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Urban Expansion and Surface Water Pollution: The Case of Beressa River at Debre Birhan City, in Amhara Regional State, Ethiopia.

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A RESEARCH THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTERS OF ART IN ENVIRONMENT AND SUSTAINABLE DEVELOPMENT STUDIES

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Declaration

I hereby declare that this thesis entitled **“**Urban Expansion and Surface Water Pollution: The Case of Beressa River at Debre Birhan City, in Amhara Regional State, Ethiopia**”** was prepared by me, with the guidance of my advisor. The work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted, in whole or in part, for any other degree or professional qualification.

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Approval Pages

This is to certify that the thesis prepared by Mr. Ashenafi Mihretie Asegie entitled “Urban Expansion and Surface Water Pollution: The Case of Beressa River at Debre Birhan City, in Amhara Regional State, Ethiopia”. The study also submitted as a partial fulfillment for the award of the Degree of Master of Art in Environmental and sustainable development complies with the regulations of the university and meets the accepted standards with respect to originality, content and quality.

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ARONYM

BOD	Biological Oxygen Demand
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
Cr	Chromium
ECSA	Ethiopian Central Statistical Agency
DBTC	Debre Berhan Teachers College
E.C	Ethiopian Calendar
EEPA	Ethiopian Environmental Protection Authority
EU	European Union
FC	Fecal Coliform
GD	Government Decision
Km^2	Square Kilometer
MCM	million cubic meters
Mg/L	Milligram per Liter
Ml/L	Milligram per Liter
MPN	Most Probable Number
ND	Not Detectable
NUPI	National Urban Planning Institute
TP	Total Phosphorus
WSP	Water Sample Point
WHO	World Health Organization

Abstract

Urbanization is one of the main drivers of surface water quality loss, which implies a transition from water to land. However, it is still unclear how urban areas affect the spatial pattern of surface water quality loss. Here, surface water quality loss as a function of distance from urban areas was studied across the Beressa River in Debre Birhan city, the capital of North Shoa Zone of Amhara Region. An exponential distance-decay model was employed. The research results provided a new and deeper understanding of the spatial influence of urban areas on surface water quality loss, which could be effectively integrated in the definition of sustainable strategies for urbanization, water management, and surface water restoration, focused on both human and environmental water needs. In addition, reduction in imperviousness was found to be a suitable strategy to adapt to these scenarios by limiting the construction of new impervious areas and decreasing the existing areas. This information can be further utilized to develop future designs, which in turn should make these systems more resilient to future changes in urbanization. In the case of the Beressa River and its surroundings, the study's primary objective were to assess the impact of urban growth on surface water quality using water quality parameters (such as ***PH*** *(highest recorded at WSP-3=7.74 and 7.66 in wet and dry season respectively),* ***BOD₅*** *(records 88.50 at WSP-4 and 98.00 at WSP-3 in wet and dry seasons respectively),* ***COD*** *(results were recorded 107.00 at WSP-4 in wet season and 84.07 at WSP-3 in dry season),* ***TP****(water sample result were recorded highly at WSP-3=2.44.00 and 0.74 at WSP-4 in wet and dry season respectively),* ***Cr*** *(high records were 1.67 at WSP-4 and 1.34 at WSP-3 in wet and dry seasons respectively), and* ***FC*** *(records 1,800 and 1,500 at the same WSP in wet and dry season respectively)) analysis and urban development trend analysis. Water sample analysis were done based on sampling and laboratory procedures and the result indicated that the river was worsen polluted and dangerous for living organisms in the surrounding. Based on the research results Beresa River was polluted by pollutants discharging from city municipality wastes, industries waste discharging to the environment, and from agrochemicals along the river watershed areas in wet and dry seasons.*

Keywords: *Urbanization, surface water, water quality, and water quality parameters.*

1. INTRODUCTION

1.1. Backgrounds of the Study

Urbanization could be a worldwide economic development phenomenon and may be a complicated handle of social and economic advancement (Freidman, 2006).The usual suggestions of quick urbanization are significant and distant coming to with the impacts regularly devastating the population development. In addition to urbanization, the occupation of communities living within the city hangs because of the multi-interface environment they have created. Because of this, the neighboring community's economic activities are migrating to an industrial zone of the city. Industrialization, combined with rapid population growth, causes progress along a waterbus in, putting extra stress on water bodies by causing water contamination and biological impediment (Olal, 2015). Due to intensive human activity, surface water pollution from point and nonpoint sources with chemical, physical, and biological pollutants are an unbelievable natural thought all over the globe (Fan and CUI, 2010).

According to (Adam, 2014**),** explains about the excessive potential of surface and groundwater assets in Ethiopia and well known as the water tower of East Africa**.** Water contamination can be defined as a change in the perfection of water from its typical state to an anomaly, as well as the warmth of its work and qualities. In developing countries like Ethiopia, pollution of water bodies by scientific work such as industrial wastes and agrochemicals are considered a minor issue, despite the fact that urban water contamination is increasing at alarmingly fast rates (Abera, 2005)**.** Most sources of contamination that enter urban surface water bodies are industries, municipal solid and liquid waste, construction wastes and agronomical used chemicals such as fertilizers(Gebre, 2009).

The historical background explanation shows on the study area settlement, established in 1454 G.C, was the administrative center during the reign of Atse Zarayakob. Atse- Zarayakob established this extensive city thinking to live and ordered to build his palace there (Debre Berhan city administration Finance and Economic annual bulletin, October 2020). The Urban develops gradually when compared with other towns and cities in the country. The city also classifying in to 5- sub cities that contains 37- Kebeles in it and from these 13-of them are rural towns near and around the city and 24-of them are urban towns starting from the last three years (2021).

Currently, Debre Berhan city increases and grows continuously its infrastructure and various construction activities. In line with urban expansion, various industries were constructed and produce their products frequently and the city becomes one of major industrial zone in the region. The municipality and its surrounding areas are suitable for living and other development due to environmental suitability, comforting of security and local community willingness for any development there. In case of this, overflowing of investors and communities from different states, regions, zones and Woredas were making stressful on the city including Beresa river quality deterioration. Therefore, the number of population living in the city has its own impacts on natural environment, primarily on surface water pollution of BR in the city. Beresa River is a perennial river, which stands from the Northeast direction of the highland areas of "**Kundi**" mountain chains and passes across the city to west direction.

Consequently, generation of wastes from different sources in the city including watershed and rural areas would be making high pressure on BR pollution status. The continuous discharge of domestic and industrial wastes, and used agrochemicals entering simply into Beresa River that makes substantial decline of Beresa River quality. Toxin chemicals from industries discharged into Beressa River also has an adverse impact on the waterway's quality, as well as causing significant harm to sea-going species and downstream consumers**.** Selected parameters for the determination of water quality in the study area were PH, BOD5, COD, TP, Cr and FC and their average laboratory test results in wet and dry seasons recorded and listed properly in table 4.1. Therefore, Beresa river pollution should be analyzed through physicochemical and bacteriological analysis for the determination of river pollution level by comparing national and international applicable water quality measurement (EEPA, Romania, 2006 and EU) surface water quality standards. In addition to this, river water pollution and urban expansion trend analysis was one of the best method of determination of pollution status of the river.

1.2. Statement of the problem

Urban expansion in all over the world is an indicator of people's economic development and modernization. Urbanization also a gradual formation of people from rural areas, its surrounding and other countries for working to better life like developing country citizens migration to developed countries. Anthropogenic contamination of surface water with chemical, physical, and biological contaminants is a major environmental concern around the world (Ouyang, 2006).

Most large cities and towns in the world do have huge industries and may discharge wastes to the environment without any treatment or with partial treatment (below effluent chemical standards).
Debre Berhan city was long aged city of its establishment compared to other cities and towns in the country. Population density also increases due to industrialization and modernization in urban areas as if Debre Berhah city was a typical example in the region and at national level. Rivers are one of the most pollutant-prone water basins, taking off municipal and industrial wastes as well as run-off from farmlands (Wang, 2007). Berresa River was one of naturally gifted to the city and its surrounding communities that stand from highland area springs and stream collections and cross the city to west direction.

Human activities and natural agents are the primary sources of water quality degradation on Earth (Chaterjee, 2002). Solid and liquid wastes were generated continuously to environment, flow from their sources, and mixed with the river. Primarily, city municipal wastes from communities, industrial wastes and irrigation activities from the upper catchments were the main causes of the river pollution.

Most People living in rural areas especially in developing countries are dependent on surface water sources throughout his life due to the absence of water supply facilities including along Beressa river paths. Quality of water resource was a vital aspect affecting human health and welfare, and it was a critical component in understanding the healthiness of water body of the river. Therefore, the river was polluted due to untreated waste generated from city municipality, and an industry waste released to the river and its quality gradually worsens and imposed on the river ecology and downstream consumers. Most of the river quality change appears when it joins to the city compound and increases its pollution to downstream due to uncontrollable domestic waste generation aggravates surface water pollution status in addition to industrial and agricultural activity.

However, the level of the river quality exacerbates month to month and year to year harmfully. Especially, communities living along the river course were seriously vulnerable through this polluted river water consumption. Thus, the source and effect of pollutants in to the river shall be examine in order to recognize the contamination level of the river, types of pollutants on selected parameters of bacteriological and chemical pollution status. Furthermore, generate basic information for comparing the variation of water quality parameters in the study sites over time.

Based on national and international surface water standards, determine the constraints of river consumption sustainability for wildlife's and communities living in downstream effectively. Accordingly, this study indicate for the sources of river pollution based on laboratory water test result based on sample collection site conditions and urban expansion analysis that will be indicate solutions for the problems with mitigation measures for adverse impacts.

1.3 Objectives of the study

1.3.1.General objective

Analyse the effect of urban expansion on surface water quality in the case of Beressa River and its surroundings.

1.3.2. Specific Objectives

The specific objectives of this research are:

- ✓ To analyze the temporal and spatial variation of the river pollution due to urban expansion and development.
- ✓ To identify pollutants with significant impact on the river and pose a risk to downstream life's.
- ✓ To identify the point with high pollution load from urbanization to river by comparing the results at source, treatment efficiency and downstream distribution systems.

1.4 Research questions

The research questions of this study are:

- Why do water quality variation increases to downstream flows frequently in wet and dry seasons on Beresa Rriver course in Debre Berhan municipality compound?
- How can we prevent or reduce effectively and efficiently the causes of river pollution for long-term sustainability of river quality and assuring community utility?

1.5 Significance of the study

Rapid urban expansions in line with technologies were putting serious stress on natural environments, especially on surface water bodies. Intensive human activities were the main causes of surface water pollution worldwide. Due to this, pollutants were discharged directly into the surface water from different sources in the city and its vicinity. Beresa River was the outcome of different sources of streams and springs from highlands of “Kundi” mountain chains, which were found in the north-east direction of Debere Berhan city. It provides many benefits for local communities living around its flow course such as for human and livestock consumption, irrigation activities like vegetables and fruit productions along the river regime. However, due to urban expansion, domestic and industrial wastes discharging to the environment throughout the year without any treatment measures to the river and deteriorate its quality continuously. Therefore, pollution causes and effects would be addressed through this study, depending on the results of water quality lab analysis by comparing them with ambient national and international surface water quality standards to protect aquatic life disturbance or destruction. The significance of this study was also important to indicate the pollution status of the river for national and regional governments and local communities that can use it as an input to find the best and appropriate alternatives to prevent or reduce health hazards from toxic chemicals and any environmental pollutant waste sources to the river and environs. To make decisions about issues related to river quality and to prevent pollutants from getting to their sources, national or regional government can use the study findings. In addition to this, the study result makes it important to establish other alternatives for community water consumption living in the river regime by governmental bodies, NGOs, and communities themselves if possible.

2. LITRATURE REVIEW

2.1. Theoretical and Conceptual Review

2.1.1. Theoretical Review

Urban expansions in response to water pollution were occurring in various parts of Debre Berhan city and its surroundings. Further to urbanization, there should be industrial development in the vicinity that leads to the intensification of waste discharge in to the environment before treatment. Therefore, using six primary water quality indicator parameters that were covered below, Beresa River must conduct water quality analysis to ascertain the status of surface water pollution.

Beresa River (BR) quality deterioration depended on different sources of waste generation, but human interference in the environment with urban expansion was the main one. Urban expansion indicates that the presence of industry expansions means that people work extensively and improve their livelihoods permanently. Pathogens, nutrients, plastics, chemicals like heavy metals, pesticides, and antibiotics, as well as industrial waste discharges and individual dumping anywhere, including at riversides, were the main causes of surface water pollution. In addition, any activities in and around the city generate vast waste for the environment, causing river pollution in both dry and wet seasons. The combined effects of numerous pollutants typically have a negative impact on surface waters. According to the USEPA (1979), nearly half of the surface waters (springs, streams, lakes, and rivers) are contaminated and unfit for swimming and fishing. Surface water pollution in temporal and spatial variation patterns in wet and dry seasons.

2.1.2. Conceptual Review

Water quality primarily degraded due to agricultural activities and urbanization and categorized as impaired or unimpaired based on indicators such as the contamination potential of water quality test results in this research paper. Water quality explanatory variables were determined using different techniques, such as using water quality parameters on the river course. The selected water quality explanatory variables were further processed using either hydrologic or water quality laboratory data analysis to determine source and cause of river water quality degradation. Based on the recorded water quality results, further water quality managers and policymakers are informed and this assessment facilitate them to take the corresponding course of action to protect water quality from deterioration.

Agricultural activities degrade water quality directly or indirectly. For example, improper agricultural practices such as excessive plowing disturb soil particles, and these particles enter the nearest water bodies through soil erosion and runoff. Increased sediment concentration or load reduces oxygen levels in water as well as changes water temperature, which results in an unfavorable environment for aquatic organisms. Excessive application of fertilizer, manure, and pesticides for better crop production as well as crop protection can be harmful. For example, excessive nitrogen and phosphorus from agricultural fields enter water bodies through runoff, and an increase in these nutrient contents accelerates eutrophication, resulting in the death of fish and other aquatic organisms. Domestic waste from the city municipality of the river watershed areas is also another main cause of the surface water quality change.

2.1.3. Urbanization Trends around the World

Urbanization has existed from around 5000 B.C and is not a recent phenomenon. The ratio of the total population that has been growing in a particular year to the population who reside in urban areas can be utilized to measure the degree of urbanization. Global urbanization accelerated following the Second World War. In industrialized countries in Europe, North America, and Oceania, more than 50% of the population resided in urban areas, indicating high levels of urbanization (United Nations, 2000). The number of people living in urban areas universally increased quickly from 751 million in 1950 to 4.2 billion in 2018. Currently, cities and suburbs are home to 55% of the world's population; by 2050, this percentage is expected to increase to 68%. Based on population projections, 2.5 billion people could live in urban areas by 2050, with nearly 90% of this growth taking place in developing nations in Africa and Asia (UN, 2018). Urbanization is the gradual shift of people from living in rural to urban areas. The counties with the highest levels of urbanization today include those in Northern America (82%), Latin America and the Caribbean (78%), Europe (74%) and Oceania (67%). Asia is currently about 50% urbanized. In contrast, Africa continues to be largely rural, with only 43% of its people dwelling in cities.

Cities are expanding in dynamic, diversified, disorderly, and increasingly space-consuming ways in developing nations. Pre-urban areas frequently require precise management of land use and restrictions. They are subjected to a number of the worst effects of urbanization, including as population growth, fast social change, poverty, changes in land use, and depletion of natural resources. According to trends, 90% of urban expansion will take place in Asia and Africa, with 93% of it taking place in developing countries. In particular, the average level of urbanization in Africa is currently 40%, while Sub-Saharan Africa is about 30% urbanized (United Nations, 2018) and Ethiopia is 23%. According to (Firew, 2010) information, Ethiopia is one of the 23th nations whose urban populations are growing at a rapid pace.

2.1.4 Urban Growth in Ethiopia

Based on Ethiopian central statistical agency (ECSA, 2020) population projection information, the total number of population in Ethiopia has 100,199,988 and from these peoples who lived in cities /urban areas shows 21,828,001 which is about 21.78 percent only whereas about 78.23 percent of population lived in the rural areas. However, the country is currently experiencing one of the fastest rates of urban expansion in the world, with an average rate of 5 percent each year. This is due to the high rate of population increase in urban regions. It is said that the degradation of forests and loss of productive agrarian land result from urban growth. The environmental harm and effects on agricultural production will be severe if industrialization continues at its current rate. Additionally, there is not enough infrastructures in the country to support urban growth, making it difficult to get utilities like piped water, sanitation, sewerage system, and roads. In pre-urban areas more than in the large cities at national level, there is typically a mismatch between the capacity of the government and the requirements of the population in terms of infrastructure provision. The main factors that contribute to urban sprawl or expansion are different provisions of financial, social, and political power in response to the physical geography of an area. Population growth, migration, increasing housing income, fragmented metropolitan governments, patterns of infrastructure investment, and road buildings are some of the causes at play. Ethiopia's expansion trend is comparable to that of developing nation’s world wid. Rapid urban population growth and in-migration brought on by factors such as employment opportunities, the availability of social infrastructure, and transit facilities contribute to the rise of Ethiopia's urban centers (Getahun, 2017).

2.1.5 Trends of Population Density in Debre Berhan City

Among the most important data collected by the Population and Housing Census (ECSA, 2007, and 2020) was that on population size at Debere Berhan city grows rapidly within 12 consecutive years. It is useful for formulating various development plans and for monitoring and evaluating their implementation. In Ethiopia, Population and Housing Censuses are the main source of data that reflect the demographic, social, economic and housing characteristics of the country. The total population size of the city during 2007 CSA result was 31,658 were males and33, 556 were females; whereas the Population and Housing Census (ECSA, 2020) result shows 66,731 were males and 66,323were females and population growth was very fast compared to the two census times at national level. Double population growth with in twelve consecutive years in the city indicated that there was fast urban expansion including urbanization.

Population distribution and growth by sex in Debere Berhan city based on data's collecting from national CSA in 2007 and 2020 respectively in the table.

Table 2. 1 Trend of population growth in Debre Berhan city

Year of Ethiopian CSA	Number Of Population By Sex in Debere Berhan City		
	Male	Female	Total
2007	31,658	33,556	65,214
2020	66,731	66,323	133,054

2.1.6 Impacts of Urban Expansion in Ethiopia

Based on NUPI (1996), the rapid population growth of Ethiopia's cities and towns places huge demand and pressure on how urban land is used. Urban land was required for manufacturing, business, service, residential, recreational, and other activities. The issues and limitations of the land distribution system were primarily to blame for the unmet demand for urban land. The overall effects of urbanization in Ethiopia include uneconomical land use, unnecessary boundary disputes between adjacent land owners, illegal land encroachment into public green buffer zones, and other vacant lots and unused spaces in people's homes, businesses, and organizations.

According to Debela (2016), urban growth and its accompanying activities harm the environment by destroying habitats for wildlife, degrading surface water quality and growth waves, air quality, and landscape aesthetics. Increased demand for land to accommodate each new increment of population growth was the most conspicuous indicator of the negative repercussions of urban expansion. Urbanization and urban growth were viewed as centers of modern living and a wide range of human opportunities that can all significantly contribute to socioeconomic development. According to Tegegne (1996), the isolation of tenure rights is one of the socioeconomic issues brought on by the horizontal spread of metropolitan areas in Ethiopia. Ethiopia is becoming more urbanized, which affects the strategies and components of peri-urban populations' livelihoods and makes them more susceptible to shocks. A primate city controls Ethiopia's urban development and urbanization.

Population growth pressure, rapid and unplanned commercial expansion, and growth eventually has an effect on the natural environment. The rapid loss of current tree cover over the past 100 years has also been attributed to urban industrialization and the change of varied land uses within cities and their environs (Hanckok, 1995). Changes in land use from rural to urban activities typically have an impact on the physical form of environment as well as the economic and social characteristics of peri-urban interface. Agricultural land was a significant source of fresh land for the service and industrial sectors. However, it may negatively impact displaced households in terms of disruption to their way of life and social and cultural consequences (DFID, 1999).

2.1.7 Impacts of Urbanization on the Study Area Environs

In Debere Berhan city, development can refer to the increment of human populations from migration into urban areas from other areas. Urbanization often results in deforestation, habitat and farmland loss, and the extraction of freshwater from the environment, which can decrease biodiversity and alter species ranges and interactions. On the other hand, urbanization increases the discharging of various wastes from the city to natural environment, such as surface water (ground water, rivers, springs, streams, and soils or lands) and may cause serious pollution if no treatment of wastes is done before they are released. Beressa River pollution in the city was also mainly due to the high increment of pollutants from urban development and a few rural communities' in the upper catchment watershed areas from day-to-day activity results that were released directly to the river basins.

2.2 Climate Conditions and river flow data in the Study Area

Based on data's obtained from Ethiopian meteorological station particularly from Debere Berhan station shows that the mean monthly rainfall was read or recorded in wet seasons specially in July and August 231.9 mm and 231.2 mm respectively. On the other hand, the minimum amount of rainfall was recorded in dry seasons namely at November and December with the value of 5.7mm and 8.7mm respectively. According to information getting from national metreology station on Beresa river flow data covers from **1961- 2003** years and totally 42 years back. Maximum river flow data was documented in July with 112.500 m3/s in wet season and minimum value were records in December with zero value in m3/s in dry season. High values of mean in MCM of the river flow were recorded in August with the value of 53.882MCM in wet season and the lowest were recorded in February with the value of 0.394MCM of dry season. Therefore, climate and river flow data information the river has high-level of flow in summer (wet season) due to high mean monthly rainfall in similar season(Wet season) and the river also contaminated with pollutions discharging from all its watershed areas. All the data are presented clearly in table 2.2

and 2.3; and figure 2.1 and 2.2 under here mean monthly rainfall(mm) and river flow rate(MCM) respectively.

Table 2. 2 Summary of mean monthly rainfall (mm) at Debre Birhan metrological station and the river data flow information's.

Month	Jan	Feb	Mar	April	May	June	July	Aug.	Sep.	Oct	Nov	Dec
Average	10.8	28	65.9	78.6	61.9	101	231.9	231.2	113	22.4	5.7	8.7

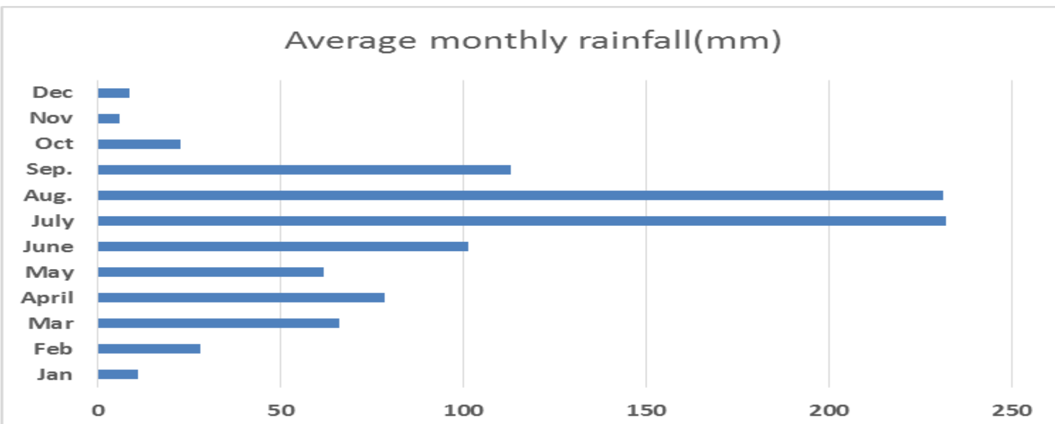


Figure 2. 1 Beresa river average monthly rainfall (mm)

Table 2. 3 Beresa river flow data (1961-2003)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Mean MCM	0.46	**0.39**	0.56	0.86	1.05	1.09	22.84	53.88	14.15	2.026	0.66	0.54	96.53
Max m3/s	0.51	2.2	6.02	5.56	13.5	12.94	**112.5**	**300**	96.44	25.93	5.88	1.62	300
Min m3/s	0.01	0.01	0.02	0.02	0.02	0.04	0.07	0.18	0.001	0	0	0	0

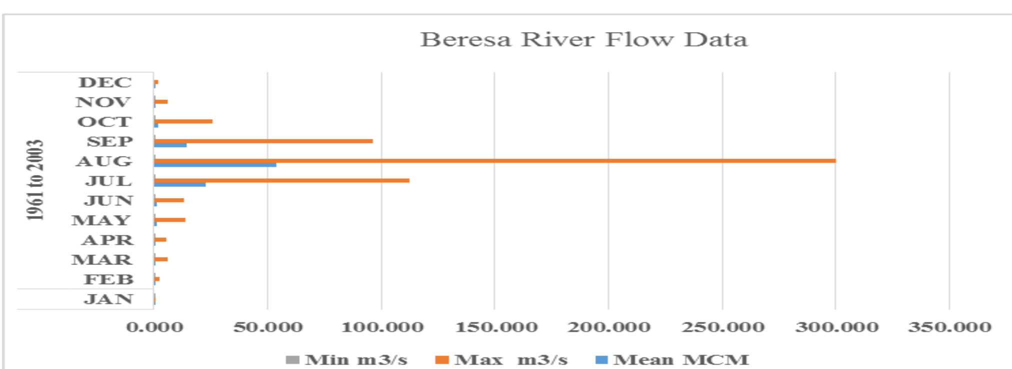


Figure 2. 2 Beresa River flow data diagram

2.3 Surface Water Contamination

Drinking water and using other products from contaminated sources can cause a wide range of illnesses and premature deaths. Man must use water for drinking purposes regardless of its cleanliness because he cannot survive without it. As a result, many people, particularly in Ethiopia, were affected by water-borne illnesses. Human and animal wastes, liquid and solid wastes from factories and garages, and agrochemicals from farmlands were the main contaminants of water in Ethiopia's rural villages and urban areas.

Many different types of bacteria have the ability to cause water-borne infections in the river. In addition to well-known pathogens like Shigella and Salmonella species, newly identified fecal pathogens are also included in the category of enteric bacterial pathogens. Gastrointestinal distressed, which includes nausea, vomiting, and diarrhea, is the most typical sign of a water-borne illness and is typically passing. The effects, however, could be more severe, chronic (like kidney damage), or even fatal in susceptible people like infants, the elderly, and those with compromised immune systems. Additional pathogens can infect the liver, eyes, skin, lungs, and skin.

2.4 Categories of Water Quality Analysis

In large terms, water quality may be categorized into three large classes, particularly physical, chemical, and biological, and every class has some parameters (Swamee & Tyagi, 2007). The evaluation of those three classes with the aid of area tracking of river offers simple statistics for detecting trends, imparting exceptional water records to water authorities, and making pointers for future actions. Water quality is one of the critical problems in water asset management.

Table 2. 4 Major physicochemical and biological parameters for water sample analysis

Chemical parameter	**Bacteriological parameter**
PH	FC (Fecal Coli Form)
COD5	
BOD	
TP (Total Phosphorus)	
Cr (total chromium)	

Water quality analysis was done according to Ethiopian ambient environmental standard guideline (EEPA, 2003). In this study, attempts have been made to prepare water quality data at the laboratory of ECDSWC in two seasons: the wet season (July and August) and dry season (March and April). In fact, following all parameters with distinct resources for pollutants coming into a river basin was exhausting and expensive. Moreover, many scientists and researchers have issues defining water pleasantness and imparting it in an easy and consolidated way. This issue exists because of the complexity of things or parameters affecting water quality and the large variability of parameters used to explain water quality of water bodies (Chapman, 1992). Surface water pollutants directly discharged into water bodies were the consequences of pollution in the environment.

2.5 Determination of Surface Water Quality

Beresa River is a type of surface water standing from various sources of springs and streams in highland areas in the proposed study area. Determining the status of river water quality requires systematically determining parameters with Ethiopian ambient environmental protection authority (EEPA, 2003); Romania, 2006(GD 161); and EU surface water quality standards.

2.6 Empirical Review Literature

An empirical literature overview is more universally referred to as a scientific literature overview, and it examines beyond empirical research to answer a selected study question. The function of the literature review is to find out the gaps in the literature. Quantitative research methods, which create numerical data and seek to establish causal links between two or more variables, would be used in the study.

According to a recent WHO report (2017), countries in the Sub-Saharan area have the most limited access to drinking water. Due to the ease with which pollutants and wastewater can be disposed of, surface water is now the most polluted. Weathering, erosion, hydrological features, climate change, precipitation, industrial activity, agricultural land use, sewage discharge, and human exploitation of water resources are just a few of the factors that affect water resources (Jarvie, 1998). Water quality assessment has been a crucial issue in most countries in recent years, owing to worries that fresh water may become a scarce resource in the future (Qadir, 2008).

Several studies have also identified the source of pollution and the potential effects of natural processes and human activities on temporal water quality fluctuations (Kannel, (2008). Water quality monitoring is a useful instrument not only for assessing the effects of pollution sources but also for ensuring efficient water resource management and aquatic life preservation (Robillard, 2008).

Due to increasing population density and development with urban expansion, disposal of wastes into the river course affects the quality of surface water in the area. The river water quality was continuously degraded and hazardous for human and other animal consumption, especially the river that crosses or existed near the city and rural villages along the river in the vicinity of Debre Berhan city. According to Boyd’s (2006) explanation, microbiological infections are the most common and essential risk that potable water presents for downstream consumers in the rural areas of the vicinity. These microorganisms would create illness outbreaks that would result in acute health problems for a large proportion of the population.

2.7 Conceptual Frame Work

According to Imenda (2014), a conceptual framework is a collection of interconnected elements and variables that aid in the solution of a real-world problem. It is the last lens the researcher will use to look at a problem's deductive resolution.

The establishment of a conceptual framework begins with the logical assumption that a problem exists and that it can be addressed using processes, procedures, functional methods, models, or theories (Zackoff, 2019). Therefore, the conceptual framework of the study was developed based on prior theoretical and empirical literature and framed by taking into account the research objectives. Primary, there shall be proper identification of urban expansion pressures on the surface water quality problem of the study area, and then, in order to reduce or prevent the source of pollutants and deal with various challenges facing the natural environs of the water body or river. The conceptual framework can be thought of as a collection of well-understood fact-based conditions that present the researcher's prescribed reasoning for resolving the problem. These circumstances provide a methodological basis for starting, executing, and identifying the outcome of problem-solving initiatives. Generally, the study lies on a very well-structured conceptual framework about the impressed core points included in it effectively and sufficiently. Hence, the framework would try to establish the whole study key points as designated here, but the conceptual framework may be reorganized depending on the conditional data collections. The whole study process of the conceptual framework could be placed hereunder with a short and clear procedure.

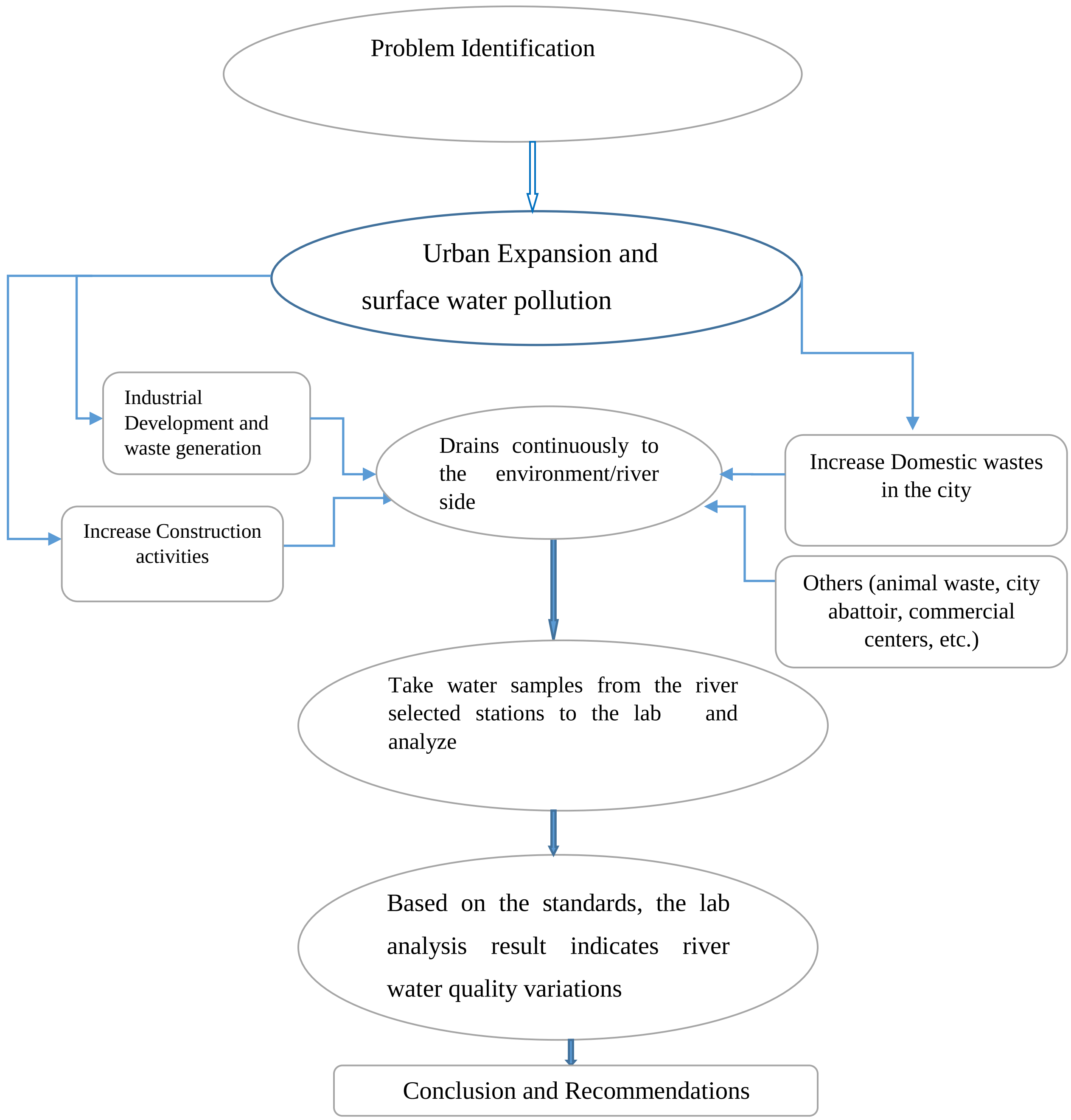


Figure 2. 3: Conceptual Framework for Beresa River Water Quality Study

3. RESEARCH METHOD

3.1. Description of the Study Area

Currently, Amhara Regional State is one of the 12th regions located in the north-western part of Ethiopia. North Shoa was also one of thirteen different zones in the region, situated in the eastern part of Amhara regional state. Debre Berhan city is a place where the administrative center of North Shoa Zone, which contains about 26-woredas, existed in and around it. It was the fastest-growing city in the region and exists on the line that passes from Addis Ababa city to Desse asphalt main road, at 130 km from the capital of Addis Ababa, Ethiopia. The study was mainly focused on Beresa River quality changes, which was located between latitude 9041' 04” North and longitude 39032' 38” East with an elevation of about 2,813 meters above sea level (source: Google Earth). The nature of the study area has naturally relatively colder and highland areas suitable for human life and industrial development. It was one of the main industrial zone in Amhara regional state, and various industries constructed in different fields of production.

The area of the city increases with the size of the population, especially within the last three decades frequently as zonal city administration information. In case of this, with the combination of industrialization and urbanization development, the city grows relatively rapidly in the region. Uncontrolled waste generation released continuously from different sources, such as construction activities, industries, and domestic wastes was discharged to the surrounding environment. The river is perennial having many tributaries that stands from highland areas in the same zone, especially from “KUNDI” mountain chains found between the historical place of Ankober and Bassona-Worena woreda around the city's municipal settlement. The river crossed the city in west direction and join to Jema River, which was one of the major tributaries of the Great Abay River. From the city, untreated waste was drained to the river in and around the city. Most local communities living along the river course used it for multipurpose for many years ago. However, now, especially communities living in the downstream areas were highly vulnerable due to the increase in waste generated from the city and the physicochemical water quality worsening for their lives. The location-based map of the study area in and around Debere Berhan city of Beresa River (BR) prepared based on watershed land features is shown here under figure 3.1.

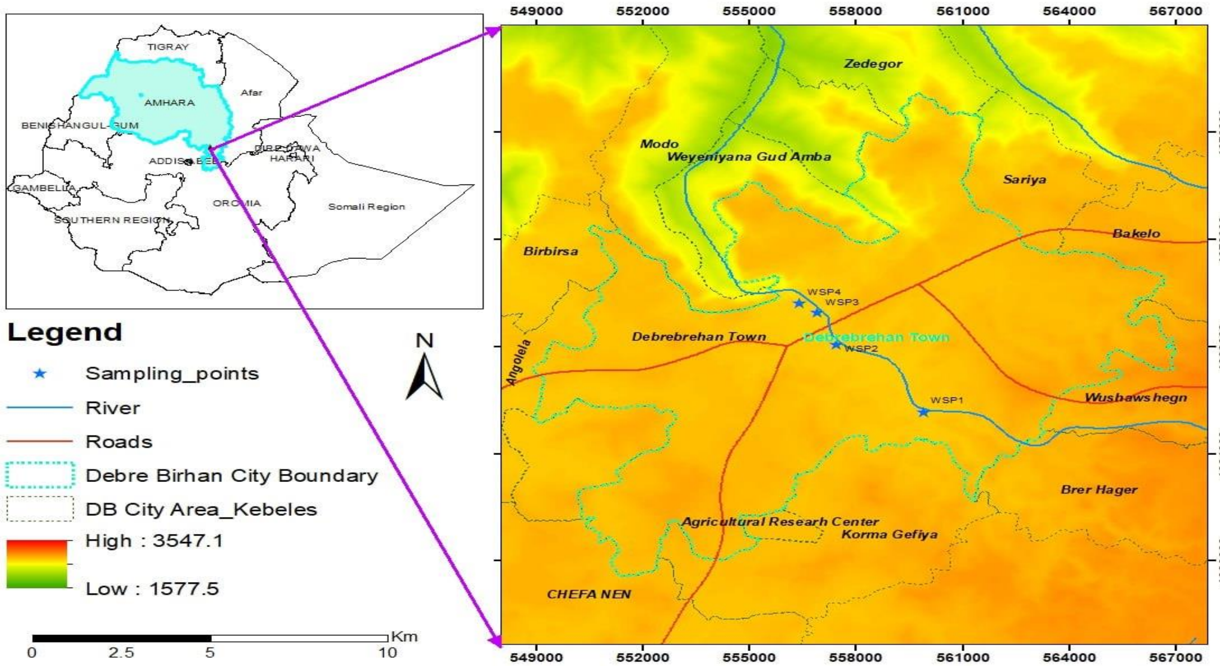


Figure 3.1. Location map of the study area including sampling stations along the river

3.2 Method of the Study

3.2.1 Data Collection

Water samples were collected from selected Beresa River (BR) points for the determination of chemical and bacteriological parameters. In this study, surface water sampling activities were started from the inlet (east direction of the city), from the city settlement bordering area up to the first sampling station were about 2.5 km and it was the longest distant from the sampling sites. The average distance of each sampling station was 0.7Km interval between each sampling stations along the river. Samples from four sampling points using the GPS coordinate point system in wet and dry were collected for bacterial analysis by using 1000ml sterilized glass bottles, stored in a 4°C ice box, and subjected to analysis within 6 hours. Five chemical parameters including a trace element were collected based on standard techniques of water and wastewater analysis (APHA, 1998).

Generally, all water samples were collected up to the last analysis of the research time schedule. Eight (8) of them were collected during wet season (starting from the last week of July to the first two weeks of August consecutively) and eight (8) samples during dry seasons (starting from the last half weeks of March to the first two weeks of April consecutively). A total of sixteen (16) samples were collected for temporal and spatial variation analysis of water quality for identification of its pollution sources at four different sampling sites along the river course.

3.2.2 Sampling Technique

The study used an experimental and descriptive design method of qualitative analysis for the determination and analysis of water quality status as well as prevention or reduction of river water quality problems in and around Debre Birhan city, particularly for downstream users. Chemical and bacteriological lab test analysis may be an indicator for the overall pollution level of the river through experimental analysis, and urban expansion may also be an indicator for various waste generations from the city communities to the environment and links directly to the river without treatment. The second type of method was to determine the pollution extent due to the fast growth of the city expansion in four directions. Accordingly, as urban expansion increases, the population continuously increases, which leads to industrial development in and around the city. Due to the above causes, waste generation also increases in to the environment.

3.2.3 Sampling Site Selection

Water samples were taken from the proposed study sites of Beresa River course. The sampling activities from the river and its course would be expected to determine the pollution level at four different selected study stations along the river. Surface water samples were collected two times from each of the four sampling sites. Total of 8 samples were collected for the first wet season and again two times each from four sites, and total of 8 samples were collected in the dry season. A total of 16 (sixteen) water samples were collected for bacteriological and chemical analysis to determine the pollution status of the Beressa River. The sampling sites were selected based on the landscape and settlement conditions, and the coordinate points' easting and northing directions are presented clearly in Table 3.1 below.

Table 3. 1 Coordinate points of each sampling stations along the river regime

Sample Sites	Sample Codes	Sampling Site Name	GPS coordinates	
			easting	northing
1	WSP_1	Milki Kebele	559909	1065558
2	WSP_2	Under DBU transitory bridge	557470	1068088
3	WSP_3	Around DB teachers college	556930	1069284
4	WSP_4	Midire genet village (Habitat) below the last bridge down to the river	556437	1069608

1. WSP-1: This water sample site (WSP-1) existed in the upper catchment areas of the river; about 2.5 km from the city settlement border in the southeast direction, and may be evaluating the extent of pollution, particularly through agricultural chemicals and feces from animals, including human feces. Water samples were collected for dry and wet seasons at the same point for physicochemical and bacteriological analysis purposes.

2. WSP-2**:** All samples taken during the winter and summer seasons were taken under the bridge that connects Debre Berhan University and other communities living around it with Kebele-4 communities including other communities in the city. Based on the topography of the land, these samples may evaluate the pollution extents of waste generated from university domestic and other wastes, city residences, and Debre Berhan blanket factory wastes.

3. WSP-3: sample three was collected from the river found under Debre Berhan teachers college and these samples can be also evaluating the pollution level of the river. High level of pollutions will be expected for comparison to the above two sampling sites due to generation of wastes increasing to downstream of the river in the city due to population density and industry augmentations.

4. WSP-4: This sample site is situated at the end of the outlet part of the river from the city and collects liquid waste from the left and right sides of the watershed areas. The test result may evaluate the overall extent of river water pollution. The four water sampling stations are located properly in Figure 3.1, and the pictures here show sample collections from the river at different points along the river in the city.

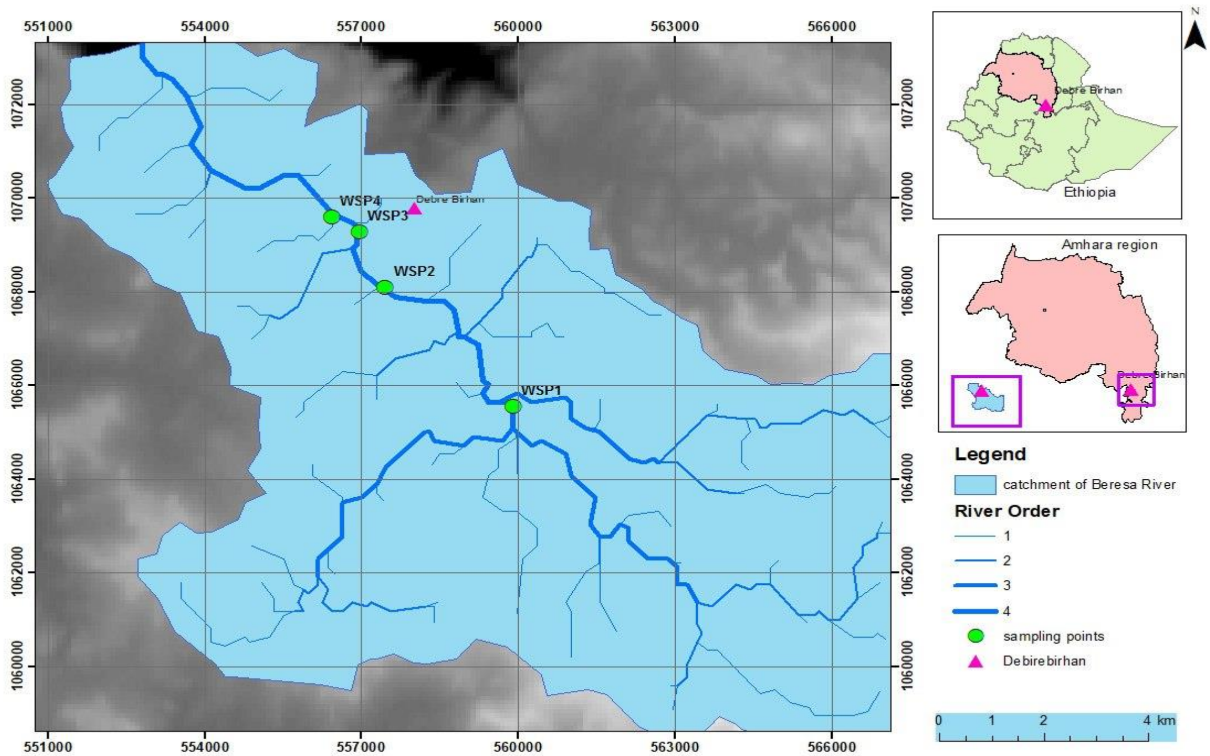


Figure 3.2 water sampling stations from Beresa River

Water Sample point (WSP)-1

Water Sample Point (WSP)-2

Water Sample point (WSP)-3 water ample point (WSP)-4

Figure 3.3 Selected water sample points along Beresa River

3.2.4 Sampling Frequencies

Water samples were collected from the river two times at each sampling site from four separated sampling points in wet and dry periods. Sampling points were also selected to estimate the quality of the river's status. The frequency of water sampling from the same point helps to compare the variation in water quality.

3.2.5 Method of Data Analysis

Sixteen (16) collected water samples from the Beresa River were analyzed based on two analytical techniques, such as bacteriological and chemical analysis, for the determination of water quality status in two different times. The general methodological diagram for the study was indicated under Figure 3.4.

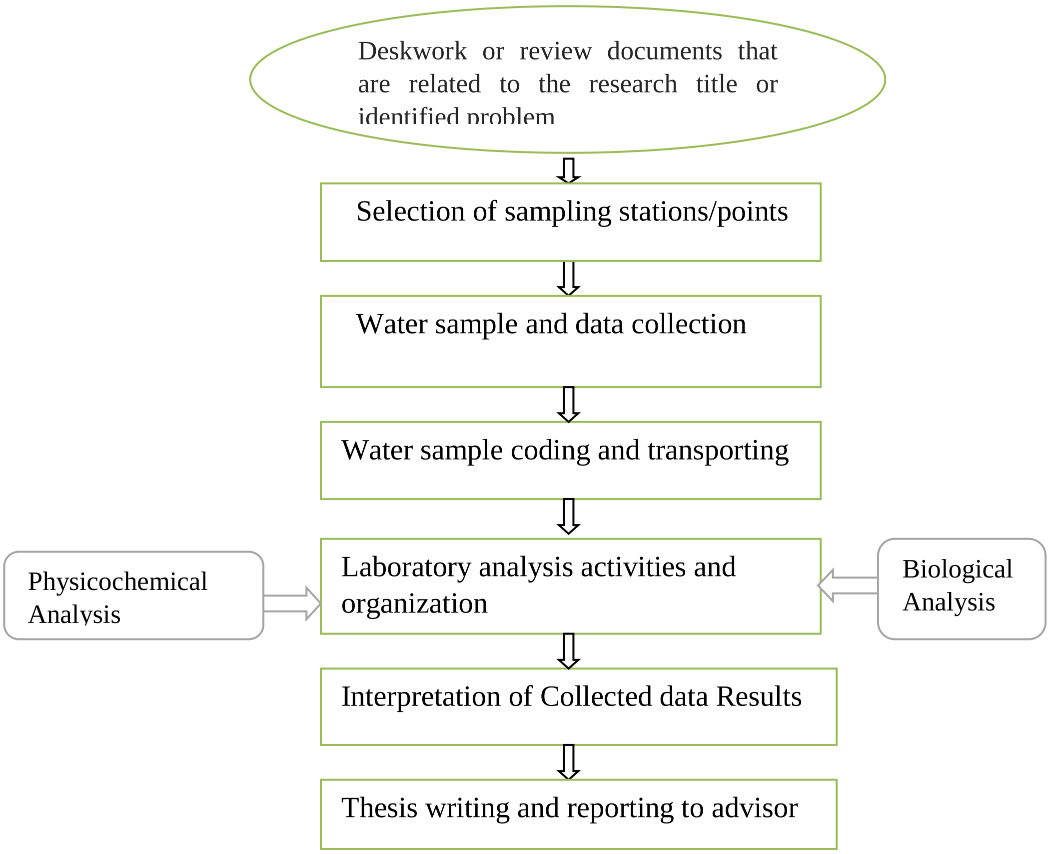


Figure 3. 4 Methodological flow diagram for the study

3.2.5.1 Bacteriological Analysis

Membrane filtration and membrane lauryl sulfate broth techniques were used to count the FC colonies after 24 hours of incubation at 44°C. 100 mL of water, aseptically filtered through a nitrocellulose filter, will be used in the tests. After that, the filters were coated with membrane lauryl sulfate broth to be analyzed for FC. FC was counted after the formation of colonies using a colony counter together with lab professionals in the lab process.

4.2.5.2 Fecal Coli form Indicators in Beresa River

Based on EEPA (2005) standards, an indicator organism is a living being whose presence, health, or quantity can reveal information about the status of a body of water. To detect the potential presence of dangerous pathogens originating from human or animal waste in surface waters, fecal coliforms are utilized. Giardia, Cryptosporidium, and E. coli O157:H7 (not all E. coli are dangerous) are a few harmful microorganisms that are of concern in water sources.

A good indicator organism should have survival properties that are comparable to any dangerous diseases while also being non-pathogenic, quickly discovered, simple to count, and non-pathogenic. Faecal coliforms, which are typically present in the intestines and excretions of humans, cattle, and wildlife, are indicator organisms used to evaluate public health risks. The detection and counting of these organisms are both relatively simple and inexpensive (Meays, 2004). The use of indicator organisms has two weaknesses. Firstly, locating the contamination's source is challenging. Second, it is impossible to determine whether bacterial contamination in source water is a sign of human disease. Additionally, it is impossible to determine whether dangerous germs are present solely by looking at fecal coli forms. For hazardous pathogens to be present, the feces must come from an infected animal or person. There are numerous connections between various land uses and the levels of fecal coliforms detected in surrounding surface waterways. Urbanization, agriculture, and the quantity of erodible soils have all been found to be positively correlated with high fecal coli form counts (Mehaffey, 2005). In addition to the entire area of a specific land use within a watershed of the river basin, high coliform counts also depend on how much precipitation the watershed got in the days prior. According to Mallin and Williams (2000), urban development and agricultural land use appear to produce the highest quantities of fecal coli forms in surrounding surface waters.

An additional factor contributing to higher fecal coliform levels in an urban watershed may be the presence of domestic animals (Young and Thackston, 1999). High concentrations of fecal coli forms were detected in urban watersheds, although Mallin, et al, (2000) determined that animal sources, not human activity, were to blame. Additionally, they discovered that septic system fecal coli form counts in an urban watershed's surface waters were extremely low in contrast to those from other fecal coli form sources. Various chemical characteristics of surface water can have an impact on fecal coli form levels. In surface water where the organisms must suffer difficult living conditions, levels of fecal coliform may be lower. By having freezing dry temperatures or extremely high pH levels, the rate of organisms' death can be speed up, potentially resulting in concentrations that are lower.

4.2.6 Chemical Data Analysis

Chemical analyses on selected parameters were used to assess the extent of organic and inorganic pollutants in the anticipated surface water quality. Due to this method of analysis, indicate the pollutant sources created by human activities. Selected parameters can be categorized into chemical analysis, which contains PH, BOD_5, COD, TP, and trace elements such as chromium (Cr). Parameters were analyzed for each of the 16 (sixteen) water samples using appropriate test procedures for each designated parameter. Furthermore, the suitability of the river for human consumption and other biodiversity in and around the river regime determine the subject of the sample test result analysis.

BOD_5 and COD parameters are selected to evaluate the existence of organic pollution along the river. The TP parameter was also selected to determine non-point sources of pollutants such as agricultural activities (inorganic fertilizer), domestic wastes through urban drainage of household wastes, and other consumptions of the river bodies.

PH value measurement is one of the main parameters for the analysis of the surface water's basicity and acidity properties. All the selected parameters were analyzed for the determination of water suitability for biotic communities and consumption purposes, in addition to indicating the water body's sustainability.

3.2.7 Physical Expansion Trends of Debre Berhan City

The area of urban geographical expansion data was taken from Google Earth and city municipality documents for about 30 years ago to determine urban growth in line with the number of population changes that could contribute to waste generation in the environment. These data describe the area in km^2 coverage of the city borders with settlements by counting each house using Google Earth information. The data shows that the area increases with the city land cover to date with new industrial construction. During the expansion of the city, the number of industries, governmental and non-governmental institutions, small-scale enterprises, and construction of standardized and high-rising hotels and buildings, commercial market centers, and other service centers were also continuously developed. Change of the river quality is due to frequent discharging of waste from the above-mentioned organizations, construction activities, domestic waste, and sludge from each residence in the city through ditches that connects directly to the river and affect the surrounding environment.

Urbanization disturbs natural resources like water bodies and their environs due to population growth. Industrialization with urban development is an additional factor on surface water quality problems in and around the city, including downstream consumers. It is clear that when urbanization increases, human consumption and waste generation activities in the environment rises. Surface water pollution aggravates when urban development and population size ultimately increases. Therefore, increase in population size and industrialization within certain year's affected Beresa River quality completely. Urban expansion data's were collected by using Google Earth information about 30 years back from the present time of development. Based on data has conducted by the national central statistical agency (ECSA, 2007), the population density in the city by sex was 31,668 men, whereas 33,563 are women, and the total sum was **65,231**; also, the average total area of the town was estimated at about **5.2 km2**.

Figure 3.5 Debre Berhan city population settlement pattern and urbanization, 2004

Source: From Google Earth, 2004

Population density and settlement pattern of the city after 10 years increases more than double when compared with the last 10 years (ECSA, 2004). Based on Google Earth, information about the house settlement and distribution of the city was clearly indicated in figure 3.5**.** During this year's interval, the total and average areas of the city were estimated at about **14.2 km2**. According to an Ethiopian central statistical agency projection, the population of the town indicated a total of **133,054**; of these, 66,731 are men and 66,323 are women (ECSA, 2020). Therefore, the total population and city area increase radically within a ten-year interval.

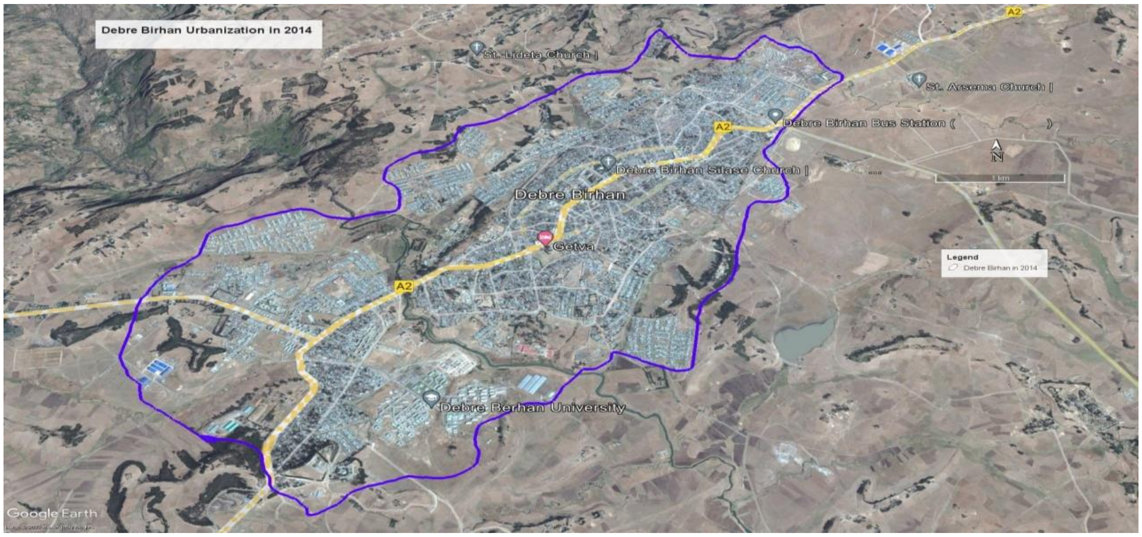


Figure 3.6 Debre Berhan city population settlement pattern and urbanization, 2014

Source: From Google earth, 2014 (the area of the town was 14.2Km2)

Figure 3.7 Debre Berhan city population settlement pattern and urbanization, 2023

Source: From Google earth, 2023

Based on Google Earth information, the total area of Debre Berhan city in 2023 population and settlement distribution covers about 17.4Km2. The settlement pattern also increases continuously and greater by 3.2Km2 comparing with the last 10-years back of 2014 settlement distribution pattern.

3.3 Data Analysis and Interpretation

To interpret water quality characterization, laboratory test results of water samples were compared and applied to the relevant standards effectively. For the purpose of comparing the results that could be recorded in the lab, the most prevalent surface water quality standards were used.

The average values for each bacteriological and chemical value were evaluated, compared to the Ethiopian environmental authority (EEPA, 2003); Romania, 2006 (GD 161); and EU surface water quality standards of allowable limits to protect aquatic species from toxic and poison chemicals were taken into consideration. These results were obtained from four various water sampling points along Beresa River. Any effects or deviations from this criterion were addressed and interpreted with respect to the associated activities.

4. RESULTS AND DISCUSSIONS

4.1 Result

Based on the objective of the study, the result of surface water samples that are collected from Beresa River in wet and dry seasons has its own implications of the river quality situation. The research also select different parameters that could be determine the river status currently for comparison to the previous research result. The analysis is used to determine trends of river quality deterioration from day today / month to month or year to year frequently. Therefor in this research result indicates that the river quality in almost all selected parameters shows out of the permissible limit value of EEP, 2003; Romania,2006 (GD 161); and EU standards for consumption purpose of surface water from Beresa River.The result could be show and clearly analyzed here under:

4.1.1 Chemical Parameter Results

4.1.1.1 PH

The PH test result of the river in all sampling station was recorded under the permissible limit of the proposed international standards in dry and wet seasons. The results also indicated that how much water quality problems increased down the river course when comparing in each sampling sites. The test result was completely various in the selected sample sites. The result shows here under in table 4.1.

Table4. 1 Beresa River an average value test results of PH at four sampling sites

Tested Parameter	Parameter Testing Seasons	Beresa River Sampled Points and average results in each sample stations				Average results	Ethiopian Surface water quality standards (EEPA, 2003)	Romania, 2006(GD 161) surface water quality standards	EU, Surface water quality standards
		WSP-1	WSP-2	WSP-3	WSP-4				
PH	Wet season	6.34	6.52	7.74	7.59	7.05	6-9	6.5-8.5	6.5-9
	Dry season	7.28	7.39	7.66	7.27	7.40			

The highest and lowest numbers which are indicated at the standard part used for comparison of the test result of the river status and if the result was more than the highest permissible level, water body becomes danger because the river was changed more alkaline in nature and distracts or not suitable for aquatic ecosystem; and if test result also becomes under the permissible the river becomes acidic in nature and may damage aquatic species partially or completely.

4.1.1.2 Biological Oxygen Demand (BOD5)

Biological oxygen demand test result of the Beresa River was the main indicator of the river water quality weather it was suitable or not for aquatic environment especially for living organisms. On the other hand, collected water sample results also indicated that discharging organic waste material lefts to the river and may disorder aquatic environment. Therefore, in all sampling station test results were recorded above the standard limits (i.e., ≤ 5mg/l or 3mg/l values) in dry and wet seasons. The average values were more recorded in dry season except sample site-1 which shows that concentration of organic waste material higher than wet season to the river from different sources around the river. The river quality in wet and dry seasons was presented in table 4.2.

Table 4. 2 Beresa River BOD_5 in mg/l at four sampling sites of an average value test results

Tested Parameter	Parameter Testing Seasons	Beresa River Sampled Points and average results in each sample stations				Average results	Ethiopian Surface water quality standards (EEPA, 2003)	Romania, 2006(GD 161) surface water quality standards	EU, Surface water quality standards
		WSP-1	WSP-2	WSP-3	WSP -4				
BOD_5 in mg/l	Wet season	29.30	19.00	57.62	88.50	48.61	≤ 5mg/l	3mg/l	
	Dry season	16.50	71.50	98.00	96.00	70.50			

4.1.1.3 Chemical Oxygen Demand (COD)

Chemical oxygen demand was one of the water quality parameters. The test values in four station was indicated above the permissible standards (Ethiopian, Romania and EU surface water quality standards) in both wet and dry seasons but more recorded in dry season except water sample point -1(WSP-1) because this sampling point was found at the upper part of the river and may be the cause of aquatic organisms living excessively and rise its test values comparing in each sampling points. Generally, when compared the value of chemical oxygen demand to other site values at water sample point -4 was more recorded that indicates oxygen consumption increased due to the presence of organisms in the river around sampled point. Ethiopia has not standard value on chemical oxygen demand for surface water. The water sample test result shows clearly in table 4.3 below.

Table 4. 3 Beresa River an average value test results of COD at four sampling sites in wet and dry seasons

Tested Parameter	Parameter Testing Seasons	Beresa River Sampled Points and average results in each sample stations				Average results	Ethiopian Surface water quality standards (EEPA, 2003)	Romania, 2006(GD 161) surface water quality standards	EU, Surface water quality standards
		WSP-1	WSP-2	WSP-3	WSP-4				
COD in mg/l	wet season	84.00	53.50	73.00	107.00	66.88	Have no Ethiopian standards	5mg/l	25mg/l
	dry season	77.97	44.17	84.07	68.65	68.72			

4.1.1.4 Total phosphorus (TP)

Phosphorus is an organic element that can be cause surface water pollution with other compounds such as phosphate compound and disturb aquatic organism's safety. Most of the environment was farm lands and the local community uses agrochemicals extensively around the watershed area of the river in dry and wet seasons. Due to this, at any rainy time it could be washed from agricultural lands to the river caused the test value rises and may affect the river aesthetical values and organisms in the river in different ways. The water sample at four sampling points was recorded and presented in table 4.4

Table 4. 4 Average value Total Phosphorus (TP) test results of Beresa River qualities at four sampling sites in wet and dry seasons

Tested Parameter	Parameter Testing Seasons	Beresa River Sampled Points and average results in each sample stations				Average results	Ethiopian Surface water quality standards (EEPA, 2003)	Romania, 2006(GD 161) surface water quality standards	EU, Surface water quality standards
		WSP-1	WSP-2	WSP-3	WSP-4				
Total Phosphorus (TP)-mg/l	Wet season	1.76	0.94	2.44	2.07	1.80	0.005mg/l	0.3mg/l	
	Dry season	0.35	0.65	0.71	0.74	0.61			

4.1.1.5 Trivalent and Hexavalent forms of total chromium

Chromium metal is grouped under a transitional metal element. The element is mostly used in industrial process and it classified under toxic heavy metal. The water samples in all sampling station have above surface water standards except at water sample point-1(WSP-1). Water sample point-1 records too much less concentration that cannot be detected by the equipment (reader) and the result indicated that there were not present industries or factories around or its watershed areas. Average laboratory test results are presented in table 4.8 below.

Table 4. 5 An average value test results of Total chromium in Beresa River at four sampling sites in wet and dry seasons

Tested Parameter	Parameter Testing Seasons	Beresa River Sampled Points and average results in each sample stations				Average results	Ethiopian Surface water quality standards (EEPA, 2003)	Romania, 2006(GD 161) surface water quality standards	EU, Surface water quality standards
		WSP-1	WSP-2	WSP-3	WSP-4				
Total Chromium (Cr) -mg/l	Wet season	ND	0.76	1.23	1.67	0.92	0.05mg/l	0.025mg/l	
	Dry season	ND	1.31	1.34	0.92	0.89			

4.1.2 Bacteriological Test Results

4.1.2.1 Fecal coliform (FC)

Fecal coliform is one of the main parameter to determine water quality status. All test results were recorded above the permissible limits. Based on lab test result of water samples, the concentration of fecal coliform increases down to the river course due to waste discharging from its watershed. At water sample point-4 shows more concentration of fecal coliforms recorded the point that indicates at the effluent area from the city. Ethiopia does not have surface water standards therefore all the results were compared with EU and Romania, 2006(GD 161) standards. Results in four sampling points were provided in table 4.6 below.

Table 4. 6 An average value test results of Total chromium in Beresa River at four sampling sites in wet and dry seasons

Tested Parameter	Parameter Testing Seasons	Beresa River Sampled Points and average results in each sample stations				Average results	Ethiopian Surface water quality standards (EEPA, 2003)	Romania, 2006(GD 161) surface water quality standards	EU, Surface water quality standards
		WSP-1	WSP-2	WSP-3	WSP-4				
Fecal Coliform	Wet season	60	95	850	1,800	701.25	Have no Ethiopian standards	MPN/100ml or CFU/100ml	
	Dry season	100	650	1,200	1,500	862.50			

4.2 Discussion

4.1. Temporal and Spatial Variation of the River Pollution with Urban Expansion and Development

4.1.1. Temporal Variation of River pollution

Based on laboratory test result of water samples at four different sampling sites, Beresa River analysis could describe the relative concentration or determination of the level of the river pollution status. The place and frequency of water sampling from the river should be given great emphasis in order to determine water quality variation in two different seasons (wet and dry). Depending on this truth, sampling time was chosen based on a weekly approach in which water samples were taken in two months for two consecutive seasons. The samples were collected from the river in April and March in dry season and July and August in wet season, which consists of eight (8) water samples in each season. The seasonal variations of the river quality test results at the selected sampling stations indicated that pollutants were discharged more from the city municipality than the upper catchment areas. The lab test result indicated that in wet and dry seasons there is a variation in all parameters of each sampling site along the river course. Results recorded in each sampled sites and in all selected parameters were completely various from place to place along the river regime. According to laboratory test results indicated in table 4.7, almost the average test results in concentration was much more in dry season except total phosphorus concentration in wet season. The temporal variations in two seasons (Dry and wet seasons) such as PH, BOD and FC (fecal coliforms) tests were recorded in all sample stations increases almost down to the river regime in both dry and wet seasons as presented in table 4.7. Based on test results on selected parameters were highly various in sample stations in the river course.

4.1.2. Spatial Variation of River Pollution

Discharging waste from the city affects Beresa river quality, which is continuously worsening for river water users, and its influence should be considered when sampling sites are selected. Sampling site selection requires attention for monitoring purposes and particular information about the environment of the water source and its routes rather than its uses and every generation of litter. According to Bernard's (2000) information, the sampling points on the rivers should, as a general rule, be established at places where water is sufficiently well mixed. The spatial variation of water sampling points was also very important for the water quality analysis and to evaluate the changes in water quality from one sampling point to the next along the river course. Based on the above facts, including test results of six parameters from four sampling points, such sampling locations indicates the variation of water quality changes in the river Beresa.

In each of the four sampling points, the results indicated that pollutants were released from their sources to the river in various ways that resulted in different test results. All the sampling points were taken at a distance interval of 1–2.5 km of the river water flow, except for sample site point one (1), which has 2.5Km from the termination of the city settlement border.

4.2. Significance Impacts of Pollutants on the River and Downstream Life's

4.2.1. PH

According to Chapman and Kimstach (1992), the pH is "the negative of the logarithm to the base 10 of the hydrogen ion concentration" and is used to determine the acid balance of a solution. The pH scale goes from 0 to 14 (very acidic to very alkaline), with a pH of 7 denoting the neutrality of certain solutions. Natural water has a pH of 6.0 to 8.5, but chemicals entering streams could change this range (Chapman, 1992). Measuring the pH value of water quality has its own significance for aquatic and terrestrial organisms. The pH value results in Beresa River could be categorized as slightly acidic and basic in nature, but all the test results fell under the permissible limit of surface water standards. Measuring the pH value of surface water was important to clearly determine the river quality situation as acidic, basic, and neutral. If the value of pH changes extremely, it should be categorized as natural or through anthropogenic activities based on environmental considerations. Therefore, based on the laboratory test results, the PH levels shown in Beresa River were harmless in an acidic or alkaline condition, and the pH had no impact on the aquatic ecosystem in either the rainy or dry seasons. All the average test results from four water sample stations in wet and dry seasons are recorded in Table 4.1.

4.2.2. Biological Oxygen Demand (BOD_5)

Primarily, the significance of the effects of pollutants discharging from their sources in and around the city municipality to the river would indicate that they are disordering the aquatic ecosystem along the river course. When organic waste matter is disposed of in the river, organisms living in the river are exposed to a shortage of dissolved oxygen concentration because of the consumption of oxygen by microorganisms and bacteria. The consequence of high biological oxygen demand **(**BOD**)** of the test result in all sampling stations indicates that depletion of dissolved oxygen in the river affects almost all organisms in the river course, causing them to become stressed, suffocate, and die. All the lab results that were recorded at all the sampling stations show the values above the permissible limit in dry and wet seasons, and the river was highly polluted with organic matter from different directions in the river regime.

4.2.3. Chemical Oxygen Demand (COD)

Based on the chemical oxygen demand (COD) test results in wet and dry seasons, all sampling stations were recorded above the permissible surface water quality standard values. The effect of this parameter on river quality determines how much oxygen the body of water can absorb while organic matter breaks down in it. The amount of dissolved oxygen in the river that is hazardous to the environment can be reduced when the concentration of chemical oxygen demand (COD) rises in the river.

4.2.4. Total Phosphorus (TP)

Total phosphorus (TP) may exist in water bodies naturally or through runoff from agricultural lands in the landscape or watershed of Beresa River, and it is essential for both animals and aquatic plants as a nutrient level. It is one of the important nutrients in surface water for the control of all green plants, including algae. The laboratory result of the river water quality indicates that above the permissible limit value in all seasons at four selected sample stations along the river flow. Based on the result, the river was seriously polluted by the nutrient, which has an effect on the river and downstream life. The results of the laboratory analysis of water samples at four selected stations were recorded and showed that they were above the permissible limit values and standards. The most common effects of a high concentration of total phosphorus that can cause dense algal blooms to happen in the river are the formation of eutrophication, depletion of oxygen, devastation of habitats, degradation of water quality, and human and animal health problems.

4.2.4.1 Eutrophication

When too much phosphorus concentration in the river promotes the growth of algae and other aquatic plants, it causes eutrophication, which prevents sunlight from reaching submerged life. Aquatic life may perish as a result, and the ecosystem may sustain harm.

4.2.4.2 Depletion of Oxygen

Algae grow on the water body during the suitability of nutrients and die when depletion of nutrients occurs or when they migrate to a salty water body. The decomposition of dead plant matter can result in the death of other organisms (Thyagarajan, 2007). The breakdown of dying algae can lower the water's dissolved oxygen content. Certain fish species may perish if their tolerance for low dissolved oxygen levels is limited. The accumulation of dead algae causes decomposition, which takes oxygen from the water and results in oxygen depletion. Excessive phosphorus levels can also cause algal blooms, which can release toxins through their life processes that are dangerous to both human and animal health.

4.2.4.3 Devastation of Aquatic Habitats

Fish, insects, and other aquatic species may experience a reduction in population or the loss of significant habitats due to the dense floorcoverings of algae obstructing sunlight from reaching submerged vegetation.

4.2.4.4 Water Quality Degradation

Low clarity and dark, greenish water due to increased phosphorus levels in the water source. The river quality problem increases starting from the city settlement to downstream, which indicates most pollutants were generated from the city communities in the form of liquid or dry wastes.

4.2.4.5 Risks to Human and Animal Health

Harmful algal blooms can be produced and contaminated by toxic chemicals in the river or water body, creating a risk to human health as well as that of humans and animals. Due to the availability and suitability of algal nutrients such as phosphorus coming from its source in the river, algal blooms produce high levels. The quantity of these algal blooms indicates their effect on humans and animals living in and around Beresa River. Many types of algal species from fresh, salty, and marine water bodies produce organic compounds known as algal toxins (Falconer, 2005).

4.2.5. Total Chromium (Trivalent and Hexavalent forms)

The total chromium metal that holds trivalent and hexavalent forms in the water samples was tested in the lab by using an atomic absorption spectrophotometer (AAS) instrument to determine the concentration of chromium metal in mg/L. All sample results were recorded above the permissible limit values, except for sample station 1, which was clearly presented in Table 4.1. Numerous industrial wastes are frequently discharged into watercourses in the study areas. Living things gradually break down the majority of these wastes into smaller, safe molecules, but certain are difficult for them to break down; rather, they build up to levels where organisms may be seriously at risk for serious health problems. According to Koropatnick (1995), certain heavy metals are necessary for life in small amounts, but in larger concentrations, they can be toxic, carcinogenic, allergic, and occasionally they can even prevent sensitive enzymes from working. Most industries release wastes containing chromium metal (Cr), such as tanneries, textiles, electroplating, and metallurgical metal, which harms both humans and animals' health and has an impact on marine life (Ajmal, 1996). Therefore, chromium-consuming industries should be responsible to expose to the environment before treatment, and they need to raise awareness and provide training for professionals and workers about the effects of chromium metal on human health, including its toxicity to the environment.

4.2.6. Fecal Coliform (FC)

Fecal coliforms are part of the total coliforms that are to be considered present specifically in the gut and feces of animals. Fecal coliforms were counted by using the fecal coliform membrane filtration method (APHA, 1989). The concentration of fecal coliforms was described in units of the number of bacterial colony formations per 100 ml of water samples. After collecting water samples from the river, they were transported to the lab in an icebox and processed within 6 hours. Based on the lab results recorded, the fecal coliform (FC) in water sample indicates that some sort of feces has found its way into the body. Consumption of this infected river by coliform bacteria raises the chance of sickness such as fever, stomach cramps, vomiting, and other symptoms that would be indicated to consumers after entering the pathogens into the body through the mouth, ear, skin, and cuts. The presence of a high level of fecal coliform counts in the water samples of the river would indicate that the cause of disease and illness including down-stream consumers. Thus, in general, rivers with high levels of fecal coliform counts are polluted with animal feces and other organic material coming from their sources around the riversides, and they need to be treated or handled properly before being exposed to the environment. The existence of a high level of fecal coliform in the river may lead to a depletion of oxygen levels in the water and may kill aquatic lives. All collective and an average laboratory test results for six selected parameters collected from four sampling stations are shown in Table 4.1.

Table 4. 7 Beresa River quality of six selected parameters at four sampling sites of an average value test results

Tested Parameters	Parameter Testing Seasons	Beresa River Sampled Points and average results in each sample stations				Average results	Ethiopian Surface water quality standards (EEPA, 2003)	Romania, 2006(GD 161) surface water quality standards	EU, Surface water quality standards
		WSP-1	WSP-2	WSP-3	WSP-4				
PH	Wet season	6.34	6.52	7.74	7.59	7.05	6-9	6.5-8.5	6.5-9
	Dry season	7.28	7.39	7.66	7.27	7.40			
BOD_5 in mg/l	Wet season	29.30	19.00	57.62	88.50	48.61	≤ 5mg/l	3mg/l	
	Dry season	16.50	71.50	98.00	96.00	70.50			
COD in mg/l	wet season	84.00	53.50	73.00	107.00	66.88	Have no Ethiopian standards	5mg/l	25mg/l
	dry season	77.97	44.17	84.07	68.65	68.72			
Total Phosphorus (TP)-mg/l	Wet season	1.76	0.94	2.44	2.07	1.80	0.005mg/l	0.3mg/l	
	Dry season	0.35	0.65	0.71	0.74	0.61			
Total Chromium (Cr) -mg/l	Wet season	ND	0.76	1.23	1.67	0.92	0.05mg/l	0.025mg/l	
	Dry season	ND	1.31	1.34	0.92	0.89			
Fecal Coliform	Wet season	60	95	850	1,800	701.25	Have no Ethiopian standards	MPN/100ml or CFU/100ml	
	Dry season	100	650	1,200	1,500	862.50			

4.3 Analysis of Chemical Parameters

4.3.1. Analysis of PH

The PH test of Beressa River was an important parameter to determine the pollution extent properly. The PH values of Beresa River vary between sampling sites along the river course in both seasons (wet and dry). According to Chapman, (1996), the pH range for most naturally occurring water is between 6.5 and 8.5. Based on lab test results in the rainy season, the PH value ranges from 6.34 to 7.74 and the WSP-3 is highly recorded in two seasons. This result indicates that the sampling sites could be categorized as having slightly acidic and slightly alkaline characters (Table 4.1), but the PH value that lies under the range of 7.27 to 7.66 is also characterized as having a neutral and slightly alkaline nature during dry (winter) season. Based on laboratory results, the minimum value of the test result from four sampling sites was indicated at water sample point one (WSP1), which was found above the city settlement area and was expected to have low contamination compared with other four sampled points along the river regime.

On the other hand, sample test results in summer (wet) season ranges in the table classified as being under slightly acidic property due to heavy rain continuously in the upper catchment areas and mixed with Natural River, may change water quality when compared to dry season lab analysis results. Generally, all six water samples from four sampling sites along the river course of the average laboratory test result lie under the permissible limit range value standards of the Ambient Ethiopian Environmental Protection authority (EEPA, 2003) for surface water quality standards.

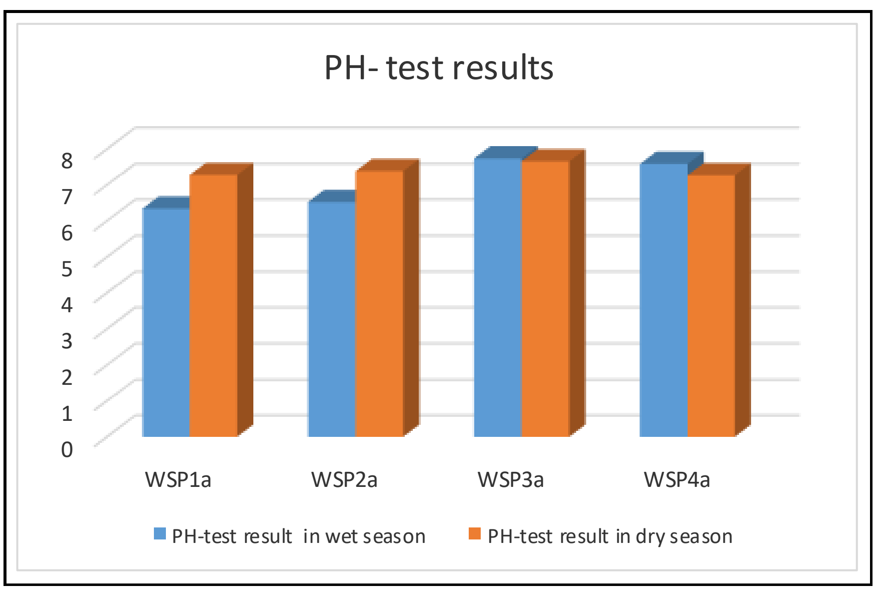


Figure 4. 1 PH- test results of Beresa River

4.3.2 Biological Oxygen Demand (BOD5)

According to Tenagne (2009), BOD is a measurement of how much oxygen is used by bacteria to break down organic matter in an aerobic situation. Wastes disposed of from domestic and industrial sources have decreased the quality of the water that can be assessed by BOD determination (Sawyer, 1994). The result of BOD_5 obtained from Beresa river laboratory analysis had an average values ranging from 19.00 mg/l to 88.50 mg/l in the summer (wet) season and was highly recorded at WSP-4 (the out-let part of the river from the city). The lower value was 19.00 mg/l at WSP-2, which was indicated around Debere Berhan University under the bridge that passes to and from the city. When comparing the two seasons (wet and dry) of biological oxygen demand test results, almost all high values were recorded in the dry season due to the concentration of waste discharging from its watershed to the river body. As the result indicated clearly in figures 4.3 below and table 4.1 above, WSP-3 (98 mg/l) near Debere Berhan Teachers College (DBTC) has the highest recorded result values because almost all the watershed wastes collected and flow through this area, increasing its biological oxygen loads. Nearly all the surrounding animals were consumed from this river in wet and dry seasons for drinking, and animal feces and urine were also excreted in the river and around it. Local communities also use washcloths, vehicles and swim in the river. Therefore, the concentration of the BOD_5 test value increases. Generally, the maximum and minimum values of the test results in wet and dry seasons were recorded at WSP-3 (98 mg/l) and at WSP-1 (16.5 mg/l) in dry season only, but the average result ranges in wet and dry seasons were recorded 48.61mg/l and 70.50mg/L respectively. All average test values of water sample points for the BOD_5 test lie completely above the permissible limits of ambient Ethiopian environmental protection authority guidelines (EEPA, 2003) and Romania, 2006 (GD 161) of surface water standard values. Surface water quality standards indicate that the river was highly polluted by waste and other organic matter generated from city municipalities, industries, institutions, and commercial market centers, including in the upper catchment rural agricultural areas.

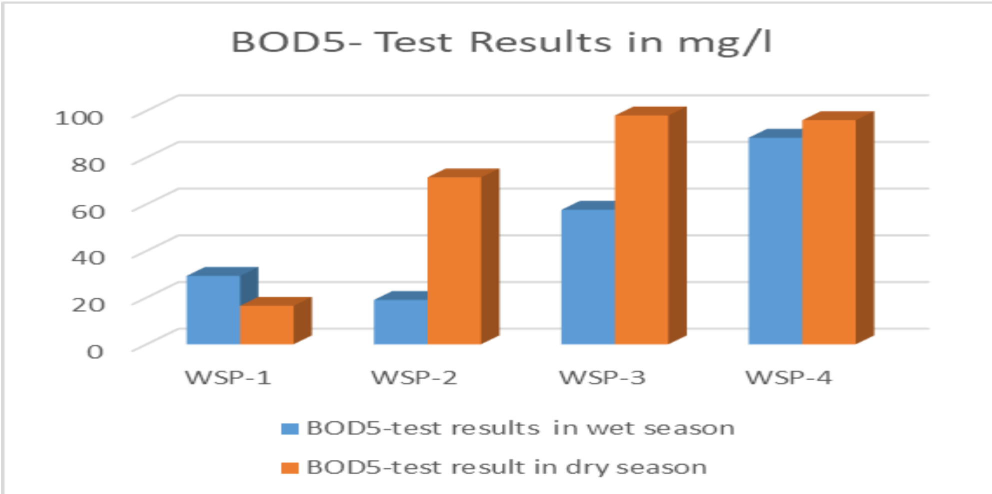


Figure 4. 2 Average BOD_5 test results of Beresa River

4.3.3 Chemical oxygen demand (COD)

The chemical oxygen demand (COD) test result measures the amount of dissolved oxygen present in the collected water samples and indicates oxidized chemical organic materials. Based on the test result of COD in the study area measures the short-term impacts that surface water (river) will have on the oxygen levels of receiving and discharging waste from its watershed areas of Debre Berhan city. Due to test analysis results at four various sample sites, a high average value was recorded at WSP-4 (107.00 mg/l)-the outlet point of the river from the city, and a low result was noted at WSP-2, which measures 53.5 mg/l in wet season. In dry season, WSP-3 was highly recorded (84.07 mg/l), and at WSP-2 (44.17 mg/l), there were low-value records. The higher COD values from collected water samples in the river course were recorded at WSP-4 during wet season indicates that there are more oxidizable organic materials present and will reduce the dissolved oxygen level in the river, which can be harmful to higher aquatic life forms because of the formation of anaerobic conditions in the water body. The average value of test results of COD in wet and dry seasons of Beresa River also has 66.88mg/L and 68.72mg/l respectively that show high level of organic material discharged to the river more in dry season. Generally, COD parameter analysis serves as an extent for the potential oxygen consumption of processes in measured solutions. Ethiopia does not have COD measuring surface water standard values, but all the test result values in wet (summer) and dry (winter) seasons were compared based on EU and Romania's 2006 (GD 161) surface water quality standards values. Based on this, all the values were above the permissible limit values that indicate pollutants were discharged into the river, putting pressure on water body quality and for aquatic organisms or lives along the river course. All the average test results from four sampling sites along the Beresa River were clearly indicated in figure 4.4 below and table 4.1 above.

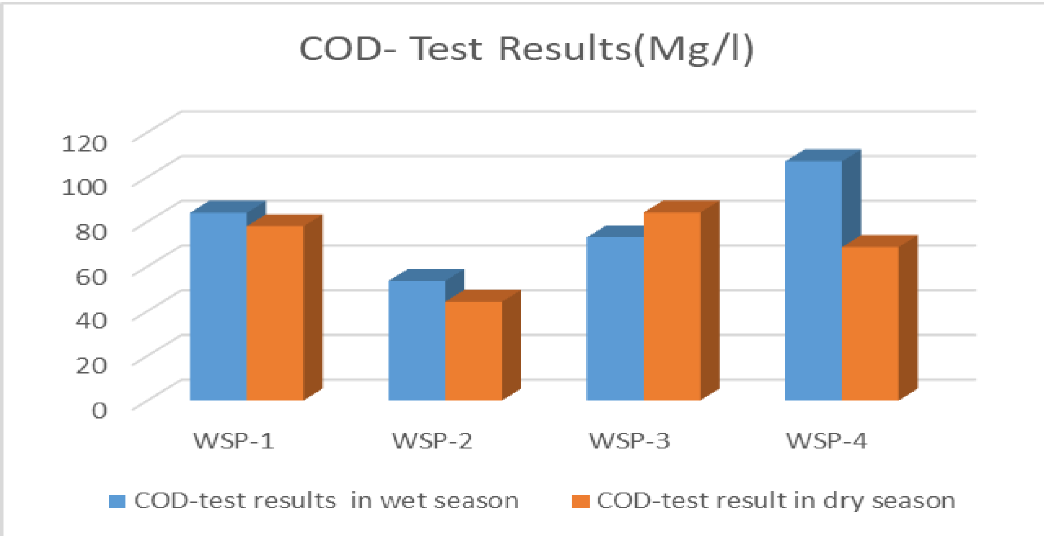


Figure 4. 3 Average COD- test results of Beresa River

4.3.4 Total Phosphorus (TP)

Using the ascorbic acid method, the orthophosphate was measured after the sample has been digested to convert all other forms of phosphorus into orthophosphate. The amount of total phosphorus in two seasons of the lab result indicates that there were great variations between them. The lab experiment results in summer (wet) season vary greatly, and they range from 0.94 mg/l to 2.44 mg/l and 0.35 mg/l to 0.074 mg/l in the dry (winter) season. However, all the results recorded above the permissible limit ranges of ambient Ethiopian environmental protection authority surface water quality standards (0.005 mg/l). The comparison of the concentration of an element was more in the summer season than the winter season results, and it may be the result of the application of agrochemicals in the upper catchment agricultural areas and washed or eroded to the river in wet or rainy season. On the other hand, traditional irrigation activities by local farmers could produce various vegetables such as carrots, onions, cabbages, potatoes, and various tree nurseries along the river way. An irrigation activity needs agrochemicals such as pesticides, fungicides, herbicides, insecticides, and fertilizers by local communities.

The study area is classified as a high geographical topographic area based on its altitudes or above sea level measurement values and has better annual rainfall in the vicinity compared to the adjacent woredas such as Shewa Robit, Kemise, Kombolcha, and Argoba special woredas in Amhara regional state. Therefore, the first reason was that the rainy time caused erosion from the surrounding Beresa River watershed areas of agrochemicals that may contain phosphorus in crop nutrients, especially in DAP (di-ammonium phosphate) fertilizer with other inorganic chemicals. These agrochemicals may be washed from farming lands to the river directly more in wet season than dry season and increases water sample test results along the river. The main source of phosphate entering surface water from agricultural or residential farmed lands through runoff was the maximum use of fertilizer. According to Davis (2015), increasing the phosphorus levels in rivers and other water bodies causes eutrophication and reduces dissolved oxygen levels.

The second reason may be a result of food garbage containing phosphorus nutrient materials, plant decay, municipal waste discharging activities, or urban runoff, such as from agrochemical fertilizers, residences, commercial market centers, industries, etc. Inappropriate liquid and dry waste disposal areas near the riverside, washed through wind erosion or urban runoff, increase phosphorus concentration in Beresa River. Generally, the total average test result of TP was 1.80mg/L and 0.61mg/l during wet and dry seasons respectively and the result also recorded more in wet season due to the above-mentioned reasons.

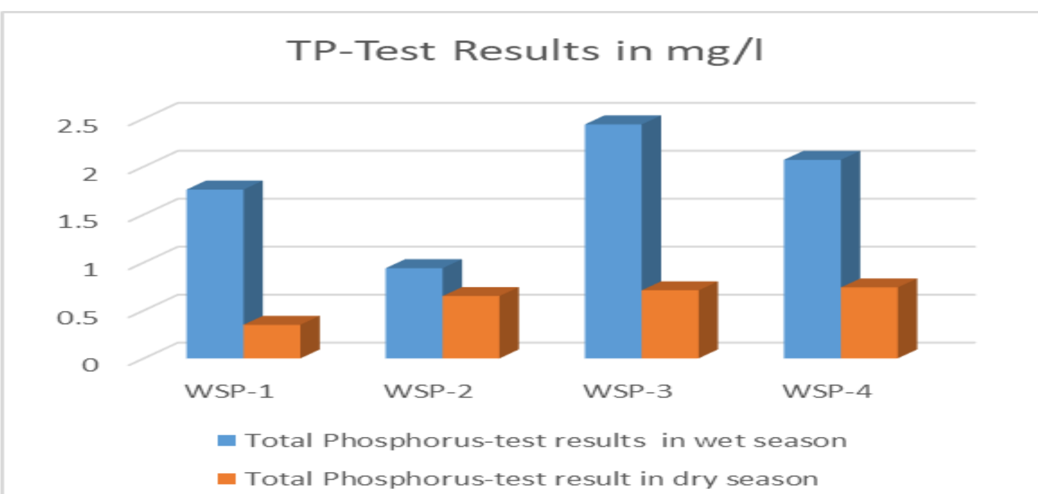


Figure 4. 4 Average TP test Result of Beresa River

4.3.5 Chromium (Cr)

Chromium has the potential to be a toxic metal in water bodies, especially for invertebrate aquatic organisms and green algae. Chromium occurs in different compositions naturally classified under dissolved and undisclosed forms in water. It is one of the most prevalent contaminants in groundwater bodies. Based on its chemical properties, which are classified under toxic heavy metal groups, it is frequently used in industrial processes, including in Deber Berhan blanket factory and tannery processes in different parts of the same city.

Based on the Beresa River water sample analysis result, it was not detected or difficult to read its concentration through the AAS (atomic absorption spectrophotometer) at sample point one (WSP-1) both in dry and wet seasons, which means it was below the reading capacity of the instrument. The sampling point site was found in the upper catchment area of the river basin, and almost no contamination was indicated with chromium metal. Water sample point-two (WSP-4) in the wet season had the highest average value recorded (1.67 mg/l) from four surface water sampling points in both wet and dry season laboratory test results. Water sampling point-2 (WSP-2) was found under the bridge that could be used to over-pass to and from Debre Berhan University in the city where the place existed under the Debre Berhan Blanket Factory. This sampling point has also been relatively high level compared to the permissible standards.

In the dry season of sample analysis, the result is lower than in the wet season in general due to erosion during rainy times, which was washed easily and mixed with the river course. The amount of chromium metal concentration in the dry season result at WSP-3 contains 1.34 mg/l, which indicates above the ambient Ethiopian environmental authority's (2003) surface water quality standards. Inanition to each sample station test result analysis, the average result in wet and dry season also has its own indication of pollution of the river. Therefore, the average concentration of chromium metal has 0.92mg/L and 0.89mg/L in wet and dry seasons respectively. The high concentration of toxic chromium metal in this area may indicate that Debre Berhan Blanket Factory utilized this element containing chemicals for the dyeing of cloths, blankets, sheets, and painting of steel for strengthening purposes with different colors without any protection mechanism to discharging to the environment. On the other hand, the place indicated around the tanning process area may cause its concentration to increase. Chromium concentration may cause cancer and other health effects for humans and other aquatic life if ingested with water more than the standard concentration of 0.05 mg/l. Chromium concentrations in Beresa River were collected from four water sample points, and based on the analysis of test results in wet season was more concentrated than in dry season, except for WSP-1 test result in wet and dry seasons, as indicated in figure 4.6 below and table 4.1 above.

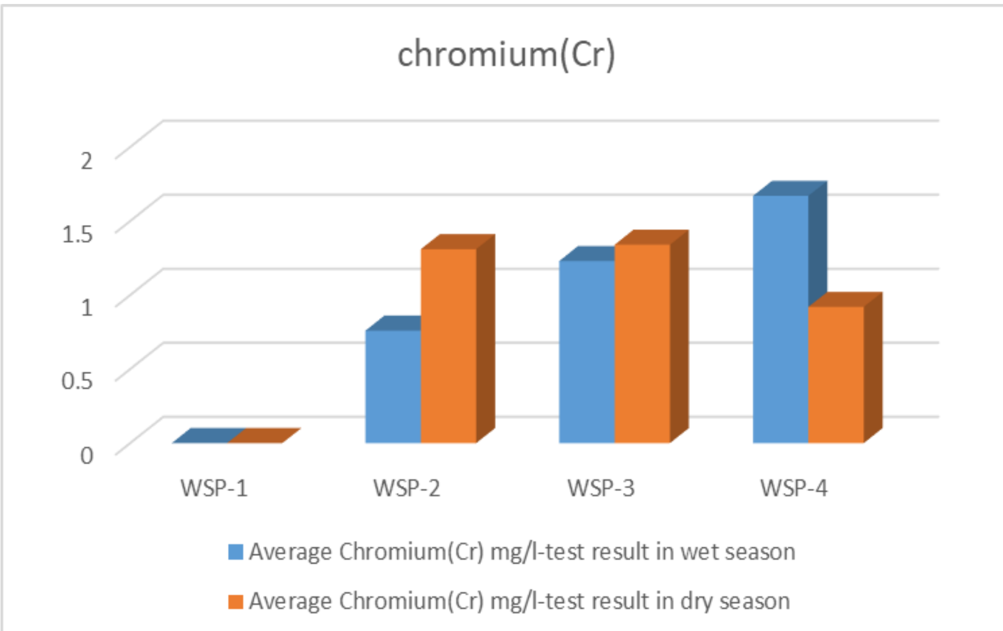


Figure 4. 5 Average Cr-Test Result of Beresa River

4.4 Bacteriological Test Analysis

Bacteriological analysis of the representative water samples that were collected from the Beresa River is an indicator of water quality status. The Beresa River is a big river in the city and contaminated by human and animal waste discharging from its watershed areas. The study focuses on the presence of fecal coliform in four representative samples, which helps to determine the status of water pollution in two consecutive seasons. The Ethiopian Ministry of Health states that human and animal feces are the main cause of biological pollutants in water bodies. Fecal contamination has great potential for chemical and physical hazards in the study zone. The physical appearance distresses the palatability of the drinking water due to the bad smell, odor, and unattractiveness of the water body. The value of laboratory result indicates that the river was highly contaminated in both the wet and dry seasons. However, there were variations shown in various seasonal test results that range from 60/100ml to 1,800/100ml in summer (wet) season and 100/100ml to 1,500/100ml in winter (dry) season. In addition to test result variations, the test result also varies down to the river course with increasing condition. Generally, the highest water sample result shows in wet season at sample point three, which was found under Deber Berhan Teachers College. This indicates that most of the river watershed and urban flood areas collected around this sample point. As indicated by the test results, all sampling points have recorded high values, and the river was polluted by human and animal waste. The average test result of fecal coliform during wet and dry seasons has 701.25/100ml and 862.50/100ml respectively and more polluted during dry season. The result shows in figure 4.7 hereunder and table 4.1 above. This test result may also lead to a community's health problems, including downstream consumers.

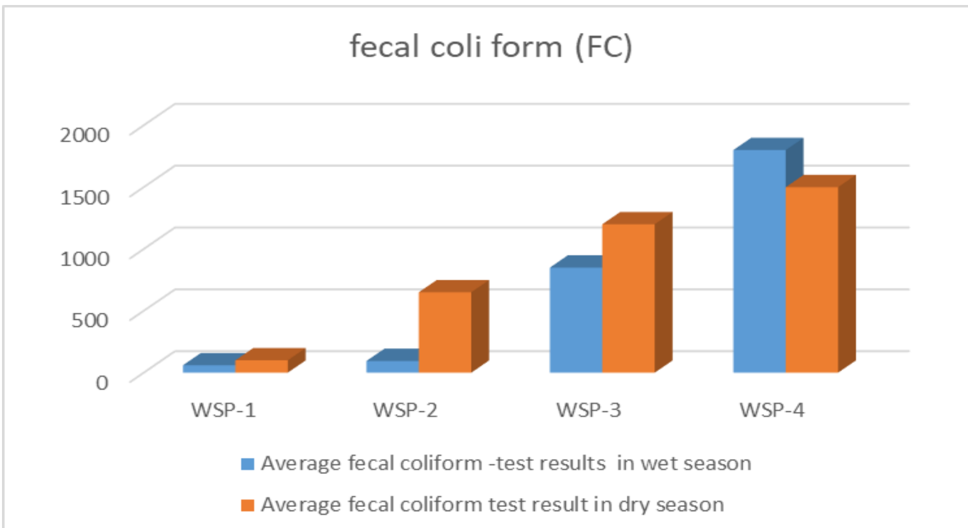


Figure 4. 6 Average fecal coliform test results of Beresa River

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Urban expansions in response to water pollution are occurring in various parts of Debre Berhan city and its surroundings. Further to urbanization, there should be industrial development in the vicinity that leads to the intensification of waste discharge to the environment before treatment. Thus, the Beresa River needs to conduct a water quality analysis to determine the surface water pollution status through six selected major parameters for water quality indicators. Usually surface water is open to the environment and exposed to pollutants, which are generated from its sources (point and nonpoint sources). Most of the pollutants are released by the interference of human beings in the natural environment. Usually, surface water is open to the environment and exposed to pollutants that are generated from its sources (point and nonpoint sources). Beresa River water was also the main one among these in Debere Berhan city. Most of the pollutants were released by the interference of human beings in the natural environment. For almost all tested parameters from four selected sampling points, test result shows that above the permissible limit values, except for the PH test result. The result was also an indicator of river water quality deterioration, especially when it joins the city settlement areas and increases down along the river course.

Bacteriological results at all sampling points (WSP1, WSP-2, WSP-3, and WSP-4), including TP-test results, BOD5 test results, COD-test results, and Cr-test results, have higher permissible values compared to EEPA,2003; Romania,2006 (GD 161) ;and EU surface water quality standards for drinking purpose. These contaminations of surface water are also threatened for aquatic biodiversity and may disorder the natural ecosystem in the area, which could contribute to environmental pollution. Pollution of Beresa River sources with pathogenic microorganisms and toxic chemicals in the river course could cause damage and may cause the death of animals and human beings along the river. The city municipality and communities that lived along the riverside and the whole watershed area together should come to an agreement to keep the quality of river water sustainable to consume for different purposes. In addition to the selected parameters used in laboratory test result analysis in this study, it needs further investigation on different parameters for more resolution of the river quality status for better consumption by the local community along the river course.

According to the study's findings, urbanization, use of fertilizers on agricultural land, industrial and factory effluents, excessive detergent use in homes and businesses, soil erosion, increased sewage pollution, open defecation, and urban runoff at rainy time are all responsible for the severe deterioration of Beresa River water quality. Furthermore, Beresa River lacks appropriate sanitation due to a variety causes, including animal waste pollution, sewage, and open-field defecation. Point sources are known to be the main source of pollution entering the river, with non-point sources such as runoff from city and farmlands following openly behind.

Large point sources (such as industry, health facilities, institutions, commercial centers, and hotels) should also be thoroughly monitored. Point sources in and around the city of Debere Berhan as major polluters, along with a number of industrial discharges, municipal wastes, and agrochemicals. Therefore, an effective wastewater infrastructure must be set up quickly. Beresa River is hydrologicaly open, so despite numerous efforts, recovery may take a while. The introduction of grasses and riparian buffer zones can help with discrete pollution from population, which primarily uses agrochemicals and latrines, and can complement direct pollution alleviation measures.

5.2 Recommendations

- Debre Berhan city administration professionals and communities should take care seriously for Beresa River quality degradation and before dead it completely, especially after connecting the river to the city border settlement areas, by preventing industrial and domestic wastes from entering to the river both liquid or solid forms without any treatment.
- The city administration cooperated with federal, regional, and nongovernmental organizations to give serious attention to waste water treatment plant development for domestic waste, which are released from city residences, hotels, cafes, commercial centers, institutions, factories, industries, etc. to treat and control the quality of wastewater at the effluent level for sustainability of river quality based on permissible limit value standards.
- Control and create awareness regularly for industry and factory owners by federal and regional EPAs cooperated with city administration about waste discharging activities to the environment

before treatment, even if after treatment it should be complete the quality of effluent discharges with national and international permissible limit standards.

- The city administration should be preparing public panel regularly for awareness creation of Beresa River pollution causes, effect and preventive mechanisms, including downstream consumers.
- Minimize the use of agrochemical chemicals in watershed areas of the river and try to substitute and use organic soil fertilizer.
- Delineate green buffer zone at the river side also helps to prevent or reduce from open defecation and animal waste contamination of the river.

References

Abera, K. A. (2005). An Overview of Environmental HealthStatus in Ethiopia With Particular Emphasis to its Organization,Drinking Water and Sanitation:A Litrature Survey. Ethiopian Jurnal Health Department.

Adam, A. (2014). Source and Determinantsof water Pollution in Ethiopia:Distributed lag Modeling Appraoch. Intel pro Rights.

Ajmal, M. R. (1996). Effect of carbon and energy sources on bacterial chromate reduction. 205-215.

Al-Gahwari, Y. (2007). Physico-chemical parameters and microorganisms as water quality indicators of Teluk Buhang Reservior and Batu Ferringhi Treatment Plant. Ph.D Thesis. Malaysia: University Sains Malaysia.

APHA (American Public Heath Association). (1998). Standard Methods for the Examination of Water and Wastewater, WEF and AWWA, 20th Edition, USA.

Assefa, H. G. (2017). “Demographic Dividend in Ethiopia: Reality and Possibility”. Discussion paper. http://www.researchgate.net/publication/28728565.

Boyd, D. R. (2006). The Water We Drink: An International Comparison of Drinking Water Quality Standards and Guidelines. David Suzuki Foundation, Vancouver, Canada.

Chapman, D. U. (1992). Water quality assessment. London: Chapman & Hall. London: Chapman & Hall.

Chapman. (1996). Water Quality Assessment. A Guide to the use of Biotic, Sediments and Water in Environmental Monitoring 2nd.ed., Chapman and Hall,London.

Chaterjee, C. R. (2002). Determination of Water Quality Index of a degraded river in Asanol Industrial area, Raniganj, Burdwan, West Bengal. Nature, Environ. Poll. Technol, 181-189.

Cyril, S. O. (2013). Urbanisation, urbanicity, and health: A systematic review of the reliability and validity of urbanicity scales. BMC Public Health., 13, 513.

Davis, T. W. (2015). Effects of increasing nitrogen and phosphorus concentrations on phytoplankton community growth and toxicity during Planktothrix blooms . Environmental Science & Technology, 49(12), 7197–7207.

Debela, G. (2016,2017). Urban sprawl and its impacts on land use change in Central Ethiopia.

DFID. (1999). DFID sustainable livelihoods guidance sheets. www.ennonline.net/dfidsustainableliving (ENN-667), (Accessed 24/04/2020).

ECSA (Ethiopian Central Statistical Agency). (2007; 2020). summary of statistical report of population and housing census.

EEPA. (2003). Guidline Ambient Environment standards for Ethiopia.

Ermias, A. B. (2019). "Analysis of city size distribution in Ethiopia: empirical evidence from 1984 to 2012". Journal of Urban Management , 8: 237-244.

Falconer, I. H. (2005). Health risk assessment of cyanobacterial (Blue Green Algal) toxins in drinking water. International Journal of Environmental Research and Public Health, 2: 43-50.

Fan, X. C. (2010). Assessment of river Water Qualityin Pearl River Delta Using Multivariate Statistical Techniques. Proceed environ.SCi., 2,1220-1234.

Firew. (2010). The Impact of Horizontal Urban Expansion On Suburban Agricultural Community.

Freidman, J. (2006). Four Theses in the study of China's Urbanization. Int.J.Urban Reg.Res., 440-451.

Gebre, G. (2009). Urban Water Pollution and IrrgatedVegetable Farming in Addis Ababa. 34th WEDC international Confrence, (pp. 1-6). Addiss Ababa.

Getahun. (2017). Urban sprawl and its impacts on land use change in Central Ethiopia. Urban Forestry & Urban.

Göbel et al. (2007). Distribution and concentration of these pollutants depends on various factors, and these pollutants have seasonal variations.

Hanckok. (1995). Changes in land use from rural to urban activities affects the physical form of environment .

Imenda S. (2014). Is There a Conceptual Difference between Theoretical and Conceptual Frameworks? Sosyal Bilimler Dergisi/Journal of Social Sciences, 38(2), 185.

Imenda, S. (2014). Is There a Conceptual Difference between Theoretical and Conceptual Frameworks? Sosyal Bilimler Dergisi/Journal of Social Sciences, , 38(2), 185.

Jarvie H. P., W. B. (1998). "Nitrogen and phosphorus in east coast British rivers: speciation, sources and biological significance". Science of the Total Environment, 79–109.

Kannel, P. R. (2008). "Assessment of spatial-temporal patterns of surface and ground water qualities and factors influencing management strategy of groundwater system in an urban river corridor of Nepal" . Journal of Environmental Management.

Koropatnick, J. L. (1995). Effects of Metal on Gene Expression. Tn R.A. Goyer and M.G Cherian,eds., Eds., handbook of experimental Pharmacology, Toxicology of metals, Biochem. Aspects. Springer, 115: 93- 120.

Lakshmi, E. M. (2014). An Assessment of Water Quality in River Periyar, Kerala, South India Using Water Quality Index. IOSR J. Environ. Sci. Toxicol. Food Technol, 8, 11–16.

Mallin, M. A. (2000). Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds. Ecological Applications, 1047-1056.

Meays, C. L. (2004). Fecal Bacteria in water. pp. 71-79.

Mehaffey, M. H. (2005). Linking Land Cover and Water Quality in New York City. Water Supply Watersheds. Monitoring and Assessment. Environ, 107, 29-44.

NUPI. (1996). National Urban Planning Report on Development Plan of Debre Markos Town.

OCDE/SWAC. (2020). Africa's Urbanization Dynamics 2020: Africapolis, Mapping a New Urban Geography, West African Studies, OECD Publishing, Paris. https://doi.org/10.1787/b6bccb81-en.

Olal, F. (2015). Assessment of the Impact of Urban Runnoff from Migori Town on the Concentration Levels of Selected Heavy metalsin Migory. J.Environ.earth Sci., 5,24-30.

Ouyang Y, W. Q. (2006). Assessment of seasonal variations in surface water quality. Water Res, 40: 3800-3810.

Qadir.A., M. R. (2008). “Spatio-temporal variations in water quality of Nullah Aik-tributary of the river Chenab, Pakistan”. Environmental Monitoring and Assessment, 140: 1–3, 43–59.

Robillard P.D. (2008). “Network design for water quality monitoring of surface freshwaters: a review”. Journal of Environmental Management, 87:4, 639–648.

Sawyer et al. (1994). The effluents disposed by domestic and industries into the surface and ground water.

Swamee,P. T. (2007). Improved method for aggregation of water quality subindices. Journal of Environmental Engineering, 133(2), 220-225.

Tegegne. (1996). Urban poverty and the environment: illustration from Addis Ababa, Ethiopia.

Tenagn. (2009). The Impact of Urban Storm Water Runoff and Domestic Waste Effluent on Water Quality of Lake Tana and Local Groundwater.

Thackston, E. K. (1999). Housing density and bacterial loading in urban streams. Journal of Environmental Engineering 125(12), . 1177-1180.

Thyagarajan.G., R. R. (2007). water technology centre, department of Agronomy, tamilnadu agricultural university, Cimbatore. Science tech.

US-EPA. (1979). Methods for Chemical Analysis of Water and Wastes. .

Wang XL, L. Y. (2007). Identification of anthropogenic influences on water quality of rivers in Taihu watershed. . J Environ Sci-China, 19: 475-481.

WHO. (2017). Progress on Drinking Water, Sanitation and Hygiene . Available online: . Retrieved November 2019, from https://apps.who.int/iris/ bitstream/handle/10665/258617/9789241512893-eng.pdf?

Young, K. D. (1999). Housing Density and Bacterial Loading in Urban Streams. Environmental Engineering, 1177-11.

Zackoff, M. W. (2019). Enhancing Educational Scholarship Through Conceptual Frameworks: A Challenge and Roadmap for Medical Educators. Academic Pediatrics, 19(2), 135–141.

ANNEXES

Annexe-1 Sampling Site Code

Sample Sites	Sample Codes	Sampling Site Name	GPS Coordinates	
			Easting	Northing
1	WSP_1	Milki Kebele	559909	1065558
2	WSP_2	Under DBU Transitory Bridge	557470	1068088
3	WSP_3	Around DB Teachers College	556930	1069284
4	WSP_4	Midire Genet Village (Habitat) Below The Bridge	556437	1069608

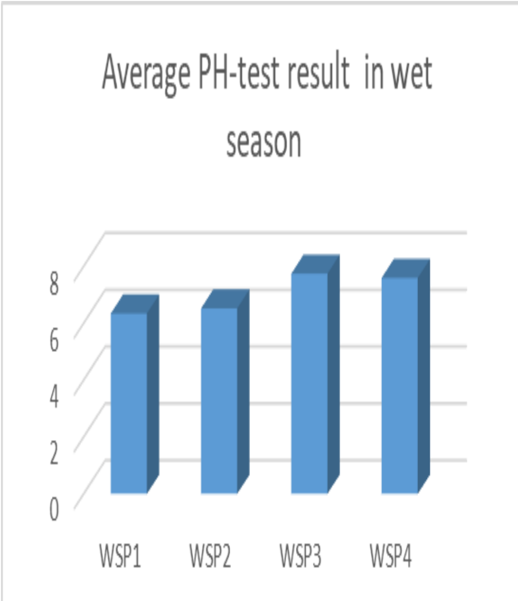
Annex 2: Quality elements and physico-chemical quality standards for assessment of Ecological status of surface water in Romania, 2006 (GD 161)

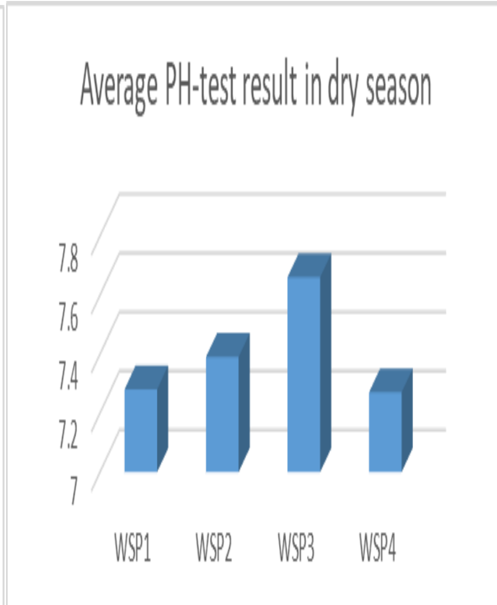
Parameter	Acronym	Unit	**I**	**II**	**III**	**IV**
pH	pH		6.5 – 8.5			
Biochemical oxygen demand (5 days)	BOD5	mg O2/l	3	5	7	20
Chemical oxygen demand	COD – Mn	mg O2/l	5	10	20	50
Ortho-phosphates	Ortho phosphates (P-PO43-)	mg /l	0.31	0.61	1.23	0.58
Chromium	Cr	µg/l	25	50	100	250

ANNEX 3

Analysis of physical parameter test results from Beresa River

Para Meter	Sampling Seasons	Sample Collection Frequencies	Sampling Points	Test Method	Test Results
PH	Summer (wet) season	First round	**WSP_1**	PH meter	**6.14**
			WSP_2		**6.16**
			WSP_3		**7.85**
			WSP_4		**7.75**
		Second round	**WSP_1**		**6.54**
			WSP_2		**6.88**
			WSP_3		**7.62**
			WSP_4		**7.43**
	Winter (dry) season	First round	**WSP_1**	PH meter	**7.11**
			WSP_2		**7.37**
			WSP_3		**7.55**
			WSP_4		**7.06**
		Second round	**WSP_1**		**7. 45**
			WSP_2		**7.40**
			WSP_3		**7.61**
			WSP_4		**7.48**

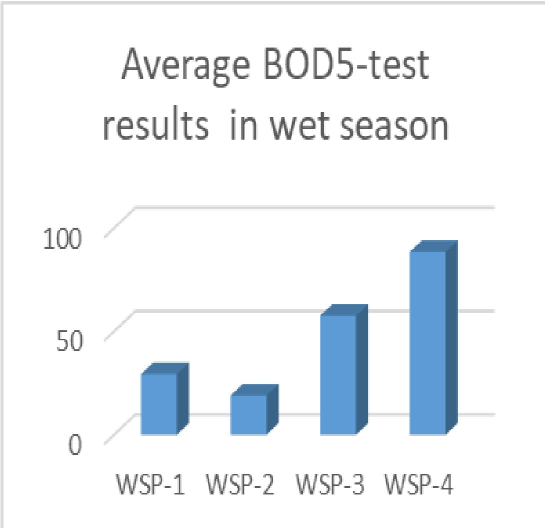


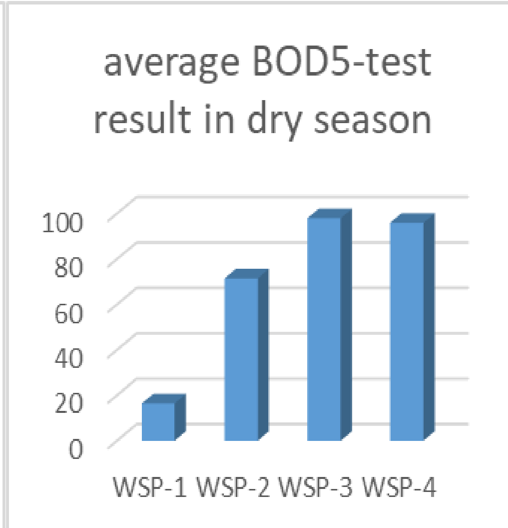


ANNEX 4: Analysis of chemical parameter test results from Beresa River

BOD$_5$

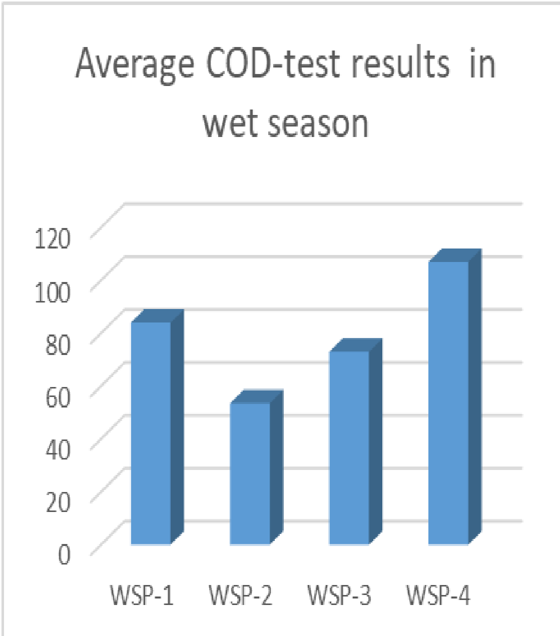
Para Meter	Sampling Seasons	Sample Collection Frequencies	Sampling Points	Test Methods	Test result
BOD$_5$	Summer (wet) season	First round water sample collection	**WSP$_1$**	**5**-day incubation (azid modification)	**30.00**
			WSP$_2$		**12.00**
			WSP$_3$		**54.00**
			WSP$_4$		**90.00**
		Second round water sample collection	**WSP$_1$**		**28.60**
			WSP$_2$		**26.00**
			WSP$_3$		**61.22**
			WSP$_4$		**87.00**
	Winter (dry) season	First round water sample collection	**WSP$_1$**	5-day incubation (azidodification)	**18.00**
			WSP$_2$		**74.00**
			WSP$_3$		**103.00**
			WSP$_4$		**98.00**
		Second round water sample collection	**WSP$_1$**		**15.00**
			WSP$_2$		**69.00**
			WSP$_3$		**93.00**
			WSP$_4$		**94.00**

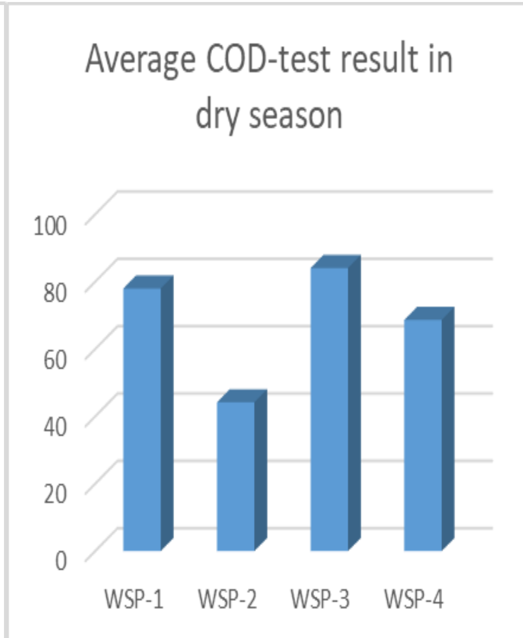




COD

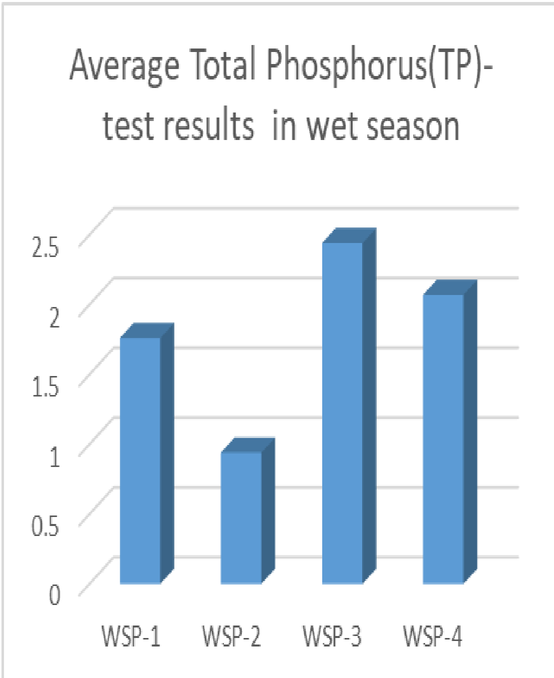
Para Meter	Sampling Seasons	Sample Collection Frequencies	Sampling Points	Test Methods	Test result
COD	Summer (wet) season	First round water sample collection	**WSP_1**	dichromate Open reflux method	**90.00**
			WSP_2		**54.00**
			WSP_3		**70.00**
			WSP_4		**110.00**
		Second round water sample collection	**WSP_1**		**78.00**
			WSP_2		**53.00**
			WSP_3		**76.00**
			WSP_4		**104.00**
	Winter(dry) season	First round water sample collection	**WSP_1**	dichromate Open reflux method	**59.04**
			WSP_2		**42.34**
			WSP_3		**78.08**
			WSP_4		**94.42**
		Second round water sample collection	**WSP_1**		**49.60**
			WSP_2		**46.00**
			WSP_3		**90.05**
			WSP_4		**88.42**

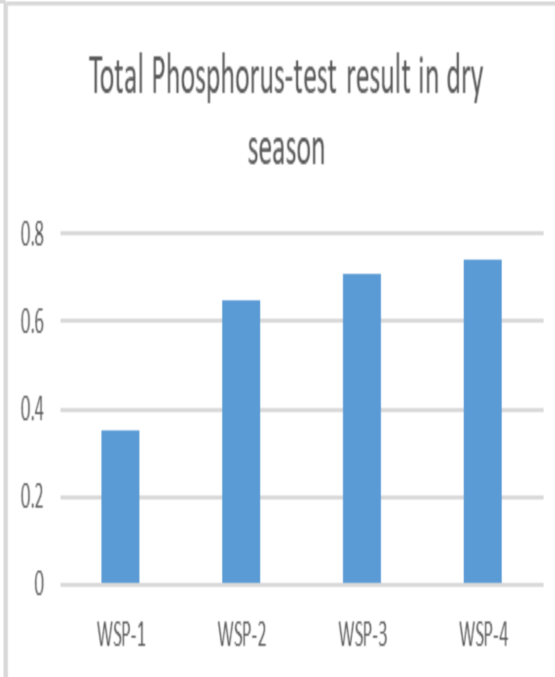




Total Phosphorus (TP)

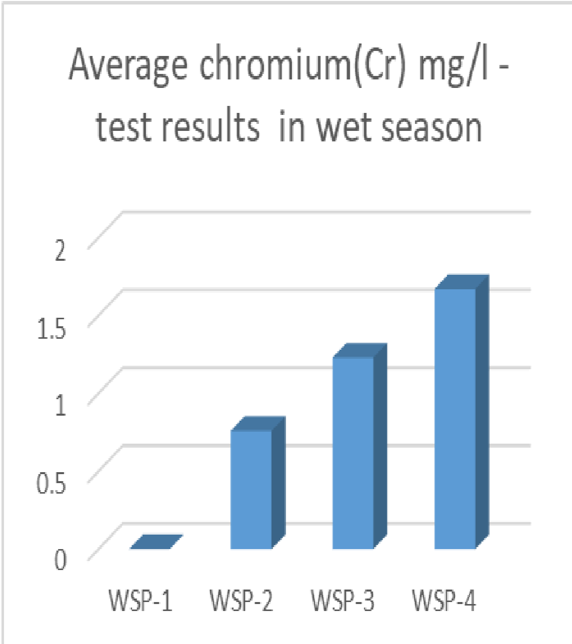
Parameter	Sampling Seasons	Sample Collection Frequencies	Sampling Points	Test Methods	Test result
Total phosphorus (TP)	Summer (wet) season	First round water sample collection	**WSP_1**	Ascorbic acid	**0.74**
			WSP_2		**0.34**
			WSP_3		**0.45**
			WSP_4		**0.50**
		Second round water sample collection	**WSP_1**		**2.77**
			WSP_2		**1.54**
			WSP_3		**4.42**
			WSP_4		**3.64**
	Winter(dry) season	First round water sample collection	**WSP_1**	Ascorbic acid	**0.36**
			WSP_2		**0.23**
			WSP_3		**0.67**
			WSP_4		**0.88**
		Second round water sample collection	**WSP_1**		**0.34**
			WSP_2		**0.26**
			WSP_3		**0.75**
			WSP_4		**0.60**

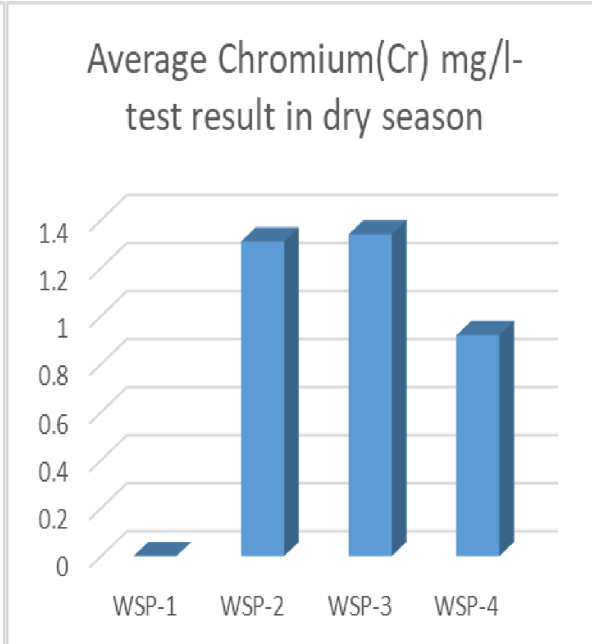




Chromium (Cr)

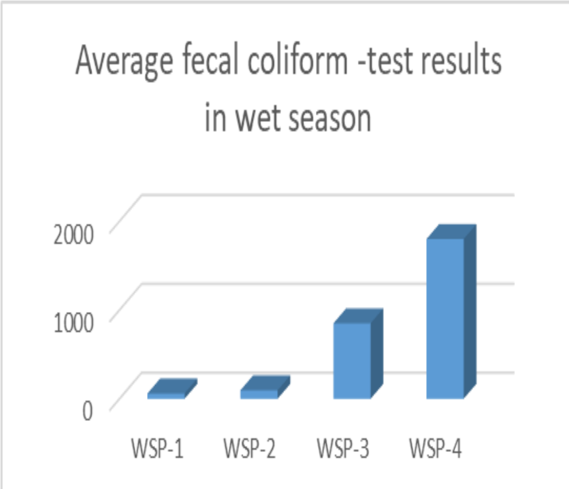
Para meter	sampling seasons	Sample collection frequencies	sampling points	Test methods	Test result
Chromium (Cr)	Summer (wet) season	First round water sample collection	**WSP_1**	Flame atomic absorption spectrometer (FAAS)	**ND**
			WSP_2		**0.83**
			WSP_3		**2.18**
			WSP_4		**2.60**
		Second round water sample collection	**WSP_1**		**ND**
			WSP_2		**0.68**
			WSP_3		**1.95**
			WSP_4		**1.74**
	Winter(dry) season	First round water sample collection	**WSP_1**	Flame atomic absorption spectrophotometer (FAAS)	**ND**
			WSP_2		**3.83**
			WSP_3		**3.53**
			WSP_4		**2.98**
		Second round water sample collection	**WSP_1**		**ND**
			WSP_2		**3.79**
			WSP_3		**3.20**
			WSP_4		**3.56**

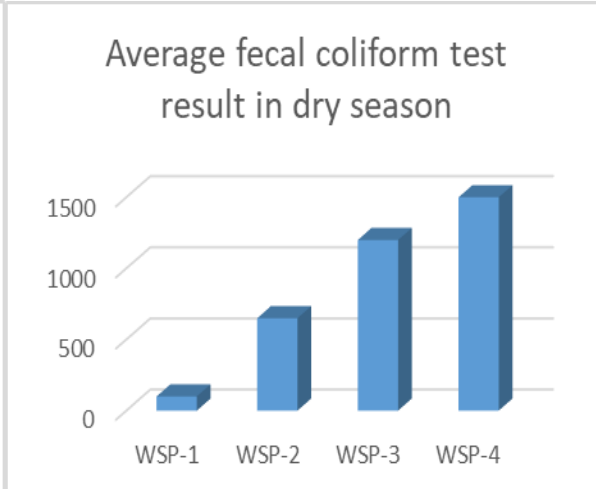




ANNEX 5: Bacteriological Test Analysis

Para meter	sampling seasons	Sample collection frequencies	sampling points	Test methods	Test results
Fecal coliform (FC)	Summer (wet) season	First round	**WSP$_1$**	Membrane filtration	**$5*10^1$**
			WSP$_2$		**$8*10^1$**
			WSP$_3$		**$10*10^2$**
			WSP$_4$		**$15*10^2$**
		Second round	**WSP$_1$**		**$7*10^1$**
			WSP$_2$		**$11*10^1$**
			WSP$_3$		**$7*10^2$**
			WSP$_4$		**$21*10^2$**
	Winter(dry) season	First round	**WSP$_1$**	Membrane filtration	**$3*10^1$**
			WSP$_2$		**$10*10^1$**
			WSP$_3$		**$3*10^2$**
			WSP$_4$		**$5*10^2$**
		Second round	**WSP$_1$**		**$8*10^1$**
			WSP$_2$		**$12*10^2$**
			WSP$_3$		**$21*10^2$**
			WSP$_4$		**$25*10^2$**





Remark: The abbreviations of WSP in all and under sampling point column means Water Sample points at station 1, 2, 3, and 4 along Beresa River.