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**College of Development studies**

**Center for Environment and Development Studies**

**Factors Pushing Key stakeholders in discharging pollutants to Nearby  
River: The Case of Akaki River, Addis Ababa**

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**A Thesis Submitted to the Centre for Environment and Sustainable  
Development, College of Development Studies, Addis Ababa University in  
Partial Fulfillment for the Requirement of MA Degree in Development Studies  
(Environment and Sustainable Development)**

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**Addis Ababa, Ethiopia**

## **DECLARATION**

First, I state unequivocally that this thesis is the result of my own efforts, and that all sources or materials used in this thesis were sponsored by WLRC. This thesis is submitted in partial fulfillment of the MA Degree requirements at Addis Ababa University in Development Studies (Environment and Sustainable Development). I can confidently state that this thesis was not submitted to any other institution for the award of any academic degree, diploma, or certificate.

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## APPROVAL

I undersigned certify that they have read and hereby recommend to Addis Ababa University to accept the thesis submitted by Selamawit Shewangizaw and entitled "Assessing determinants factors association with river pollution: The case of Akaki river." in partial fulfillment of the requirements for the award of a Master of Arts Degree in Development Studies (Environment and Sustainable Development)

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## Table of Contents

DECLARATION .....	i
APPROVAL .....	ii
Acknowledgement .....	iii
List of Tables .....	viii
List of Figures .....	ix
ACRONYMS AND ABBREVIATIONS .....	x
SYMBOL AND NAME OF PHYSICOCHEMICAL PARAMETERS AND HEAVY METALS.....	xi
ABSTRACT.....	xii
CHAPTER ONE .....	1
1.INTRODUCTION .....	1
1.1 Background.....	1
<b>1.2 Statement of problem .....</b>	<b>2</b>
1.3 Objective of the Thesis .....	3
1.3.1 General objective .....	3
1.3.2 Specific objectives .....	3
1.4 Research questions.....	4
1.5 Significance of the study.....	4
1.6 Scope and limitation of the study.....	4
1.7 Organization of the thesis paper.....	5
CHAPTER TWO .....	6
2. Review of related literature.....	6
2.1 Concepts in surface water quality .....	6
2.1.1 Surface water .....	6
2.1.2 Surface water quality .....	6
2.1.3 Conventional water quality parameters.....	6
2.2 Potable water standards.....	8
2.3 Surface water pollution .....	8
2.3.1 Definition and concept of surface water pollution.....	8
2.3.2 Types of water pollution based on sector.....	8
2.3.3 Water pollution based on entry .....	9
2.3.4 Causes of water pollution.....	10
2.3.5 Impact of water pollution.....	11

2.4 Existing Situation of the Akaki River Bank in Addis Ababa.....	12
2.3.1 Akaki river bank settlement characteristics .....	12
2.4 Theoretical framework.....	13
2.4.1 Stakeholder analysis theory .....	13
2.4.2 Theory reasoned action (TRA) and theory planned behavior (TPB).....	13
2.5 Riverine community and river pollution.....	14
2.5.1 KAP of households in river pollution .....	14
2.5.1.1 Knowledge in river pollution.....	15
2.5.1.2 Attitude in river pollution .....	15
2.5.1.3 Practice in River pollution .....	16
2.6 Small and medium scale agriculturalists.....	19
2.7 Industries and river pollution .....	19
2.7.1 Industries in Addis Ababa.....	20
2.7.2 Challenges of industrial waste management.....	21
2.8 Government institutional set up and responsibilities in river.....	21
2.8.1 Cross-sectorial collaboration of institutions.....	22
2.8.2 Ethiopian policies, laws and regulations on environmental management, pollution and water quality issues.....	22
2.8.3 Capacities and Gaps for monitoring and analysis of the River environment.....	23
2.9 Conceptual Framework.....	24
<b>2.10 Operational Definition .....</b>	<b>26</b>
CHAPTER THREE .....	27
3. MATERIAL AND METHODS .....	27
3.1 Description of the study Area .....	27
3.2 Research design .....	28
3.3 Research approach .....	29
3.4 Target population.....	29
3.5. Sampling procedure .....	30
3.5.1. Sampling technic.....	31
3.1.2 Sampling size.....	32
3.6 Primary data source.....	34
3.6.1 Data collection instruments.....	34
3.6.1.1 Household survey.....	34

3.6.1.2 Key informant interviews.....	34
3.7 Secondary data.....	35
3.7.1 Type and nature of the secondary Akaki River water quality data.....	35
3.7.2 Description of Sampling Points Location for River water quality.....	35
3.7.3 Sample Collection Method for water quality assessment.....	35
3.7.4 Methods of water sample analyses.....	36
3.7.5 Analyses of Physicochemical Parameters.....	37
3.7.5.1 Determination of Temperature.....	37
3.7.5.2 Determination of pH.....	37
3.7.5.3 Determination of Total Dissolved Solute (TDS).....	37
3.7.5.4 Determination of Conductivity (EC).....	37
3.7.5.5 Determination of Total Hardness (Ht).....	38
3.7.5.6 Determination of Alkalinity (TA).....	38
3.7.6 Determination of heavy Metals concentration.....	38
3.7.7 Methods of statistical data analysis and interpretation.....	39
3.7 Definition and hypothesis of variables.....	39
3.7.1 Dependent variables.....	39
3.7.2 Independent (Explanatory) Variables.....	39
3.8 Techniques of data Analysis.....	40
3.8.1 Empirical analyses of determinant factors on Akaki river pollution causes.....	40
3.9 Reliability and validity.....	42
3.10 Ethical consideration.....	42
CHAPTER FOUR.....	43
4. RESULTS AND DISCUSSION.....	43
4.1 Spatiotemporal variations in Akaki River water quality.....	43
4.1.1 Physiochemical spatiotemporal variation in Akaki River.....	43
4.1.2 Spatiotemporal variation in concentration of heavy metals in Akaki River.....	46
4.2 Results of descriptive statistics.....	51
4.2.1 Demographic characteristics of sampled households.....	51
4.2.2 Socio Economic Characteristics of the Sampled Households.....	53
4.2.3 Basic services in Akaki river bank settlement.....	54
4.4 Akaki river bank Physical environmental characteristics.....	56
4.5 Knowledge of the respondents about Akaki River pollution.....	56

4.6 Household perception on pollution of Akaki River water in the study area .....	60
4.7 Practice on discharging pollutant to Akaki River .....	63
4.8 Akaki river bank settlement characteristics by discharging pollutants index .....	65
4.8.1 Demographic and socio economic characteristics by discharging pollutants index .....	65
4.8.2 Accessibility and affordability of infrastructure by discharging pollutants index .....	70
4.8.3 Behaviors and training factors by discharging pollutants index .....	73
4.9 Determinant factors toward discharging pollutants to Akaki River.....	75
4.9.1. Assessment of goodness fit of binary logistic regression analysis.....	75
4.9.2 Result of binary logistic regression analysis.....	76
4.10 Interview with industries environmental quality officers .....	80
CHAPTER FIVE .....	95
5. CONCLUSION AND RECOMMENDATIONS.....	95
5.1 Conclusions.....	95
5.2 Recommendation .....	96
Reference .....	98
Appendix-I temporal spatial Physiochemical characteristics of the Akaki river at four sites .....	101
Appendix-II Heavy Metals concentration Standards limits. ....	112
Appendix - IV. Variance Inflation Factors (VIF) of Continuous variables .....	113
Appendix-V QUESTIONNAIRE (ENGLISH VERSION) .....	114

## List of Tables

Table 1 Water Quality Parameters .....	7
Table 2 Environmental impact of some pollutants .....	11
Table 3 Locations of Akaki Riverbank Informal settlement .....	12
Table 4 Sampled Industries.....	30
Table 5: Distribution of sample respondents proportional to the size .....	33
Table 7 Heat chart showing variation in heavy metal During Dry and Wet seasons, along with cell limits for drinking and irrigation used .....	48
Table 8 Distribution of respondent's age and family size .....	51
Table 9 Household's Socio demographic Characteristics .....	53
Table 10 household's livelihood and annual income.....	53
Table 11 WASH Facility .....	55
Table 12 knowledge of households about Akaki river pollution.....	57
Table 13 knowledge of households about the causes of Akaki river pollution .....	58
Table 14 knowledge of households about the Impact of Akaki River due to pollution .....	59
Table 15 knowledge of households about the solution of Akaki river pollution.....	59
Table 16: Households attitudes about Akaki River water pollution.....	60
Table 17: Household's attitudes about causes of Akaki river pollution .....	61
Table 18: Household's attitudes about Impact of Akaki River due to pollution .....	62
Table 19: Households Attitudes towards Tackling of the River Situations.....	62
Table 20: Practice Causing Akaki River pollution .....	64
Table 21: Demographic and Socio economic Characteristics by contribution to pollution Index .	69
Table 22: Accessibility and affordability of Infrastructure by pollution contribution index.....	73
Table 23: behaviors and training factors by pollution contribution index.....	74
Table 24: The binary logistic result of independent variables .....	76
Table 25: Textile industries process .....	83

## List of Figures

Figure 1 Conceptual framework of the Determinant Factors associated with Practice towards the Akaki river pollution.....	25
Figure 2 Map of the Study Area (own prepared).....	28

## **ACRONYMS AND ABBREVIATIONS**

<b>AAEPA</b>	<b>Addis Ababa Environmental Protection Authority</b>
<b>ESDW</b>	<b>Ethiopian Standards for Drinking Water</b>
<b>EPA</b>	<b>Environmental Protection Agency</b>
<b>EU</b>	<b>European Union Directives for drinking water guidelines</b>
<b>FAO</b>	<b>Food and Agricultural Organization</b>
<b>KII</b>	<b>Key Informant Interview</b>
<b>SPSS</b>	<b>Statistical Package for Social Sciences</b>
<b>SWM</b>	<b>Solid Waste Management</b>
<b>WASH</b>	<b>Water, Sanitation, and Hygiene</b>
<b>WHO</b>	<b>World Health Organization</b>

## **SYMBOL AND NAME OF PHYSICOCHEMICAL PARAMETERS AND HEAVY METALS**

<b>As</b>	<b>Arsenic</b>
<b>Co</b>	<b>Cobalt</b>
<b>Cr</b>	<b>Chromium</b>
<b>Cu</b>	<b>Copper</b>
<b>EC</b>	<b>Electrical Conductivity</b>
<b>Fe</b>	<b>Iron</b>
<b>Ht</b>	<b>Total Hardness</b>
<b>Mn</b>	<b>manganese</b>
<b>NH3</b>	<b>Ammonium</b>
<b>Ni</b>	<b>Nickel</b>
<b>NO2</b>	<b>Nitrite</b>
<b>NO3</b>	<b>Nitrate</b>
<b>Pb</b>	<b>lead</b>
<b>PO4</b>	<b>phosphate</b>
<b>SO4</b>	<b>Sulphate</b>
<b>TA</b>	<b>Total Alkalinity</b>
<b>TDS</b>	<b>Total dissolved solids</b>
<b>TEMP</b>	<b>Temperature</b>
<b>Zn</b>	<b>Zinc</b>

## ABSTRACT

Water is a vital natural resource that we use for drinking and other purposes in our daily lives. The socioeconomic features and exponential population growth, horizontal physical expansion, high levels of poverty, low quality housing, low level of access to water supply and sanitation services, irrigation land along the river sides and inefficient facility and practice of industries in waste management have significant input to pollution of the river and because of this pushing factors key stakeholders discharge pollutant to Akaki river. However it is rare to find studies assess these pushing factors and because of this specific knowledge gap this study conducted to fill knowledge gap. The major objective of this study was to assess pushing factors for key stakeholders in discharging pollutants to Akai River. The study used secondary data from Water land research center on spatial and temporal variation data of physical and chemical parameters and Heavy Metals concentrations of the Akaki river water and the river water quality interpreted by drinking, domestic and irrigation water use quality standards of various guide lines. As well as to assessing behavior of key stakeholders and Akaki river bank characteristics the researcher select a representative sample from the target population those are households and industries settled along the Akaki river by purposive sampling method which was used to select Akaki kality, Lafto Nefasesel, Kolfea Keraniyo and Addis Ketema sub cities as sampling areas and tannery and textile industries and EPA, AAWSA and sampling areas sub city offices and by systematics sampling method 222 sampled respondents sizes selected out of 503 populations. Descriptive research design with mixed approach method was used. Descriptive statistics and binary logistic regression model were used to identify factors that determine the pushing factors of key stakeholders in discharging pollutant to Akai River. The result showed that 63.5% of the household heads had poor practice and (36.5%) household heads had good practice in discharging pollutants to Akaki River. The resulting distribution further, Variables such as educational status, family size, accessibility and affordability to Waste management facility/service and WASH facility, toilet discharging service access and affordability, Knowledge and Poor Attitude of households and industries Economical capacity and behavior on Akaki river pollution are significantly affects the households and industries practice on discharging pollutant to Akaki river. Thus, the researcher recommended that in the process mitigate further river pollution; including near-term coordination and longer-term mitigation responses, these variables should be considered by the government decision makers, donor agencies at different level and individual household heads.

Key Terms: Physiochemical, Heavy metals, spatial variation, temporal variation

# CHAPTER ONE

## 1. INTRODUCTION

### 1.1 Background

The city Addis Ababa has grown to become the country's largest urban and commercial center, with a population of 5,228,000 people and an annual growth rate of 4.43% (CSA, 2021). However, due to the lack of proper urbanization, which takes into account equivalent growth in waste removal facilities, water pollution has become a side-effect of economic growth, rapid population growth, and inadequate sanitation infrastructure (Teklehaimanot, 2015).

There is an increase in informal settlements in various parts of the city, where a large number of people live and engage in various activities along the Great Akaki riverbank on sloppy terrains and marshy lands. The Great Akaki River, which runs from north to south, accommodates a large number of people working in various economic sectors such as urban agriculture, parks, quarries, animal husbandry, and so on. The River has a large network of tributaries from smaller rivers and streams that run through the city (Mekonnen, 2017).

Registered industries in Addis Ababa gets bigger and bigger, with the majority of them located along the river banks and Tanneries, breweries, textile factories, pharmaceutical factories, paint factories, and chemical factories are the most polluting industries in the city (AAEPA, 2020).

Only 11.4% of Addis Ababa's urban slum population and 41.2% of the city's total population currently have access to improved sanitation. The majority of people in urban slums (80.4%) used unimproved sanitation facilities, and 8.2% relied on open defecation (Alayu, 2017).

The riverside areas are home to both legal and illegal residents. The settlers have been the primary causes of river pollution. The socioeconomic features of the city are the city's exponential population growth, horizontal physical expansion in the city's peripheral areas, high levels of poverty, low quality housing, low level of access to water supply and sanitation, and inefficient wastewater management, as well as the city's narrow revenue base (Mekonnen, 2017).

## **1.2 Statement of problem**

Rivers and other surface waters are used for a variety of reasons in the transportation, agriculture, industrial and home water supply sectors. However, the river was also utilized for dumping and cleaning. The prevalence of this practice is greater in underdeveloped nations, primarily in Africa (Botkin, 2018).

The Akaki River has been the subject of different types of research and project from numerous domains. Using physicochemical parameters Ayele (2018) evaluated anthropogenic impacts on the Akaki River and found that the factors affecting the Akaki River were pre- or partial-treatment from various industries around the river.

As well as, study tells a similar story that the Akaki River is heavily polluted due to the growing human population, out of control urbanization (Hamere 2017).

At the suitability evaluation of the Akaki River tells the Akaki River had an excessive danger of bacterial contamination and consequently couldn't be used as it is (Mekonen, 2017). Further research by (Mekuria, 2021) study that Concentrations of heavy metals in Akaki River water exceed permissible limits set for ingesting water, cattle watering, aquaculture, agriculture, and leisure water quality, and the suitability of the water for those improvement activities. Many studies like as well discovered that Addis Ababa's rivers are deteriorating in its physical, chemical, and biological properties and situations.

According to (Aschale, 2015) the Akaki River is considered one of the most polluted rivers in Ethiopia. This scenario is proscribing the use of the river. As a result, Akaki River has failed to find significant services other than urban irrigation due to deteriorating water quality conditions. The service has also raised public concerns about the health hazards of vegetables irrigated with contaminated water.

As a result, because of very limited attention by various departments and all other responsible stakeholders in the city of Addis Ababa, the Akaki River, contamination levels are at great concern and face more serious problems and lead to health impacts, social and economic costs to governments and various organ (Aschale,2015).

Weak multi-stakeholder cooperation on river governance, as well as the lack of information on Attitudes and behaviors amongst distinctive stakeholders and mentioned that the stakeholders knowledge and attitude along with their practice needed to be studied sufficiently to apprehend the intensity of the problem (Workineh, 2020).

Although there is extensive literature assessing the nature and level of pollution, cause and impact of the pollution, value of the river, stakeholders collaboration but assessment of pushing factors for discharging pollutants to Akaki River in Addis Ababa are relatively rare.

This study was conducted because of the specific knowledge gaps that are gap in inadequacy of knowledge in assessing pushing factors for key stakeholders to discharge pollutants to the Akaki River. Therefore, the study was conducted to investigate how riverbank characteristics, infrastructures, community behavior on pollution, and training influence the key stakeholders' practice in discharging pollutants to the Akaki River. As a result then fill the gap with give some guideline information for concerning various bodies to mitigate further Akaki river pollution, work on future plans as well as. Support the sequencing of policy actions, including near-term coordination (improving services, infrastructure, education, and advocacy) and longer-term mitigation responses (wastewater treatment, regulation, enforcement) along the Akaki river bank.

## **1.3 Objective of the Thesis**

### **1.3.1 General objective**

The general objective of this study was to examine Factors Pushing Key stakeholders in discharging pollutants to Akaki River.

### **1.3.2 Specific objectives**

- To examine the spatiotemporal water quality variation of Akaki River.
- To characterizing Akaki river bank settlement and community behavior.
- To analyze the determinant factors of key stakeholders in discharging pollutants to Akaki river.

## **1.4 Research questions**

The study answers the following questions

- What are the spatiotemporal variations of Akaki river water qualities?
- How do the settlement and community behavior along the banks of the Akaki River are characterized?
- Which determinant factor influence key stakeholders in discharging pollutants to Akaki River?

## **1.5 Significance of the study**

The fundamental importance of this research is to advance and enrich the knowledge of researchers who primarily conduct research, complete academic courses, and provide information and to play its own role to other researchers in the related topic.

As well as, this study will help Support the sequencing of policy actions, for policy makers, administrative managers, community leaders, NGO researchers and environmental protection agencies who seek to improve challenges of pollution by including near-term coordination (improving services, infrastructure, education, and advocacy) and longer-term mitigation responses (wastewater treatment, regulation, enforcement) through feeding information as input on detection and attribution of the spatiotemporal pollution of Akaki river, ensuring the rightness of the usability of the River, better understand the general characteristics of river pollution causes and pushing factors, the Riverbank characteristics, behavior of all community associated with their practice toward Akaki river water pollution incidents

## **1.6 Scope and limitation of the study**

Geographically the study area for this study is on Akaki River in the city of Addis Ababa only. Thematically the study focuses on the assessing pushing factors in discharging pollutants to Akaki River. Specifically on how sanitation and waste management Practices activities, behaviors were adopted among Key stakeholders and how that contribute to the river pollution.

This study, like all studies, was subjected to many limiting factors. The first of these is the research area which is confined to only assess the River bank characteristics in Addis Ababa even the Akaki River are beyond the city. This was due to financial and Data constraints. Future research will hopefully be able to study this subject on a larger scale and provide a more wholesome picture of the problem. Another limitation imposed on this research was during the collection of data, it was difficult to collect data at the appropriate time due to Weather condition and geographical location of respondent's household, Fear of respondents since they were illegally settled on the river bank area were problems for data collection.

### **1.7 Organization of the thesis paper**

This research paper is divided into five main chapters, each of which is structured as follows: The first chapter covers the introduction, which includes the study's background, problem statement, purpose, and research questions as well as its importance and its scope and limitations. The conceptual framework of the study is reviewed in the second chapter along with a review of related literature. The third chapter examines the research methodology, including the subject area's description, the research design, data gathering methods, and methods for data analysis. Results and debates are covered in the fourth chapter, while conclusion and recommendations are covered in the last chapter.

## **CHAPTER TWO**

### **2. Review of related literature**

#### **2.1 Concepts in surface water quality**

##### **2.1.1 Surface water**

These include streams, rivers, lakes, estuaries, wetlands, and oceans, and are essential to the Earth's chemical and biological systems, as well as to the functioning of human culture and the economy. As sources of food and drinking water for humans, many surface water bodies are also closely related to human health (Harold, 2015).

##### **2.1.2 Surface water quality**

It is most commonly used in society to explain the bodily, chemical, and organic traits and the conditions of an aquatic ecosystem that affect its ability to support its intended use. Water quality is measured using various physical, chemical and biological variables, parameters, indicators and measurements. The chemical and physical properties of water and sediments influence aquatic biota and the ecosystems in which they live. Although biological measurements are considered more integrative, at the same time as the everyday physicochemical outcomes from water samples provide a 'snapshot' of the state at the time of sampling (Environment, 2015). Good water pleasant is crucial for human well-being, to be used in agriculture, aquaculture, and industrial use and to assist freshwater ecosystems and the offerings they provide. Improving water pleasant is a essential detail of the 2030 Sustainable Development Goals, satisfying an crucial function in lowering poverty and ailment and selling sustainable growth (Harlod, 2015)

##### **2.1.3 Conventional water quality parameters**

Surface Water Quality Standards refers to requirements and acceptable quality standards for the physical, chemical, microbiological, and radiological properties of water that are used to evaluate quality (WHO, 2011).

The physical properties of water quality can be divided into numerous topics, and understanding the physical appearance of water quality requires consideration of the nature of the physical

parameters of the ecosystems surrounding water resources. Water chemistry can affect aesthetic qualities such as Appearance of water and testicles. This can also affect its toxicity and whether water can be safely used for any purpose. The chemical quality of water is critical to the health of the people, animals and plants that live in and around streams, so water chemistry must be assessed (Environment, 2015).

Table1: Water Quality Parameters

Temperature	<ul style="list-style-type: none"> <li>The rate of chemical reactions increases with increasing temperature, and the rate of biochemical reactions typically double for every 10.0°C increase in temperature.</li> </ul>
Alkalinity	<ul style="list-style-type: none"> <li>measure of a river's "buffering capacity," or its ability to neutralize acids</li> </ul>
Electrical Conductivity	<ul style="list-style-type: none"> <li>Ability of water to conduct an electric current.</li> </ul>
Total Hardness	<ul style="list-style-type: none"> <li>Important parameter in decreasing the toxic effect of poisonous element. This is because, Calcium and/or Magnesium competitively inhibit the uptake, and hence, toxicity of trace metals at the cell membrane surface</li> <li>Aesthetic quality of water, and is caused mostly by the minerals calcium and magnesium.</li> </ul>
Ph	<ul style="list-style-type: none"> <li>Measures the acidity or alkalinity of the water on a scale from 1-14(1 is very acidic 7 neutrals and 14 is very alkaline</li> <li>acidity increases, most of metals become more in water and this substance can make soluble and more toxic water resources</li> <li>As. Runoff, sewerage, geology (limestone is associated with more alkaline condition), high nutrient levels are some of the cause to acidity or alkalinity.</li> </ul>
Total dissolved solids	<ul style="list-style-type: none"> <li>higher TDS in the river water from agricultural runoff discharge of domestic solid and sewerages from households and town and human activity</li> </ul>

Phosphorous	<ul style="list-style-type: none"> <li>• Controls plant (algae and saprophytes) growth in the freshwater.</li> <li>• Found in fertilizers, human wastes, animal wastes, and yard wastes transported into the water bodies via urban runoff, and soil erosion because many form of phosphorus tend to be absorbed to soil particles.</li> </ul>
Nitrate	<ul style="list-style-type: none"> <li>• essential nutrients of green plants for growth and reproduction</li> <li>• together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream</li> </ul>

Source: Daniel Azaze, (2017)

## 2.2 Potable water standards

The Compulsory Ethiopian Standard for Drinking Water Specification (CES58) outlines the physical, chemical, and bacteriological standards for water for drinking and household use in order to guarantee access to clean drinking water. It establishes quality and safety standards that adhere to all hazardous, bacteriological, and organoleptic requirements and is in line with the new SDG aims.

## 2.3 Surface water pollution

### 2.3.1 Definition and concept of surface water pollution

Water pollutants may be described as any bodily, organic, or chemical adjustments in water best that adversely impacts residing organisms or makes water flawed for favored uses. Pollution alters the best of a water body. It notably disturbs the herbal entity of the bodily and organic additives of a water body. It additionally undermines the socio-financial values of the rivers or different water bodies (FEPA, 2015).

### 2.3.2 Types of water pollution based on sector

Based on the sector that serves as source of pollutants, water pollutions are classified into three; municipal pollution; industrial pollution; and agricultural pollution

✓ Municipal water pollution

Urban pollution (residential emissions) includes various wastes generated by households and Released into water bodies. A typical form of urban pollution is a waste water discharge. Domestic wastewater is a major source of surface water pollution, but generally poses less of an overall threat to water quality than industrial wastewater (Kenneth, 2013).

✓ Industrial water pollution

Industrial pollutants refer to industrial wastewater that causes water pollution when: (1) there may be a right away release of industrial waste into water bodies. (2) there may be an improper operation and poor overall performance of installed industrial treatment systems; (3) improper management of waste that cannot be eliminated via standard treatment processes; (4) improper management of certain chemicals that are toxic at low concentrations and difficult to dispose completely (Kenneth, 2013).

✓ Agricultural water pollution

Agricultural pollution is another common source of pollution as the sector produces large amounts of chemicals and pesticides (Sharma, 2012).

### **2.3.3 Water pollution based on entry**

According to water pollution sources are distinguished into two. These are point and nonpoint pollution sources:

1. Point sources: Emissions from a single easily identifiable source. Entering from factory lines, sewage treatment plant outlets, power plants, underground coal mines, and oil wells to bodies of water are classified as point sources. These sources are distinct and identifiable, as pollution emitted from specific locations. Relatively easy to monitor and adjust. It is generally possible to divert effluents from the waste streams of these sources, treat them before they are released into the environment, and contaminate the water. Point sources are fairly consistent and predictable throughout the year (Chapman, 2013).
2. Nonpoint sources: These kinds of water pollutions are scattered or diffuse and do not have specific locations where they are discharged into specific bodies of water. Non-point sources

include effluents from farmlands, lawns, gardens, construction sites, logging areas, roads, roads, and parking lots (OECD, 2014).

### **2.3.4 Causes of water pollution**

Water pollution can be caused by natural processes or human intervention. One of the natural sources of water pollution is non-point pollution, storm water or surface water runoff. Storm water runoff means that rainwater runs off without penetrating the surface. Storm water runoff contains many pollutants. For example, spills from roads and parking lots often contain oil, gasoline, and other automotive fluids (Gupta, 2016). In addition, rainwater discharges from agricultural lands pollute water bodies with organic matter and bacteria from animal waste. This Storm water runoff is a non-point source because it comes from a wide area rather than a single source (Kenneth, 2013).

#### ✓ Caused artificially

Anthropogenic pollution, on the other hand, is caused by urban, industrial and agricultural pollution. Until recently, anthropogenic pollution was mainly caused by household waste and industrial waste, and pollution problems were usually local and required local solutions. However, as the country's economic development progressed, the production of commodities increased significantly, and along with that, the production of general industrial waste also increased significantly. Additionally, new processes in manufacturing have created new and complex wastes that cannot be easily handled by current control technology (Kenneth, 2013).

#### ✓ Seasonal and Spatial variation of river pollution

Rivers play an important role in the assimilation and transport of domestic and industrial wastewater from persistent sources of pollution and agricultural runoff, which over time are often affected by climate. Because rivers are highly polluted, there is a need to control surface water quality and interpret temporal and spatial variations (Gupta, 2016). Water chemistry represents seasonal variations in the behavior of major ions and catchment characteristics. Domestic and industrial wastewater discharges and climate-related seasonal runoff have a significant impact on river runoff and water quality. Pollutants entering river systems usually originate from many transport routes. This Includes storm water runoff, ditch and stream runoff, seepage, groundwater

infiltration, and atmospheric deposition. These routes also vary depending on the season (Guta, 2015). Understanding the spatial distribution and causes of water pollution sources is critical for research and efficient water resource management. The impact of watershed runoff on eutrophication is highly dependent on land-use patterns. Understanding the impact of spatial variability in water quality can aid in the identification of recovery areas and the success rate of ecosystem restoration projects (Kenneth, 2013).

### 2.3.5 Impact of water pollution

While these wastes are improperly dumped into open spaces and natural resources such as rivers, they cause water and soil pollution leading to nuisances, health impacts, social impacts and ecological problems. Pollutants, including phosphates and nitrates, emitted from industrial, agricultural, and municipal wastes reason excessive growth of algae, which kill fish and other aquatic organisms. Fish deaths can occur when toxic biocides leach from farmlands into rivers and streams after rainfall. These can lead to changes in the biological and aquatic environments and cause ecosystem disruption (Gupta, 2016).

Table 2: Environmental impact of some pollutants

<b>Pollutant</b>	<b>Effect</b>
Organic	Increased oxygen demand resulting from high population of decomposers that break down biodegradable organic materials into simpler organic and inorganic substances (oxygen is used in this process); food provided for organisms lower down in food chain
Toxic chemicals	Toxic to humans, animals and plants
Acids/alkalis	Lowering/raising of pH (only narrow range of pH is tolerable for most plants and animals)
Suspended solids	Reduction in light penetration, blanketing, introduction of color; thus, photosynthesis reduced, blanketing of benthic plants and animals;
Immiscible liquids	Formation of a layer at the water surface that could prevent O <sub>2</sub> /CO <sub>2</sub> , thus insect breeding affected

Source: IWMI (2021)

## 2.4 Existing Situation of the Akaki River Bank in Addis Ababa

### 2.3.1 Akaki river bank settlement characteristics

The rapid urbanization process has drawn large numbers of people to urban centers in search of employment opportunities and a better life. The Great Akaki river and other river front areas are occupied by large numbers of informal settlers who have no legal title to their land or permits from the appropriate authorities, leaving low-income residents and middle-income land speculators. It developed as a residence and workplace for. Because of their illegality, no government or non-governmental organization bothers to intervene and rehabilitate the existing physical features, social life, and legal status of neighborhoods (Mekonnen, 2017).

Table 3: Locations of Akaki Riverbank Informal settlement

River	Length of the river(km)	Location	
		Area	Sub City
Great Akaki	35.6	Kolfe on both side of the river at Lomme Meda and Sore Amba	Addis Ketema
		Mekanissa Amrachoci and Gurage sefer	Nefase selk-lafto
		Lafto costa sefer beyond Bihere Tsige park	Nefase selke-Lafto
		Sarris(beyond Buna Bord)	Akaki kality
		Kality around the waste water treatment plant, settlement along the river	Akaki kality
Little Akaki	20.5	Mesalemia, locally named Shankila river and Kacha fabrika	Addis Ketema All along the river line

Source: Mekonen (2017)

The Akaki River is the city's largest river, crossing the north-south axis, accommodating many people in various fields of economic activity such as urban agriculture, parks, quarries, and cattle ranching. The region was occupied by informal and formal settlers as well (Tegegn, 2016).

Living conditions for informal settlers in such areas are generally poor, although some are in very good condition. Some of them have proper services such as WASH Facility, waste Management Facility and access roads; most of them still don't have the proper streets to access them (Mekonnen, 2017).

## **2.4 Theoretical framework**

### **2.4.1 Stakeholder analysis theory**

Theory of Stakeholder analysis in a water pollution incident is the process of identifying all stakeholders affected by pollution and assessing their roles and responsibilities in pollution and response actions. This involves identifying people and groups that may be contributing to contamination, ensuring that all parties are aware, identifying the people involved and the issues that are important to them, and a very useful exercise to help understand perception of key stakeholders towards river pollution in better. Approaches to river pollution, assessing people within groups, strategizing interventions, how different groups interact and how their interactions help or harm river conditions. Identify key stakeholders (those with the greatest interest and impact on contamination) and uncover potential risks, problems or misunderstandings that could confound interventions, and social Ensuring acceptance and proactively addressing concerns to improve outcomes of mitigation actions (Jim, 2022).

### **2.4.2 Theory reasoned action (TRA) and theory planned behavior (TPB)**

This theory are used in this study on be on Knowledge, Attitude, and Practices towards households practice in discharging pollutant to Akaki river in understanding, explaining and predicting behavior. These theories are also useful as a guide for designing intervention strategies to maintain or change a particular behavior. The theory is based on the assumptions that individual behavioral intentions are directly associated with their attitudes. The theory of reasoned action views an individual's intention to perform or not to perform as an immediate determinant

of the action. This behavioral intention has two determinants: (a) attitude towards the behavior, and (b) the subjective norms. Ajzen (2018) argue that the beliefs related on attitude towards the behavior are called behavioral beliefs, while normative beliefs are for the subjective norms. The theory planned behavior further views an individual's determination is influenced by attitude, 10 social support and perceived behavioral control. Thus, it is best to examine human behavior related to their awareness of, attitude towards be on Knowledge, Attitude, and Practices towards discharging pollutants to river and are voluntary and under an individual control (Gamba, 2014). Therefore, this theory is suitable to predict the researcher's intent to be aware of, show positive attitude and engage in practicing of discharging pollutant to river in the study area.

## **2.5 Riverine community and river pollution**

Cities in developing countries are experiencing unprecedented population growth as they are expected to offer more economic and social opportunities than rural areas. For this reason, migration from rural areas to urban areas is very high. Ethiopia is one of the developing countries with a high rate of urban population growth (Farrell, 2017).

Population growth and imbalance in urban facilities can lead to urban pollution. Therefore, it is clear that one of the causes of water pollution is municipal solid waste from urban areas. The hazards posed by municipal and domestic pollution of the Akaki River, particularly its upper tributaries, have been identified by previous studies. Drainage systems intended to collect runoff (rainwater) are also used to dispose of almost all categories of solid waste, including domestic, industrial, commercial, private, public, etc. Municipal wastes are the main cause of frequent blockages and water overflows on streets and in surrounding areas (NWD, 2014).

### **2.5.1 KAP of households in river pollution**

The KAP survey turned out to be the most suitable tool for research. It is a representative study of a particular population to gather information about what is known, believed, or done about a particular topic. A fundamental premise of the KAP research is that knowledge shapes attitudes and that both knowledge and attitudes are components of practice (Emanuel, 2020).

The needs, attitudes and actions of concerned communities contribute significantly to the occurrence and subsequent prevention of water pollution incidents. Stakeholder analysis is therefore undertaken to protect not only the interests of stakeholders and vulnerable groups, but also the long-term best interest of improving river conditions (Meklit, 2016).

#### **2.5.1.1 Knowledge in river pollution**

Environmental consciousness is being aware of the surroundings round us (Toriman, 2015). A river pollution knowledge evaluation of stakeholders was conducted to determine how well-informed stakeholders are about the relevant problems, causes and opportunities of river pollution. This type of evaluation also aimed to capture the continuing cycle of water pollution and its effects, and how actors interacted with the river and other actors during this period. The best way to describe the problems and opportunities affecting river water are those directly involved in and affected by river water pollution. This stakeholder expertise on river specific changes, upcoming challenges, and future opportunities provided insights into the data analysis for River Water Assessment (Jim, 2015). There is a correlation between knowledge levels and sustainable environmental practices (Ahmad, 2015).

A survey performed in Malaysia discovered that residents rejected the announcement that the Malacca River became clean. River water can't be utilized by residents on an everyday basis. Respondents agree that commercial waste darkens, stinks, and pollutes water. Respondents additionally strongly agree that polluted water reasons ailment and is an unclean habitat for animals. They understand that polluted water can cause the extinction of aquatic life. Finally, they agree that water pollutants can have an effect on plant species. Finally, approximately a 3rd of respondents did now no longer understand who's accountable for nearby water aid management. About 69% of the 35 respondents stated they have been blind to commercial pollutants with inside the Msimbazi River. This indicates a want for more public schooling and session on such troubles and more public recognition of wastewater troubles in all WCR member countries (Ofosuhene, 2013).

#### **2.5.1.2 Attitude in river pollution**

Communities are diverse and can have different value systems, norms, situations and knowledge bases that influence human behavior and attitudes, which can help design environmental management strategies (Raymond, 2014). Understanding the peculiarities of different

stakeholders can therefore help to address the complexities of managing river water resources. Local people, who are also major users of river water resources, contribute to the social environment. It may give you a better understanding of the situation (Stringer, 2013).

In addition, stakeholder perception analysis helps identify various indicators of water pollution causes and their impacts. It is important to know which factors are relevant to stakeholders. This helps identify which actions should be emphasized in the design and implementation of water policies and helps avoid costly environmental mistakes. Knowing what is important to stakeholders can help strengthen efforts to change perceptions where necessary (Carwardine, 2016).

Understanding the perspective of contributors to river pollution and integrating them into policy Formulation and implementation will help address key issues, gain community support, improve ownership of mitigation projects, and ensure that guidelines are in place. Helps avoid being rejected by locals. People feel a responsibility to protect river water and support initiatives to protect water resources (Murat, 2020).

Stakeholder awareness of river water quality is important, especially when the water is used for multiple purposes (Juahir, 2015). Stakeholder perceptions of river water quality can arbitrate whether people use rivers for productive purposes or display adversary attitudes about water resources (Siwakoti, 2015).

#### **2.5.1.3 Practice in River pollution**

Approximately 97% of surveyed interviewees Malaysia use pesticides on their plots, and 100% use pesticides to destroy insects that can destroy various vegetables on their plots. They have also awareness on Pesticides that are also sources of heavy metals, knowing about the bad impact of its use, they still continue and according to a study in Malaysia, attitude is not a good predictor for sustainable environment practices and such practices are usually a result of desperate poverty and the lack of access to awareness and education (Leonard, 2012).

On average, surveyed households are willing to pay between \$5 and \$10 per month to address various potential concerns identified in the survey. Analysis of a study showed that there was a strong positive relationship between environmental awareness and environmental attitude and their practice among the communities (Siwakoti, 2015).

Ultimately, it is up to the respondent to decide whether to act on it or live lazily. Even if the public does not necessarily participate in the initiative, it is necessary at the moment, but at least something can be done to reduce the impact on an individual level (Commission, 2012).

#### ❖ **Liquid waste management practice**

Liquid waste in Addis Ababa city comes from various origins. These sources include restrooms, gas stations, workshops, industries, and more. All of these sources contribute significant pollution (Development, 2014).

Nowadays sewage collection in Addis City is partly based on toilet pits and partly on a centralized system. Nevertheless due to imperfect sanitation, there are clear signs that surface water is being contaminated. Housing information indicates that along the Akaki River there are a total of 380,300 housing units. Of these, the sewage network covers 20,000 households, of which only 6,000 are active for economic reasons (Preceup, 2017). Addis Ababa produces an estimated 100,000 m<sup>3</sup> of domestic wastewater daily. Hydrological studies show that 70% of all water supplied to cities is returned as wastewater with high organic content. About 60% of this sewage pours right into the two Akaki Rivers (Adane, 2014).

In Addis Ababa, 74% of houses have toilet facilities. However, due to the region's financial difficulties and geography, only 12% of residents have access to central sewerage. Based on the Wastewater Master Plan study, this value will increase to 16% (456,000 inhabitants) and 22% (848,000 inhabitants) by 2005 and 2015 respectively. The remaining households (about 60% of households) are now served by pipes connected to septic tanks, flush toilets or dry toilets. Due to the intermittent sewage collection and transportation service in the city, septic tank overflow is a major problem. In addition, abused sewers are used as sewage pipes to collect and transport sewage which is major contributor to Addis Ababa rivers pollution (Teklehaimanot, 2015).

Addis Ababa City's main sewage treatment facilities are located at Kality and Kotebe, currently receives waste from sewers and waste trucks below their capacity. This indicates that the plant still has the capacity to process more sludge as the collection and transportation capacity increases. Apart from its underutilized services, treated sludge remains unused despite its potential positive contribution to agriculture (Campbell, 2014).

However, waste water contamination of surface waters is only one index and one aspect of the pollution problem. Fecal and fecal viruses in relevant wastewater effluents are a mixture of contaminants encompasses endocrine disruptors, heavy metals, pharmaceuticals and pathogens these chemicals, like fecal viruses, are good index of wastewater contaminant (Wear and Thurber, 2015).

#### ❖ **Solid waste management practice**

The dramatic population growth of cities has created a solid waste disposal problem. Municipal solid waste ranks as the biggest ambient problem in Addis Ababa (Preceup, 2017). This is understandable given that disposal options are insufficient and house waste is dumped near rivers (Gebre, 2013).

Ethiopia's urban solid waste treatment system is neither adequate nor proper. Unsanitary dumps and disposal systems in some cities are breeding grounds for vectors and unsightly. For example, Addis Ababa's solid waste intensity is approximately 0.4 kg per person per day, of which approximately 60% to 80% is collected and disposed of. Nearly 40% of the surveyed households dumped their solid waste in vacant lots, roads, or rivets (Preceup, 2017).

The large amount of solid waste produced, coupled with ineffective means of collection and transportation, is a major contributor to river pollution as leachate carried out during the rainy season enters surface waters in the region (Adane, 2014).

In general, about 95% of uncollected municipal solid waste is indiscriminately dumped in free and bare lots disperse throughout the city. Given the current low service capacity and rapid urbanization, solid waste collection efficiency is expected to decline. Increased urbanization will require efforts to keep up existing coverage in waste management. Hygiene exercises are also generally poor. Because solid waste is not separated into applicable fractions (organic, chemical, or other categories) during disposal, toxic compounds can enter rivers from households and other sources. The situation is threatened in market areas such as Mercato, where large amounts of waste are generated. Even in small towns like Akaki, where garbage collection is sporadic, the situation is critical (Campbell, 2014).

## **2.6 Small and medium scale agriculturalists**

Chemical fertilizers added to accelerate productivity also enter rivers as a result of soil erosion. This leads to eutrophication of Addis Ababa and its surrounding streams. Urea, one of the main constituent of chemical fertilizers in Ethiopia, is a major source of pollution in groundwater network this is mainly due to connected nitrates, which move in underground flow systems (Teklehaimanot, 2015). For example Ayele (2018) shows elevated nitrate concentrations in shallow groundwater around Laga Dadi (2.7 mg/L). This may be a result of heavy use of fertilizers on the surrounding cultivated land.

In the suburbs of Addis Ababa, agriculture and livestock's husbandry are predominantly private or communal. Animal husbandry is the main economic activity in Addis Ababa's urban areas (Teklehaimanot, 2015). These livestock's are raised in individual owner pens or in open areas or along river banks. No figures are available, but livestock production is expected to generate significant amounts of organic waste. In rural areas, the main agricultural activity is crop production on small plots. The major contaminant associated with agriculture is soil erosion in upstream river basins. This is especially noticeable during the wet season when surface runoff is high (Mekonnen, 2017).

## **2.7 Industries and river pollution**

Because it contributes to economic growth and human well-being, industrialization is the backbone of development. However, increased industrial activity is causing pollution and ecosystem destruction all over the world. Untreated and partially treated industrial wastes, in particular, pose the greatest threat to aquatic ecosystems (Firdissa, 2016). Ethiopia is generating industrial waste, including hazardous waste, due to rapid industrialization (Teku, 2016).

Industrial wastes are a major source of direct and often continuous input of pollutants into aquatic ecosystems, resulting in adverse impacts on ecosystems, such as changes in food availability and extreme threats to the self-regulatory capacity of the biosphere and have long-term effects on the function of ecosystem. These industrial effluents or wastes include heavy metals, pesticides,

polychlorinated biphenyls (PCBs), dioxins, polyaromatic hydrocarbons (PAHs), petrochemicals, phenolic compounds, and microorganisms (Fakayode, 2015).

Industrial wastes with high concentrations of microbial nutrients clearly promote repopulation of *E. coli* and other microbial forms significantly higher. While some heavy metals in these wastewaters have been shown to be carcinogenic, other chemicals present are toxic depending on the dose and length of exposure. Industrial and residential effluents discharged into another environment without treatment can upset the ecological balance of such environments. Industrial wastewater contributes significantly to the flow of rivers during the dry season (Botkin, 2018).

The factors that determine the nature and extent of industrial pollution according to (WHO, 2017) are the type and quantity of products produced, the manufacturing processes used, the type, quantity and content of raw materials used, the use of energy, water, air, Size, Location of facility, amount of toxic materials stored on site, quality and efficiency of disposal technology, location of facility, etc.

### **2.7.1 Industries in Addis Ababa**

Addis Ababa is one of the major cities of highly industrialized in Ethiopia. Most of Ethiopia's medium and large industries (over 65%) are located in Addis Ababa and along river sides. In other words, the major industries in Addis Ababa and its surroundings can be classified as follows: Food & Beverages, Leather & Footwear, Wood, Paper & Prints, Textiles, Tobacco, Chemicals, Non-Metals & Metals (CSA, 2019).

Industrial waste and its environmental impacts are more widespread in Addis Ababa than elsewhere in the country. This is because most industries were settled without environmental impact assessments, nearly all industries in the city are located near waterways, and about 90% of them discharge their wastewater into nearby rivers (Teklehaimanot, 2015).

Ethiopia has few industries, but the pollution impacts from this industry are huge (Fenta, 2014). Industrial waste from unmanaged industries is a major cause of Addis Ababa river water pollution. This is because most factories in Ethiopia do not have sewage treatment plants as a result, Ethiopian industries simply dump untreated toxic wastewater into nearby rivers, lakes and

streams, leaving industrial wastewater untreated) that Accelerating the load of nutrients and toxins in rivers (Alayu, 2017).

### **2.7.2 Challenges of industrial waste management**

Solid industrial waste disposal problems vary greatly depending on the industry, location and type of waste disposal. In addition, an assessment of the types of waste generated is essential to arrive at suitable solutions for better administration of solid industrial waste. Industry must collect and dispose of waste at designated landfill sites and such collection, treatment, and disposal shall be authorized by the appropriate State Pollution Control Board (SPCB) or Pollution Control Board in the Union Territory. It must be overseen by a commission (PCC) (Teku, 2016).

There are many problems in managing industrial waste. One of the problems is that the industry's industrial behavior has not changed. According to Pollution Issues (2016) polluting companies may be resistant to social, political and governmental pressure, and even when there is strong evidence to the contrary, companies deny responsibility for pollution. I'm here. Other companies, after acknowledging responsibility, offer strong countermeasures but offer nothing.

As such, it is not uncommon to hear stories of untreated toxic and hazardous industrial waste being dumped into rivers through canals from manufacturing companies in developing countries. Many others bury hazardous waste due to lack of education and costs (Foz, 2019). Cost issues have been seen as a major obstacle to proper industrial waste management. Reduction of industrial waste can lead to process changes. This includes changes in procedures, storage of materials and products; etc. This poses challenges for the industry not to comply with proper industrial waste management systems (Mohammed, 2020).

## **2.8 Government institutional set up and responsibilities in river**

When considering rivers, the main problem is the deterioration of their water quality. Regular monitoring and monitoring of river water quality are therefore of paramount importance as a prerequisite for implementing mitigation measures. Such regular monitoring is also necessary for the sources that flow into it. In this context, the institutional capacity of laboratory facilities and technical staff is an area of focus. Capacity building in these aspects, along with supporting

legislation to protect water quality, will ultimately lead to improved water quality in rivers (Workineh, 2020).

Government responsibilities depend on the structure of policies and strategies. Federal agencies focus on local regulatory and support activities, while regional and city level agencies focus on the functional aspects of various activities. There are also several state universities and research centers that conduct water-related research and training activities. These actors have various institutional affiliations and functional relationships (Teklehaimanot, 2015).

### **2.8.1 Cross-sectorial collaboration of institutions**

Cross-sectorial collaborative governance has become a key component of the management of natural resources and has developed as a way to address river issues. Coordination and collaborations across numerous agencies boost productivity make it possible to share risks and benefits, and make it easier to analyze the state of urban river flows (Zhao, 2015).

Coordinating and collaborating on surface water pollution activities with a variety of stakeholders at all status will help foster synergies and ensure effective implementation. Coordinating of stakeholders allow national priorities and avoiding duplication of activities and unnecessary overload. The reduction of point and non-point sources of contamination depends on coordination, which is the synchronization of interactions. IWRM offers inter sectorial coordination and cooperation in addition to facilitating stakeholder active involvement, transparency, and cost-effective regional management (GWP, 2015).

All stakeholders, including the federal government, city governments and local communities, are strongly encouraged to participate in the development of policies, standards, guidelines and other activities that will help reduce the pollution of Addis Ababa's river (Hamere, 2017).

### **2.8.2 Ethiopian policies, laws and regulations on environmental management, pollution and water quality issues**

Ethiopia's Environmental Policy (EPE), issued in 1997, aims to maintain the wellbeing and standard of living of every Ethiopian while fostering enduring social and economic growth. This is accomplished through utilizing resources wisely and protecting the environment as a whole, in

line with the ideals of sustainable development. It considers the rights and responsibilities of individuals, groups, and governments to conserve the environment as outlined in the Ethiopian Constitution (EEP, 2019).

The main guidelines and legal frameworks for surface water management are: Environmental Policy (1997), Water Resources Management Policy (1999), Public Health Policy (1993), Water Sector Strategy, Environmental Pollution Prevention Declaration 300/2002, Water Resources Management Declaration, Environmental Impact Assessment Declaration 299/2002, Public Health Declaration 200/2000, Solid Waste Management Declaration 513/2007, Industrial Pollution Control Regulation 159/2008, Water Resources Management Regulation 115/2005 and various environmental standards.

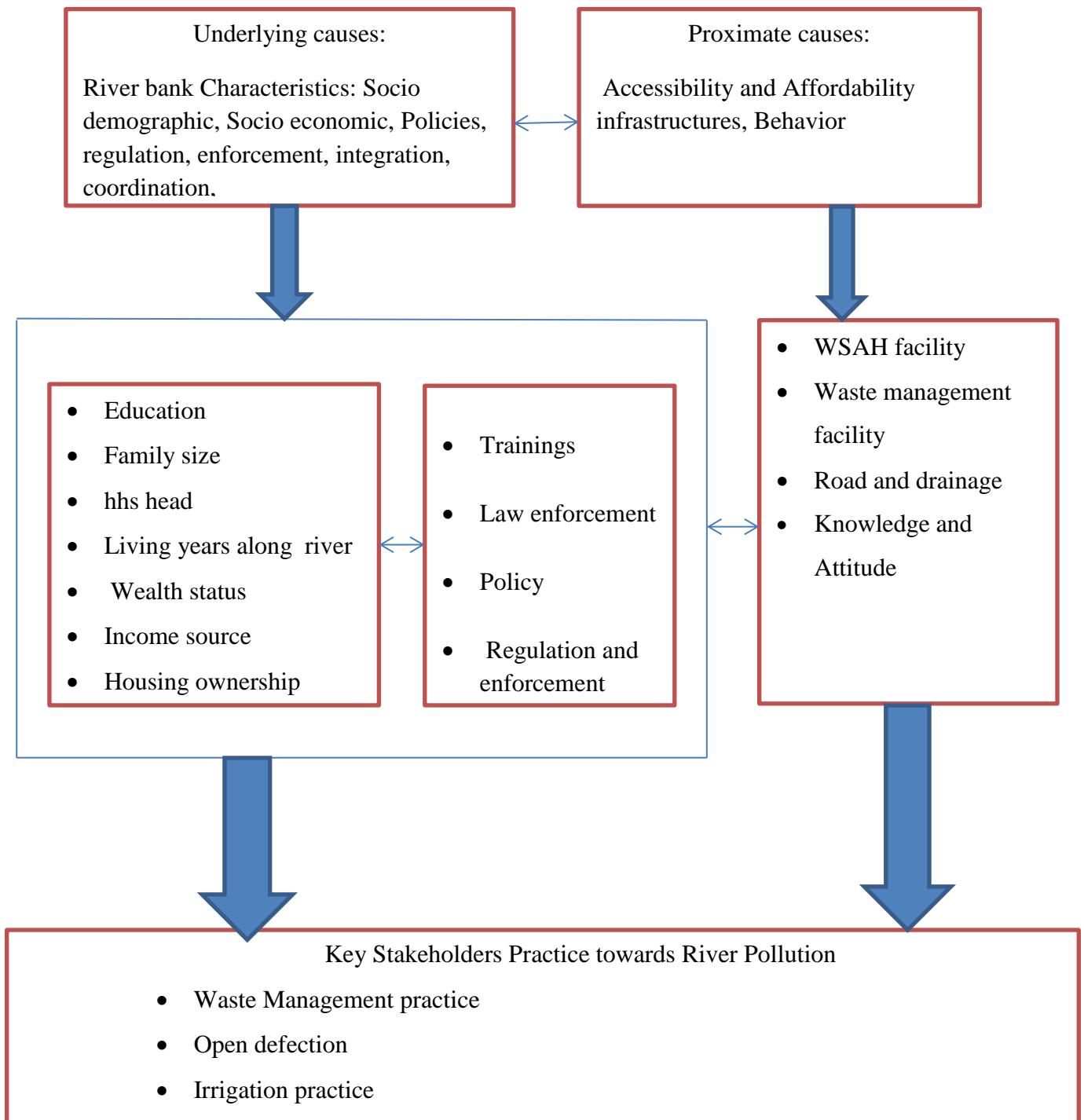
### **2.8.3 Capacities and Gaps for monitoring and analysis of the River environment**

Existing reviews (MOWR, 2022), list and the lack of coordinated efforts as one of the major shortcomings in water resource development and management in Ethiopia. They pointing and identified problematic areas in water resource development and management which include: low public participation, lack of integrated management information system (MIS), legislative aspects, the sectorial nature of legislation, existing gaps in environmental law, and lack of water quality standards, institutional deficiencies, and administrative problems, lack of coordination, institutional instability and overlapping powers, capacity and finances.

## 2.10 Conceptual Framework

The Conceptual framework of this thesis articulates the road map for the current study which is about the how River bank characteristics and Knowledge and Attitude influence the causes of the pollution. The framework categorizes the pushing factors in discharging pollutant to River into proximate and underlying, which interact with each other to result in River pollution. Proximate pushing factors for discharging Pollutants to river are those that have a direct effect on the households and industries practice in waste management, WASH behavior. The proximate pushing factors are further divided into River Bank Characteristics such as accessibility and affordability of waste management facility service, WASH infrastructure, road and drainage, behavior of key stakeholders on River pollution which are their Knowledge and Attitude on river pollution causes, impacts and solutions.

The underlying causes of river pollution are those that indirectly affect the proximate causes of river pollution, such as socio economic which are source of income, housing conditions, Wealth Status and socio demographic such as education level, household head sex and years living along the river, as well as trainings and law enforcements. For example poverty could lead to the unimproved WASH infrastructure used, improper waste management facility. Each pushing factors had complex relationship with each another such as the wealth status of households are related with their education level, source of income as well as the accessibility and affordability of waste management service and WASH facility. As study area Akaki River were Households and industries along the river sides directly and indirectly affect the Akaki river water quality and its environment.



## 2.9 Operational Definition

**Knowledge:** facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject. It is an awareness or familiarity gained by experience of a fact or situation.

**Attitude:** It is a settled way of thinking or feeling about something.

**Practice:** is the actual application or use of an idea, belief, or method, as opposed to theories relating to it.

**Spatiotemporal variation analysis:** Spatial refers to space. Temporal refers to time. Spatiotemporal, or spatial temporal, is used in data analysis when data is collected across both space and time. It describes a phenomenon in a certain location and time.

**Physiochemical parameter:** these are the intrinsic physical and chemical characteristics of a substance. These include appearance (color, odor and taste), boiling point, density, volatility, water solubility and flammability etc and designed to ensure that the water is palatable and safe for drinking before it can be described as potable.

**Heavy metal concentration:** Heavy metals are defined as metallic elements that have a relatively high density compared to water. The ranges of concentration of heavy metals ( $\mu\text{g/L}$ ) determined in water ranges in River Iron (Fe), Manganese (Mn), Nickel(Ni), Chrome(Cr), Lead (Pb), Copper (Cu), Zinc (Zn), Cobalt (Co), and Cadmium (Cd) were the most common heavy metals present in rivers.

**Water quality standards:** any regulation or restriction put in place by the state, territorial, authorized tribal or federal law approved by EPA; that includes one or more designated uses for state waters as well as water quality standards for those waters based on those designated uses.

## CHAPTER THREE

### 3. MATERIAL AND METHODS

#### 3.1 Description of the study Area

Ethiopia's capital city is Addis Ababa and the city lies at an altitude of 7,546 feet (2,300 meters) and is a grassland biome, located at 9°1'48"N 38°44'24"E Coordinates: 9°1'48"N 38°44'24"E (Addis Ababa city.gov, 2021). There is a lengthy rainy season that lasts from June to mid-September. It is the primary winter season in the nation. Despite the fact that it is summer at this time of year, the frequent rain and hail, dense cloud cover, and limited sunshine cause temperatures to be substantially lower than they would otherwise be. The days and nights during this time of year are particularly gloomy, chilly, and rainy (Addis Ababa city.gov, 2021).

There are 7 major rivers and 6 medium-sized rivers fed by 75 smaller tributaries. These rivers are primarily seasonal, originating north, northwest, and northeast of the city and flowing southwards, merging at various points of confluence. Each river has its own characteristics (Mekonnen, 2017).

Conducted by the Flood Control Project on the Great Rivers of Addis Ababa, the study shows Great Akaki River is the largest of all rivers and crosses the city from the north. It is about 35.6 km long and heads south on the axis and terminates at the Aba Samuel Reservoir. Currently, various activities are being carried out along the Akaki River in addition to irregular settlements (Tegegn, 2016)

Akaki River is a River that starts from or stream at and flow through the City of Addis Ababa. The upper catchment of Little Akaki (Upper city) comprises small streams which drain from different parts of mount Entoto to join together a little below the Ethio-Marble factory. The stream which flows down-stream from the mountain beneath Dire Leather factory turns its way to the west suburbs and joins with other small streams that originate from Gefersa to become a major tributary of Little Akaki River (Girma , 2014).

The middle catchment of Little Akaki (in the city) includes the full course of the river inside the city before leaving the suburbs of Kality and Akaki town. This part of the river contains tributaries than the upper catchment and they are draining the Addis Ababa cement factory and

joining the main river at a point near Behere tsiqie Park. The river is also traversing through highly populated and big commercial sections of the city. Down below the middle catchment there exist a very intensive concentration of large and medium size industries, workshops and big garages. The type of industries in the area include Ethio-pickling and tanning, Awash and walia tanneries, Addis Ababa Abattoirs, oil factories, beverage factories are found established at the river banks of Little Akaki (Girma , 2014).

The lower catchment of Little Akaki (outside the city) traverses through the rural parts of the city and finally enters into the Aba-Samuel dam. In this part of the catchment there is a point source where wastes are discharged from Kaliti sewage treatment plant. After the treatment of the collected sewage from the city, the final waste is dispose into Little Akaki. The lower part of the catchment is also used for agricultural purposes and the rural population also uses the river for domestic purposes (Girma, 2014).

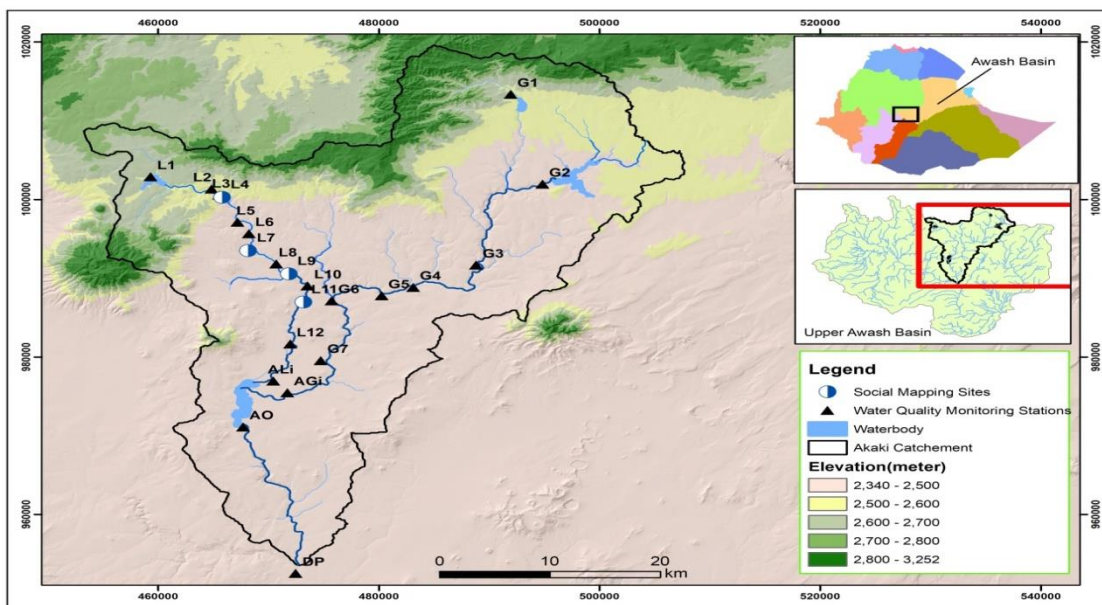


Figure 2: Map of the Study Area, (WLRC)

### 3.2 Research design

Descriptive research study design was used in this study, with mixed research approach methods that are both qualitative and quantitative approach methods. In this approach qualitative and

quantitative data are collected and analyzed at the same time to describe the current situation, terms, or their relation to problems in a particular. This descriptive approach used because it is expected to provide primary data and facts about respondent's habits, feelings, attitudes and opinions. This type of design can provide adequate room for description of activities, persons and objects it also predicts relationships among variables of the study. Further, the descriptive survey design helps the researcher to make accurate assessment, relationship of phenomenon, event/issues and conclusion (Creswell 2019).

Designed as an interdisciplinary research approach, this study will combine water quality monitoring, household surveys, direct observation of river settlement characteristics with key informant interview for addressing and better understanding of all key stakeholders.

### **3.3 Research approach**

All qualitative and quantitative research (mixed research approach) were used to complete identified gaps, address stated general and specific objectives, and offer a deeper understanding of the study problem than either method solely might provide. The research was guided by the idea of various sources and recognition of collected information through the use of various gathering tools and quantitative and qualitative data analysis techniques.

This research required and used the collection of numbers/statistics/data using quantitative methods as the primary approach to express descriptive statistical results.

Also the study used A qualitative approach based on a narration of conclusion on data obtained out of respondents by integrate data attain from the KII by applying open-ended questions to studied the selected sites.

### **3.4 Target population**

The Target Population was the local community, government institutions from federal to local levels, private sectors based on their responsibilities and contribution to Akaki River water pollution

- For the community stakeholders the target populations of this study were all settlements within 30m buffer zone along the river which are total population of 503 households on four selected sites.

Additionally, qualitative and secondary data were collected from key informants of

- Private sectors(industries) ;

Table 3: Sampled Industries

Name of Industry	Sub City and Worda	Ownership
Addis Ababa Tannery	Addis Ketema	Private
Awash Tannery	Lafto Nefase Selke	Private
Batu Tannery	Akaki Kality	Private
KK textile	Akaki Kality	Private

Source: own

- Government officials: In order to get the right response and understanding, it is crucial to address the Akaki River plans, obstacles, and the state of law and regulation enforcement with the relevant authorities. Due to this, I have nominated 1) Addis Ababa City Environmental Protection (EPA), 2) Addis Ababa water and Waste Management, and 3) Addis Ababa Water and Waste Management (AAWWA) 3) and sub cities officials had a thorough discussion with the sample sites sub cities Environment Protection Office. The responsible individual for the organization are chosen organizations that have significant roles and duties in the management of Akaki river water quality.

### 3.5. Sampling procedure

The study also found that sampling was much more effective than surveying for collecting information rapidly; saving costs and preventing additional costs, and obtaining results with

known accuracy that could be easily calculated mathematically. As a result, well-designed sampling techniques, as detailed below, are used to improve the research quality.

### **3.5.1. Sampling technic**

To select a representative sample from the target population, both probability and non-probability sampling techniques was used for appropriate and precise data obtain from different respondents.

From the non-probability sampling the researcher was used purposive sampling. Purposive sampling procedure depends on the researcher judgment on the elements which will use in identifying the reason for selecting.

- The selection criteria for study areas were based on the research question and rationale. Also, compared to most other areas on the banks of the Akaki River in Addis Ababa, the selected sites had considerable information on the cause of river pollution and it represented the all type of cause of pollutions and characteristics of Akaki river bank settlements in the Addis Ababa picture in a very good way.

Some of the considerations for the selection are the following:

1. Akaki- Kality sub city- Woreda 6: behind Buna board and near to Awash Tannery, The type of industries in the area include Ethio-pickling and tanning, Awash and walia tanneries, quite a large number of animal husbandry exist side by side. Help to able assess all type of cause of pollution.
2. Nifas silk Lafto sub-city- Woreda 10 which behind Gofa camp and Gofa condominium: This part of the river has an upper tributary, which flows into the Addis Ababa Cement Plant and joins the main stream near Behere Tsigue Park. The river also crosses the city's densely populated and large commercial areas. Below the middle reaches, the banks of Little Akaki have a high concentration of large and medium-sized industries, workshops and large workshops.
3. Kolfe Keranio sub-city Woreda 6 behind Alert Hospital. The effects of riverside irrigation, settlement patterns and polluted river waters impact, risk of settlers and their contribution of pollution on the general river environment suggest studying the site's unique characteristics.

4. Addis Ketema sub-city Woreda 14 in Addis Sefer, near Addis Ababa tannery: At the same time the site is where large number of urban agriculture and residential areas meet and where the Addis Ababa Tunnel Factory is at the edge of the Akaki River which discharges all liquid waste into the river.
- By this method sample households is selected from all settlements within 30m buffer zone along the river for the four selected sampling areas. Since Households in 30m buffer zone of Akaki river are directly involved in contributing the river water pollution and they are the best sources of information about the Akaki river's pollution causes and river bank characteristics selected for the study. For making participants and inclusive the whole population was difficult; the research from the sampling frame of households in each wordas used simple systematic random sampling sample of the 3rd value of the each HHS was selected to give an equal chance of getting into the sample.
  - Environment beautification and Green development bureau Institutions at the sub-city level were selected based on the authority and responsibilities assigned by concerned government offices to protect the Akaki River, manage solid and liquid waste, and control pollution of rivers.
  - According to the discussions made with the Environmental Protection and Pollution Control head of Addis Ababa Environmental Protection Authority (AEPA) had identified some industries and pollutants from each product category with that in mind and industries in the selected sites have selected. But due to finance constrain only sensitive factories were interviewed.

### **3.1.2 Sampling size**

Determining the sample size of study households was the next step following sample location selection. The total number of sample households was determined by the site of interest, all settlements within a 30-meter buffer zone along the river, and according to secondary data from the Wordas Maheberawi Tesatefo office, the number of household heads within a 30-meter buffer zone along the river: In Akaki-Kality sub city, Woreda 6 there are 136 hhs, Nifas Silk lafto Sub-City - Woreda 10 there are 116hhs, on Woreda 6 kolfe Keranio Sub-City 111hhs, 140hhs in the last Addis Ketema Sub-City Woreda 14, total of 503hhs.

Due to time constraints, the total number of households was sampled with a 95% confidence level and 5% error. The scientific sampling method described by (Yamane, 1967) was then used to determine valid samples for study. Based on this calculation, 222 sample households were selected and interviewed from 503 households within a 30m riverside buffer zone in the study area.

$$n = \frac{N}{1 + N * (\delta)^2}$$

n - Sample population

N- Total number of households in 30m buffer zone along the river

$\delta$  - Error (%)

$$\delta = 1 - 95\% \text{ of confidence interval} \quad \delta = 0.05$$

$$n = \frac{503}{1 + (503) * (0.05)^2} \quad n = 222$$

These 222 selected households were interviewed using the random walk method and every 3rd household within each settlement was selected. If a consenting adult was not present at the time of the visit, the nearest household was selected instead. A sample size for the selected four locations is then determined in proportion to the population.

Table 4: Distribution of sample respondents proportional to the size

	Akaki Kality sub city worda 6	Lafto Nefase selke sub city worda 10	Kolfea Keraniyo sub city worda 01	Addis Ketema sub city worda 14 total	Total
Total HHS	136	116	111	140	503
Proportion of Sample HHS	60	51	49	62	222

## **3.6 Primary data source**

### **3.6.1 Data collection instruments**

Three types of data collection tools were used to achieve the general and specific objectives of the study and obtain reliable information from the respondents.

#### **3.6.1.1 Household survey**

During the household survey, a multiple-choice questionnaire was developed and applied to collect data from selected household respondents. The tool was easy and suitable for conducting surveys and getting the information needed from a large number of respondents.

Under the household survey cross sectional data was obtained by Seven trained enumerators using a close-ended questionnaires on Kobo collect, a mobile data collection platform and These questionnaires were first prepared in English and it was translated into Amharic to ease the data collection and reduce the communication gap between respondents and enumerators. Each member of the survey team was trained for two Days and collected the data for four consecutive days.

The Questionaries' consists of five parts. Part one of this study enabled to collect socio demographic and economic information of the river bank settlement community. While part two of this study comprises the state water and sanitation facilities and basic services. The community Knowledge and Attitude with the river comprises in part three. Furthermore, this study comprises interaction practice of river bank settlers towards Akaki River Pollution with their detail variables.

#### **3.6.1.2 Key informant interviews**

Semi-structured interviews were used for this study because they give the researcher the freedom to probe the interviewee for more information or pursue a new line of inquiry that is suggested by what they are saying. They also allow the researcher to ask a series of open-ended questions based on the topic areas they want to cover.

Interview Key informant interview was used to generate qualitative information; to know the Attitude and Responsibility, practice, challenges to wards general situation of Akaki river water quality and settlement around the river, Industries wastes practice.

### **3.7 Secondary data**

The use of secondary data is common when conducting various studies prior to engaging in compilation of primary data to enhance the content of the study. In this study, secondary data were collected from a variety of sources including articles, journals, books, reports, relevant literature and publications related to the cases under investigation. Compared to primary data, secondary data is cheaper, saving time and money

The Secondary data on Akaki river water spatiotemporal variation in physiochemical and Heavy metal concentration have been taken from Water Land and Research center

#### **3.7.1 Type and nature of the secondary Akaki River water quality data**

The river water quality data type that has been used for this research is entirely of secondary data. The heavy metals concentration include: iron (Fe), Manganese (Mn), Chrome (Cr), Cobalt (Co), Nickel (Ni), Copper (Cu), Zink (Zn), lead (Pb) and the physicochemical parameters include: temperature, pH, total hardness (Ht), total dissolved solute (TDS), Electrical conductivity (EC).

#### **3.7.2 Description of Sampling Points Location for River water quality**

Four sampling sites of Akaki River were selected to represent the spatiotemporal water quality variations based on discrepancies in elevation, longitude and latitude. These four major sampling points were selected based on the nature of human interference (discharges of wastes) that has been taking place near the River. These four sampling points were taken in systematic manner by which such points are believed to show the relative water quality changes along the River.

#### **3.7.3 Sample Collection Method for water quality assessment**

Spatiotemporal and grab sampling techniques have been used. Grab water sampling method was employed during collection i.e. a single volume of water taken all at one time from a single point. This means the water samples from the four different sampling sites collected from February 2021 to August 2022 and have been analyzed independently without combining the samples so as to assess the spatiotemporal variations in water quality across the River.

Total of eight water samples at each four sample points of Akaki River were taken and studied for the physicochemical and heavy metal concentration water quality status. For the physicochemical analyses, 500 ml of water sample has been sampled from the selected representative sampling points. The materials used in sampling were clean polyethylene plastic bottle, ice coolant, marker and kit container. The sample was labeled and stored in the dark to prevent the entry of light i.e. lightproof amber colored plastic bag cover has been wrapped on the kit. Ice coolant has been used to keep the sample at low temperature and thus avoid the fluctuation of the parameters. The sample was delivered to laboratory as quick as possible i.e. the time gap between sampling and analyses was below 3 hours. For the heavy metal concentration analyses, 500ml of water samples has been sampled from the selected representative sampling points. The materials used in sampling were sterile glass bottle, ice coolant, marker, sterile gloves and kit container (i.e. a lightproof insulated box containing melting ice or ice-packs). The sample was delivered to laboratory as quick as possible i.e. the time gap between sampling and analyses was below 3 hours. Water sampling and preservation techniques followed the standard methods of water sampling and preservation techniques.

### 3.7.4 Methods of water sample analyses

The analysis of the water samples has been carried out in the laboratory of Water land research center. The water samples were analyzed for the selected physicochemical and heavy metal concentration which are listed in Table

	Physiochemical	Heavy metal Concentration
1.	Temperature	Iron (Fe)
2.	Ph.	Manganese (Mn)
3.	Electrical Conductivity(Ec)	Chrome (Cr)
4.	Total Alkalinity (TA)	Cobalt (Co)
5.	Total Hardness (TH)	Nickel (Ni)
6.	Total dissolved solids (TDS)	Copper (Cu)
7.		Zink (Zn)
8.		Lead (Pb)
9.		As (Arsenic)

### **3.7.5 Analyses of Physicochemical Parameters**

#### **3.7.5.1 Determination of Temperature**

A handheld or portable pH meter with thermometer as its integral part was calibrated with pH=4.01 and rinsed with distilled water and again calibrated with pH=7.00 buffer and then rinsed with distilled water. The reading has been taken after 3minutes of stability (i.e. after allowing the thermometer to adjust its reading to the water temperature for a few minutes). The Temperature of the River water was measured on the spot to get reliable data as temperature fluctuates with air temperature (WHO, 2016).

#### **3.7.5.2 Determination of pH**

A handheld or portable pH meter with thermometer as its integral part was calibrated with pH=4.01 and rinsed with distilled water and again calibrated with pH=7.00 buffer and then rinsed with distilled water. The reading has been taken after 3minutes of stability (i.e. after allowing the pH meter to adjust its reading to the water pH for a few minutes). The pH of the River water was measured on the spot to get reliable data as pH fluctuates with temperature.

#### **3.7.5.3 Determination of Total Dissolved Solute (TDS)**

The conductivity meter was calibrated following the manufacturer's instructions before use. Normally, a calibration standard with a conductivity of 1413  $\mu\text{S}/\text{cm}$  at 25°C is used. The electrode was rinsed with distilled or sample water before measurements are made. To measure TDS content of the sample, 50 ml of the sample was poured into a beaker and then conductivity electrode was inserted. Once the readings have stabilized, the TDS content of the water sample was recorded.

#### **3.7.5.4 Determination of Conductivity (EC)**

The conductivity meter was calibrated following the manufacturer's instructions before use. Normally, a calibration standard with a conductivity of 1413  $\mu\text{S}/\text{cm}$  at 25°C is used. The 40 electrode was rinsed with distilled or sample water before measurements are made. To measure conductivity of the sample, 50 ml of the sample was poured into a beaker and then conductivity electrode was inserted. Once the readings have stabilized, the conductivity of the water sample was recorded.

### 3.7.5.5 Determination of Total Hardness (Ht)

The total hardness of the water sample was measured by titration method and the test procedure is in accordance to IS: 3025 (Part 21)-Reaffirmed 2002. For measuring the total hardness of water, 0.01M (0.02 N) EDTA solution was used as a chelating agent and as a titrate (titrant) (i.e. 3.722 gm of EDTA was dissolved in 1000ml of distilled water). 100ml of the EDTA solution was poured into the burette. 50ml of sample water was placed inside the beaker. 2ml of NH<sub>4</sub>OH was used as a buffering agent to adjust the pH of the sample water. One tiny drop of Erichrome Black T (EBT) was added into the water sample with spatula and used as indicator. The change in volume of the titrate (EDTA solution) consumed was recorded from the burette reading (ml) as the color of the water sample changes from wine red to light blue. The titration has been repeated three times and the average value of the titrant (EDTA) solution consumed has been taken (i.e. not the concordant value but the average value) (APHA, 2016).

The formula that has been used in the calculation of Ht is as follows:

$$\text{Total Hardness} = \frac{\text{Average Volume of EDTA} * \text{N of EDTA} * \text{Equivalent weight of CaCO}_3 * 1000\text{ml}}{\text{L Volume of sample taken}}$$

### 3.7.5.6 Determination of Alkalinity (TA)

In the field a 100ml sample of water is collected in a well rinsed measuring cylinder and transferred to a 250 ml conical flask. To this 6-8 drops of Bromocresol-green Methyl-red indicator are added turning the sample blue-green. The titration can be performed using a Hach digital titrator (model 16900-01) with 1.6N H<sub>2</sub>SO<sub>4</sub> as the titrant until the sample turns to light violet grey (pH 4.5). The total alkalinity is then read directly from the digital display and expressed as mg/L CaCO<sub>3</sub>.

### 3.7.6 Determination of heavy Metals concentration

Pb, Cd, Cr, and Cu, Zn were among the heavy metals whose concentration levels were examined using inductively coupled plasma optical emission spectrometry (ICP-OES). The water samples were stored in the refrigerator after being acidified with 10 ml of strong nitric acid. To dissolve the organic matter, the acidified water samples were digested. The digested wastewater samples were then analyzed by ICP-OES using ES ISO 11885:2007 testing standard procedures to determine the concentration levels of heavy metals (Pb, Cd, Cr, Zn and Cu). In ICP-OES, samples

are heated to a temperature between 5000 and 10,000 K and then exposed to a high energy source, such as inductively coupled plasma (ICP), where the elements produce light with a spectrum that is unique to each element. A photomultiplier collects the emitted light, and the intensity of that light is directly correlated with the elemental concentration of the sample using the ET Environmental Protection Agency's (EPA) method 2020.

The WLR Centers of Laboratory analyzed urine metals Arsenic (As), Cobalt (Co), Nickel (Ni), Manganese (Mn) using inductively coupled dynamic reaction cell plasma mass spectrometry (ICP-DRC-MS) and sector field inductively coupled plasma mass spectrometry) using the ET Environmental Protection Agency's (EPA) method 2020.

### **3.7. 7 Methods of statistical data analysis and interpretation**

The analyzed laboratory result taken from Four sample points of Akaki River has been evaluated for each physiochemical and Heavy metal concentration values and compared with the WHO and the Draft Ethiopian drinking water quality standards, FAO and interpreted in accordance with the result obtained from the River Akaki and with the maximum allowable limits. To assess the water quality distribution, the descriptive statistical measures for each physicochemical and heavy metal concentration parameter values have been analyzed by using SPSS Version 20.

### **3.7 Definition and hypothesis of variables**

There are Two Variables in this study

#### **3.7.1 Dependent variables**

The key stakeholders practice in discharging pollutant to Akaki River.

#### **3.7.2 Independent (Explanatory) Variables**

The independent variables of this study were; Age, household head sex, education, Living years along the river. Family size, Housing ownership, wealth status, total income, access and affordability of infrastructure services, Trainings and Law enforcements, knowledge and attitude of household on Akaki river pollution.

### **3.8 Techniques of data Analysis**

To interpret water quality characterization, standards for water quality were employed. The laboratory results, which were obtained from WLRC on Selected Four Sample Points of the Akaki River, were evaluated for each physiochemical and Heavy Metals concentration values and compared to the WHO and the Draft Ethiopian Drinking Water Quality Standards, FAO Irrigation Water Quality, and interpreted in accordance with the results obtained from the Akaki River and with the maximum WHO, EP, and FAO Allowable Limits.

The qualitative and quantitative data were analyzed, interpreted and synthesized to address identified research issues. Analyze primary data collected in household surveys through quantitative data analysis. Data collected from households using survey questionnaires are checked for accuracy, coded and entered into the Social Science Statistics Package (SPSS) version 20 for windows program was employed for descriptive and inferential statistics. The descriptive statistics was presented as frequency, percentage, tables, mean and standard deviation. The inferential statistics was used to identify factors that affect practice of households in Akaki river pollution cause. Binary logistic regression was employed to estimate the level of determination of the dependent variable. By referring to various related materials of qualitative data, it was most helpful to enrich my research and gain a deeper understanding of the big picture, as well as to make simple notes and organize and classify the data by theme. Therefore, all qualitative data were transcribed and analyzed through narrative descriptions.

#### **3.8.1 Empirical analyses of determinant factors on Akaki river pollution causes**

Gujarati (2004) claims that a logit or probit regression model should be used when the dependent variable is dichotomous, or only accepts a value of 0 or 1. When the dependent variable is dichotomous (has only two categories) and the independent variables are either continuous or categorical, binary logistic regression is often utilized. In order to predict the effects of independent variable on dummy (variable) kinds of dependent variables, this study used the binary logistic regression model.

Model Specification

$$\ln \left( \frac{p_i}{1-p_i} \right) = \beta_1 x_i \dots\dots\dots(1)$$

$$P_i = \frac{e^{x_i' \beta}}{1+e^{x_i' \beta}} \dots\dots\dots(2)$$

Where

$P_i$ : Is the probability of households having practice that contribute to Akaki River Pollution

$x_i$ : is set of independent variables of households who have bad practice ( $1-P_i$ ) and who have good practice

$I$ : is the an individual household observation

$E$ : the base of natural logarithm and

$\beta$  is the vector of unknown variable to be explained from the model

According to Pindyck (1981) and Garson (2008) the final estimated model expressed as follows:

$$p_i = \frac{1}{1+e^{-x_i' \beta}} \dots\dots\dots(3)$$

In the question below  $Y$  is a dichotomous dependent variable whether each sample household will have good practice or poor practice: a value 1 indicate household good practice (not contributing to pollution), 0 indicates poor practice and  $\epsilon_i$  is error term

$$Y_i = \log(\text{odds}(\text{event})) = \log\left(\frac{\text{pro}(\text{event})}{\text{pro}(\text{non event})}\right) \dots\dots\dots(4)$$

$$Y_i = \beta_0 + \sum_{n=1}^{\infty} (X_i \beta) + \epsilon_i \dots\dots\dots(5)$$

Thus, Households practice in contribution of Akaki pollution =  $\alpha$  +  $\beta_1$  age of respondent +  $\beta_2$  sex of hhs head +  $\beta_3$  educational status of respondent +  $\beta_4$  family size +  $\beta_5$  living years along the river bank +  $\beta_6$  solid waste management facility/service +  $\beta_7$  liquid waste management facility/access +  $\beta_8$  WASH facility +  $\beta_9$  accessibility and affordability of using AAWSA service to toilet discharge +  $\beta_{10}$  Road and drainage +  $\beta_{11}$  wealth status +  $\beta_{12}$  Trainings +  $\beta_{13}$  Law enforcements +  $\beta_{14}$  Knowledge +  $\beta_{15}$  Attitude +  $\epsilon$

Where, River pollution cause= 0 if Poor practice that contribute to pollution of rive, 1 if Good Practice that did not contribute to pollution practice

$\alpha$ : is an intercept

$\beta_i$ : coefficients for the independent variables

$\varepsilon$ : error term changing variable

X: independent variables that determine the factors affecting on the use of SSI.

### **3.9 Reliability and validity**

Through repeated, critical evaluation of this instrument for data collection by academicians, when required alterations and additions were made, the validity of the questionnaires utilized in the study was ensured. However, to ensure validity, questionnaires were created based on those from prior research, and the methodology was refined before the final data collection was administered by reviewing pertinent literature and objective facts about the study location.

### **3.10 Ethical consideration**

A clear purpose of the study was presented when the enumerators questioning, to inform and investigate whether the respondent was willing to participate in providing data. In this regard, investigators were trained and well-informed to take ethical considerations into account during the investigation. During this process, researcher validated the conduct of the study according to ethical consideration protocols. Therefore, 222 respondents were interviewed and fully agreed. During interviews, respondents were informed that codes would be used in lieu of names and other characteristics that could lead to the identification of each respondent and that the analysis would be conducted accordingly. Respondents were also informed that all records will be used for research purposes only and will be kept strictly confidential at all times, which was agreed with the respondent.

As well as on using secondary data of Akaki river spatiotemporal variation of water quality the researched had taken the data by assessing and taking information of how the water samples taken from the river and by make sure the laboratory analysis of the samples is up to the standard and also by considering the date of the data which are in 2021.

## CHAPTER FOUR

### 4. RESULTS AND DISCUSSION

#### 4.1 Spatiotemporal variations in Akaki River water quality

##### 4.1.1 Physiochemical spatiotemporal variation in Akaki River

From WLRC collected and monitoring of 11 Physiochemical parameters and 10 heavy metals data on water samples from Akaki River in Four sampling sites during dry and wet seasons the following interpretation were performed.

Water quality along the Akaki River shows spatial and temporal variation in physiochemical parameters and heavy metal concentrations in all sampled sites (Check ANNEX-I 1).

The highest value PH (8.27) recorded at sampling site (S4) during wet season, indicating slightly alkaline river water, can be causes of the discharge of untreated industrial wastewaters into the Akaki River from Addis Ababa tanneries, and soap factories waste with inside the location and human wastes. The lowest pH value was detected at the same sampling site (S4) during dry season. As well as on site S11 (Akaki kality sub city) the PH Level during dry and wet seasons indicating slightly Alkalinity. These values are within the permissible limit of WHO and EP for drinking water and FAO set permissible limit for irrigation purposes.

TDS of the Akaki River ranged from 41.39 mg/l– 513.60 mg/l from across all sampling stations. A maximum TDS concentration of 513.60 mg/L was observed at beheretsgea (S9) during dry season and a minimum 41.39 during wet season at lomeameda (S4). A high TDS value indicates that the Akaki River is highly mineralized (WHO, 2011). High TDS concentration in S9 (513.60) and S11 (509) is the result of big garjes, tannery, Alcohol factories, Textile factory and municipal waste discharge. The lower TDS values of the River water at S4 (41.39mg/L) during wet season and generally in all sites at wet seasons indicates that the presence of solid particles at these sites are low which may be due to the heavy rain in sites so it is suitable for agricultural point of view. The ET standard for TDS on Surface water for drinking water is 500mg/l from this in S9 and S11 the Akkai River is passes the drinking water quality.

As shown in Annex I, The highest temperature 22.5 was recorded at the sampling site Akaki kality(S11) during dry season. The river receives industrial waste water from tanneries and textile mills at this sampling size. Paints may also leak warm water into the river system, which may affect the temperature value. While the shade provided by the riverine vegetation that grow along the river banks may have contributed to the lowest temperature of 14.05 that was recorded at the sample location Lomea Meda(S4). If the river water temperature is below 40°C, then it is normal (WHO, 2018). Naturally water bodies show changes in temperature daily and seasonally due to different activities that can contribute to changes in surface water temperature. Generally the Water temperature obtained during the sampling period for all sites did not differ significantly.

The result obtained from the laboratory analysis of electrical conductivity of the River water was recorded and ranged from 82.6 during wet season at S4(Lomea medda) to 1026 during dry season at S9 (beheretsega). The EC value of Akaki River water in S4 and S7 wet and dry season was within the limit of the Ethiopian Environmental protection authority standards (1000  $\mu\text{S}/\text{cm}$ ) (Admasu, 2017). This indicates that the effluent that enters of the river contains lower inorganic ions. On the other hands, the maximum value of EC was recording at sample point S9 And S11 (1025 and 1026) the high EC value indicates the effect of waste discharges into the River as anthropogenic interferences are expected to be high and which could be due to high presence of inorganic solids released. High conductivity (1000 to 10,000  $\mu\text{g}/\text{l}$ ) is an indicator of saline conditions. Waters that have been heavily impacted by industry can fall into this range according to Ethiopia EPA. Around S9 (Beheretsgea) there were big garages, oil stations, Tanneries (Awash Tannery) as well on S11 (Akaki kality the sub cites of factory industries) sampling point there where tannery industry and other bleaching and gas factories, Alcohol factories, Textile factories. Comparing the seasonal variation along the Little Akaki River the dry season showed significantly higher concentration peaks which could be due to the absence of mixing during the dry season and the higher evaporation rate that leaves salt behind.

The temporal concentration of EC in S7, S9 and S11 during dry season had crossed the threshold value of the World Health Organization (WHO) and the upper control limit which is 500 $\mu\text{g}/\text{l}$ .

Results obtained from laboratory water quality analysis for Akaki River at the four sampling points on total hardness ranges from 140 mg/l  $\text{CaCO}_3$  at Lomeamedda (S4) to 2480 mg/l  $\text{CaCO}_3$  at Kolfea keraniyo (S7). Besides, there is a significant difference among the sampling sites. The

total hardness value at the S7, S9 and S11 during both seasons do not comply with the limit of the WHO standards 250 mg/l CaCO<sub>3</sub> except at S4 during Dry Season the river water was slightly hard. Accordingly, the status of the River water in the S4 during dry season is categorized as slightly hard water while it is excessively hard water in the both seasons in all three seasons (S7, S9 and S11) and Wet season in S4. The data indicates that the Ht of Akaki River water is not suitable for drinking purposes since the river is excessively hard. According to EPA EU, 2001; the following is one of several such arbitrary classifications of waters by hardness: Soft up to 50 mg/l CaCO<sub>3</sub>, Moderately Soft 51-100 mg/l CaCO<sub>3</sub>, Slightly Hard 101 - 150 mg/l CaCO<sub>3</sub>, Moderately Hard 151-250 mg/l CaCO<sub>3</sub>, Hard 251-350 mg/l CaCO<sub>3</sub>, and Excessively Hard over 350 mg/l CaCO<sub>3</sub>.

The highest total Alkalinity recorded during wet seasons as well. Total hardness and alkalinity were significantly higher in rainy season than in the dry season. These were due to effluent discharge at the start of the rainy season. Besides, there was increased sewage, domestic waste, and animal excreta, during the rainy season

The value of Nitrate, and Nitrite, in Akaki river water during dry season ranged from 0.74 at S4 to 1.29 at S9 and during wet season 1.87 at S11, 7.56 at S 4 and For Nitrate during dry season ranged from 10.4 at S7 to 17.33 at S11 and during wet seasons 8.05 at S11 to 10.31 at S7.

EPA has set an enforceable standard called a maximum contaminant level (MCL) in water for nitrates at 10 parts per million (ppm) (10 mg/L) and for nitrites at 1 ppm (1 mg/L) [EPA 2002; EPA 2012]. The Health Department recommends taking action to remove or lower nitrates if levels are above 5.0 mg/L.

The 19.08 maximum nitrate concentrations observed during dry season in S9 and 8.05 minimum during wet seasons at S11. Overall, in all sampling sites of the Akaki River during both seasons Nitrate concentration was found in agreement with the limit of 50 mg/L of Canadian surface water standard but not for drinking purpose. On the other hand, in all of study sites' nitrite concentration was found above the standard. The presence of nutrients in the Akaki River is may be originated from overland runoff from riverine agricultural fields where irrigated crops are grown and the use of inorganic fertilizers is rather frequent. The high concentration of nitrites may also originate from decomposition of nitrogen containing organic compounds such as

proteins and urea occurring in industrial and municipal wastewater discharges or open defecation practiced along the course of the river. Moreover, study (Mohammed, 2022) indicated that in the presence of high levels of organic matter, nitrate can be reduced in some extent to nitrite, what could explain the high concentration of this. Comparing the seasonal variation along the Akaki River, however, the wet season exhibits somewhat larger concentration peaks, which may be caused by mixing brought on by the wet season's rainfall, which eventually neutralizes the nitrate concentration. This is also related to high concentration of Ammonia in the Akaki River with maximum value of 51.16 mg/L.

The Phosphate concentration in Akaki River gets higher during wet season than dry season in Lomeamedda (S4) and Beheretsgeaa (S7) while in Kolfeakeraniyo (S9) and Akaki kality (S11) the concentration were got lower during wet seasons this may be due to the consequences of more municipal wastewater discharge and urban-agricultural practices during wet seasons since these are an important component of detergent and inorganic fertilizers. The maximum of Phosphate which is 16ug/l at Behere Tsege Park during wet season likely happen due to used fertilizer for better growth and beauty of flowers/vegetables. Another reason could be the presence of Batu tannery at the heart of the city and their usage of inorganic phosphate in order to enhance removal of Chromium (Cr) from the tannery silage through bioleaching.

The concentration of phosphate in both seasons in all sites showed a higher variation than any of the other parameters. And both seasons displayed a concentration above the maximum permissible WHO limit.

The maximum concentration of  $\text{NH}_3$  observed during the rainy season in all seasons which is indicated the influence of urban domestic waste and raw sewage on River.

#### **4.1.2 Spatiotemporal variation in concentration of heavy metals in Akaki River**

In Table 7 Akaki River samples trace metals concentrations are presented. The concentration of trace elements varied across different sampling sites and seasons, reflecting sources and amount of metal inputs. The Guideline for maximum limit of heavy metals in Drinking water and irrigation water was adopted from the reference by WHO/FAO, European Union Standard and USEPA.

The lowest concentrations of Zn, Cr, Pb which were observed at sampling sites S11 during dry seasons, S4 during both seasons, S9 during wet seasons were; 149ug/L, and 15.8mg/L, 6.34ug/l respectively. The minimum level of lead was detected in S4 (8.97) sampling sites during wet seasons was ascribed and this due to relatively to the absence of many industrial disturbance

The highest concentration of Zn was recorded at the sampling site bheretsgea (S9) during dry seasons (770ug/l) and wet seasons (758ug/l) which may be attributed to the use of agricultural chemicals like Pesticides and fertilizers which the farmers used for crop production, wastewater released from Awash Tannery, Garajes. It was found that Zn in all sites except in S11 during dry season is the highest with a concentration higher than the recommended maximum value set by both the European and the Chinese standards for Soil (200 mg/kg). There was a significant seasonal variation in Zn concentrations. On the other hand, there was significant difference in zinc concentration among the sampling station. Whereas the highest concentration of Cr (1178.50ug/l) occurred at Akaki kality (S11) during dry season might be due to the discharge of wastewater into the river from the nearby industries. A high concentration of the most significant toxin of the heavy metals Pb 103ug/l was detected at the sample site (S9) during dry season. Lead contamination of the Akaki River is primarily caused by industrial discharges from smelters, paints, and ceramics, vehicular emissions, runoff from contaminated land areas, atmospheric fallout, and sewage effluents.

Table5: Heat chart showing variation in heavy metal During Dry and Wet seasons, along with cell limits for drinking and irrigation used

		Sites Names						
Heavy metals		S4	S7	S9	S11		Min	Max
Fe	Dry	1832	5682	14766	7814		300	5000
	Wet	1832	18130	23230	2172			
Mn	Dry	2026	2521	2831	2444		50	200
	Wet	2026	2313	1323	1399			
Cr	Dry	15.78	186	65	1178.5		50	100
	Wet	15.78	101.2	26.8	33.02			
Co	Dry	LOD	1	29	2			50
	Wet	LOD	1	19	2			
Ni	Dry	13	23	19	11		20	200
	Wet	10.69	25.1	13.13	12.96			
Cu	Dry	42.16	51	17	81		200	2000
	Wet	22.16	46.21	91.72	60.58			
Zn	Dry	211	414	770	149		2000	5000
	Wet	210.5	443.8	758.4	327.5			
Pb	Dry	LOD	40	103	91		7.2	5000
	Wet	8.97	26.77	6.34	9.77			
As	Dry	6.2	LOD	2	LOD		10	100
	Wet	6.2	LOD	LOD	0.67			

Source: own (2022)

Lead is used to stabilize land pipes/plastic pipes in some cases, resulting in lead contamination of river water (WHO, 2019).

This S9 location is situated in an area where irrigated vegetable farming is carried out. There are numerous car garages, auto battery repair shops, and gas stations nearby that discharge their garbage directly into the Akaki River. Vehicle garage wastes that may contain scrubbed solders,

pigment, paints and cable covers vehicle batteries, rust inhibitors and this vehicle emission are key sources of pollutants when without fully treatment released (Melaku 2005). Other potential sources for Pb buildup in the sediment include unlawful disposal of outdated batteries in the environment. The concentration of lead in the study area varied from 103-6.4  $\mu\text{g/l}$ . Lead levels in drinking water must not exceed 7.2  $\text{g L}^{-1}$ , according to Ethiopian standards. Except at site S9 during wet seasons, the levels found in all of the samples that were examined were above this limit.

In European Union Directives for drinking water guidelines for drinking water guidelines, no health-based guideline values for Zn in drinking water have been proposed (WHO,2012). However, according to the Food and Agricultural Organization (FAO), none of the values obtained for irrigation water exceeded the worldwide guideline threshold of 2000  $\text{g/L}$ .

The acceptable limit of Pb in drinking water according to the WHO, EU and Ethiopian standards is 10  $\mu\text{g/L}$  and Pb in all sites except in S9 during wet season were surpasses guidelines limits of Drinking water . However, the Pb levels were less than the international guideline value for irrigation water of 5000  $\mu\text{g/L}$  (FAO 2014).

Cr limit in drinking water According WHO, EU and ES is 50  $\mu\text{g/L}$  and during both seasons in S7 and during dry season at S9 and S11 were surpasses guidelines limits of Drinking water. As well for irrigation purpose the standard limit of Food and Agricultural Organization (FAO) for irrigation water (Ayers and Westcot, 1994) is 100  $\mu\text{g/L}$  and in S2 during both seasons and S11 during dry season are above the limit.

The concentrations of Cu in the water samples ranged from minimum of 17 during dry season to maximum 91.72  $\mu\text{g/L}$  during wet season at bheretsgea (S9). The recommended limit of Cu in drinking water is 2000  $\mu\text{g/L}$  as given by the EU, WHO and Ethiopian standards. All of the samples had lower Cu concentrations that were safe for drinking and irrigation water, as indicated in Table 7 The seasonal variation and differences in Cu concentration between the sampling stations were both significant.

Fe values ranged from Minimum of 1832 during both seasons at S4 to maximum of 18130  $\mu\text{g/L}$  during wet seasons at S7. The concentrations in all the water samples exceeded the recommended limit stipulated by the Ethiopian Standards (300  $\mu\text{g/L}$ ) for drinking water. As well, the Akaki river

water exceeds the standards for irrigation value of 5000  $\mu\text{g/L}$  (FOA 2014) during dry seasons except S1 and wet season at S7. The high Fe concentrations in this river water may be due to the Fe ore tailing from the metal workshops and discharge of iron-loaded industrial wastes.

The concentrations of Mn in the analyzed water samples ranged from 1323 during wet season to 2831  $\mu\text{g/L}$  during dry season at S9. Mn contents in all the water samples in all samples sites exceeded the recommended limit stipulated by the EU (50  $\mu\text{g/L}$ ) and for drinking water. The water samples from all sites as well were unfit for irrigation purposes (200  $\mu\text{g/L}$ ) (FOA 2019). These elevated Mn concentrations in the Akaki River may be linked to the industrial activity, municipal, domestic and hospital wastes that discharge treated and untreated wastewater into the various drains feeding into the river.

Water bodies are exposed to cobalt (Co) through effluents released by companies that deal with corrosion- and wear-resistant alloys. Other sources of Co pollution include lithium-cobalt batteries, permanent magnets, and pigments used to color glass and ceramic items. Between 1 during both seasons at S7 and 29 g/l during the dry season at S9, it was discovered in the tested water samples. The WHO, EU, and Ethiopian regulations do not include a recommendation value for the amount of Co in drinking water. This is most likely because Co does not present a health risk at the levels typically seen in drinking water. When compared to the Maximum Co concentration of 8.85 g/l previously reported by Minbale (2016), the Co concentration in this study was greater. The contents, however, were below the 50 g/L international guideline standards for irrigation water (FAO, 2019).

In the present case, the concentration of Ni in water samples S7 during both seasons ( dry and wet season ) are getting higher relatively. But falling below the permissible limit of drinking water stipulated by EU guidelines. Nickel (Ni) contamination can arise from various industrial activities, domestic wastes, municipal sewage, multicolored paints, electroplating, coal and oil combustion, household appliances, pigments and batteries. There are no limits set in Ethiopia. The obtained values were also much less than the international guideline values for irrigation water, 200  $\mu\text{g L}^{-1}$  (FOA, 1994).

The levels of As in the analyzed water samples were in the range of 0.67 during wet seasons at S11 to 6.2  $\mu\text{g/L}$  during both seasons at S4, all were within the acceptable limit specified as 10  $\mu\text{g/L}$  for drinking water, 25  $\mu\text{g/L}$  for surface water and 100  $\mu\text{g/L}$  for irrigation water.

## **4.2 Results of descriptive statistics**

The response rate of a study helps to determine the statistical power of a test. A higher response rate increases the test statistic. This in return increases the accuracy of the test. In this study, 222 questionnaires were distributed and all filled and returned. This shows that the return rate is 100 % which is considered as adequate to conclude the collected data. Based on the analysis of the collected data the characteristic of the households in which the survey was done is discussed briefly under this section.

### **4.2.1 Demographic characteristics of sampled households**

The demographic characteristic included under the study is age, sex, marital status, educational level, family size and Years Living along the river. Out of total survey respondents 120(54%) were Female respondents, while 102(46%) were male.

Looking first to the age of respondents as shown in Table 8, the average age was 38.59 years with standard deviation of 13.946 from the mean age of the respondents. The analysis result indicated that most of the respondents of the study were adults given the mean value of age with its average variation. When the age variation is considered the respondents have a huge difference in their age where the minimum age was 20 years while the maximum respondent 76.

Results from descriptive statistics in Table 8 indicate that, the average family size of respondents was 5 members with standard deviation of 2.032 from the mean family size of the respondents. The result indicated that most of the respondents of the study have nuclear family given the mean value of family size with its average variation. When the family size variation is considered the respondents have a reasonable difference in their family size where the minimum family size was members while the maximum respondent family size was 18 members. The reasonable gap in family size between sampled respondents enables to better understand the practice among household to contribute the Akaki river pollution.

In all studies sites sampled surveyed households the average years to living along the river was 10.37 years with in 30m radius with a maximum of 30 years and minimum of 1 year. Though in Addia Ketema Sub city relatively to other sub cities there are high amount of settling recently and from Government Office Interview we were able to identify that the informal settlement around the river bank have increased for the last 5 years.

Table 6: Distribution of respondent’s age and family size

Variable	Observation	Mean	Std.Dev	Min	Max
Age of respondents	222	38.59	13.946	20	76
Family size	222	5.00	2.032	1	18
Living years	222	10.37	6.053	1	30

Regarding the Marital status of the survey households, the majority 166 (75%) of the respondents, were married, both single and Widowed sampled respondents households are equal size 24(11%).

The survey revealed that most 103(46.4%) of sampled respondents were categorized under illiterate group (0 years of schooling) 51(23%) were primary school, 45(20.3%) were secondary School and 19(8.6%) have a Higher education Degree or diploma & certificates. Therefore, in general, the education status of survey households was at a very low level. Studies indicate that the educational level of the respondent is directly related to WASH practice, Waste Management.

As the Communities’ understanding and educational level increase their commitment to proper waste Management practice and prevention of the further pollution increase with others practice of protecting the river from more pollution and impact on human health, environment. Education is believed an important factor to influence Behavior, Practice and technology adoption (Tamiru, 2014).

Table 7: Household’s Socio demographic Characteristics

Variables	Category	Frequency	Percent
Sex of respondents	Male	102	46
	Female	120	54
Sex of Household head	Male	180	81.1
	Female	42	18.9
Education	No read and no write	103	46.4
	Primary(1-4)	55	24.8
	Secondary(9-12)	44	19.8
	Higher Education	20	9.0

#### 4.2.2 Socio Economic Characteristics of the Sampled Households

The survey also revealed most of the respondents’ occupations were business/trade, crop production, casual labor work, employment (salary based) and few households have additional income both crop and house rent.

As shown in table 10, the majority sampled household’s income sources of survey household are Business/trade for about, which 68(30.6%) households who earn an Annual average 40,200 ETB and followed by irrigation along the Akaki River. From Irrigation the average annual income for 56(26.2%) households was estimated about 34,926 Ethiopian birr (ETB). As indicated above 36(16.2%) of them were hired to the government and private organization and depend on a monthly salary, and earn an average birr 62,000 ETB Annually , About 37(16.7 %) of the households are involved in unskilled labor and small business like gulete, weaving of traditional clothes, pottery making, and collecting fuel wood collection from the nearby forest and earn an average 26,821 ETB Annually .There are also 25(11.3%) households which income sources are remittance and earn an Average 13275 ETB annually. Crop production were observed in all sub cities as income source though more common in Addis Ketema and Lafto Sub city using Akaki River.

Table 8: household's main livelihood and annual income

No	The major income sources (livelihood means) for the households	HHs who reported the major income sources from the list		Average annual income (Birr)
		Frequency	Percent (%)	
1	Business/ trade	68	30.6%	40,200
2	crop production	56	25.2%	34926
3	Casual labor work	37	16.7%	26821
4	Employment (salary based)	36	16.2%	62000
5	Retired	25	11.3%	13275
	Total	222	100%	

### 4.2.3 Basic services in Akaki river bank settlement

The respondents were asked the kind of toilet facility they have, accordingly, 153 households which were 68.9 % of them answered they use a toilet that have connected to the river or open field, and the rest 25(11.3%) answered pit latrine ,44 (19.9%) had no latrine(open space). However, pit latrines are not without limitations. Apart from the latrines closeness to their homes, the 46(20.7%) number of people answered that they were using one latrine for at least 4 other households also it were able to know that in this River Bank settlements there were 85(38%) households whom use toilets with more than five other households. As well according to 177(79.7%) respondents the toilets they were used is no guarantee for their cleanness, and they are not gender-segregated and not safety regarding their privacy, covered with plastic tent serve as a temporary toilet. There were observable faces in the compound of most households. Mostly In all sampled sites most of sampled respondent households unit has one communal dry pit latrine covered with a plastic tent that serves as a temporary toilet. Because of a lack of proper sanitation facilities, residents in selected sampled sites defecate in the river, open air, and the forest. From Survey on Access/capacity to pay for to Emptying organization service 187 (84.2%) of the households respond they have no capacity to afford this services.

In the study area, piped water in was a common source for drinking water use. 167(75.2%) of the respondents used piped water shared with other household's public water as of their drinking water and the remaining 55(24.8%) use piped water on their premises. Regarding the water source for questioned sample households use for their various household consumptions like cleaning, cooking, bathing etc. majority of respondents 139(62.6%) used public/shared piped water 59(26.6%) used premise owned pied/tap water and it also able to analyze exclusively on Addis Ketema sub city that there are respondent household who had used protected dug wells on their premises for household consumption except for drinking purpose.

Table 9: Sanitation infrastructure Facility

Variables	Category	Frequency	percentage
Toilet Facility system	Open space	44	20
	Connected to pit/septic tank which have been discharged/emptisized	25	11.3
	Connected to open field, River	153	69
sanitation facility arrangement	Private	91	41.0
	shared with Less than 4 households	46	20.7
	Shared with above 5 households	85	38
Access/capacity to pay for to Emptying the toilet	Yes	187	84.2
	No	35	15.8
Main Drinking water source	Piped water on premises	55	24.8
	Piped tape shared in public/other households	167	75.2
Main Source of water for Households consumption (cleaning, cooking)	Piped water on premises	59	26.6
	Piped tape shared in public/other households	139	62.6
Toilet safety	Yes	45	79.7
	No	177	20.3

#### **4.4 Akaki river bank Physical environmental characteristics**

According to the observations and key informants, in recent years, new settlers on land adjacent to the Akaki River have cleared a large portion of the forest and irrigation field to build their homes. This dramatic conversion of land functions without any government approval has had a significant impact on the Akaki River environment as a whole. The majority of the time, the settlement's residents are cutting down trees to produce charcoal as a source of energy, building material components, and financial income by selling it to the nearby wooden market area. There are construction diggings, which are causing endless deforestation, increasing soil erosion to the river, frequent flooding, and desertification along the river bank.

At the moment, it is physically observed that the damages to the river caused by river bank land erosion are numerous, including eroded land becoming unproductive, an increase in the volume of runoff surface water, and contaminated water from irrigation (fertilizers and pesticides) polluting the river even more. As a result, the river is unfit for human consumption, serves as a breeding ground for water-borne diseases such as typhoid and amebic dysentery, and is uninhabitable for indigenous plants, wild animals, and aquatic species.

When the surface is exploited, the quarry depth may reach below the riverbed. These factors, combined with the frequency of flooding, have exacerbated soil erosion, land degradation, and landslides.

The liquid waste from industries has been directing all liquid waste towards the Akaki River, either directly or through open ditch drainage.

#### **4.5 Knowledge of the respondents about Akaki River pollution**

The level of Knowledge of the households on the level of Akaki river pollution had been surveyed. The results revealed that the majorities 191(86.0%) of the respondents were aware about existence of water pollution In Akaki River and 12(5.4%) of the respondents were not aware about Weather the Akaki River Polluted or Not. Also 19(8.6%) replied the Akaki River is not polluted.

According to their knowledge on understanding of Akaki river water pollution status, respondents questioned their understanding of Akaki river water quality in the last five years. The most widespread view among them is that the quality of Akaki river water has remained the same, neither improved nor deteriorated, and 49 (22.1%) observe as it deteriorated for these five years. Of course, there are people 65 (29.3%) who do not have knowledge of the river status over the past five years. Even though the majority of sampled respondents have awareness that Akaki river is polluted and for the past five years polluted and remained polluted 119 (53.6%) and 125 (56.3%) have no knowledge of the River seasonal and spatial water quality change respectively.

Table 10: knowledge of households about Akaki river pollution

Variables	Category	Frequency	%
Akaki river Water is polluted	Yes	191	86.0
	No	19	8.6
	I don't Know	12	5.4
Akaki river Water Quality In Last Five Years	Remained the Same	107	48.2
	It Has Deteriorated	49	22.1
	I don't Know	65	29.3
notice Akaki river water quality seasonal change	Yes	103	46.4
	No	119	53.6
Spatial variation in water quality exist	Yes	97	43.7
	No	125	56.3

On assessment of Akaki river pollution causes 175(48.8%) respondent aware that industry (industrial effluents, car wash, oils) alongside of Akaki river contribute to the river pollution also 109(49.1%) recognize chemicals like pesticides and fertilizers from irrigation erosion along the river bank as polluter of the river so far. Most of Sampled Respondents 107(48.2%) Participants endorsed that the biggest sources of Akaki river water pollution were too much solid wastes from homes (trashes, plastic materials, dusts, etc.).79(35%) and 48(21.6%) respondents know home sewage and liquid waste discharges as pollutant of the river respectively.

As well 69(31.1%) respondents replied that they know the drainage with in the neighborhood lasts to Akaki River. About the government rules and laws, penalty on causing river Pollution 147(66.2%) answered they didn't know any of it at all.

Table 11: knowledge of households about the causes of Akaki river pollution

Variables		Frequency	%
Causes of the River Pollution	Irrigation	109	49.1
	Industry effluents	175	78.8
	Household's solid waste	107	48.2
	Household's liquid waste	48	21.6
	Sewage release	79	35.6
	Internal Road drainage destination to Akaki river	69	31.1
	know government rules and laws, penalty on causing river pollution	I know	75
I don't Know		147	66.2

Below Table-14 investigated that what impact did Akaki river so far have on Human health's due to pollution and 83 (37.4%) of respondents able to mentioned the river have caused Respiratory diseases due to pollution, 84(37.8%) Skin disease, 46(20.7%)Eye problem,149(67.1%) water borne diseases. on depth Analysis of Akaki river pollution impact 92(41.4%) of respondents had able to mention due to pollution Akaki river Became unfavorable to Aquatic life's. From the

above table 182(82.0%) and 123(55.4%) the respondents said that due to the pollution the river were inappropriate for home use and lost its economic value.

Table 12: knowledge of households about the Impact of Akaki River due to pollution

Variables	Categories	Frequency	%
Akaki river water Pollution impact on the human Health's?	Respiratory	83	37.4
	Skin disease	84	37.8
	Eye problem	46	20.7
	Water borne diseases	149	67.1
Akaki river due to Pollution lost its value for	Unfavorable habitat for aquatic specious	92	41.4
	Lost the economic value	123	55.4
	Lost value for household consumption	182	82.0

Out of 222 respondents most of them mentioned ways of tackling Akaki river water pollution, and 89(40.1%) respondents said Introducing Heavier fines, 129(58.1%) More awareness, 103(46.4%) better enforcement in regulations and rules for all stakeholders, 84(37.8%) respondents mention improvement on Waste management will tackle the river from more pollution. For question Do You Know where to raise your concern regarding Akaki river issues? 158(71.2%) answered that they know where to raise their concerns regarding the river issues.

Table 13: knowledge of households about the solution of Akaki river pollution

Variables		Frequency	%
ways of tackling Akaki river water pollution	Introducing Heavier fines	89	40.1
	More awareness/information	129	58.1
	Better enforcement on regulations	103	46.4
	Adequate waste management facility	84	37.8

I know where to raise concerns regarding Akaki river.	Yes	158	71.2
	No	64	28.8

After assessment of 10 knowledge questions on the section (total score: 26), each correct response (yes) was assigned a score of 1, and incorrect responses (no and I do not know) were assigned a score of 0. Participants' overall knowledge score was categorized using the mean as cut-off point and 125(56.3%) have poor knowledge and 97(43.7%) good knowledge

#### **4.6 Household perception on pollution of Akaki River water in the study area**

Contrary to these studies, 89(40.1%) agreed/ strongly Agreed on the respondents feel very well informed about the Akaki river water problems in the community. And 128(57.6%) Disagreed/strongly disagreed on feeling informed at all about the Akaki river water problems. In the further analysis, their concerns towards Akaki river water pollution had asked and 100(45%) Strongly agree/agree that they are concerned about the river pollution causes and impact situation and 100(45%) have no any concern at all about the river.

Table 14: Households attitudes about Akaki River water pollution

Variables	SD	Disagree	Neutral	Agree	Strongly A
Feeling informed about Akaki river water pollution	30 (13.5%)	98 (44.1%)	5 (2.3%)	45 (20.3%)	44 (19.8%)
Do you worry about the Akaki river water conditions?	10 4.5%	90 40.5%	22 9.9%	50 22.5%	50 22.5%

Regarding their contribution on pollution of Akaki river 106 (47.7%) respondents (Strongly agree/agree) their contribution to Akaki river pollution is not negligible and 107(48.2%) believe their contribution as causes of Akaki river pollution is negligible. from this and community discussion it were able to understand that due to their economic level and lack of government Attention for their basic services like Waste management facilities they believed disposing their

waste to the river is option less that they can't do anything about it and its beyond their economic level so that gives them to not look their contribution as big concern for the river.

69(35.9%) of respondents agreed strongly agree/Agree that poor waste 111(50%) management system as Major challenge of Akaki river water pollution while and 131(59%) disagree that community trainings, information dispensation for improvement of Akaki river will not do anything to improve the river while 57(36.6%) agreed/strongly agreed that community discussion ,information dissemination will help to improve the river water status.

Table 15: Household's attitudes about causes of Akaki river pollution

Variables	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
My contribution to problems related to river water pollution is not negligible	4(1.8%) 1.8%	103 46.4%	9 4.1%	86 38.7%	20 9.0%
Poor waste management practice causes of pollution	4 1.8%	107 48.2%	31 14.0%	44 19.8%	25 16.1%
Do you think community trainings, information dispensation might reduce more pollution	0	131 59%	33 14.9%	55 24.8%	3 1.4%

For understanding how the seriousness of the Akaki river water pollution for the stakeholders community sampled respondent were asked on how Akaki river pollution is seriousness on the environment and socioeconomic activity of the city and survey showed that 105 (47.3%) were strongly disagreed/disagreed that Akaki river have not caused or not serious problem for the city and community however, and 79(35.6%) believed the river pollution are or have caused Very serious problem/issues.

Generally, on impact of the pollution 76(49.3%) strongly disagree /disagree statement of use of Akaki river for irrigation have long term impact while 76(49.3%) believe usage of Akaki river on irrigation have impact due to its pollution. in depth analysis of Akaki river value most of

respondents 61(39.4%) strongly agree/agree that even with treatment of river water at home wont treat the river for household consumption.

Table 16: Household’s attitudes about Impact of Akaki River due to pollution

Variables	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Akaki river pollution serious matter for the City and riverbank community general life	9 4.1%	96 43.2%	38 17.1%	36 16.2%	43 19.4%
use of Akaki river for irrigation have long term impact	35 15.8%	69 31.1%	29 13.1%	62 27.9%	27 12.2%

On perception of households towards Solutions and tackling of the river pollution majority 85(55.2%) strongly disagree/disagree that they would be confident raising a concern about water pollution to local water management authorities however 14(9%) they would be complain about any issues to concerned body regarding Akaki river. Out of 222 sampled respondents 46 respondents strongly disagree/disagree on that they are stakeholders of Akaki river pollution.

On assessing their willingness to pay for an improved latrine service/waste management facility 107(69%) agreed/strongly agreed for willingly pay in time and money to improve their latrines and waste disposal methods though 18(11.6 %) disagreed they were not willing to pay for better service. Similarly 88(57.7%) were answered strongly agree/agree that they will Pay prices in money and time in order to protect the Akaki river environment.

Regarding protection of Akaki river 97(62.6%) strongly disagree/disagree that they know how to protect the River.

Table 17: Households Attitudes towards Tackling of the River Situations

Variables	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I would be confident raising a concern about water pollution with local water management authorities	29 13.1%	84 37.8%	30 13.5%	50 22.5%	29 13.1%
Not Only Government but I am too responsible for Akakai river protection	5 2.3%	41 18.5%	36 16.2%	95 42.8%	45 20.3%
to pay for an improved latrine service/waste management facility		63 28.4	70 31.5	65 29.3	24 10.8
Pay prices in money and time in order to protect the Akaki river environment	4 1.8%	91 41.0%	42 18.9%	61 27.5%	24 10.8%
know what to do to protect the Akaki river Environment	18 8.1	127 57.2	16 7.2	39 17.6	22 9.9

After assessment of (12 likers, Strongly Agree=5 Strongly Disagree=1) perception questions on Status of Akaki river water quality and causes, impacts of the pollution with intervention measures for improvement of The river quality and using the mean as a cut-off 137(61.7%) have unfavorable Attitude and 85(38.3%) favorable attitude.

Assessments were undertaken to determine the Attitude of the respondents on the existence and causes, impacts as well solutions of Akaki river water pollution in the study area.

#### **4.7 Practice on discharging pollutant to Akaki River**

Afterwards from their toilet system assessment the sampled households asked whether directly or indirectly their toilet destined to Akaki river and 191(86%) answered their toilet last to Akaki river directly or indirectly while 31(14.0%) replied that there toilet never last to the Akaki river.

on their waste management practice 162(73%) and 212(95.5%) answered their solid and liquid waste respectively discharged or deposited to Akaki river.

On Practice question of hhs weather source of income not at all discharge wastes/chemicals to the Akaki river 86(38.7%) answered their livelihood directly or indirectly discharge solid or liquid waste to the Akaki river.As Well as the above table reviled 130(58.6) sampled respondents expose the Akaki river environment for pollution through disposing of Animal dung, deforestation along the river area, Open defection, toxic chemicals.

Table 18: Practice of discharging pollutants

Variables	No	Yes
My Toilet System is not directly/indirectly discharge sewages to Akaki river	191 86.0%	31 14.0%
My household did not dispose solid waste other than human excreta are poor(river, open ditch, latrine)	162 73.0%	60 27.0%
My household Liquid waste other than human excreta management directly/indirectly did not goes to Akaki river	212 95.5%	10 4.5%
The source of income for my households were not at all discharge wastes/chemicals to the Akaki river	86 38.7%	136 61.3%
I never expose the river environment for pollution(Animal dung, deforestation, toxic chemicals, open defection)	130 58.6%	92 41.4%

After assessment of Five practice questions for Akaki River pollution causes, each Good practice (Practice not discharging pollutants) ‘yes’ was assigned a score of 1, and Poor Practice (Practice discharging pollutants) ‘no’ were assigned a score of 0. Participants’ overall practice for discharging pollutants to Akakai River score was categorized using the mean as cut-off point and 141 (63.5%) has poor practice and 81(36.5%) good practice

## **4.8 Akaki river bank settlement characteristics by discharging pollutants index**

### **4.8 .1 Demographic and socio economic characteristics by discharging pollutants index**

This section presents the basic characteristics of sample household heads and their practice in discharging pollutants to the Akaki River.

One of the factor that have seen under individual or demographic characteristics versus in household practice in discharging pollutant to Akaki River are sex of household head. The majority of the sample household heads (54.1%) were female headed households while the remaining (45.9%) of the respondents were male headed households. As shown from the below (table 21) sex of the household head has a significant impact on the ability of the household practice to discharging pollutants to Akaki River. Male-headed household is most of the time less likely to discharging pollutants to Akaki River than female-headed households. Thus, the result of the discharging pollutants to Akaki River index by the sex of the household head indicated that among all household heads who have poor practice 44.1% belong to female headed households while the remaining 19.4% were male headed. On the other hand, among all good practice households 26.6% were male-headed, while the remaining 9.9% were female headed households. Besides, proportion of female headed poor practice group 44.4% is significantly higher than good practice group (9.9%). Furthermore, the chi square test showed there is significant systematic association between household head of sex and discharging pollutants to Akaki River.

An earlier study by Tamiru (2014) found that household head sex has an impact on river pollution in poor nations through differences in the adoption of waste management and WASH facility technologies, in addition to the accessibility and affordability of infrastructure. According ONE WASH Plus report (2017) Female-headed households in the ONEWASH Plus project areas were found to be not only more likely to have an income under minimum wage, but also to be less likely to have access to improved drinking water compared to male headed households, especially in the Akaki river illegal settlement urban areas which leads to more environmental problems.

The survey result showed that, 46.4% of the sample household heads were not able read or write and the remaining respondent's households were above read and write level. Furthermore, the result also indicated that higher number of households that had poor practice (33.3%) is under no read and no write group. The Pearson chi-square result revealed there is systematic association between educational status and practice of the sampled household heads in discharging pollutants to Akaki River. Educated households are able to use modern technologies, perform improved WASH and waste management practice and generally be less vulnerable to shocks and risks as well discharging pollutants to Akaki River (Mekelit, 2016).

Table 21 shows that out of total (58.6%) households was with more than five family member in the study area was (44.6%) having poor practice and the remaining (14.0%) were having good practice source, which shows when the family member size get increased the household consumption and waste production increased which leads to frequently waste disposal, sewage discharge and more resource demand. The family members with less than five family member (22.5%) slightly having good practice than (18.9%) poor practice households. finding from household survey is further strengthened by Pearson chi-square test demonstrating a significant positive relation at 1% on family size with practice on discharging pollutants to Akaki River. A study by Mekonen (2018) revealed that extended family size settlement growth along the Akaki river banks increases the need to produce consumer products and this need, in turn, intensifies the trend to over-exploit and misuse of Akaki river in Addis Ababa. As well this research survey showed that Family size is one of the important entities towards discharging pollutants to Akaki River.

The study result revealed that, (52.7%) of respondent from poor practice grouped household has lived in the river adjacent area more than five years, whereas, (23.4%) in good practice grouped household heads. On the other hand, out of the total households (23.9%) of the households respondent live around the Akaki river (10.8%) were having poor practice and (13.1%) were having good practice. This implies that, there is a relationship between households practice and discharging pollutants to Akaki River. Besides, the chi square result confirmed that there is a systematic significant between the two groups of households living years along the river with their discharging pollutants to Akaki River.

The cross tabulation of housing ownership with practice of households in discharging pollutants to Akaki River show that the (44.6%) most of dwellers informally settled Around Akaki river have poor practice due to lacking of government support in basic needs and waste management which leads to increment of the river pollution and their explosion to pollution. As well as respondents who rented house out of (19.4%) most of them (14%) grouped under poor practice relatively (4.5%)dependent households in some way have less poor practice than(5%) good practice dependent households. However the Pearson Chi square test shows there is no significant association between the housing ownership and having poor practice.

There are similarities between the informal housing characters and developments in selected sites as well this site housing character describes well the all Akaki river Bank settlement housing characteristics within Addis Ababa; Exclusively site one (S11) houses are small in size located on very sloppy surface semi-urban environment and they were attached to one another; In each single house of there are many small size rooms ranging accommodating basic services, but they do not have adequate space for solid waste collection and improved toilet system as well don't have improved liquid waste disposal sites. Most of which consist not more than two rooms and housing units connected by much unpaved road. This settlement is completely segregated by the internal access roads and their irrigation field is mostly affected when there is heavy rain on the upper part of the Akaki River. Where as in site four (S4), the informal settlement houses are small in size and located in a rural type of environment. The area is frequently hit by flooding: at times houses, domestic animals and even human being are drowned by flood. From the observation it can be concluded in this site the liquid and solid waste management is poor.

The informal settlements on riverbank area, despite their illegality and lacking of government support, houses have been built randomly in a similar manner. The physical content of the building is mostly determined according to the immediate need of settler as well as their financial capacity not the Akaki River with environmental consideration. Most of housing units are located on the irrigation field, edge of the river and on hilly terrain. Some of them, due to continuous flooding and land degradation, part of their structure are suspended on the air as a result they are always under fear of collapsing and cause of more pollution of the river (Mekonen, 2017).

The survey reveals a high clustering of poverty in Akaki river bank settlement communities, with (45.5%) of the households belonging to the poor wealth class and very few sampled households (5.9%) belonging to wealthiest wealth class. The table revealed that having practice of discharging pollutants to Akaki River get higher when the wealth status of households get poorest. For poorest and poor households (23.9%) and (25.7%) households grouped under poor practice and the remaining (5.4%) and (19.8%) grouped to good practice. The richest group households relatively most of them (3.6%) out of (5.9%) grouped to good practice. Proportion of poorest to richest poor practice group is slightly decreases. Furthermore, the chi square test showed there is significant systematic association between household head of sex and discharging pollutants to Akaki River at 5% significance level.

Housing conditions in each area reflect the poor economic background of the inhabitants. There are a number of distinctive household characteristics such as different socio-economic characteristics and behaviors of respondent households with access of infrastructure determine the level of discharging pollutants to Akaki River (Adane, 2014)

Table 19: Demographic and Socio economic Characteristics by discharging pollutants Index

Variables	Practice				Total (frequency & %)		Chi Square
	Poor Practice		Good Practice				
	N	%	N	%			
Sex of the household head							
Male	43	19.4	59	26.6	102	45.9	37.454***
Female	98	44.1	22	9.9	120	54.1	
Educational level of the respondent household							
Not read or no write	74	33.3	29	13.1	103	46.8	14.307**
Primary ( 1-8)	38	17.1	17	7.7	55	24.8	
Secondary (9-12)	22	9.9	23	22	44	19.8	
Diploma and above	7	3.2	13	9.9	20	9.0	
Size of family member							
1-4	42	18.9	50	22.5	92	41.4	21.629***
Above 5	99	44.6	31	14.0	130	58.6	
Living along the area							
0-5	24	10.8	29	13.1	53	23.9	9.985**
Above 5	117	52.7	52	23.4	169	76.1	
House ownership							
Owned by informal	99	44.6	58	26.1	157	70.7	4.244
Rented from individual	31	14.0	12	5.4	43	19.4	
Dependent	10	4.5	11	5.0	21	9.5	
Wealth status							
1(Poorest)	53	23.9	12	5.4	65	29.3	14.990**
2	57	25.7	44	19.8	101	45.5	
3	26	11.7	17	7.7	43	19.4	
4(Richest)	5	2.3	8	3.6	13	5.9	

## **4.8.2 Accessibility and affordability of infrastructure by discharging pollutants index**

Regarding waste management facilities/systems in the neighborhood, respondents were asked if they have access to solid waste management facilities, and 115 responded that are 51.8% of sampled respondents answered that their households do not have access to any solid waste management facility/service. Total of (51.8%) respondents whom mentioned they can't access/afford any kind of solid waste management service/facility most (44.1%) of them having poor practice and few of them (7.7%) had good practices. The chi-square also indicates that there is a relationship between affordability and accessibility of solid waste management service/facility and practice at 1% significant level.

Study by Gebre (2019) the facility and services of solid waste management are very inadequate and despite the fact that a city municipality arranges kind of solid waste management ways like door to door/container at some distance, but due to the road and illegal housing around the Akaki river banks as well distance of their house from the container they were unable to access the solid waste management facility/service which leads them to dispose the waste to Akaki river.

On Liquid waste management in all sampled sub cities almost all 174(78.4%) respondents were have not any proper/government provided liquid waste management/disposal sites/facility/service at all and from observation researcher were able to notice that each respondent's households have system (pipe connected) of liquid waste disposal to Akaki River directly. Due to the fact that most of households cannot able to access the proper liquid waste service/facility (58.1%) respondents having poor practice and (16.2%) out of (21.6%) respondents able to access the facility/service had good practice. The finding from household survey is further strengthened by Pearson chi-square test demonstrating a significant positive relation at 1% on facility and affordability capacity to have proper liquid waste management service and facility and practice towards on discharging pollutants to Akaki River.

Out of 222 sampled respondents (86%) households mentioned they were not able to access and afford to have improved toilet system while(14%) answered they had improved toilet system. For (86%) respondents grouped to poor practice (59.9%) and remaining (26.1%) grouped to good practice. The finding from survey is further strengthened by Pearson chi-square test

demonstrating a significant positive relation at 1%. These figures shows that clearly WASH facility have a significant role in river pollution.

In Addis Ababa, 74% of houses have toilet facilities. However, due to the region's financial difficulties and geography, only 12% of residents have access to central sewerage. Based on the Wastewater Master Plan study, this value will increase to 16% (456,000 inhabitants) and 22% (848,000 inhabitants) by 2005 and 2015 respectively. The remaining households (about 60% of households) are now served by pipes connected to septic tanks, flush toilets or dry toilets. Due to the intermittent sewage collection and transportation service in the city, septic tank overflow is a major problem (Tamiru, 2017).

As well as on assessing the association of the accessibility and affordability of households to have service of AAWSA toilet emptying service out of (84.2%) sampled respondents' (59.9%) respondents' were having bad practice and remaining (24.3%) have good practice. Furthermore, the chi square test also shows that there is significant relationship between discharging pollutants to Akaki River and having access and capacity to afford the toilet emptying service.

Housing information indicates that along the Akaki River there are a total of 380,300 housing units. Of these, the sewage network covers 20,000 households, of which only 6,000 are active for economic reasons and believe the others released their sewage directly to the Akaki river which is major source of the river pollution (Preceup, 2017)

The selected household's samples (68.9%) replied there is no any formal and accessible internal road and drainage that are Proper/ accessible and most of (45.0%) household said they didn't able to access proper drainage have poor practice. the other (23.9%) respondents grouped to good practice .besides proportion of respondents able to access proper road drainage (45.0%) grouped to poor practice highly varied with those (23.9%) said they can't able to use grouped to good practice. the Pearson Chi-square test show that there is no association between having bad practice and having poor road drainage system.

Mekonen (2017) in his study showed that in the case of the settlement of the Akaki river bank In terms of internal access roads, it was very common to see no clearly identified street system, just narrow and irregular foot paths that provided access to various houses. A large portion of the settlement has very narrowed partially gravel roads with no defined street pattern or proper

drainages. It was discovered that the road drainage had been used as a liquid waste disposal site by the dwellers, with the drainage leading to the Akaki River and during the rainy season, when the surface water is high, gullies form, internal access roads become clogged with mud and dirt, and the river sometimes overflows its banks. As a result of the Akaki River's frequent flooding, the general settlement has suffered physical, social, economic, and health consequences.

Table 20: Accessibility and affordability of Infrastructure by discharging pollutants index

Variables	Practice				Total (frequency & %)		Chi Square value
	Poor Practice		Good Practice				
	N	%	N	%			
proper solid waste management							
No	91	41.0	34	15.3	125	56.3	48.500***
Yes	50	22.5	47	21.2	97	43.7	
proper liquid waste management system/facility							
No	115	51.8	33	14.9	148	66.7	39.19***
Yes	26	11.7	48	21.6	74	33.3	
improved toilet system							
No	133	59.9	58	26.1	191	86.0	22.107**
Yes	8	3.6	23	10.4	31	14.0	
emptying service for toilet							
No	133	59.9	54	24.3	187	84.2	29.637**
Yes	8	3.6	27	12.2	35	15.8	
Proper internal road drainage							
No	117	52.7	58	26.1	175	78.8	.724
Yes	24	10.8	23	10.4	47	21.2	

### 4.8.3 Behaviors and training factors by discharging pollutants index

Table 22 indicates From the total respondents (46.8%) of them didn't participated and conducted in river revitalization activities (e.g. planting trees along river basin, awareness programs, gatherings or protests, trainings, educations or take any lesson or training related to Akaki river pollution causes, impacts and penalties as well as solutions and (31.5%) of them have poor practice but (53.2%) of the respondents took training/lesson related to it and (21.2%) of then have good practice.

On question of whether there is strong law enforcement on protecting the river from pollution out of 222 sampled respondents (83.3%) answered they were didn't notice or experienced strong Environmental police enforcement. According to table (51.8%) of the respondents had poor practice and (11.7%) had good practice. Bothe factors taking training or participating in various educational programs and experiencing penalty on polluting the river on chi-square test didn't show relationship with having good or bad practice in.

On Assessment of knowledge on Akaki river pollution and using mean as cut of point (66.7%) were had poor knowledge and out of them (48.2%) had poor practice the remaining (18.5%) had good practice. On other hand (33.3%) of respondents had good knowledge and most of them (18.0%) had as well good knowledge. The chi-square also indicates that there is a relationship between knowledge and practice in discharging pollutants to Akaki River at 1% significant level.

On Attitude (61.7%) sampled respondents were groped to unfavorable attitude and the remaining (38.3%) grouped to favorable attitude. For those households with unfavorable attitude (45.0%) respondents' were had poor practice and (16.7%) had good practice on river pollution. The chi-square also indicates that there is a significant relationship between Attitude and practice of households in discharging pollutants to Akaki River at 1% significant level.

Table 21: behaviors and training factors by discharging pollutants index

Variables	Practice				Total (frequency &		Chi Square
	Poor Practice		%)Good Practice				
	N	%	N	%	N	%	
Trainings/education/participations							
No	70	31.5	34	15.3	104	46.8	1.215
Yes	71	32	47	21.2	118	53.2	
Law Enforcement							
No	115	51.8	70	31.5	185	83.3	.875

Yes	26	11.7	11	5.0	37	16.7	
Knowledge							
No	107	48.2	41	18.5	148	66.7	14.783***
Yes	34	15.3	40	18.0	74	33.3	
Attitude							
No	100	45.0	37	16.7	137	61.7	13.874***
Yes	41	18.5	44	19.8	85	38.3	

## 4.9 Determinant factors toward discharging pollutants to Akaki River

Households along the side of Akaki river in 30m radius have a input lot to pollution of Akaki river and their practice on discharging pollutants to Akaki River is determined by various Demographic, Socio economic and Institutional and Environmental, infrastructural, behavioral factors. In view of this, efforts were made to include variables found relevant in the model in order to clarify the contribution of hhs in the study area. The variables in the model were selected on the basis of theoretical explanations, personal observations and the results of the survey studies. Households practice discharging pollutants to Akaki River is considered as the dependent variable of the model, while the variables listed in Table 24 are independent variables that determine the likelihood of households of being discharging pollutant to Akaki river or not .

### 4.9.1. Assessment of goodness fit of binary logistic regression analysis

The goodness of fit of a model measures how well the model describes the response variable. Assessing goodness of fit involves investigating how close values predicted by the model are to the observed values. The appropriateness of the fitted logistic regression model needs to be examined before it is accepted for use as in the case of all regression models. The validity of inferences drawn from modern statistical modeling techniques depends on the assumptions of the statistical model being satisfied. In order for the analysis to be valid, our model has to satisfy the assumptions of logistic regression, such as: Logistic regression requires the dependent variable to be dichotomous. The dependent variable is binary outcome taking 1 for practice that did not discharge pollutant to Akaki River and 0 for bad practice which is practice that discharging

pollutants to Akaki River. Larger samples are needed than for those in linear regression analysis. A minimum of 50 cases per predictor is recommended for logistic regression. Here in this study 222 samples are involved, the problem of multi-collinearity among explanatory variables was checked by using Variance Inflation Factor (VIF) and contingency coefficient tests for both continuous and dummy variables that are hypothesized to influence the decision of households to discharge pollutants to Akaki river. As it is presented in the attached annex (i.e. Appendix IV) the value of VIF for each continuous variable, prove that the problem of multi-collinearity was not serious among variables, as VIF values are less than 10.

#### 4.9.2 Result of binary logistic regression analysis

The binary logit model identified a total of nine significant variables out of 15 hypothesized variables. All the factors considered in the model are found to have a positive influence on households practice in discharging pollutants to Akaki River. The interpretation and discussion of these significant variables are presented as follow.

Table 22: The binary logistic result of independent variables

Variables	<i>B</i>	<i>S.E.</i>	Wald	Sig.	Exp (B)
Household head sex	2.047	.487	17.631	.000***	.129
Age					
18-35	.695	.515	1.819	.177	2.004
36-50	-.173	.616	.079	.779	.841
>60	-.728	.949	.588	.443	.483
Education					
Primary	.132	.365	.132	.717	1.142
Elementary	.937	.373	6.318	.012**	2.552
Degree/diploma	1.556	.517	9.039	.003***	4.739
Family size	1.374	.441	9.699	.002***	3.952
Living along the river	1.033	.563	3.364	.067*	2.810

Wealth status					
2	.657	.535	1.509	.219	1.929
3	.160	.684	.054	.816	.852
Access to proper solid waste management	.697	.438	2.536	.100*	2.00
Access to proper liquid waste management	1.751	.467	14.063	.000***	5.761
Access to improved toilet system	1.316	.627	4.412	.036**	3.73
Access/capacity to afford service for toilet discharge	1.971	.641	9.449	.002***	7.17
Proper internal road and drainage	-.247	.524	.221	.638	.78
Trainings/education/participations	.260	.439	.350	.554	1.29
Law enforcement	.708	.581	1.488	.223	2.03
Knowledge	.696	.457	2.326	.122*	2.007
Attitude	1.138	.461	6.105	.013**	3.12
Constant	-6.510	1.260	26.678	.000	.0001
Correctly Predicted 85.6%	Poor Practice 91.5%				
Good Practice 75.3%	Chi-square value 134.88				
Sample size 222					

Note: \*\*\*, \*\* and \* are significant at less than 1% and 5% and 10% probability level respectively.

Source: Model output

Sex of household head (SEX) -In the study areas, the female-headed households are higher likely to discharging pollutants to Akaki River compared to male-headed households. The sex of the household was statistically significant at 1% significance level. The odd ratio of bad practice of female-headed household was higher by a factor of 0.129 compared to male-headed households.

Education level of households (edu) - the education level of households was found to have a significant ( $p < 0.05$ ) influence on discharging pollutants to Akaki River practice. The predicted result of the binary logistic regression indicted that holding other factors constant, going from no formal schooling to primary school ( 1-8) decreases the odds of having bad practice by factor of 1.142 compared to those who have no formal schooling. In addition, when educational status of the respondents going from no formal schooling to secondary school, it decreases the odds of having bad practice by factor of 2.552 compared to those who have no formal schooling. When educational status of the respondents going from no formal schooling to diploma and above it,

decreases the odds of having bad practice by factor of 4.739 compared to those who have no formal schooling.

Household family member size (FAM siz)-As the model result indicates, the variable of family member size had statistically significant influence on discharging pollutants to Akaki River at 1% significance level. The study found that household with more than five family members are highly likely to have poor practice than those have less than five family members. The odd ratio of the households with family member more than five was higher by factor of 3.952 ( $p < .002$ ) compared to households with less than five family members.

Living years along the river (liv.yr)-As the years of living in 30m radius along the river sides gets increases, the probability of having poor practice in discharging pollutants to Akaki River gets increased. the estimated result reveal that living in the area for more than five years had effect on discharging pollutants to Akaki River at 10% significant level. If a household live in the area for more than five years the odds of having poor practice gets higher by factor of 2.810 compared to those households live in the area for less than five years.

Solid waste management facility/service (solid)- the binary result show the Accessibility and affordability of proper solid waste management facility and service in the Akaki river bank settlements up to 30m radius adjacent to the river sides had significant effect on discharging pollutants to Akaki River of households at 10%Significance level. Households able to afford and access proper solid waste management service which may be municipal solid waste management service are less likely to compare with others. This confirms that respondents who are unable to access or afford the service and facility was 2.00 times more likely to contribute to the Akaki river pollution compared to those able afford and access the facility/service. The study conducted by Adane (2014) stated that the large amount of solid waste produced, coupled with ineffective means of collection and transportation, and is a major contributor to river pollution as leachate carried out during the rainy season enters surface waters in the region.

Liquid waste management facility/service\_ in 30m radius of Akaki river bank the households whom unable to access and afford proper liquid waste management facility was found to have a effect on their practice of discharging pollutants to Akaki River at 1% significance level. When households unable to access and afford the liquid service/facility the odd of having poor practice

increased by factor of 5.761 compared to those households able to access and afford the service facility.

WASH-The Hardware part of WASH facility which is having improved and unimproved toilet system statistically significant ( $p < 0.036$ ) influence of households in Akaki river bank. Households had Toilet systems which are shared with other households and directly dispose to open field/river, not pit toilets with unsafe system in very nearest area of the river and houses are highly likely to have poor practice that discharging pollutants to Akaki River by the factor of 3.73 compared to them have improved toilet system. On physiochemical and heavy metal concentration studies of Akaki River in this research as well as research from (Ashenafi, 2018) the Akaki river water quality shows Fecal and fecal viruses a mixture of contaminants encompasses heavy metals and pathogens which enters to the river from sewage disposal. These chemicals, like fecal viruses, are good index of wastewater contaminant.

Service for discharging /emptying toilet- The ability of accessing to use toilet emptying municipality service by AAWSA and the affordability capacity of households to use the service in the study area shows a statistical significant effect on the household's in discharging pollutants to Akaki River at 1% significance level. Then the odd ratio of households not to able affords and access to this service was 7.178 times higher to have bad practice than others able to access and afford the service by factor of 7.178. Previous research result reported by Teklehaimanot (2015) due to the intermittent sewage collection and inadequacy of the service in the city, septic tank overflow is a major problem. In addition, abused sewers are used as sewage pipes to collect and transport sewage which is major contributor to Addis Ababa rivers pollution.

Knowledge- Knowledge of households on Akaki river pollution causes and impacts as well as solution in this study shows significant effect on the households in discharging pollutants to Akaki River practice at 10% significance level. This means the probability of households having poor practice with having poor knowledge on Akaki river pollution is higher than having good practice. The odds ratio of poor practice of households with poor knowledge was higher by factor of 2.007 compare to households having good knowledge. Workine (2020) on his study highlight that the lack of information on behaviors amongst distinctive stakeholders on River pollution issues are one of the issue in protecting rivers from pollution and mentioned that the stakeholders

knowledge and attitude along with their practice needed to be studied sufficiently to apprehend the intensity of the problem solutions. Therefore understanding the stakeholder community members on river pollution is one of the important steps in long and short term mitigation and adaptation measures.

Attitude- Based on result of regression Analysis the Attitude of households on river pollution having favorable Attitude and Unfavorable Attitude on Akaki river pollution shows a statistically significant ( $P < 0.001$ ) effect on discharging pollutants to Akaki River. Households with unfavorable attitude highly likely to have poor practice than those households have favorable Attitude. This means the probability of having poor practice of households with having unfavorable Attitude is higher than favorable Attitude. The odds ratio of having poor practice of households with having unfavorable Attitude was higher by factor of 3.12 compared to favorable Attitude households. The study result by Mohammed (2020) Understanding the peculiarities of different stakeholders can therefore help to address the complexities of managing river water resources. Local people, who are also major users of river water resources, contribute to the social environment. It may give you a better understanding of the situation. A study by Anetor (2013) showed that there was a strong positive relationship between environmental awareness and environmental attitude and their practice among the communities.

#### **4.10 Interview with industries environmental quality officers**

According to discussions with Addis Ababa Environmental Protection Authority and Pollution Control head, EPA has identified major polluter industries, and with that in mind, Addis Ababa Tannery, Awash Tannery, Batu Tannery, and KK Textile Factory was interviewed from the list of listed industries.

- ✓ Type of solid, Liquid Hazardous wastes from industries and their managements (treatment plants, disposal methods).

According to Awash Tannery Quality

“In Tannery industry huge portions of water and distinctive chemical substances were used in the course of tanning system and different solid, gaseous and liquid wastes are generated which have

an adverse impact at the Akaki river environment. These wastes have distinctive traits because numerous number of chemical substances are implemented to the uncooked hides in different ratios. Solid wastes generated in tanneries particularly consist of salts, uncooked trimmings, hair wastes, Fleshing's, splitting wastes, chrome shavings, buffing dusts, crust trimmings and completed trimmings and. Generally the whole system of tanning is often observed with the aid of using the intake of huge volumes of water and with blending water the tanning system generate liquid wastes with heavy poisonous chemical substances like nitrates, acetic acid, soaps, and heavy metals like copper, lead, cadmium, mercury, nickel, and cobalt, Arsenic, chromium (Cr), sulphides (S<sub>2</sub>) and sure auxiliary chemical substances”

The Addis Ababa tannery Forman as well list the same type of wastes additionally he mentioned.

” Typically, from 1,000 kg of rawhide, about 800 kg of solid waste is generated in the leather manufacturing industry, and only 200 kg of raw material is converted into a usable product.”

He also mentioned:

“Rawhide processing tannery effluent, the wet blue, crust leather or manufacture finished leather, in most cases contain trivalent chromium compounds (Cr) and sulfides. Organic and other ingredients are responsible for high BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) values and represent an immense pollutant load.”

On assessing the type and amount of generated solid and liquid wastes from industries it is most common in most industries to generate very toxic and huge amount of wastes that are needed to dispose in a very careful ways.

The Quality control of KK textile factory about the type of waste that are created in process were asked expressed

“Since the factory most waste generation is from dyeing process but the other process of the factory are Dry process which means does not need adding of chemicals, doing the dyeing of fibers is only have significant liquid waste generation amount. In the case of the Akaki KK textile dyeing process, color is added to the fibers during the dyeing process, and various chemicals may be used to improve the adsorption process between color and fibers. When the finished product is ready, some of the dyes and chemicals become part of the textile industry effluent. In this particular case,

hazardous toxic waste Color and organic chemicals from dyeing and finishing salts, sulphur, naphthol, vat dyes, nitrates, acetic acid, soaps, and auxiliary chemicals are present in effluents. However, soft fiber wastes, hard fiber wastes, beaming wastes, off-cuts, packaging, spools, and creals wastes generated as solid waste from the general process."

As well KK textile Factory mentioned also

"Depending on the type of dye used specific water consumption for dyeing ranges from 30 to 50 liters per kg of cloth. The dyeing section accounts for 15% to 20% of total waste water flow. Water is also required for washing dyed and printed fabric, as well as for achieving washing fastness and bright backgrounds. Washing agents such as caustic soda-based soaps, enzymes, and so on are used for this purpose. This cleans the substrate of excess color and paste. Water is also required to clean printing machines in order to remove loose color paste from printing blankets, printing screens, and dyeing vessels."

According this interview it is concluded that industries process to convert raw materials to final goods they had used very toxic chemicals and used lot amount this process by itself needs very careful way of waste disposal practice. It is observed that the nature of the contaminants present in industrial wastewater depends on the type of the factory and the industry. Wastewater from various industrial sectors contains many pollutants that are toxic and have hazardous effects on human and aquatic life as well as on agriculture. Such pollutants include heavy metals like chromium (Cr), zinc (Zn), lead (Pb), copper (Cu), iron (Fe), cadmium (Cd), nickel (Ni), arsenic (As).

#### ✓ **Industries Waste management and Akaki River**

The Quality Head of Awash Tannery mentioned that

"The chemical characteristics of wastes determine how they are disposed of and valorized, depending on whether they are generated in a beam house or after tanning. This distinction could be between untamed and tanned wastes. Before being discharged into the collection network, waste water generally passes through a primary treatment plant, whose role is to remove large particles while also significantly reducing the content of chrome and sulphides. To adjust the pH, To significantly reduce the BOD/COD load and thus simplify and reduce the cost of the

biological treatment phase before proceeding to the secondary treatment plant, the main goal at this stage is to further reduce the amount of organic (expressed as BOD) and other substances still present in the effluent after the primary treatment and thereby satisfy the standards/limits for discharge into Akaki river. On solid waste disposal the Forman mentioned they use private solid waste collectors which they have collect every day.”

The Addis Ababa Tannery Forman, Batu Tannery Quality Head and KK textile Industry Quality Head as well mentioned the same steps. Though for Questions of how you treated highly oxidized chemicals all industries representatives replied they used nothing special treatment for very toxic substance they just discharged with liquid waste and though Batu Tannery mentioned they have Drying the chrome and disposing it as solid waste using private sectors. The industries representatives were interviewed

On the quality checking of waste water and From the interviewee most of them have expressed that The temperature, pH, electric conductivity (EC), and dissolved oxygen (DO) of the waste water of industry were measured on the industries facility but for further waste water quality test they are sending their samples abroad or other facility centers in every two or three months. As well the expert from Batu and KK textile factory mentioned that they buy some Biological Bacteria’s to treat the waste water since these bacteria’s neutralize the very toxic chemicals in wastes. but the issues is that this bacteria’s still remained in waste water after neutralizing the toxic chemicals and the waste water with partially treated this bacteria discharged to the Akaki river.

According to the interview from the industries, the industrial waste management practices of the industries show that industries in some way follow industrial waste disposal methods. KK Textile and Awash Tannery recycle solid waste, but none of them use waste reduction or avoidance technique

Table 23: Textile industries process

Industry Names	Land Fill	River dumping		waste recycling		
		Solid	Liquid	Solid waste	Liquid waste	Waste reduction

Addis Ababa Tannery	No	No	Yes	No	No	No
KK textile Factory	No	No	Yes	Yes	No	No
Awash Tannery	No	No	Yes	Yes	No	No
Batu Tannery	No	No	Yes	No	No	No

All industries have established waste water treatment plants; none of the industries have recycled liquid industrial waste. All interviewed industries explained that Recycling waste water for the industries process would be very expensive and the technology in Ethiopia is not there yet .therefore out of cost and benefit analysis they did not prefer to recycling the water.

Exclusively KK textile mentioned

“In Ethiopia rather than treating waste water and recycling having dip or dug wells are cheap plus Water Is cheap in Ethiopia so why we considering recycling the waste water”

From the interview it is observed rather they practice of discharging partially or fully treated waste water by way of canals or directly to the Akaki River Commonly known as ocean dumping is applied by all of the industries. Waste management Only the Awash Tannery Industry and KK Textile engage in waste exchange. It is a good practice to market waste to those who will use the waste as raw materials for other processes. These industries use chemicals that are highly pollutant of the water source physical and chemical behavior and the need of treating the waste water quality in its color, odor as well as its chemical quality is mandatory if we need to keep the water sources safe.

#### ✓ **Challenges of Industries in Waste management**

According to an interviewee from KK textile quality head expert mentioned in the existence of insufficient equipment and facilities for waste water treatment, that

“Effluent methods are classified as physical, chemical, and biological. Using only one of these three methods has proven insufficient for removing color and other effluent from dyeing process

wastewater. While some dyes are difficult to biodegrade, a small number of dyes, particularly hydrolyzed reactive and acidic dyes, are not readily absorbed by active sludge and thus escape treatment. The resulting effluent is typically colored. However, the EPA standards for waste water discharge to water sources do not include a color standard, so industry experts in quality stated that they did not care about the waste water color at all and discharged it to the river with very black waste water. In future the industry planned to have Combination of various effluent treatment methods that can remove more than 85% of unwanted matter.”

Regarding toxic waste removal, the kk textile expert stated unequivocally that

“There is no facility, technology, or technical guidance in Ethiopia for dealing with expired toxic chemicals. The scope of the problem in Ethiopia is dramatically high and significant, with over a lot of tons of toxic wastes, much of it over 20 years old, being stored in the kk textile industry. This can lead to high pressure being generated in the containers, which can sometimes explode and corrode the container. It becomes more serious when they are handled by unprofessional or untrained people, particularly during storekeeping, and this concerns them.”

According to the expert, they have frequently reported to the EPA, but there is currently no solution. Storage and transportation of these chemicals present significant hazards to those working nearby therefore some industries release the expired chemicals directly to the Akaki River.

All the tanneries have primary wastewater treatment plants that filter and treat most of the hazardous chemicals and heavy metals before discharging into the rivers. However interviewee from Addis Ababa Tannery industry responded that advanced technology followed in developed nations are not available and feasible in developing nation due to this Addis Ababa tannery industry waste water treatment facilities have backwardness of the technologies. The Forman expressed that

“The industry waste treatment plant have not adequate capacity and performance in waste treatment but due to financial limitation we still used this low performance treatment plants for treating waste water discharged to Akaki river.”

Batu Tnnery industry as well interviewed on challenges of waste water treatment and disposal and the expert mentioned

“Due to a lack of laboratory facilities and trained professionals for waste water quality testing and chemical control, determining whether waste water is within acceptable standard limits and whether a chemical can still be used after its indicated shelf-life has expired is difficult. Inadequate labeling and the absence of a manufacture/release date on labels or on the container may complicate matters.”

All industries mentioned their difficulties in dealing with industrial waste. The major obstacle, according to all industries, is a lack of financial resources and trained personnel. In addition to the aforementioned challenges, Addis Ababa Tannery cited a lack of space as a barrier to implementing proper industrial waste management practices.

✓ **How is the collaboration with stakeholder government bodies on keeping the Akkai River from industrial pollution?**

Key informants were asked during interviews about current procedures for working with various government agencies to address the issue with the water quality of the Akaki River caused by industrial wastes.

An interviewee from all sampled industries explained that the collaborative practice that has been exercised by responsible sectors concerning the issue of surface water quality management, support and technical guidance in waste management is weak. So far, there hasn't been any consistent, transparent, or frequent follow-up communication.

#### **4.1.1 Interview with government stakeholders officials**

In Ethiopia, various entities have various responsibilities for managing the quality of surface water. These organizations range in size from the federal to the local. Depending on what interests them, they serve different purposes. Some work to develop water resources, while others are regulatory agencies, and the other ones are service providers. To determine the suitability and effectiveness of these institutions for the management of surface water quality, key informant interviews have been conducted.

### ➤ Profiles and responsibilities of Stakeholder Government offices

The EPA authority was established in 1985 by Declaration and again updated in 2014. Their mandate is classified into two. Pollution control and natural resource protection the pollution control mandate include the: laboratory testing, environmental impact assessment, pollution, and ECRG. Natural resource protection that includes forestry, mines, and rehabilitation through Ratifying and Distributing Seeds. The office's general responsibilities include developing water pollution control declarations, regulations, and action plans at the local government level. Give projects ESIA clearance and monitor its implementation, examine industries' environmental practices, and take administrative and legal action against those who flout the law. frequent monitoring and evaluation of the river's water quality at the municipal level, increase societal understanding of environmental conservation and garbage management.

The AAWSA Office has Mandate and responsibility on picking up liquid waste and treating liquid waste. The first one is the modern sewerage system, which includes collecting liquid waste from individual households with pipes provided in a three-meter range from their fences. This takes a small coverage of total liquid waste in the city. The other is vacuum tanks, which are sent to the Kotebe wastewater treatment plant and receive only sludge from vacuum trucks that empty septic tanks. Accordingly to an interviewee from AAWSA expert,

“Currently, fewer than 10% of the city's liquid waste is treated or disposed of by the organization. When normal ways of providing waste management services are unavailable or not convenient in undeveloped regions, it is up to individuals to manage waste.”

The office is also in charge of supplying the city of Addis Ababa with clean water, monitoring the provision of drinkable water to Addis Ababa, constructing a sewerage system for Addis Ababa, Responsible for the overall management of domestic and municipal wastewater, Collecting and handling sewage, conducting research on the many water resource concerns in the city.

According to officials their mandate also was awareness creation and monitoring.

The selected sample sites Sub cities and wordas job under the environmental division is pollution monitoring and control expert. Identified pollution releases were from institutes, industries, and

service providers like hotels and producers. They take compliments, monitor the sites, and take action.

➤ **Perception of Key stakeholder's government offices on Akaki river water quality**

The Interview continued with asking official about the general believes on Akaki River as an expert from AAWSA

“It is difficult to call Akaki river as river rather it fits to be called Sewage since there is sewage that doesn't find its way to their treatment center. One example could be above Arat Kilo where there is no proper sewerage system and therefore sewages are disposed to the river illegally. but the AAWSA has no part in the pollution of the rivers in Addis Ababa city. The waste they receive would not be discharged to the environment if it did not fit the standard.”

The kaliti waste treatment plant can treat hundred thousand liters of waste per day within a standard, which is the second largest in Africa, which then discharges downstream. Out of the parameters they check, only the biological parameter is not done because the downstream of Akaki river water usage is for irrigation purposes only and since it is the Akaki River is not preferable for drinking purposes.”

EPA Expert as well mentioned how she think of Aakki river and

“Akaki River have exposed more from Industries waste water rather than municipal wastes. Due to the presence of lead, arsenic, and chromium on starch vegetables such as potatoes which have been irrigated by Akaki River which are carcinogenic, can cause adverse health effects. Deformed animals and skin rashes on kids are some of the observed effects. Therefore the River has lost its Value for household or livelihood Activities.”

➤ **Key stakeholders Governments role and responsibility on Akaki River**

The interviewed official from EPA, only deals with environmental pollution control. Their work activities include pollution monitoring and control in Addis Ababa. It takes compliments from society and takes action. The second activity is an environmental audit, which assesses how industries or any facility are working with the environment. Lastly, they perform assessments on industry effluents that discharge to Akaki river. They take routine laboratory checks, give

feedback, and take actions ranging from a warning to sealing the polluting body. The complaints that come from society mainly focus on sound pollution rather than environmental pollution.

The EPA expert expressed that

“The major contributors to the pollution of Akaki river are factories within the city.”

They test BOD, COD, and chromium, nitrogen for checking the wastewater. They perform pollution control at point sources as their mandate does not include non-point sources. When asked about the color standard, the official replied that

“There is no standard present. The color comes from dyeing in two ways; those that have chemicals and those that don't have them.”

AAWSA experts expressed that As a stakeholder on the Akaki river the office perform water quality test and Water samples taken from Akaki river have shown higher BOD, COD, and TDS characteristics. This has been attributed to the illegal release of sewage into the Akaki River. As an institute, they found it difficult to treat these non-point wastes in the river.

When asked AAWSA official about the services they provide to the informal settlements in the Akaki River, the official replied that

“No service is given to the settlements to encourage them. Those who have a permit from the authorities can collect sewage from these places, and they will get an inspection of whether or not they collected industrial wastewater since it will affect the bacteria medium in the treatment plant.”

When asked about their responsibility on creation of awareness about the harmful impacts of liquid waste on the river,

“The official states that most people are concerned about the utility they get from the authorities rather than the proper sewerage handling process but mentioned that always when their staffs are on reading water bills they use flyers to create awareness on good waste management practice. Public education through the media has been used by the authorities on the Addis media network to promote the overall activity of the Addis Ababa water and sewerage authority.”

Authorities have created awareness for society, and collaborative ventures have also been carried out. The collaborative were the Ministry of Commerce and Industry, the ministry of culture and tourism, urban greenery and beautification bureau

On interview of Nefase selke Wordas the officials expressed that

“Their mandate at the woreda level is to protect riverside areas and the watershed. They are also working on protecting erosion. As the Nefas silk is located on downstream of the Akaki River, The collected wastewater comes from polluted urban sources. At the woreda level, they were only able to perform one clean-up service in the previous year. Inspect the site where compliments have come from and check whether the treatment is within the standard. There are collaborative agents at the enterprise level who assist in taking compliments and evaluating the pollution status. Training has also been given to selected potential polluters and collaboration with the health offices has taken place as well.”

The expert from this sub city also mentioned that

“The measures to keep the environment clean at the woreda level were plantation and picking up waste. The households near the river dump their wastewater into the river. Solid waste cleaning unions are collaborating with the woreda to collect solid waste. Previously, the health bureau at the woreda was working with the environmental protection division to monitor the impacts and pinpoint the source of the waste using a tester. Since the health bureau has moved out of the woreda and currently works under the sub-city administration, we could not follow up on the health issues related to pollution.”

Official as well mentioned

“Mainly, the primary usage of the river is for irrigation purposes.”

The official confirmed that there are plenty of farmlands in the sub-city.

Kolfea keraniyo officials expressed that

“As a bureau, they monitor discharges from industries at the outlet of the treatment plant. Also, discharge of waste that leaches into rivers from garages, they assessed the hazardous chemicals

present in the waste water with a private environmental impact assessment agent. They also conduct awareness creation and monitoring.”

➤ **Challenges of Key Government Stakeholders on Akkai river** According to AAWSA official The Challenge they faced was

“Lack of infrastructure, connecting sewer lines in sub-cities according to the master plan. The theft of pipes which lies 3m beneath the surface. The lack of industrial waste water being discharged in these pipes that are cut would be a challenge for treating.”

As well the AAWSA official mentioned

“The involvement of all stakeholders in addressing the water quality problem on Akaki River is weak. The concerned bodies are too weak to secure the participation of all stakeholders towards the management of the River. There is a resistance of different sectors and head of sectors for collaboration. These are the challenges that we have faced so far.”

On interviewee from EPA expressed that,

“Although the institution lacks resources like a modern laboratory for water quality monitoring and is heavily influenced by political intervention, the current institutional framework for the control of river water quality can be viewed as good. Although some institutions' duties conflict, it is not a particularly serious issue.”

The expert also brought up the issue of the responsible industries' significant leader and expert turnover. She came to the conclusion that institution heads had been changing often over the past few years. Due to this issue, the sector is unable to be managed effectively due to a shortage of skilled leaders. Professionals with extensive knowledge have also started moving to other institutions for greater relief. Due to these factors, government sectors are losing the ability to handle and address the complicated environmental challenges.

According to the official,

“Many requests for hazardous waste treatment are coming from various institutions. However, even in the national state or standard, there is no proper treatment of these wastes. A high-level incinerator was tried on, and hospitals were trying to treat them. But waste from pharmacies and

tanner factories is large. The waste was trying to be treated by sending it to countries like Finland. The challenges identified were that most industries are located in urban areas. One of the drawbacks was the failed treatment plant, which was expensive due to its infrastructure. Lack of cooperation between the state and the owners of factories “

EPA expert as well expressed that

“The major setback identified is politics. As the officials seal the polluting bodies, their bosses will avert the decisions. As well as a lack of involvement from the community is other challenge. In addition, officials proposed the lack of policies on punishing society for its wrongdoing as well.”

The industries were put forth by these officials as the major contributors of pollution to the Akaki River, and all of them agreed on the seriousness of the issue. From their response, they haven't received any feedback from society concerning any effects the river has had on them. We were told that they observed some of the industries improving their waste water treatment and some of them are still polluting the river despite continuous warnings from the sub-city environmental protection officials. Community inclusive awareness creation and training were conducted by these officials, some of them showing good signs, but still more work is needed.

Accordingly the expert the bureau was able to perform different physical, biological, and chemical parameters. But currently, they can only perform physical parameters. This is due to the limitation of the laboratory.

From the kolfeakernayio sub city officials

“The clean-up process depends on the willingness of the community to participate in the cleanup process. Volunteers participate in the activity too. The major issue was a lack of finance for the service.”

On the interviewee from the official expressed that

“A number of institutions have been set up at the Addis Ababa City level to deal with the pollution issue in Akaki water. These organizations have a variety of responsibilities, tasks, and interests when it comes to managing river water quality. According to my observations, these

institutions lack the financial resources, laboratory facilities, and qualified human resources necessary to address the current issue of the Akaki River's water quality. However, if they work together and pool their resources, they may be successful.”

The office as well mentioned on Kolfe keraniyo

“The division identified a lack of materials as a major challenge, as well as a lack of budget for activities, which is a common issue at the city administration and woreda level.”

The Nefase selk lafto officials state that

“There is a lack of cooperation and involvement from the community and different factories. Not only the water is polluted in the area soil pollution takes place as sewage and other liquid wastes containing a variety of pollutants passes through it. Some of the industries have a waste water treatment plant but not efficient in fully treating the waste water.”

Akaki kaliti environmental expert mentioned that the challenges that the office faced to do their tasks which is protecting the river environment.

“A lack of involvement from the community, lack of policies on punishing society for its wrongdoing as well. The industries were put forth by these officials as the major contributors of pollution to the Akaki River, and all of them agreed on the seriousness of the issue. From their response, they haven't received any feedback from society concerning any effects the river has had on them.”

We were told that they observed some of the industries improving their waste water treatment and some of them are still polluting the river despite continuous warnings from the sub-city environmental protection officials. Community inclusive awareness creation and training were conducted by these officials, some of them showing good signs, but still more work is needed.

The expert also expressed

“Few factories had asked a land to build waste water treatment which was provided and they performed better waste treatment. The rest discharges their wastes at night which is difficult to monitor for the officials even though they perform routine analysis on the discharge points from different institutes.”

As well the challenges identified were a lack of cooperation between the top officials and lower-level officials. Also, lack of manpower and budget. Informal settlements around the lake are a major setback for treating the river. The top-down approach is not suitable for cooperation.

The experts on Urban Beautification and Green Development Office also expressed that

“On office works with woreda level law reinforcements on fining the polluting bodies. The Informal settlements near the river have affected the route of the river and are putting stresses on the river getting larger and larger.”

According the wordas Key informat of Akaki kality sub city Urban Beautification and Green Development Office

“In recent years the new settlers on land adjacent to Akaki River have extensively cleared large part of forest area and irrigation field for constructing their habitation space. This dramatic conversion of land functions without any government approval has brought huge repercussion on the overall Akaki River environment.”

## **CHAPTER FIVE**

### **5. CONCLUSION AND RECOMMENDATIONS**

#### **5.1 Conclusions**

This study use observation supported by water quality monitoring and household surveys, KKI and then reflects three main findings.

First, Water quality assessment on Akaki River was conducted based on Physiochemical water quality parameters namely; temperature, pH, total hardness (Ht), total dissolved solute (TDS), conductivity, and heavy metals concentration in seasonal and spatial variation namely Fe, Mn, Cr, Co, Ni, Cu, Zn, Pb, As which shows relevant to indicate the Akkai river is polluted or not and its suitability of water for drinking and irrigation purposes in the selected four sites.

Those parameters were compared to threshold water quality. The quality of the River water at each sampling points shows, the quality of water was going down and exceeding the WHO and Ethiopian drinking water quality standards as well the FAO standard limit for irrigation purposes. Particularly, the presence of Heavy metals of Fe, Cr, Mn, As, Pb and characteristics of physiochemical parameters EC, TH, nitrite and nitrate, TDS in Akaki River water indicate that the River water is unsafe for drinking and domestic purposes and poses a threat to anyone who consumes these water sources without some forms of physical and chemical treatments.

Second the overall research finding revealed that the highly dilapidated and informal housing of arrangements, spontaneous population growth and the government's lack of consideration on the overall neighborhood WASH and waste management service/infrastructure have a negative impact and triggered more pollution on the Akaki river. The Availability of waste management facilities and the general Infrastructure status functionality was worst in Addis Ketema sub city when compared with other sites.

Third on knowledge and Attitude of stakeholders at household level on Akaki river pollution the majority of community stakeholders have poor knowledge's and Attitudes which contribute to their practice of discharging pollutants to the Akaki River.

Generally, all the above factors have contributed to the pollution of the Akaki River. Community and Industries Practice on discharging pollutants to Akaki river were influenced significantly by Poor socio-economic background of the settlers, compact and inaccessible settlement pattern and poor road and drainage, inadequate sanitation and waste disposal management facility/system, very narrow spider web foot paths, bad housing conditions with the community status of knowledge and attitude on river pollution causes and its impacts, solutions and finally has totally makes the Akaki river more polluted.

The industries alongside the Akaki River, waste management practice is generally not favorable for the Akaki river environment. The waste discharge to the river from the industries are not meet the country standaHamerd for the industrial liquid waste and both the government and the industries have their reasons to allow this which are the backwardness of technology, limitation of finance and poor collaboration among stakeholders, political influence.

## **5.2 Recommendation**

Based on the findings of the study, the researcher recommended that in the process mitigate further Akaki river pollution which could be including near-term coordination and longer-term mitigation responses, the WASH and Waste management facility, road (drainage) should be considered as underlying causes so the concerned government offices, donor agencies and individual wants to work on the improving the situation of the Akaki River recommended to improve the accessibility of improved infrastructure of WASH, Waste management, road (drainage) and their service. As well as, on stakeholders at household level awareness on the Akaki River pollution causes and its impacts and their responsibilities should be given by having community discussions and trainings.

It is necessary before industries are founded; it is preferable to think about their location, planned system, and waste management technologies, among other things. It is preferable to emphasize preventive measures than remedial ones. Industries that are already established may not be relocated to locations so for these industries recommended to upgrade the waste management

system. Along with the basic criteria, licensing agencies should consider the sort of product produced, the type of waste, etc. As well without any intervention from the EPA, or licensing organizations, industries have been discharging their trash. But because of this carelessness, the communities close to the industry are now in risk. There is a need for the industries to take corrective action. They, industries should focus on establishing connections with organizations working on the environment both domestically and abroad in order to cover knowledge shortfalls.

The general people need to be made aware of the hazardous substances that can be detected on vegetables cultivated in areas where dirty water is utilized for irrigation. These locations include the riverbanks along the Akaki River vegetable farms. The general public should be made aware of these specific locations and advised not to purchase the veggies grown there because it is obvious that dirty waters were used. The use of public media should be made for this. When people are aware of the harms caused by industrial waste, they may be less likely to purchase goods made by polluting industries. This could also result in the emergence of a social movement opposed to polluting industries and abhorring industrial growth that disregards society and the environment.

Government agencies that have an interest in the environment or public health, licensing agencies, and other organizations must collaborate honestly rather than acting alone. Institutions at the federal and municipal levels also advocated for giving enough financial and human resources to the sectors that uphold responsibility.

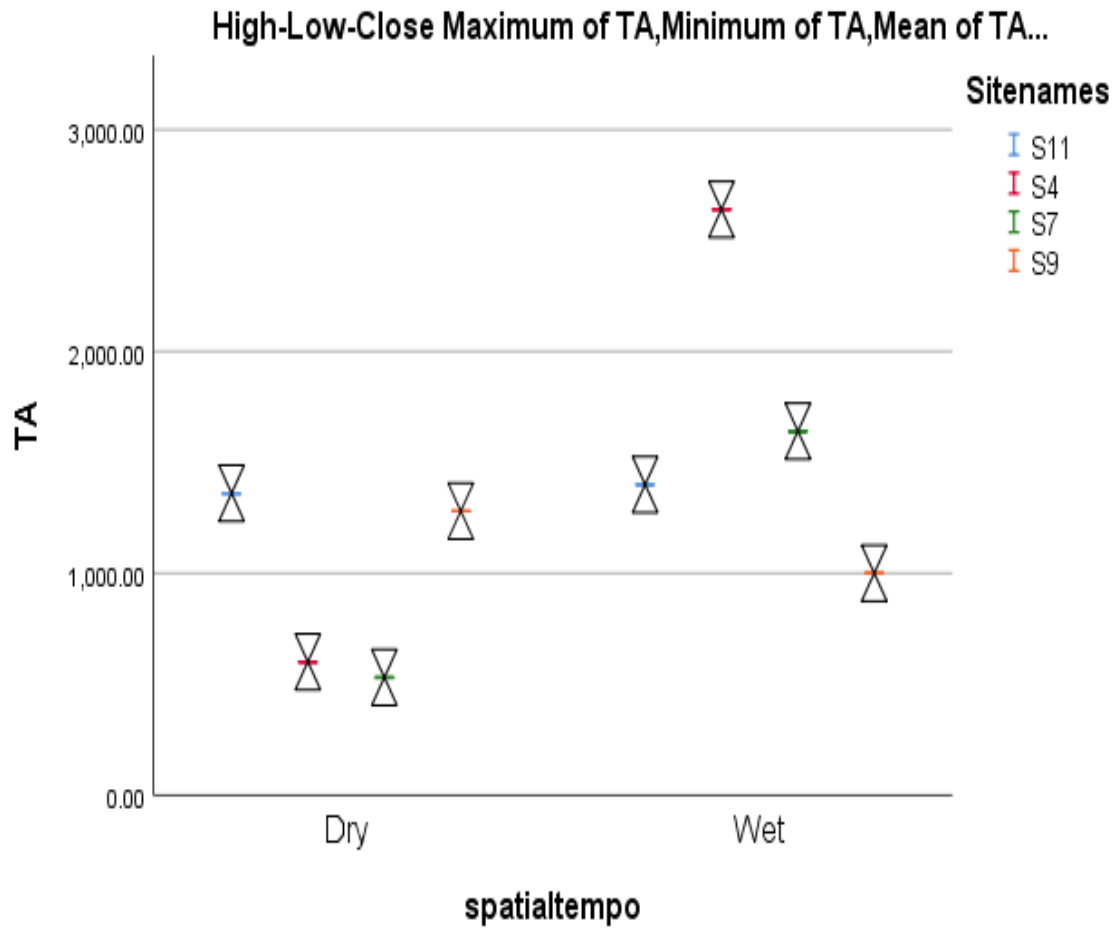
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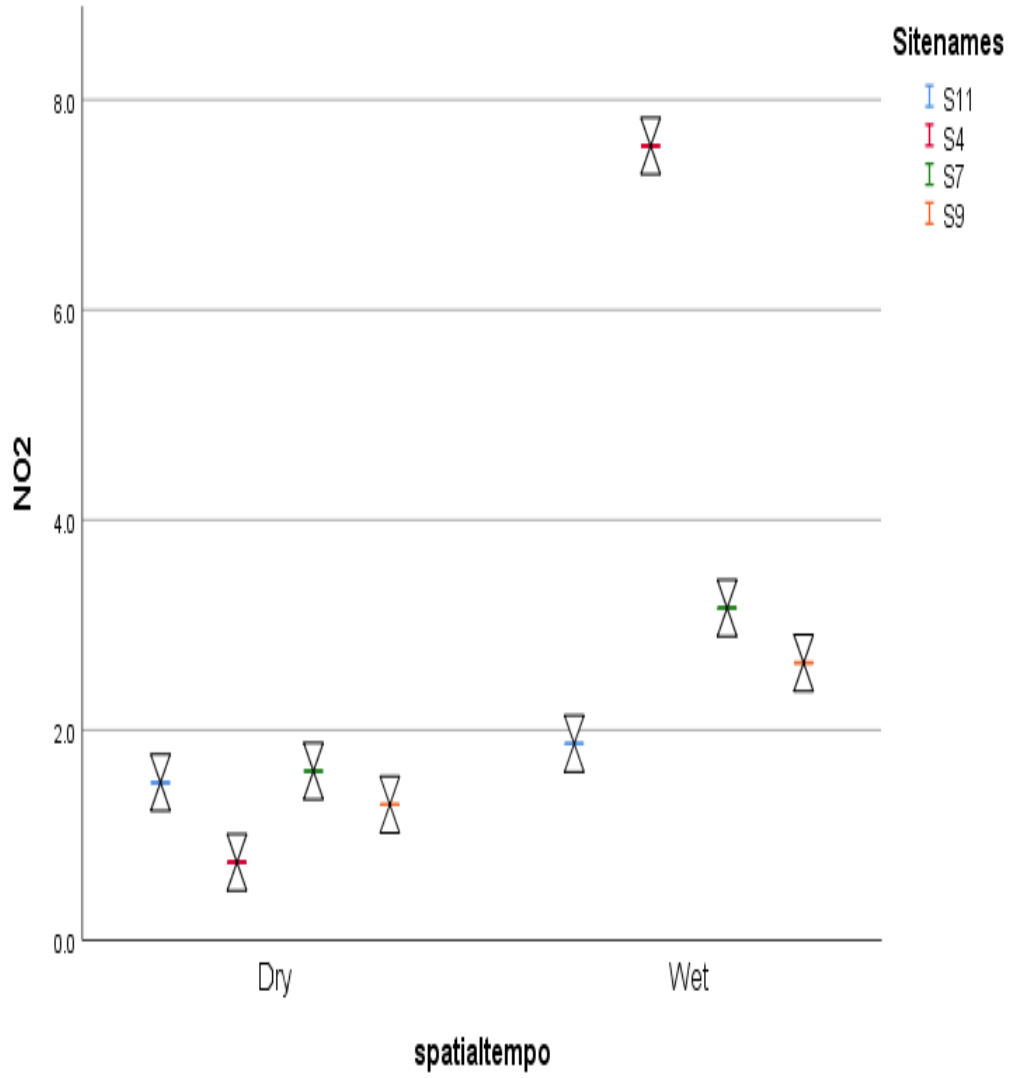
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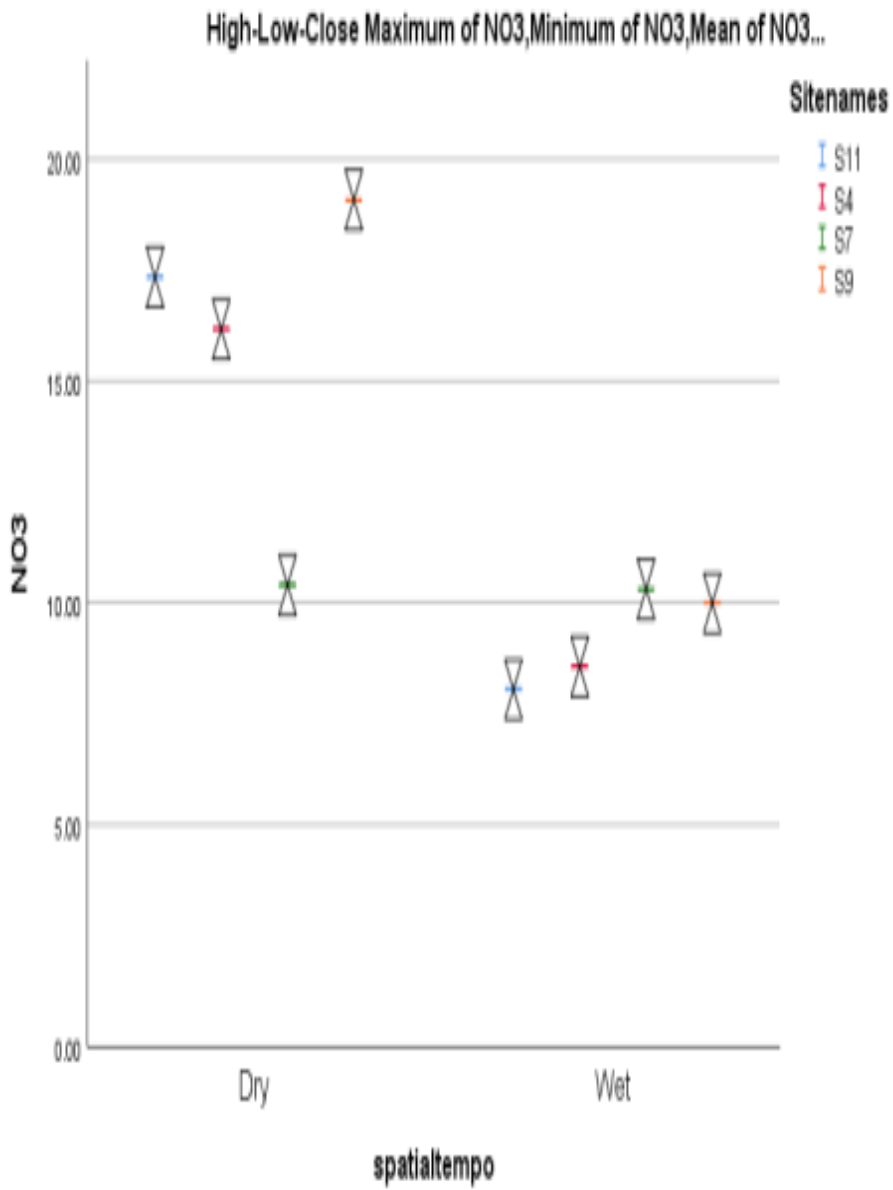
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# Appendix-I temporal spatial Physiochemical characteristics of the Akaki river at four sites

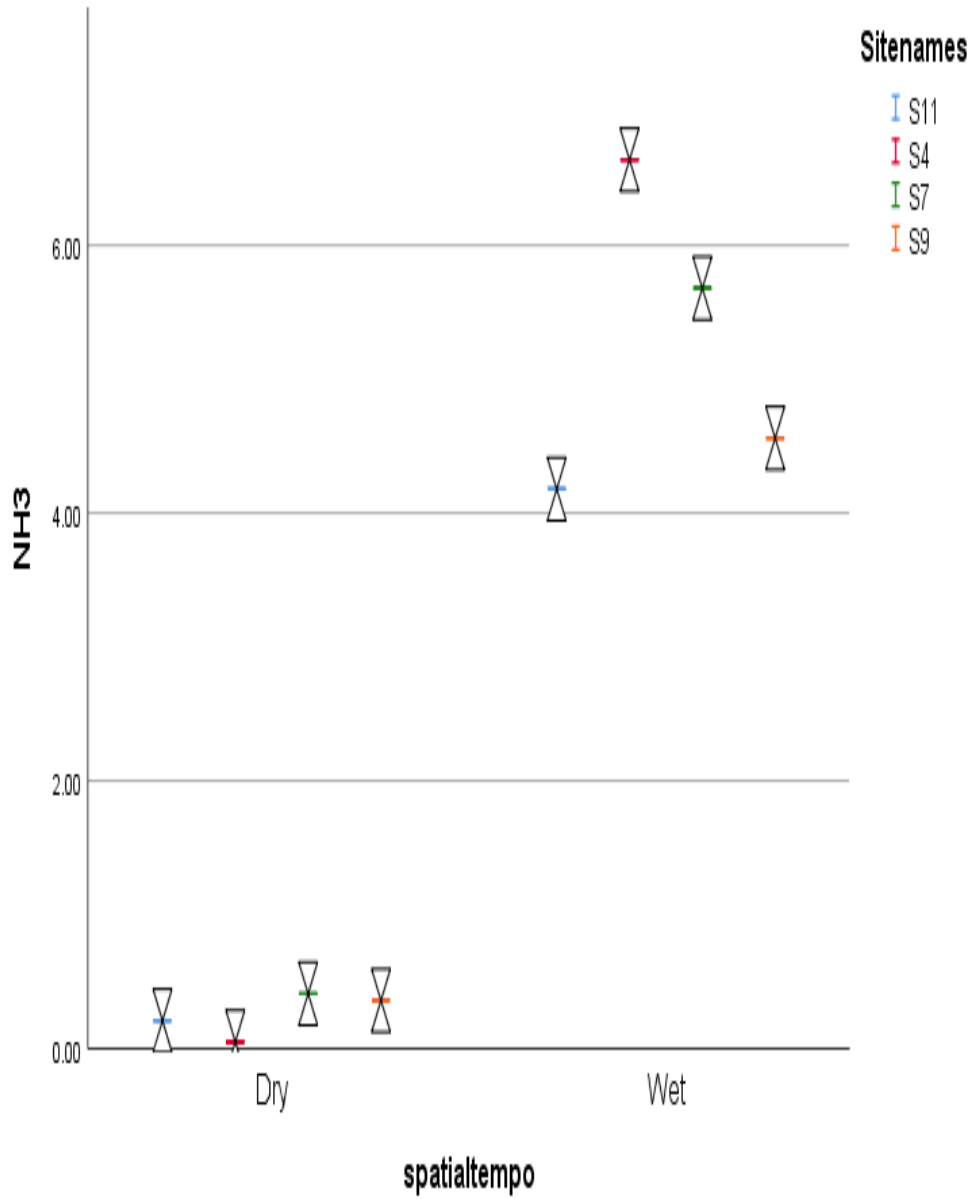


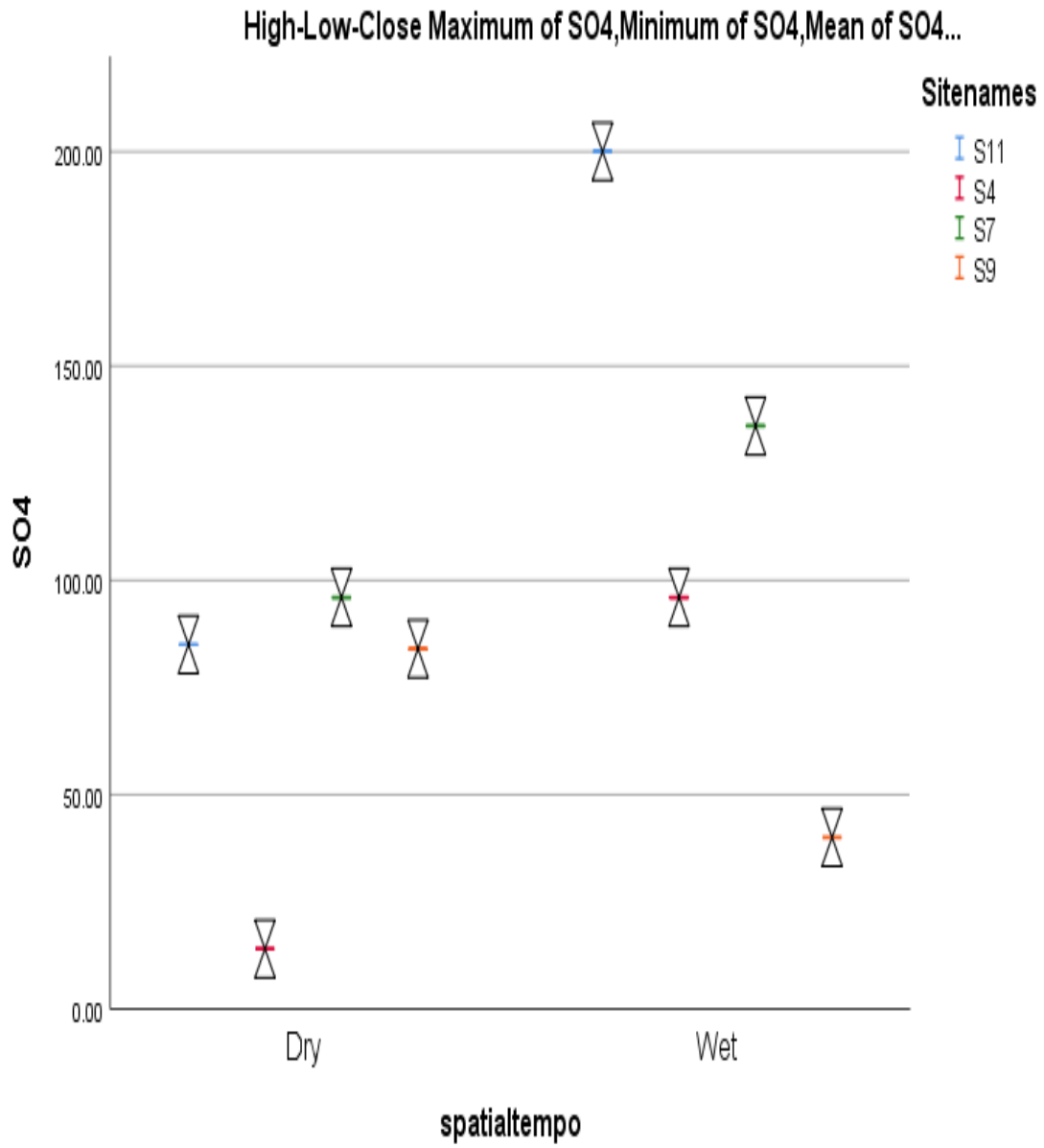
High-Low-Close Maximum of NO2,Minimum of NO2,Mean of NO2...



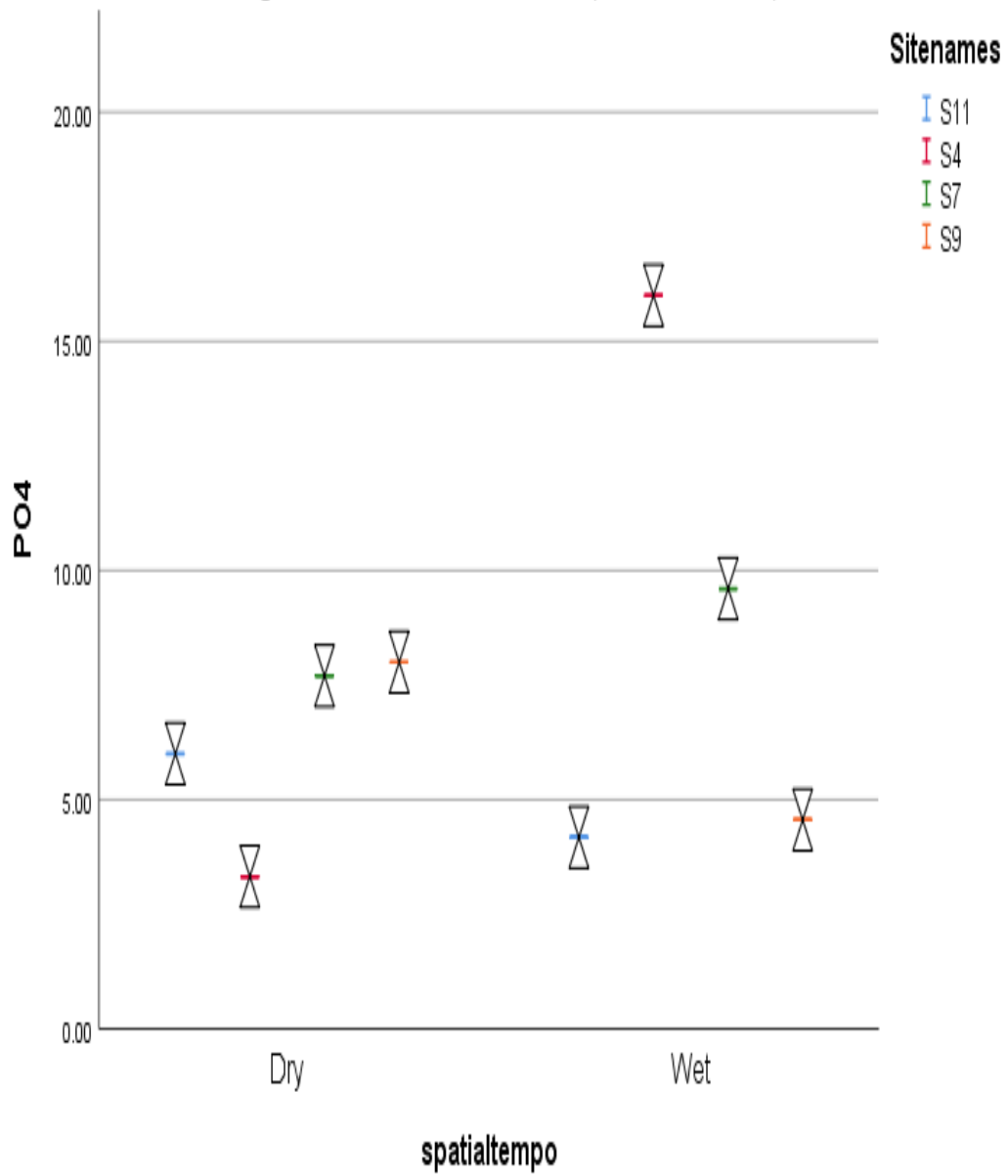


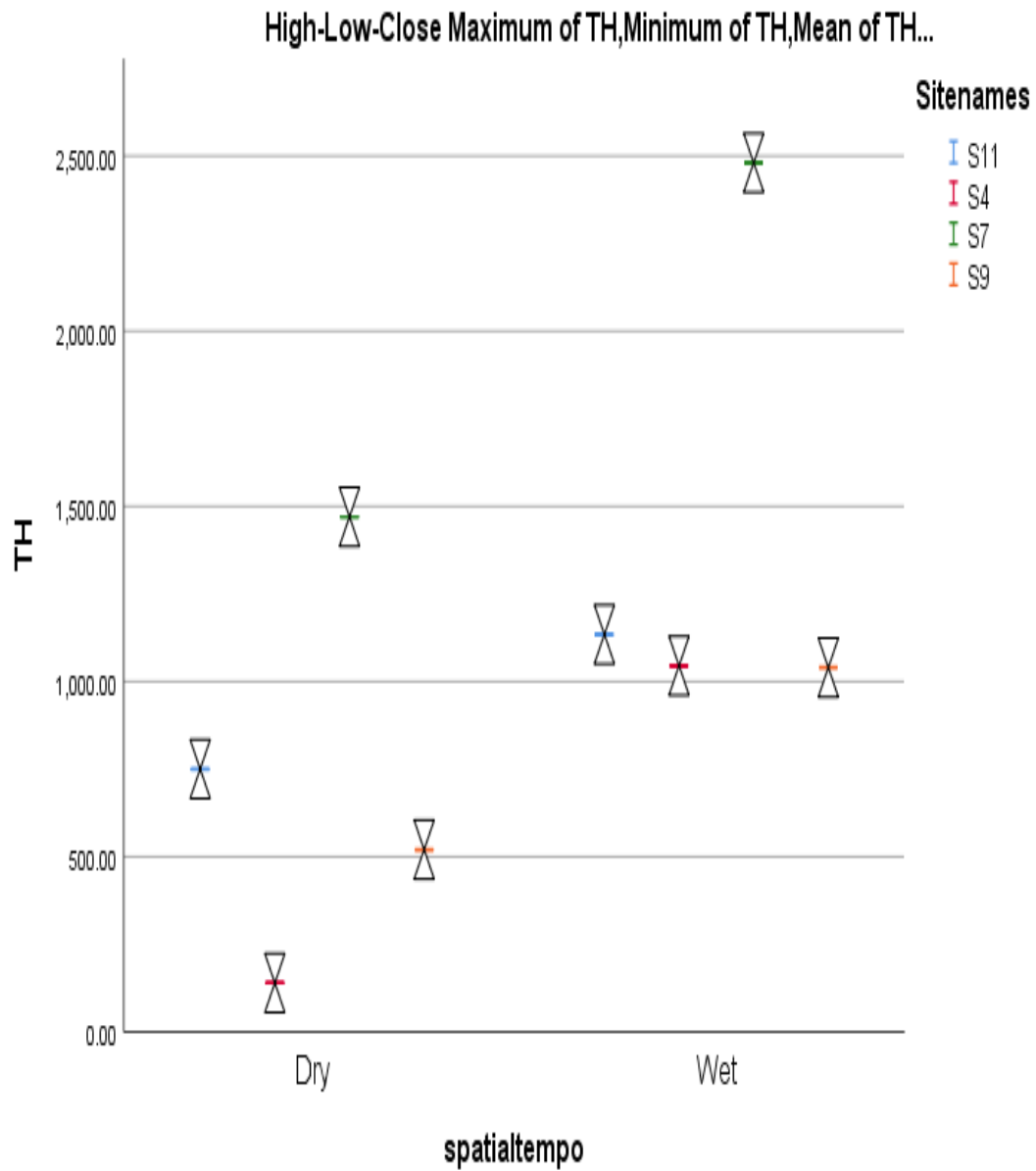
High-Low-Close Maximum of NH3,Minimum of NH3,Mean of NH3...

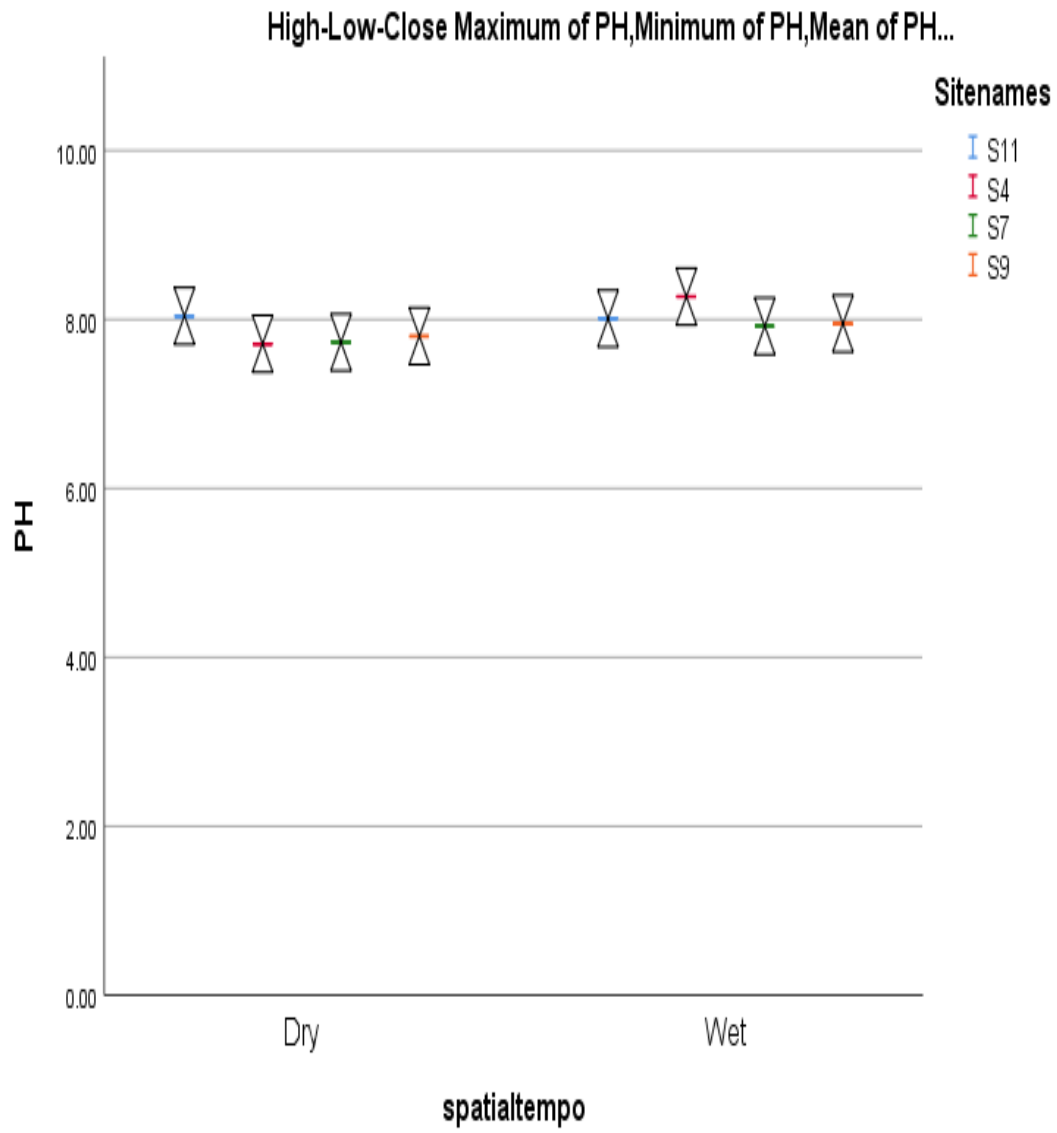


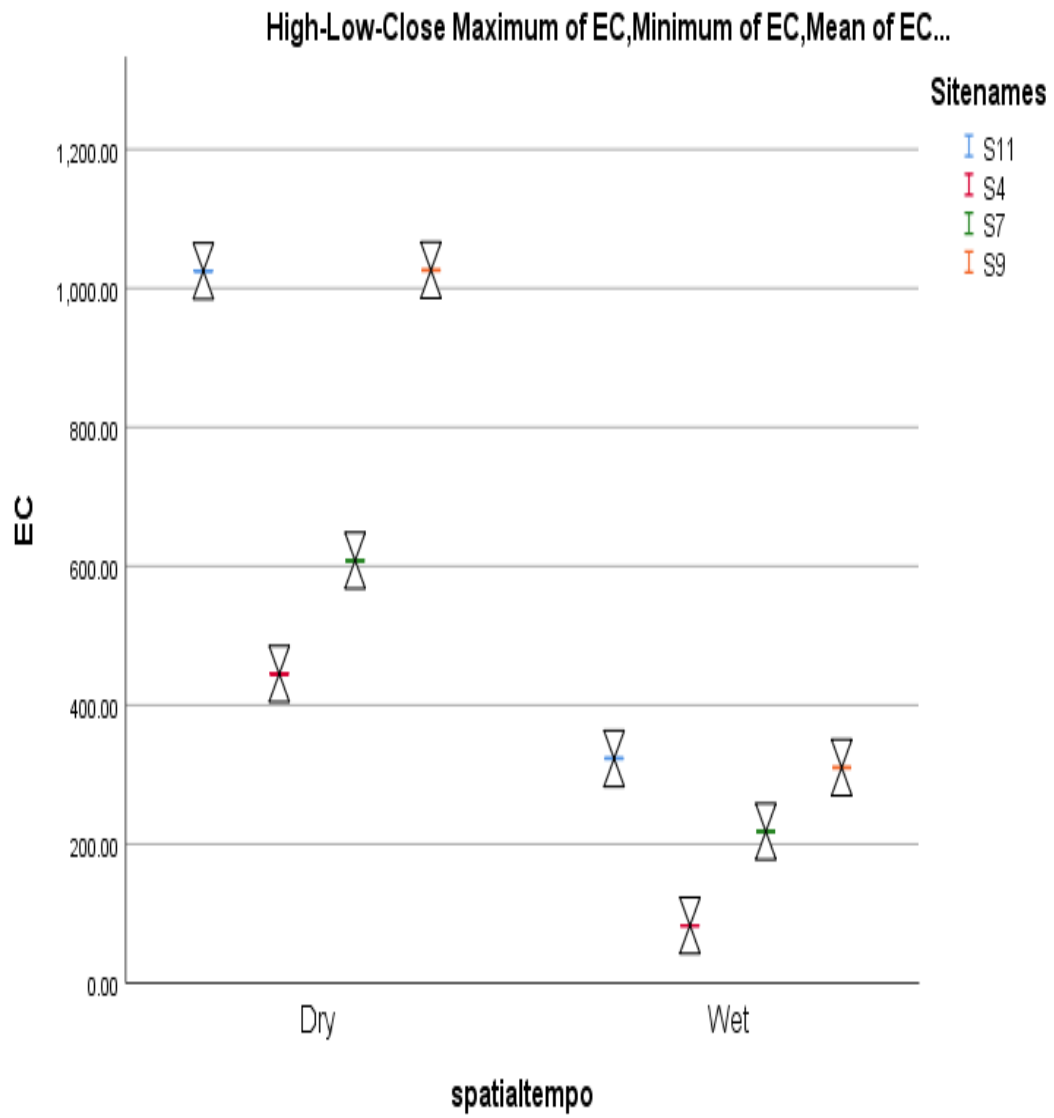


High-Low-Close Maximum of PO4,Minimum of PO4,Mean of PO4...

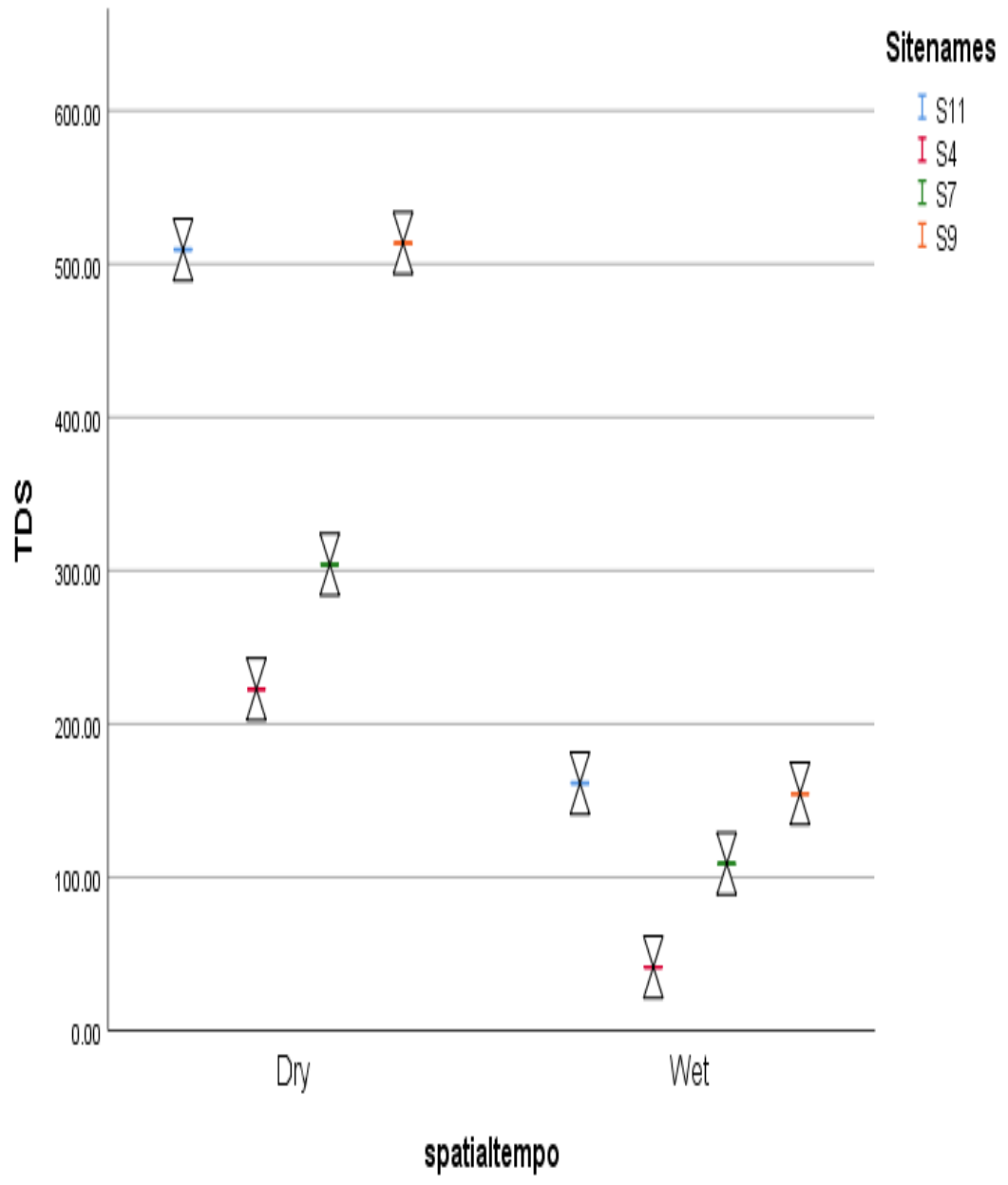




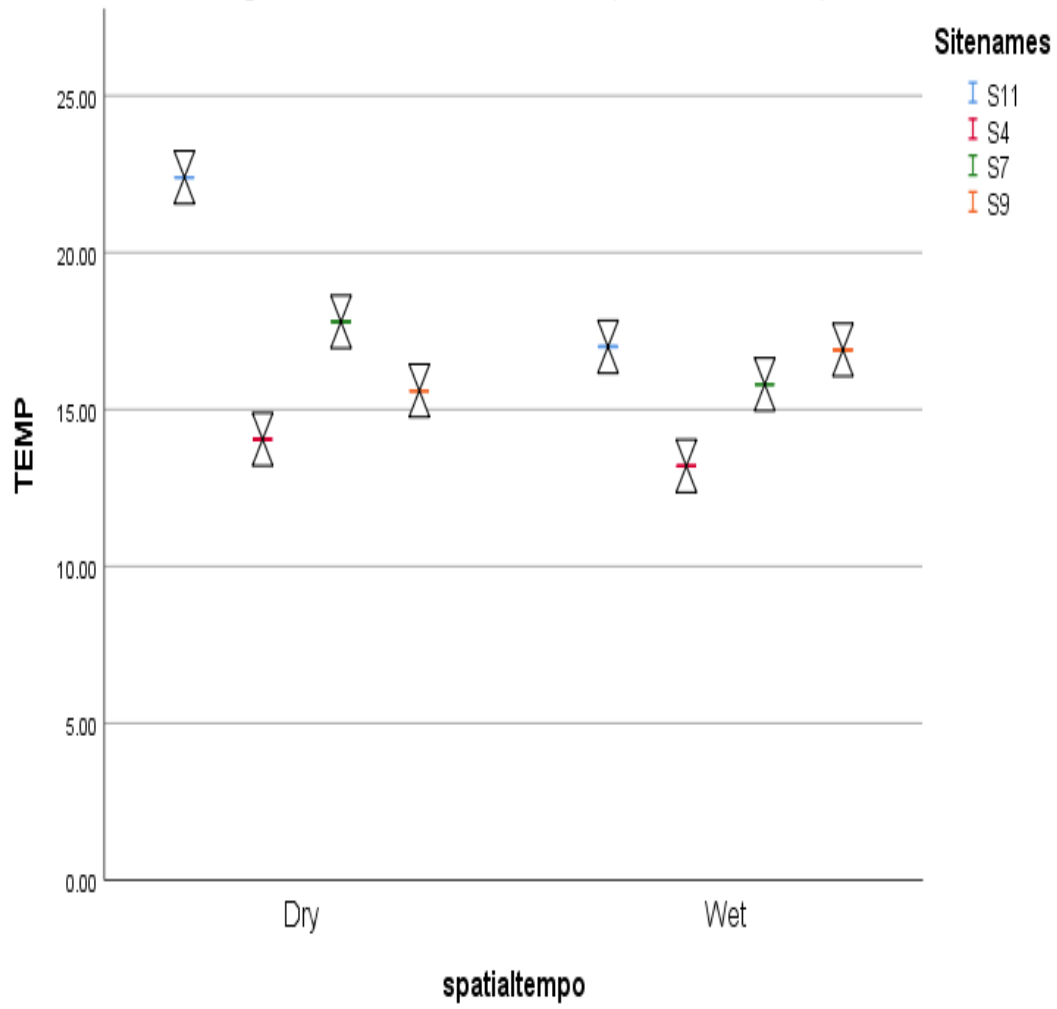




High-Low-Close Maximum of TDS,Minimum of TDS,Mean of TDS...



High-Low-Close Maximum of TEMP,Minimum of TEMP,Mean of TEMP...



**Appendix-II Heavy Metals concentration Standards limits.**

	As	Cr	Zn	Cd	Co	Cu	Fe	Pb	Mn	Ni
ES	10	50	5000	50		2000	300	10	500	
WHO	10	50		50		2000		10	400	70
FAO	100	100	2000	50		200	5000	5000	200	200
EU	10	50		100	50	2000		10	50	20

ES: Ethiopian Standards For Drinking Water Guidelines  
 WHO: World Health Organization  
 FAO: Food Agriculture Organization for irrigation water  
 EU: European Union Directives For Drinking Water Guidelines

**Appendix-III physiochemical Standards limits.**

EC	TH	TA	Temp	PH	TDS	TSS	Po4	So4
ES								
WHO								
FAO								
EU								

ES: Ethiopian Standards For Drinking Water Guidelines  
 WHO: World Health Organization  
 FAO: Food Agriculture Organization for irrigation water  
 EU: European Union Directives For Drinking Water Guidelines

**Appendix - IV. Variance Inflation Factors (VIF) of Continuous variables**

Variables	Rj 2	VIF(Xj)
Household head sex	.859	1.165
Age	.904	1.106
Education	.778	1.285
Family size	.922	1.084
living along the river	.791	1.265
Wealth index	.843	1.186
Access to proper solid waste management	.857	1.167
Access to proper liquid waste management	.804	1.244
Access to improved toilet system	.837	1.195
Access/capacity to afford emptying service for toilet	.775	1.29
Proper internal road and drainage	.832	1.202
Trainings/education/participations	.913	1.095
Law enforcement	.925	1.081
Knowledge	.864	1.157
Attitude	.922	1.0

## Appendix-V QUESTIONNAIRE (ENGLISH VERSION)

ID No-----

ADDIS ABABA UNIVERSITY College of Development Studies Environment and Sustainable Development A QUESTIONNAIRE PREPARED TO Stakeholder Assessment in Akaki river in Addis Ababa. (Aughest 2022)

We are here on the behalf of Water and Land Resource Center (WLRC). The main purpose of this study is to analyze pushing factors in discharging pollutants to Akak River by stakeholders. We want to find ways to improve the Akaki river situation, and it will help us understand who and when to prioritize spatial and temporal interventions in addressing the Akaki river pollution impact on the surrounding community. Whatever information you provide will be kept strictly confidential. The questionnaire will not include your name. You may be asked to provide some relevant documents for the study as part of the study. You have the right to withdraw from this study at any time, without having to explain why. We value your input in making this study a success. Do I have your permission to continue?

Yes  No

**I. Socio-Demographic Characteristics of households living along the Akaki River.**

No	Questions	Options	Remark
1.	Where is location of your house?	1.Sub city      2.Worda	
2.	How old are you?	_____	
3.	What is your gender?	1.Male      2. Female	
4.	What is your highest level of education?	_____	
5.	What is your Marital status?	1. Single      2. Married 3. Widowed      4. Divorced	
6.	How many people live in this household?	In Numbers:_____	
7.	Number of years you have been living in this river's surrounding	_____	

**Socio-economic and housing characteristics in areas**

Part I.	Questions	Code	Remark
8.	Housing ownership	1.Owned Formally 2. owned informally 3. Rented from Individuals 4.Dependent	
9.	Income source	1.Business/trade 2. crop production/Agriculture 3.Government/ Private firm employee 4.Remittance/	
10.	Other Income source of the family	1.No      2. Yes	
11..	What is your total net income per month?(birr)	_____	

12.	What type of fuel does your household mainly use for cooking?	1.Electricity 2. Wood/kerosine 3.Other	
13.	Electric mitad	1.Yes 2.No	
14.	Radio	1.Yes 2.No	
15.	Television	1.Yes 2.No	
16.	Refrigerator	1.Yes 2.No	
17.	stove	1.Yes 2.No	
18.	Mobile telephone	1.Yes 2.No	
19.	Table	1.Yes 2.No	
20.	Chair	1.Yes 2.No	
21.	Sofa	1.Yes 2.No	
22.	A bed with cotton/sponge/ spring mattress	1.Yes 2.No	
23.	Does any member of this household have a bank account	1.Yes 2.No	
24.	What is the main material of the floor in your household	1.Earth/ mud 2 Brick/ cement	
25.	What is the main material of the exterior walls in your household?	1.wood with mud 2 Brick/ cement. 3. Salvaged material/plastics	
26.	What is the main material of the roof in your household?	1.Metal / corrugated iron 2.Other	

27.	What is the main source of drinking water for members of	1.Piped water on premises or Public taps 2. Protected Tube ,dug wells or boreholes
-----	--	---

	your household?	3.Protected springs 4.Rainwater collection 5.Surface water /river 6.Unprotected dug well /spring 7.Cart with small tank/boti 8.Bottled water
28.	What type of sanitation facility arrangement does this family have?	1. private 2. Shared with the public 3 open space
29.	Your household toilet system	1.directly connected to pit/septic tank a 2.directily connected to river/open field
30.	What kind of toilet facility do members of your household usually use?	1.Flush/pour flush 2. Pit latrine with slab 3.Pit latrines without a slab or platform 4.Bucket latrines
31.	Source of water for your household?	_____

- Basic services

No	Questions	Code	Remar
32.	Are there times your household latrine/septic tank been emptied?	1.yes 2.No	
33.	When was the last time it was emptied?	1.within two years 2.within 4 years 3.within 6 years 4. above 8 years	If yes to 1
34.	How did you manage to emptied when the latrine is full?	1. Use empathizing service 2.Dran it to open ground or watercourse 3. to open drain 4.Others (specify)-----	
35.	The type of solid waste generated in the household (multiple answer possible)	1. Sweeping and (Yebet Tiragia) 2. Food left over 3. Plastic/bottles 4. Other (specify)___	
36.	How often do you get rid of/dispose the solid waste?	1. Every day 2. Once a week 3. Twice a week 4.once a month 5. Other (specify) _____	
37.	Where do you dispose solid waste other than human excreta?	1. Sock pit/collector/container 2. open field/Open ditch 3. Latrine 4. river course/river 5. Other (specify) _____	
38.	Where do you dispose liquid waste other than human excreta?	1. Sock pit 2. open field/Open ditch 3. Latrine	

		4. river course/river 5. Other (specify) _____	
39.	If you have livestock Where do you put the animal manure?	1.No don't have live stock 2.sock pit 3.Open ditch/open field 4. Latrine 5.Akaki river 6. Other (specify) _____	
40.	Electricity	0. No 1. Yes	
41.	Proper Road and Drainage	No 1. Yes	
42.	Solid waste facility/system accessible by hhs	No 1. Yes	
43.	Proper Liquid Waste management Facility/system for your hhs	No 1. Yes	
44.	Neighborhood Health centers accessible for you and family members	No 1. Yes	

- KAP on River pollution

#### Knowledge on River pollution

45. Where do you get the majority of your information about river pollution issues?

1 . Observation 2. Media 3. Community 4. Government 5. Advertisement in Health centers

46. Do you know where you can express your concerns about the nearby Akaki River water pollution 1 . Yes 2. No

In your Awareness how much do you agree with the following statements

	Variables	Frequency
47.	From Where did you get information about Akaki river pollution	Observation Community discussion Media Health centers
48.	river pollution means	color river pollution Bad smell/Odor Observable solid waste appearance Hazards waste existence I Don't Know
49.	Akaki river Water is polluted	1. Yes      0.No      3. I don't Know
50.	Akaki river Water Qulaity In Last Five Years	Remained the Same It Has Deteriorated Idont Know
51.	Akaki river water quality seasonal change in	I don't know      color change      Odor Change Seasonal      Suspended      Solid      Waste      amount Change      Seasonal      Toxic      Chemical      amount Change
52.	Spatial variation in water quality exit	1. Yes      0. No      3. I don't Know
53.	Causes of the Akaki river River Pollution	1. Yes      0. No      3. I don't Know
54.	Irrigation	Industry effluents Household's solid waste Household's liquid waste Sewage release
55.	Internal Road drainage destination To Akaki river	1. I know      0. I don't Know

56.	I know policies,laws and penaltyies on river pollutions	1. I know      0. I don't Know
57.	Akaki river water Pollution impact on the human Health's?	Respiratory Skin disease Eye problem Water borne diseases (Typhoid, diarrhea, cholera)
58.	Akaki river due to Pollution lost its value for	Unfavorable habitat for aquatic specious Lost the economic value Lost value for household consumption
59.	ways of tackling Akaki river water pollution	Introducing Heavier fines More awareness/information Better enforcement on regulations Adequate waste management facility
60.	I know where to raise concerns regarding Akaki river.	0.No                      1.yes

	Questions	SD	D	N	A	SA
1.	Feeling informed about Akaki river water pollution					
2.	Do you worry about the Akaki river water conditions?					
3.	My contribution to problems related to river water pollution is not negligible					
4.	Poor waste management practice causes of pollution					
5.	Do you think in weak law enforcement on polluters tiger more pollution					
6.	Akaki river pollution serious matter for the City and riverbank community general life					
7.	use of Akaki river for irrigation have long term impact					
8.	Due to pollution treatment at home wont treat the river for household consumption					
9.	I would be confident raising a concern about water pollution with local water management authorities					
10.	Not Only Government but I am too responsible for Akkai river protection					
11.	to pay for an improved latrine service/waste management facility					
12.	Pay prices in money and time in order to protect the Akaki river environment					
13.	I Know what to do to protect my family from Impact of the pollution of Akaki river					

Practice

	Questions	Frequency
14	My Toilet System is not directly/indirectly discharge sewages to Akaki river	0.No 1.Yes
15	My household did not dispose solid waste other than human excreta are poor(river, open ditch, latrine)	0.No 1.Yes
16	My household Liquid waste other than human excreta management directly/indirectly did not goes to Akaki river	0.No 1.Yes
17	The source of income for my households were not at all discharge wastes/chemicals to the Akaki river	0.No 1.Yes
18	I did report to the authority when there is misconduct of people throwing rubbish or sewage Waste into the river	0.No 1.Yes
19	I never expose the river environment for pollution(Animal dung, deforestation, toxic chemicals, open defection)	0.No 1.Yes

**Key Informant Interview**

Key Informants – Head of the Institution/Director Generals or Directors or Senior Experts/

Name of the Interviewee \_\_\_\_\_

Interviewee's Position \_\_\_\_\_

Age \_\_\_\_\_

Sex \_\_\_\_\_

Responsibility \_\_\_\_\_

Number of staff members under his/her supervision \_\_\_\_\_

Date of the Interview \_\_\_\_\_

1. Tell me about this institution: How long has it been operating, how and why it started, its purpose, its history, its structure.
2. Tell me the role of your institution towards the water of Akaki River in Addis Ababa City?
3. Does your institution undertake activities for counteracting the effects of river pollution in Addis Ababa City?
6. Does your organization have further plans to improve the water quality of Akaki River in Addis Ababa City?
7. Does your institution have collaboration with other institutions regarding the pollution of the Akaki River? With whom? And on what?
9. Do you think this is an issue for the institution? Why?
10. Tell me what are challenges in your office regarding the Akaki river pollution?

### **Key Informant Interview**

Key Informants – Head of the Institution/Director Generals or Directors or Senior Experts/

Name of the Interviewee \_\_\_\_\_

Interviewee's Position \_\_\_\_\_

Age \_\_\_\_\_

Sex \_\_\_\_\_

Responsibility \_\_\_\_\_

Total work experience \_\_\_\_\_

Work experience for the current position \_\_\_\_\_

Number of staff members under his/her supervision \_\_\_\_\_

Date of the Interview \_\_\_\_\_

1. Background of the industrie and process, work, input, output, use of the river
3. Industrial wastes: solid, liquid, sludge and hazardous wastes? Any waste treatment, recycling plants?
4. Practices such as waste avoidance, waste reduction method s etc. why/why not?
5. The industries' view on whether they are contributing in Akaki river pollution?
6. Major problems of the industries in following proper industrial waste management Systems.
7. What are the interventions of the Authority in regulating the industrial waste problem?