area)(N/MM2)**	**Average Compressive strength (N/MM2)**
Potable water (control sample)	P5PW 25/07	382.6	17.00	17.00
	P5PW 25/07	382.6	17.00	
	P5PW 25/07	382.6	17.00	
Sample 1 Banteyiketu	P5PW 26/07	392.4	17.44	17.88
	P5PW 26/07	412.0	18.31	
	P5PW 26/07	402.2	17.88	
Sample 2 Bulbula	P2BL 26/07	431.64	19.18	18.17
	P2BL 26/07	392.4	17.44	
	P2BL 26/07	402.21	17.88	
Sample 3 Betel	P3BT 25/07	372.78	16.57	17.44
	P3BT 25/07	402.21	17.88	
	P3BT 25/07	402.21	17.88	
Sample 4 Mekanisa	P4MK 25/07	412.02	18.31	16.57
	P4MK 25/07	313.92	13.95	
	P4MK 25/07	392.4	17.44	



	7th day	14th day	28th day
Point 1 (Bantyeketu)	11.40	13.28	17.88
Point 2(Bulbula)	11.89	14.97	18.17
Point 3 (Betel)	11.61	13.16	17.44
Point 4 (Mekanisa)	11.01	13.50	16.57
Potable water(control sample)	11.40	14.25	17.00

Figure 4.3 compressive strength test analysis

The comprehensive analysis based on ACI and BS standards shows that river water from all four sampling points has the potential for use in concrete mixing. The Bulbula sample consistently demonstrated the highest strength at all test intervals, making it a particularly promising source. Banteyketu and Betel samples also showed strong performance, especially by the 28th day, suggesting their suitability for concrete production. The Mekanisa sample, although slightly lower in strength, still falls within an acceptable range for structural concrete.

In summary, the river water from these sampling points in Addis Ababa can be considered for concrete mixing, provided that other factors such as chemical contamination are within permissible limits

4.6 Estimating River Water Substitution Volume for Construction Use

The construction's total water use was 2,606 m3 over 295 days, resulting in an average daily water consumption of approximately 8,830 liters/day. The daily water use for the construction, averaging

8,830 liters per day, is equivalent to the daily water consumption of an urban population of 883 people if 10 liters per person per day is assumed, or 442 people if 20 liters per person per day is assumed. This analysis highlights the significant volume of water used in construction and compares it to the daily water needs of a typical urban population in Ethiopia.

The construction of the three-storied building consumes water equivalent to the daily needs of 442–883 people in urban Ethiopia which is almost equivalent to 88-176 households. For example, the household number in a typical condominium blocks where residents live differs in different blocks from 30 - 40 in one block with an average of 5 people in each household. (Bekele T. H., June 2015). If we assume this three story building construction is taking place in the middle of the city, it would take the daily consumption of 3 to 6 blocks people in it.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The research examined the chemical and physical characteristics of the river water from Addis Ababa and how it affects the compressive strength of concrete. It proved that by taking sample sites, the water found in Addis Ababa Rivers can be used for construction purpose as an alternative. The outcomes demonstrated that, despite the different pollutants in the river water samples, all of the samples produced concrete with a suitable strength. This result implied that Addis Ababa river water can be utilized to mix concrete without substantially reducing the concrete's strength.

The study further revealed that some river water samples led to concrete with strength almost the same as potable water. However, the presence of impurities in the river water can have an impact on the concrete's performance over time and it requires a continuous follow-up. These findings underscore the importance of monitoring and possibly treating river water before its use in concrete production, especially in large-scale construction projects where long-term durability is critical.

Using the river water for construction improves the city water supply system. For example, construction of three-story building consumes water equivalent to the daily needs of 442–883 people or 88–176 households in urban Ethiopia. This is comparable to the daily water use of residents in 3 to 6 condominium blocks, each housing 30–40 households. Such high water demand highlights the need for sustainable water management in urban construction.

In conclusion, all river water samples from Addis Ababa produced concrete that met or closely approached the required 28-day compressive strength of 17.00 N/mm^2 for C-25 grade concrete. Three samples—Banteyketu (17.88 N/mm^2), Bulbula (18.17 N/mm^2), and Betel (17.44 N/mm^2)—exceeded the target, while Mekanisa (16.57 N/mm^2) remained within an acceptable range. These results indicate that, with proper quality control and routine water testing, river water from the area can be suitable for concrete production.

5.2 Recommendation

Given the water shortage in Addis Ababa, it is crucial to balance the need for high-quality concrete with the realistic limitations on water availability. The following recommendations aim to optimize the use of river water while ensuring the production of durable concrete:

Prioritize river water usage with rigorous testing:

- Prioritize the use of river water for concrete mixing to conserve potable water for essential needs. Implement quality control measures to ensure that river water meets the necessary standards for concrete production. This approach allows sustainable use of local water resources while maintaining the structural integrity of buildings.

Develop affordable on-site water treatment systems:

- Construction companies should develop and use cost-effective on-site water treatment solutions such as chemical treatments, settling tanks, or basic filtration systems to mitigate potential fluctuations in river water quality. Treated river water ensures the production of high-quality concrete, allowing for the conservation of potable water.

Update and implement supportive regulatory policies:

- Regulatory bodies should update and enforce policies that support the use of alternative water source for construction projects, considering water scarcity while ensuring public safety. Government incentives and support can help the construction industry adapt to water shortages without compromising building quality.

Research and innovate alternative concrete production methods:

- Invest in further research on suitability of river water for concrete mixing as well as the long term effects on the building quality. Also it is recommended to do a further research on admixtures that enhance concrete strength or reduce water consumption in concrete production. This can lead to long-term solutions to water scarcity in the construction industry, fostering a resilient building sector in Addis Ababa.

- In the meantime, the test result indicated that there is no major problem in using river water for comprehensive strength. Further detailed study is very important.
- Blending river water to pipe water also another alternative

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Appendix I

Impacts of Water Quality on the Compressive Strength of Concrete: Case of Addis Ababa Rivers

Aklesia D. and Dr Tillahun D.

Abstract— **This study evaluates the impact of using water from four Addis Ababa rivers—Bantiketu, Betel, Bulbula, and Mekanisa—on the compressive strength of concrete. Water samples were tested for pH, solids, and chemical composition, and results were compared to potable water using ASTM and ACI standards. Findings revealed that Bantiketu and Mekanisa had the cleanest water, while Betel required caution due to higher acidity and nitrates. All samples met permissible limits for concrete use, with Bulbula achieving the highest compressive strength. The study concludes that with quality control, river water can be a sustainable alternative for construction, mitigating water scarcity in Addis Ababa.**

INTRODUCTION

Addis Ababa, the capital of Ethiopia and headquarters of the African Union, is traversed by tributaries of the Akaki River, including Kebena, Bantiyketu, Kortame, Bulbula, Lequ Soramba, and Kotebe rivers. These tributaries converge into the Akaki River, which flows into the Aba-Samuel reservoir, consisting of two main branches: Little Akaki, originating in the Wechacha Mountain area (40 km long), and Big Akaki, rising from Entoto Kidane Miheret (53 km long). The city's reservoirs, including Legedadi, Geferesa, and Dire, supply water for municipal use, while Aba Samuel, Ethiopia's first hydropower dam, is no longer used for potable water due to pollution.

Urban expansion, population growth, and migration have strained Addis Ababa's water supply system, with the Addis Ababa Water and Sewerage Authority (AAWSA) meeting only 50-60% of demand. The city also faces significant water shortages due to competing needs from the construction industry, which relies heavily on AAWSA's supply, further burdening the system.

Exploring alternative water sources is critical to alleviating this issue. Addis Ababa's rivers offer an untapped opportunity for construction water use, but the impact of river water quality on concrete performance remains under-researched. Poor water quality can affect the compressive strength and durability of concrete structures. This study investigates the suitability of untreated river water for construction, comparing its effect on concrete compressive strength to that of piped water. The research highlights the potential for sustainable water management in urban construction.

Objectives

- To analyze the concrete comprehensive strength that prepared by the river water and compare with piped water.

Materials and Methods

Samples are collected from four rivers found at various locations of Addis Ababa. The sites are selected purposively taking into account accessibility, the rivers flow properties, and the reach of the rivers. More emphasis was given to upper and middle reach of the rivers since the quality more deteriorates in the downstream with the interventions of the human activities. The water sample was collected using 20-liter jar and took at the center of the river flow using wadding technique. A part of the sample sent to the water quality laboratory for test and the remaining part used to mix concrete specimens and curing purposes. List of tests were prepared and labelled considering the concrete quality requirements. Tests were conducted following the laboratory procedures. The maximum time between the sampling and testing was 8 hrs.

The research used experimental to identify the parameters. The portion of the mixture which is the amount of cement, aggregate and water is kept constant through all the mixes. The mixture is designed as C-25 concrete. The sources of water used for the mixture was water taken from the four sampling locations chosen (namely Sample 1, Sample 2, Sample 3, Sample 4) and were compared to reference concrete specimen which was mixed with potable water to serve as a control. A total of 45 cubes were casted. The comprehensive strength of cubes was tested on 7th, 14th and 28th days at EiABC material laboratory. During the period, the cubes were cured with similar source of water.

Study area

The study area for analyzing and investigating an alternative water sources for the construction demand is Addis Ababa. The Akaki River system, a sub-basin of the Awash River, originates from Mount Entoto and Wechacha Mountain, flowing through all 11 sub-cities of Addis Ababa before reaching the Aba Samuel Reservoir. The Small Akaki (Small)) tributary spans 40 km, while the Big Akaki (Tiliku) flows 53 km, providing vital economic, socio-cultural, and environmental services along their courses.

River water samples were collected from four distinct sites to assess quality variations along the course, from upstream to downstream. Sampling locations were chosen based on flow rate, accessibility, and expected quality. Sample 1, from the upstream Banteyiketu River, showed minimal contamination due to limited human activity. Sample 2, at the confluence of the Banteyiketu and Bulbula Rivers in a densely populated urban area, exhibited pollution from wastewater discharge. Sample 3, from the upstream Big Akaki (Tiliku) River near moderate settlements and agricultural fields, showed slight contamination and odor. Sample 4, at the confluence of the Small) and Big Akaki (Tiliku) Rivers, was the most contaminated, with turbid water and noticeable impacts from farming and settlements.

Result and Discussion

A) Laboratory Test Result

Parameter	Unit	Banteyiketu (P1)	Bulbula P2	Betel P3	Mekanisa P4
pH	mg/L	6.72	6.90	6.72	7.24
Acidity test	mg/L	1.30	0.90	4.00	0.40
Alkalinity test	mg/L	8.80	8.30	8.00	8.40
Chloride	mg/L	0.86	0.80	1.50	0.61
Sulphate	mg/L	24.40	21.40	36.37	23.13
Nitrate	mg/L	24.87	23.70	58.43	8.30
Calcium	mg/L	38.50	44.67	52.44	30.87
Magnesium	mg/L	4.26	3.93	4.99	2.98
Potassium	mg/L	38.63	39.57	55.63	24.83

B) Total solid results, mg/L

Generally, all four water samples from different locations in Addis Ababa are suitable for use in concrete mixing as per ASTM C1602/C1602M standards. Banteyiketu P1 and Mekanisa P4 have the cleanest water quality, with the lowest concentrations of total, inorganic, and organic solids. However, Betel source has higher acidity level and need to reclaim. These findings suggest that water from these sources can be effectively used in concrete mixing without compromising the quality of the concrete. This analysis highlights the importance of ensuring water quality in construction to achieve the desired properties and durability of concrete structures.

Parameter	Banteyiketu P1	Bulbula P2	Betel P3	Mekanisa P4
Total solid	0.0103	0.0274	0.0312	0.0259
Inorganic Solid	0.0043	0.0204	0.0208	0.0235
Organic Solid	0.006	0.007	0.0104	0.0024

C) compressive strength test analysis (N/mm2)

The river water from these sampling points in Addis Ababa can be considered for concrete mixing, provided that other factors such as chemical contamination are within permissible limits.

	7th day	14th day	28th day
Banteyiketu (P1)	11.40	13.28	17.88
Bulbula (P2)	11.89	14.97	18.17
Betel (P3)	11.61	13.16	17.44
Mekanisa (P4)	11.01	13.50	16.57
Potable water	11.40	14.25	17.00

Conclusion

The research examined the chemical and physical characteristics of the river water from Addis Ababa and how it affects the compressive strength of concrete. It proved that by taking sample sites, the water found in Addis Ababa Rivers can be used for construction purpose. The outcomes demonstrated that, despite the different pollution levels in the river water samples, all of the samples produced concrete with a suitable strength. This result implied that, generally speaking, Addis Ababa river water can be utilized to mix concrete without substantially reducing the concrete's strength.

The study further revealed that some river water samples led to concrete with strength almost the same as potable water. However, the presence of impurities in the river water can have a subtle impact on the concrete's performance over time and it requires a continuous follow-up. These findings underscore the importance of monitoring and possibly treating river water before its use in concrete production, especially in large-scale construction projects where long-term durability is critical.

Appendix II

Photos

The selected image shows the study process flow shown as follows:

A) samlple collection locations

B) Concrete cubes for compressive strength test

 

C) Laboratory Setup

APPENDIX III

Requirements and test procedures for preliminary inspection of mixing water

		Requirement	Test procedure
1	Oils and fats	Not more than visible traces.	6.1.1
2	Detergents	Any foam should disappear within 2 minutes.	6.1.1
3	Colour	Water not from sources classified in 3.2: The colour shall be assessed qualitatively as pale yellow or paler.	6.1.1
4	Suspended matter	Water from sources classified in 3.2	A.4
		Water from other sources: Maximum 4 ml. sediment.	6.1.1
5	Odour	Water from sources classified in 3.2. No smell, except the odour allowed for potable water and a slight smell of cement and where blastfurnace slag is present in the water, a slight smell of hydrogen sulphide.	6.1.1
		Water from other sources. No smell, except the odour allowed for potable water. No smell of hydrogen sulphide after addition of hydrochloric acid.	
6	Acids	pH □ 4	6.1.1
7	Humic matter	The colour shall be assessed qualitatively as yellowish brown or paler, after addition of NaOH.	6.1.2

Maximum chloride content of mixing water

End use	Max. chloride content mg/l	Test procedure
Prestressed concrete or grout	500	6.1.3
Concrete with reinforcement or embedded metal	1 000	
Concrete without reinforcement or embedded metal	4 500	

Requirements for harmful substances

Substance	Maximum content (mg/l)	Test procedure
Sugars	100	6.1.3
Phosphates; expressed as P_2O_5	100	
Nitrates; expressed as $\overline{N}O_3$	500	
Lead; expressed as Pb^{2+}	100	
Zinc; expressed as Zn^{2+}	100	

Solid material in water

Density of the water (kg/l)	Mass of solid material (kg/l)	Volume of mixing water (l/l)
1,02	0,038	0,982
1,03	0,057	0,973
1,04	0,076	0,964
1,05	0,095	0,955
1,06	0,115	0,945
1,07	0,134	0,936
1,08	0,153	0,927
1,09	0,172	0,918
1,10	0,191	0,909
1,11	0,210	0,900
1,12	0,229	0,891
1,13	0,248	0,882
1,14	0,267	0,873
1,15	0,286	0,864

Compressive Strength of Concrete at Various Ages

ASTM C39/C39M

Age	Strength percent
1 day	16%
3 days	40%
7 days	65%
14 days	90%
28 days	99%

Grade of Concrete	**Minimum compressive strength N/mm^2 at 7 days**	**Specified characteristic compressive strength (N/mm^2) at 28 days**
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40
M45	30	45