



Addis Ababa University
Ethiopian Institute of Architecture
Building Construction and City Development
Department of Urban and Regional Planning

**Analyzing the Effect of Manufacturing Industries on Environment in Sheger City:
Implication for Sustainable Industrial Development**

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**A Dissertation Submitted to Ethiopian Institute of Architecture, Building Construction
and City Development, Addis Ababa University, in Fulfillment of the Requirements for
the Degree of Doctor of Philosophy in Urban and Regional Planning**

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January, 2025

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Department of Urban and Regional Planning

Declaration

I, the undersigned, declare that this Dissertation is my own original work and has not been presented for a degree in any other University. All sources of material used for the Dissertation have been duly acknowledged, following the scientific guidelines of the Addis Ababa University.

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Results of Laboratory Analysis Report (waste water, soil and vegetable) done at Oromia Environmental Protection, Forest and Climate Change authority at Oromia Environmental Laboratory Center, Burayu town.

APPENDIX 2: Published Articles

Milkessa Jagemma, Hailu Worku (2024). Spatial Distribution vis-a-vis Agglomeration of Industry in Oromia Special Zone Surrounding Finfinnee, Ethiopia, International Journal of Contemporary Economics and Administrative Sciences ISSN:1925 – 4423 Volume: XIV, Issue:1, pp. 01-13

Milkesaa Jagemma, Hailu Worku (2021).Economic impacts of the manufacturing industry in Sululta. Review/Preglednirad UDK/UDC 338.45:338.1(630) DOI:<https://doi.org/10.32676/n.7.1.5>.

Milkessa Jagemma Tolerra, Hailu Worku, Bedane Shata Gemed, Fekede Terefe Gemed (2023).Variability in space effects of industrial wastewater on river physicochemical characteristics in a sample of towns of Oromia. International Journal of Environmental Science and Technology. <https://doi.org/10.1007/s13762-023-04874-0>

Milkessa Jagemma, Hailu Worku (2024).Concentration of heavy metals in water, soil, and vegetables irrigated with industrial wastewater in Oromia Special Zone Surrounding Finfine, Ethiopia. DOI:10.34172/JAEHR.2024.433010.1368

Milkessa Jagemma Tolerra, Hailu Worku (2021). The effectiveness of industrial development strategy in Ethiopia.P-ISSN: 2204-1990; E-ISSN: 1323-6903 DOI: 10.47750/cibg. 2021. 27. 02.537

List of Acronyms and Abbreviations

| | |
|--------|---|
| ADLI | Agricultural Development Lead industrialization |
| API | Application Programming Interface |
| ANOVA | One-Way Analysis of Variance |
| APHA | American Public Health Association |
| BCF | Bio concentration Factor |
| BOF | Bio Concentration Factor |
| COD | Chemical Oxygen Demand |
| CSA | Central Statistics Authority |
| EiABC | Ethiopian Institute of Architecture, Building Construction and City Development |
| EIA | Environmental Impact Assessment |
| ECBA | Environmental Cost-Benefit Analysis |
| EPA | Environment Protection Agency |
| EU | European Union |
| E.C | Ethiopian Calendar |
| EDI | Estimated daily intake |
| FAO | Food and Agriculture Organization |
| EPRDF | Ethiopian People’s Revolutionary Democratic Front |
| FDRE | Federal Democratic Republic of Ethiopia |
| FGD | Focus Group Discussion |
| GDP | Gross Domestic Product |
| G.C | Gorgonian calendar |
| GPS | Global Positioning System |
| GIS | Geographic Information System |
| KII | Key Informant Interview |
| WHO | World Health Organization |
| OUPI | Oromia Urban Planning Institute |
| OWWDSE | Oromia Water Works and Design Enterprise |
| LULC | Land use/land cover |
| NGO | None Governmental Organization |

| | |
|--------|---|
| PCI | Policy-Related Principles, Criteria and Indicators |
| TN | Total Nitrogen |
| TDS | Total Dissolved Solids |
| TP | Total Phosphorus |
| NSRL | National Soil Research Laboratory |
| THQ | Target Hazard Quotient |
| HI | Hazard Index |
| TCR | Target Cancer Risk |
| PCC | Pearson Correlation Coefficient |
| SPSS | Statistical Package of Social Science |
| PMTDI | Provisional Maximum Tolerable Daily Intakes |
| SDPRP | Sustainable Development and Poverty Reduction Program |
| SPD | Spatial Development Plan |
| GTP | Growth and Transformation Plan |
| PASDEP | Plan of Action for Sustainable Development and Eradication of Poverty |
| IDS | Industrial Development Strategy |
| IMF | International Monetary Fund |
| FFYP | First Five Year Plan |
| SFYP | Second Five Year Plan |
| TFYP | Third Five Year Plan |
| OECD | Organization for Economic Co-operation and Development |
| OSZSF | Oromia Special Zone Surrounding Finfinne |
| PPP | Public-Private Partnership |
| PCI | Policy-Related Principles, Criteria and Indicators |
| PLC | Private Limited Company |
| MOFED | Ministry of Finance and Economic Development |
| MOI | Ministry of Industry |
| UNIDO | United Nations Industrial Development Organization |
| WB | World Bank |
| WHO | World Health Organization |
| WEF | World Economic Forum |

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Abstract

Urbanization-driven industrialization refers to the growth of industries as cities and towns expand due to migration, population growth, and infrastructural development. This transformation leads to economic benefits but also creates significant environmental challenges. A balanced approach is required, emphasizing sustainable industrial development to mitigate adverse environmental effects while ensuring positive economic growth. Ethiopia's urbanization-driven industry has disrupted the environment and social well-being, as it does in many other emerging nations. The implications for sustainable industrial expansions and the impacts of Sheger city's manufacturing industry on the environment were the main objectives of this study. To evaluate the effectiveness of industry expansion strategies, economic impacts, and industrial agglomeration effects, survey questionnaires were used. Furthermore, laboratory research was conducted on the geographical differences in the physicochemical properties and heavy metal concentrations in the areas of industrial wastes, water, soil, and vegetables. To quantitatively analyze the data, common statistical tools such as one-way ANOVA, correlation coefficient, hazard index, bio concentration factor, and regression analysis were employed. The findings of this study showed that the levels of heavy metals and physicochemical characteristics were higher than allowable limit, which had an impact on the soil, water, and plants on land. In addition, the country's industrial policy has failed to take advantage of the potential to efficiently employ locally accessible resources and promote connections between isolated industrial zones. This study conclude that industry policy has to be initiated, accessible industrial effluence control standards should be enforced more strictly, installing plant treatment, industrial leftovers should be converted into biogas products, and public awareness should be increased.

Keywords: *Agglomeration, heavy metal, Industrial wastes, physiochemical, Spatial*

CHAPTER ONE

1. INTRODUCTION

Manufacturing industries are businesses or sectors involved in the production of goods, typically involving processes like assembly, fabrication, chemical processing and others industries. The effect on the environment refers to the environmental consequences of manufacturing activities (Arora et al., 2008). These can include pollution in air, water, or land, the depletion of natural resources, waste production, and the release of greenhouse gases or harmful chemicals. The analysis suggests that a systematic study of these environmental effects.

In Sheger City Administration of Oromia Regional State, the effects of manufacturing industries on the environment were examined in this research. As a result of the industrial wastewater produced by the industries in the selected towns in Shaggar City, measurements were being made, specifically focusing on the types of industrial waste that are collected from rivers and streams in specific sub city (Sululta, Laga Tafo Laga Dadi, Galan, Sabata, and Burayu) and the levels of heavy metals were identified in water, soil, and vegetable products.

In many fast growing built-up areas, especially in emerging nations, unrelenting economic growth, urbanization, and population expansion have all contributed to the rapid rise in volume and diversity of household and industrial trash (Fakayode, 2005). Since most of Ethiopia's industrial facilities are situated near bodies of water, it is simple to discharge untreated effluent into rivers, lowering the water's quality. Due primarily to its aesthetic value, recreational potential, agricultural applications, and domestic uses, water is given in unhealthy built-up regions around the nation (Ferezer Eshetu, 2012). According to research started by Tamiruet al. (2005), 90–96% of Ethiopian companies release their- trash that was untreated into surrounding rivers and open areas.

Untreated wastewater from a number of Shaggar City industries, including textile, tannery, cement, paint, plastic, paper and pulp, gesso, food processing, and metal manufacturing, is released into the lake body. As a result, there was industrial waste pollution in irrigated water. Irrigated water contaminated with industrial wastes has caused significant heavy metal pollution in crops and soils. Because wastewater is used to

irrigate the soil, vegetables consumed by the local population will have higher levels of heavy metals (Arora et al., 2008).

Examining the levels of heavy metals in soil, water, and vegetable products as a result of the industrial effluent produced in Sululta, Laga Tafo, Galan, Sabata, and Burayu towns was the goal of this study. This would have resulted in pollution of the environment, which would have had a negative impact on the health and welfare of those who depend on vegetables grown under irrigation. Policy makers can use the findings of this research to create plans for industrial expansion that are both ecologically friendly and socially inclusive. In addition, studies of how industrialization affects the environment from the viewpoints of local, national, and development actors were carried out. Utilizing a compound water sampling technique, the physico-chemical parameters taken into consideration at the various study locations were identified.

In the end, a mixed research approach involving quantitative and qualitative techniques was employed, along with survey questionnaires, focus groups, heavy metal assay in soil, water, and irrigated vegetables influenced by wastewater from manufacturing industries, Key Informant Interviews (KII), and laboratory scrutiny of the physicochemical parameters of industrial wastewater. The World Health Organization (WHO, 1994), the Environment Protection Agency (EPA) of the United States of America, the Industrial Pollution Standards of Ethiopia (2003), and the European Union (EU) were the guidelines used when conducting the quantitative testing.

1.1. Background

The inhabitants along with its relationship with the environment were altered by the Industrial Revolution, which also increased the consumption of conventional resources and sped up the development of newly created goods and processes (Westkamper, 2014). This has resulted in long-lasting alterations to the patterns of human habitation and the ecological balance, as well as the depletion of resources, the shifting of natural habitats, and contamination from post-consumer waste and unnecessary production byproducts at the end of their useful lives (Herman, 2016). The manufacturing sector has been actively involved in the development of greener production practices and environmentally friendly product design in recent decades due to growing environmental concerns.

According to Westkamper (2014), the goal is sustainable growth, in which waste from one production process is recycled into raw materials for another, creating a more productive cycle that resembles the natural system.

Today's industry is changing quickly, which will have an impact on people everywhere (Tucek, 2016). According to Tucek (2016), Povolna and Svarcova (2017), Rajnoha & Lesníková (2016), and other scholars, the processes of globalization and technological breakthroughs yield new products, services, and trade models for their provision. Moreover, the institutional, social, economic, and environmental facets of sustainable development are greatly impacted by industry (Nemcova, 2012; Piekarczyk, 2016; Sachpazidu-Wojcicka, 2017)

Several studies highlight the industrialized sector's status as a vital industry segment in both developed and emerging nations. Due to its large contribution to GDP, employment, and income as well as its role in fostering sustainable fiscal development, the manufacturing sector serves as the cornerstone of many national economies (Herman, 2016; Eurostat, 2017). This fundamental idea is covered in a number of recent studies, including those by McKinsey (2012), Naude & Zirmai (2012), and Westkamper (2014).

Based on Kaldor's and Chakarvarty 2008; Dasgupta & Singh, 2005; Jeon, 2008 findings, empirical research shows that the manufacturing sector in developing nations is the main force behind budgetary development and expansion. In addition, Loto (2012) states that the manufacturing sector generates a significant quantity of money for expansion and research, pays comparatively high wages, and employs a sizable number of people in other industries, including services. It also suggests a more robust export sector.

Due to the toxicity of heavy metals, cropland pollution by these substances is a severe environmental problem that is present in developing nations (Agca Ozdel, 2014). Significant heavy metal pollution in soils and crops has been caused by irrigation water contaminated with industrial wastewater. In the current era, the concentration of heavy metals and metalloids in farmed crops, soil, and irrigation water has been continuously rising due to the growth of industry and urbanization.

Furthermore, the amount and variety of industrial waste as well as household waste in various rapidly expanding built-up districts, especially in developing nations, have

rapidly increased due to unsustainable financial intensification, modernizations, and alarming population growth (Fakayode, 2005). The bulk of industrial companies in Ethiopia are located near bodies of water, and untreated effluent may be easily released into rivers without any problems, which lowers the quality of the water. Due of its aesthetic value, frivolous uses, agricultural potential, and family needs, water is given in hazardous built-up regions around the nation (Ferezer Eshetu, 2012).

Since Marshall (1920), a number of economists have argued that the geographic agglomeration, or clustering, of enterprises can lead to improved company performance. One of the main goals is that by placing an organization close to suppliers, customers, and rivals, it may be able to benefit from knowledge spillovers, have easier access to (skilled) workers, suffer lower transaction costs, and more. Henderson (1997) provided empirical evidence that agglomeration economies had a major impact on employment growth in five U.S. manufacturing industries between 1977 and 1990. However, as far as we are aware, there is no quantitative information on these processes for less developed economies, and none at all for Sub-Saharan Africa.

It has long been believed that industrial progress is the main force behind economic growth and structural change (Prebisch, 1950; Singer, 1950 as mentioned in Mulu, 2013). Proactive industrial policy has been crucial for industry development for a number of reasons, including a strong commitment to global integration and private sector-driven growth, a strong and wise government guiding the private sector, securing enough policy tools for industrialization, ongoing policy learning through concrete projects and programs, internalizing knowledge, skills, and technology as a national goal, effective public-private partnerships (PPPs), and the government and private entrepreneurs gathering and sharing adequate industrial information (Rodrik, 2004; Hausmann and Rodrik, 2003 as cited in Mulu 2013).

Shaggar city is rapidly modernizing and developing industrially. As such these practices and modernization are boosting economic growth. However, most industries are located close to bodies of water, and discharging manure into these areas is a straightforward process. Water bodies that are directly contaminated will, in particular, have declining water quality, which will affect human health. This study's goal is to examine how

Shaggar City's manufacturing sectors affect the environment and what that means for the city's further industrial development (Sululta, Laga Tafo Laga Dadi, Galan, Sabata, and Burayu).

1.2. Statement of the Problems

According to Nebiyeleul (2006), Mulu (2013), and Tesfaye (2014), Ethiopia's development strategy aimed at gaining a more significant position in the industry could result in an increase in the environmental load. The disruption of the environment and related economic changes may also have caused social unrest, impoverishment among the local populace, and a widening of regional disparities.

More specifically, when the growth of a local economy is not given equal weight at the national or regional level, the target stakeholders (local residents) may undercut the efforts and underestimate the necessity of founding manufacturing firms or other economic operations. When economic activities expand, stakeholders who are not treated fairly run the risk of experiencing many negative outcomes, including lost opportunities, jobs, employment, marginalization, illness and demise, paucity, refutation of admission to regular properties, public dislocation, and destitution (Cernea, 1997a). Furthermore, according to Parker and Liddle (2017), Treimikiene et al. (2016), and Zhang et al. (2017), the industry consumes a considerable amount of energy and environmental pollutants.

Studies have also revealed negative environmental effects of manufacturing companies, such as elevated pH, temperature, and total suspended solids (TSD). The physiochemical properties of the meat and tannery sectors were found to be much higher than the permitted pollution load standard downstream of the Modjo and Akaki rivers (Abrha et al., 2015). Dangerous chemicals from industrial waste from the Tinishu Akaki River (TAR) poisoned neighboring land, affecting farms downstream that relied on irrigation (Samuel, 2005). Industries upstream from Addis Ababa emit a notably large amount of chemical pollutants and heavy metals (Eticha, 2015).

Communities surrounding large industries demonstrate against the health and environmental impacts of the textile industry in Bahir Dar (Assefa Ayalew, 2014). However, many of these studies lacked the comprehensiveness necessary to address the various schemes (such as soil and vegetable, wastewater), as well as the various

businesses that use a range of chemicals, inputs, processes, and environmental effects. By expanding on the topics already addressed by other academics, this study aims to close some of the current gaps.

According to the findings of other researchers, smallholder farmers in the Gelan-Dukem firm region have suffered a notable and depressing socio-economic impact as a result of the unfair distribution of farmed land for industrialization and public land uses during the previous eight years (Diriba, 2016). The study also showed how industrial contamination impacted freshwater availability and quality, local residents' health, and the health of household pets. As a result, it suggested a governmental decision to reexamine investment rules and regulations.

This research aims to close this gap by using triplicate parameter laboratory investigation of soil, waste water, and vegetable and proportional analysis of economic impacts. Generally speaking, previous research focused on how industrialization affected the well-being of specific farmers who were expelled and/or relocated, but they did not address the effects of industrial projects and industrial wastes on the neighborhood population and environment using detailed environmental parameters, industrial agglomeration, distribution, and the effectiveness of the industrial development policy in the area.

1.3. Objective of the Study

The general objective of this study was to examine analysis of the effect of manufacturing industries on environment in Sheger City and it's implication for sustainable industrial development

1.3.1. Specific Objectives

The study's specific objectives were to:

1. Explore the spatial agglomeration and distribution of industries in Sheger City
2. Examine the economic impacts of industrial firm in Sululta Sub city of Sheger City
3. Analyze the impact of industrial effluents on the physiochemical nature of streams and rivers in Sheger City
4. Investigate the distribution of heavy metals in water, soil, and vegetable in the field of irrigated with industrial wastewater in Sheger City
5. Evaluate the effectiveness of industrial development strategy in Ethiopia

1.4. Research Questions

The research questions corresponding to each specific objective are presented in Table 1.1

Table 1.1 Research questions corresponding to each specific objective

| No | Specific objectives | Research questions |
|----|--|---|
| 1 | Analyze the spatial agglomeration and distribution industries in Sheger City | How industries were distributed and agglomerated in Sheger City? |
| 2 | Examine the economic impacts of industrial firm in Sululta sub city of Sheger City | What is the economic impact of industrial firm in Sululta sub city of Sheger City? |
| 3 | Analyze the impact of industrial effluents on the physiochemical nature of streams and rivers in Sheger City | What is the impact of industrial effluents on the physiochemical nature of streams and rivers in Sheger City? |
| 4 | Investigate the distribution of heavy metals in water, soil, and vegetable in the field of irrigated with industrial wastewater in Sheger City | What is the distribution of heavy metals in water, soil, and vegetable in the field of irrigated with industrial wastewater in Sheger City? |
| 5 | Evaluate the effectiveness of industrial development strategy in Ethiopia | Is there any industrial policy in Ethiopia to solve industrial problems? |

1.5. Rationale for the Selection of the Study Area

This study will help the decision makers in developing a win-win strategy in industrial development sector policy in terms of achieving economic growth and improved industrial expansion. Given the appropriate dissemination mechanism, it is hoped that the results of this study will have an impact on the academic community, governmental and nongovernmental organizations, policy makers and the public at large.

Sheger city is embraced by the larger towns like (Sululta, Laga Tafo-Laga Dadi, Galan, Sebeta, and Burayu, etc.) and the neighboring rural villages. Sebeta, Burayu, Lega Tafo, Sululta, and Gelan towns, which surround Addis Ababa City from all directions, are now clustered as a single city under a single mayoral administration. The total area of Sheger city is about 160,892.9 (55.8% rural) hectares. The Sheger city covers both urban and rural areas, where there is booming of manufacturing industries in these areas. The special zone covers an estimated area of 363,375km². Out of the total number of

manufacturing industries in Finfine and its surrounding, about 1,505 (87 %) are located at the urban centers of the Sheger City, for instance, some 418 located in Sebeta town and 443 in Gelan and Dukam towns.

However, most of the manufacturing activities are incompatible with the proposed land uses. For instance, the existing manufacturing industries in Gelan and Laga Tafo –Laga Dadi towns are located within the residential areas and social services. Most of the industrial activities located in the Special Zone of Oromia discharge industrial wastes into Rivers such as to Atabala River (Sebeta), Akaki River (Gelan) & Dukam River (Dukam). Accordingly, the local community frequently and strongly complains about pollution of rivers. A snapshot of evidences on surface water pollution is shown in Figure 1.1. This study was conducted at the towns in the Sheger City to identify the ongoing impacts of the increasing industrial and manufacturing activities on the general environment of the Sheger City. Moreover, potential recommendations will be proposed to minimize such impacts on the general environment. Each town in the Sheger City has their own characteristics in relation to their location, topography, hydrological parameters, expansion of industries, environment and etc and as a result, the influence they have on the environment varies from one location to the other.

Besides, between 1977 and 1990, employment growth in five U.S. manufacturing industries was significantly influenced by agglomeration economies, according to empirical findings presented by Henderson (1997). However, to the best of our knowledge, there is absolutely no quantitative data on these processes for Sub-Saharan Africa, and none at all for less developed economies. A strong commitment to global integration and private sector-driven growth, a strong and astute government directing the private sector, obtaining sufficient policy tools for industrialization, continuous policy learning through tangible projects and programs, internalizing knowledge, skills, and technology as a national goal, successful public-private partnerships (PPPs), and the government and private entrepreneurs gathering and sharing adequate industrial information are some of the reasons why proactive industrial policy has been essential for industry development (Rodrik, 2004).



Figure 1.1: Existing polluted surface water in Gelan town

1.6. Description of the Study Area

1.6.1. Population

Sheger city covers 160,892.92 hector jurisdictional area, incorporated six urban centers and 36 rural centers. Sheger city now administers a vast and diverse geographic area that accommodates 2,336,942 people and extends from Sululta district in the north to Gelan district in the south and Burayu in the west to Koye Feche district in the east.

1.6.2. Topography

Topographically, Sheger City is mainly classified as flat plains to undulating plains, moderate to high relief hills and high to mountains relief hills with its elevations ranging from 1000 to 1300m asl.

1.6.3. Climate

The mean annual temperature of the Special Zone was in the ranges of 10-20⁰ C and this temperature is within the ranges of physiological requirement for agricultural production. The agro climatic situations of the project area covers Cool Humid, Cool Per-humid, Moderately Cool Humid, Moderately Cool moist, Moderately Cool Per-humid and Moderately Cool Sub-humid. Accordingly, 67percent of the study area belongs to the moderately Cool thermal zone with mean average annual temperature of 15 – 20⁰C and the remaining 33 percent are in cool thermal zone.

1.7. Delimitation of the Study

The study's scope is restricted to Sheger City, Ethiopia, which was selected for the study due to the growth of industrialization on the built-up edge of agricultural areas and the expansion of the municipality in terms of size, structure, and space. It also examines the economic aspects of industrialization, spatial agglomeration, environmental effects of industrial activities, and the efficacy of industrial development strategies. Additionally, the study's thematic scope examined institutional and legal frameworks, examined the physiochemical effects of industrial effluents on rivers, examined the levels of heavy metals in soil, water, and irrigated vegetables, and examined the financial effects of industrialization.

1.8. Significance of the Study

The study area is a vibrant place with a variety of environmental impacts from industrial development. The study region under inquiry revealed that the soil, water, and terrestrial plants were all impacted by the physicochemical characteristics and heavy metal levels that were above the allowable limit. Additionally, the country's industrial policy has not taken use of the potential to efficiently use locally accessible resources and promote connectivity across distant industrial zones. The results of the study indicate that the implementation of industry policy, stricter enforcement of accessible industrial effluence control legislation, the installation of plant treatment, the conversion of industrial waste into biogas products, and increased public awareness are all necessary. Therefore, analyzing the environmental impact of manufacturing businesses and highlighting the implications on sustainable development is vital for policymakers, academia, international organizations, local governments, and financial institutions, among others.

1.9. Limitation of the Study

Due to the short history of the private sector's presence and participation in the Ethiopian industrial sector (Asubonteng, 2011), a lack of relevant and sufficient data about changes in industrialization and industry within the sector posed a some problem. Particularly in Ethiopia's urban and rural industries, as well as the Oromia special zone surrounding Finfinne, significant facts about industry's environmental repercussions were scarce. As a result, the researcher is required to generate significant portion of primary evidence and

data to corroborate his claim. The fact that this study used the Oromia special zone encompassing Finfinne as a thorough reference makes it difficult to replicate precisely to other situations. A significant issue encountered was a lack of needed and up-to-date data. In relation to the qualitative research, the data obtained through key informant interviews and the analysis of these data may result in a variety of interpretations by different readers.

1.10. Analytical Framework

This research utilizes conceptual framework to describe the relationship between inputs and outputs in the manufacturing process. It is assumed that the input sides comprise inputs such as raw material, chemicals for input, energy, water usage, and fresh air. The material is transformed into industrial goods and wastes (in the form of solid wastes, liquid wastes, pollutants, and other effluents) through a systematically organized flow of the manufacturing process (from product design to final output). The material product contributes favorably to industrial development, whereas waste output has an impact on the environment (water pollution, soil pollution, and emissions).According to the framework, promoting sustainable industrial development would require achieving improved conversion efficiency of inputs to valuable products while reducing the volume of waste that would have adverse environmental impacts.

The growth and extension of industries that produce goods and services and advance the economy is referred to as industrial development. The detrimental effects of industrial operations on ecosystems, biodiversity, water resources, air quality, and human health are commonly referred to as environmental impact. Emissions, waste, and the loss of natural resources are frequently included in the environmental cost. The likelihood of increased pollution, resource use, and habitat destruction increases with industrial expansions, all of which fuel climate change, degrade soil, and reduce biodiversity.

Agglomeration is the term used to describe the concentration of enterprises and industries in a certain geographic area, frequently creating industrial clusters (such as manufacturing zones or tech centers).Agglomeration can affect the environment in both beneficial and harmful ways. On the one hand, nearby industries can pool resources, cut down on transportation expenses, and increase productivity, which lowers environmental

costs per unit. For example, shared infrastructure, such as energy or waste management systems, can result in more sustainable behaviors and lower emissions. However, if the concentration of enterprises results in congestion, more waste, greater emissions, and excessive use of local resources, agglomeration can aggravate the environmental impact of economic activity.

The goal of sustainability is to satisfy current demands without endangering the capacity of future generations to satisfy their own. It seeks to strike a balance between environmental preservation, social inclusion, and economic growth. In order to achieve sustainability in industrial expansion and agglomeration, adverse environmental effects must be minimized while economic growth is maintained or improved. Adoption of eco-friendly infrastructure, resource efficiency, circular economy models, and clean technologies can all help achieve this. Utilizing renewable energy sources, reducing waste, and making sure that natural resources are managed in a way that doesn't negatively impact the environment are the main goals of sustainable industrial development. One type of sustainable industrial agglomeration is eco-industrial parks, where businesses pool resources and trash to cut expenses and their environmental impact.

Economic expansion is frequently fueled by industrial progress, but unless it is offset by sustainable practices, environmental damage results. By increasing resource sharing and operating efficiency across industries, agglomeration can improve sustainability by lowering the environmental effect per unit of production. However, if it is not well managed, it can also increase environmental harm. Agglomeration and industrial growth must be in line with environmental objectives for there to be true sustainability. This entails using green technologies, effectively managing resources, and motivating enterprises to lessen their ecological impact, waste, and emissions. The difficulty of attaining sustainable industrial development in the face of agglomeration and environmental effect is thus highlighted by the relationship between these ideas. Effective agglomeration and sustainable practices can help offset the negative consequences of industrial growth on the environment and establish a balance between environmental stewardship and economic development.

Lastly, the idea of pursuing industrial growth while making sure that the environmental impact is kept to a minimum and that resources are used effectively is known as sustainable industrial development. It entails actions like recycling, cutting waste, utilizing renewable energy, and implementing greener technologies. According to the implications, the study will go over the outcomes or suggestions for Sheger City's sustainable industrial growth. The objective is to make recommendations for ways to enhance regional industrial practices in order to better align them with sustainability objectives, including resource conservation, environmental preservation, and long-term economic viability.

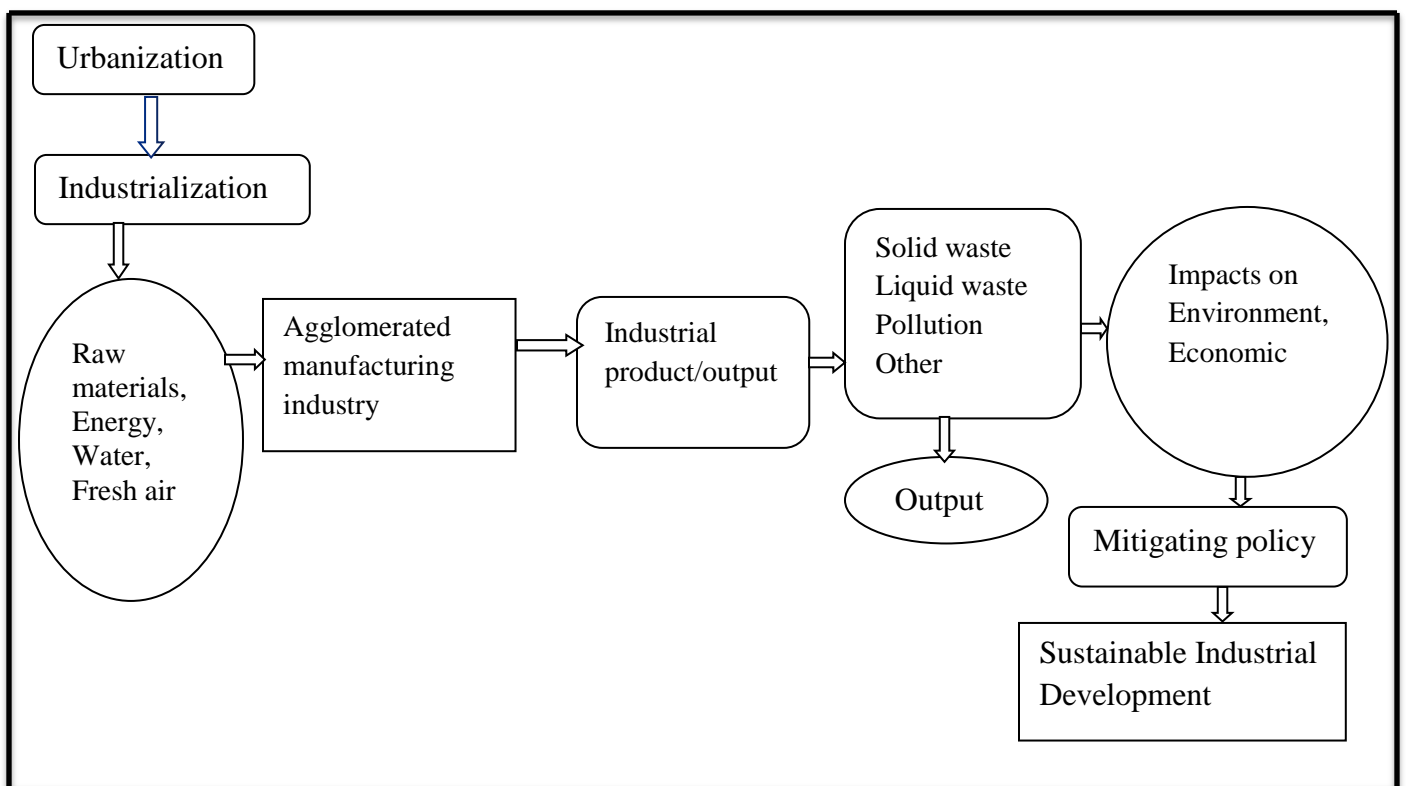


Figure 1: Analytical Framework
Source: Own constructed, 2023

1.11. Organization of the Study

The Dissertation is organized into six chapters; the contents of these chapters are discussed briefly as follows. The first chapter gives general introduction and background information of the study subject, statement of the problem, objectives of the study, the research questions, the rationale for the selection of the study area, describing the study area, analytical framework, and scope, limitation of the study area and structure of the dissertation. The second chapter presents the literature review. It explains the academics discourses that were important for this study. It mainly explains the summary of the area of literature which are highly related to the specific objectives. The review are related to general theoretical concepts on Physicochemical and heavy metals concentration in waste water, soil and vegetables and Industrial development strategy, economic impacts of manufacturing industry and spatial distribution of industry. The third chapter is discussing about research methodology used for this study. The fourth chapter describes the spatial distribution vis-a-vis agglomeration of industry. It explores the nature of spatial distribution and agglomeration of industry in Sheger City. The fifth chapter discusses the spatial variability effects of industry wastewater on the physicochemical characteristics of rivers. It analyzes the amount of physicochemical of industry effluents or wastes emitted in streams and rivers in towns of Sheger City. The Sixth chapter explains the distribution of heavy metals in water, soil, and vegetables irrigated with industrial wastewater. To detect the magnitude of trace metals in water, soil, and vegetable irrigated from wastewater. The seventh chapter analysis the economic impacts of the manufacturing industry in the case of Sululta Sub City of Sheger City. The Eighth chapter evaluates the effectiveness of industrial development strategy in Ethiopia. The Ninth Chapter describes the general results and discussion of the study. The last chapter is presenting recommendations based on the findings of the research.

CHAPTER TWO: LITERATURE REVIEW

2. Introduction

Contemporary economic history has repeatedly demonstrated that a society's socioeconomic development is rarely possible without industrialization. The remarkable success of various Asian economies over the last half-century is clear evidence of the importance of industrialization as the most effective means of poverty reduction. Industrialization, on the other hand, is not a structural necessity. It necessitates the careful management of policy alternatives as well as the continuous monitoring of sectoral dynamics (Pack and Saggi, 2006).

Besides, Ethiopia has long struggled to achieve structural reform that will diminish the country's reliance on agriculture. Over the last decade, authorities in the country have become increasingly convinced that long-term poverty reduction is impossible without fast industrialization. As a result, in 2002/03, the country developed a comprehensive industrial growth strategy, which was put into action through consecutive national and sector development plans (Gebre-Egziabher, 2007).

However, one of the long-standing critics of industrial strategy points to state bureaucrats' incompetence to identify winners and the strong likelihood that they favor rent seekers instead (Pack and Saggi 2006). Recent industrial policy proponents (Hausmann and Rodrik 2003) have emphasized the importance of planned association among the private sector and the government in order to identify where the most noteworthy barriers to reshuffle and what types of involvements are most probably to eliminate them. However, outside of the well-known cases of East Asia, there is little systematic research on the manufacturing aspects of public-private collaborations was done (Page 2010).

According to Naude and Szirmai, industrialized has historically been “the engine of fiscal development, structural transformation, and catch-up” (2012). Manufacturing has elongated been considered a "keystone" of various nationwide economies, a critical industry that engenders high-paying works and long-term fiscal development. According to a World Economic Forum (WEF) analysis, manufacturing is essential to a country's economy, with "almost 70% of the income disparities of 128 nations explained by changes in manufactured products export data alone" (World Economic Forum, 2012).

Manufacturing, after all, has multiplier effects because it is so intertwined with the rest of the financial system. Based on the report, these relations could be "rearwards" or "onwards" (Veugelers, R., 2013). The links among industrialized as well as services have been highlighted in a number of up to date researches (Spelman, M., 2013). Manufacturing, compared to other industries, is regarded to have more spillover effects (Herman, E., 2011). Demand for manufactured goods is increasing, which supports job creation, investment, and innovation (Herman, E., 2011).

According to empirical studies of Kaldor's commandment (Chakarvarty, 2008), the manufacturing segment in emerging states is the locomotive of fiscal development and growth. Other experiential studies (Westkamper, E., 2014) as well as numerical facts suggest that manufacturing is an elevated- export sector that pays comparatively lofty wages, making it a major driver of employment in extra segments, such as services, and a major source of outlay in study along with growth. Manufacturing is also vital for schooling as well as innovation (Westkamper, E., 2014).

The importance of manufacturing in the economy evolves through time and varies depending on the country's economic growth stage, according to the McKinsey Global Institute (Warren, J. H., 2013). Manufacturing has the power to impel production intensification, modernization, as well as deal in industrialized economies. In addition, this industry contributes significantly to the reduction of energy and resource consumption.

As Krugman pointed out, concentration is without a doubt the most noticeable feature of economic activities (1991a). However, different fields have varied perspectives on this subject. The majority of economists are concerned about the relationship among development and manufacturing clustering, and numerous studies in various nations have found a favorable association (Lin *et al.*, 2011). These studies, on the other hand, simply considered the amount of space-based clustering and neglected other agglomeration features such as space-based scale clustering and sector inconsistency.

Geographic analysis, on the other hand, is based on space, place, and size (Coe et al., 2007). The spatial scale, at which industrial agglomeration occurs, as well as the sectoral range, is at least as essential as its scope in terms of geography. Furthermore, taking a

spatial approach to the problem can aid in limiting the use of natural resources during the industrialization process. Indeed, this method has reduced land resources in underdeveloped states. In China, for instance, the creation of a huge figure of growth districts has resulted in the loss of important agricultural land (Yang and Wang, 2008).

2.1. Environment and Economic Theories

Simon Kuznets, who postulated that as economic progress advances, income inequality initially increases and subsequently decreases, is honored by the EKC (David I. Stern, 2004). Energy use is closely linked to emissions of many pollutants, including sulfur, nitrogen oxides, and carbon dioxide. The EKC is therefore a model of how energy consumption, economic expansion, and the environment are related.

However, managing industrial pollution is a complicated effort that requires the involvement of businesses and local governments. Therefore, it is crucial that businesses and local governments use a variety of approaches to address industrial pollution. As a result, this is a decision dilemma with competing goals. Conflict resolution, a specialized area of game theory, is the most effective method for handling this class of multi-objective conflict resolution problems, as demonstrated by Raquel et al.(2007). Morgenstern and Von Neumann (1953) initially formulated the theory of games in relation to human economic behavior, and it has since been applied to a variety of topics, including nuclear accidents, emergencies, and climate change. Game theory has advanced quickly since then. This approach has been used by numerous academics to manage environmental contamination (Cason et al., 2016). These auditing systems are crucial to how governments implement policy. Cason et al.(2016) investigated the efficiency of both new social information schemes and conventional regulatory schemes in attaining compliance.

Li et al. (2019) examined the decoupling of economic development from resources and the environment in the Beijing-Tianjin-Hebei region using the Tapio Elastic Decoupling Index. Luo et al. (2021) examined the overall comprehensive pressure brought on by resource and environmental elements when the economy and the resource environment are decoupled. They measured the relationship between resources and the environment using the Tapio Elastic Decoupling Index. There has been discussion of the decoupling

effects of resource-environmental issues on the economy and environment, such as solid waste and fossil fuels. However, the decoupling analysis of numerous towns with radically varied natural geographical surroundings and socioeconomic processes was not included in any of the aforementioned research.

Multi-player, multi-objective optimization issues can be solved using techniques from differential game theory (R. Isaacs, 1999; T. Basar and G. Olsder, 1999). For instance, if all other players follow the Nash equilibrium policies and no player may change their policy to better their outcome, the collection of policies is referred to as a Nash equilibrium solution to a multi-objective optimization problem (J. Nash, 1951). Since no actor has an incentive to deviate from their equilibrium policy, the Nash equilibrium offers a safe set of strategies. As a result, a common solution idea in differential game-based control systems is Nash equilibrium.

Dual theory indicates that certain significant facets of the issue at hand may be overlooked by conventional theoretical models of capital flows and environmental policy. For instance, most theoretical research is organized in a static framework, even if dynamic factors could be significant (Kydland and Prescott, 1977). The date on which the environmental policy is put into effect in relation to the household's investment and consumption choices is a pertinent issue. The time-inconsistency issue in a dynamic setup will significantly impact the government's ability to commit to the environmental policy (Kydland and Prescott, 1977).

Multinational corporations will move the manufacture of their pollution-intensive products to developing nations under free trade, according to the pollute haven hypothesis (PHH), which takes advantage of the lax environmental monitoring in these nations. Developing nations will eventually gain a competitive edge in industries that produce a lot of pollution and become into "havens" for the world's polluting businesses. Therefore, it is anticipated that trade will improve the environmental condition of wealthy nations while harming poorer nations. Developing countries may set lenient or moderate environmental revolution as a strategy to lure industrial investment.

CIF-ELECTREE, a complex intuitionist fuzzy ELECTREE approach, is used to evaluate the environmental impact of various sectors. The approach offers a thorough and trustworthy evaluation of the environmental impact of companies by fusing the ideas of CIF sets with the ELECTREE method. When the suggested approach is used on actual data, the outcomes show how well the CIF–ELECTREE method works to limit and manage the environmental impact of industries. The findings demonstrate that, in comparison to conventional techniques, the CIF–ELECTREE method can offer a more accurate evaluation of the environmental impact of companies (Ashraf S,et al.,2023)

2.2. Empirical Analysis

2.2.1. Agglomeration and Distribution of Industry

Marshall (1890) utilized the notion of externalities to explain why proximity is beneficial to production. Such external factors have steadily been recognized in industrial location theories since then. According to Fujita (1988); Krugman (1991a; 1991b) and Venables (1999), to predict how firm agglomeration provides growing returns, new economic geography is based on Marshallian externalities. Furthermore, the achievement of various groups, such as '3rd Italy' and Silicon Valley, has demonstrated in fact the hypothetical relation among fiscal clustering as well as provincial development in reality. As a result, during the 1990s, there has been a revived curiosity in industrial clustering.

As Krugman pointed out, agglomeration is without a doubt the most noticeable feature of economic activities (1991a). Nonetheless, different fields have varied perspectives on this subject. Ciccone (2002); Bertinelli Decrop (2005); Brulhart Sbergami (2009); Lin et al., (2011) demonstrated that the majority of economists are concerned about the relationship among development and industrial clustering, and numerous studies in many nations have found a favorable alliance. These studies, on the other hand, simply planned the level of space-based clustering and neglected other agglomeration features such as space-based level clustering and sector divergence.

Space, place, and scale, on the other hand, are all fundamental to geographic investigation (Coe et al., 2007). In terms of geography, the space-based level at which industrial clustering occurs, as well as the sectoral range, is at slightest as important as its

size. Besides, looking at the problem from a geographic outlook can assist to limit the use of natural resources during the industrialization procedure. In fact, in poor countries, this approach has depleted land resources. For example, Yeh & Li (1999); Yang & Wang (2008) narrated that in China, the establishment of a huge number of development zones has resulted in a significant loss of agricultural areas.

Longer-term economic growth is influenced by the geographic distribution of agglomeration and specialization. Because of inherent or historical comparative advantages, as well as lower innovation and transaction costs in specialized input and labor markets, specialized locations provide enterprises better cost and production functions. Furthermore, there is evidence that due to cross-pollination of ideas, individual industries expand quicker in more diversified urban areas (Glaeser et al., 1992). Henderson et al. (1995) suggest that established industries want the urbanization economics of diversity in the metropolis, whereas youthful dynamic industries seek the urbanization economics of diversity in the metropolis.

Haining, 2003; Fischer and Getis, 2009 pointed out that in modern years, a diversity of pointers plus techniques have been proposed to quantify the space-based clustering of firm. Nevertheless, according to HUallachain and Leslie (2009) in glow of discriminated aspires and datasets, there is nix agreement regarding what approaches are more suitable.

Duranton Overman (2005) used K-density to analyze the manufacturing space-based prototype in the United Kingdom, as well as established 5 basic requirements for a 'good' measure of geographic agglomeration. Duranton and Overman used a relative measure over the absolute measure employed by Ripley's algorithm. Explicitly, the concentration of a sector is determined by comparing its distribution to that of the entire industry. This method was also used by Barlet et al. (2013) in an empirical study on France. According to the findings, a distance-based technique is better appropriate for analyzing service site patterns than the typical EG cluster-based index of space-based clustering. While the majority of the literature focuses on establishing and enhancing methodologies, empirical research, particularly at the town level, is still needed. In this study, Duranton and Overman's method was used to check the manufacturing space-based prototype in an urban-edge locale.

Finally, examining Ethiopia's industrial policy trajectory reveals that the philosophy of efficiency dictates the driving forces that drive the location of industries, despite the incumbent regime's claim that maintaining interregional industrial parity is also a priority. The existing industries in Ethiopia have been concentrated in and around Addis Ababa (Eshetu, 2004; Mulatu, 1994). Despite the existence of various laws and rules that state the necessity for balanced industrial growth, the government's industrial policy menu appears to pay little consideration to the uneven distribution of manufacturing industries in the country.

For example, during the imperial era, the key industrial actors were foreigners who sought to operate in places with a huge consumer base, skilled labor, and low transportation costs. Regardless of where industries were placed, the government was in favor of supporting them to their maximum potential. In other words, they engaged in industrial activity in order to increase their profit margin in every way feasible. Huge abroad investors were enticed in with tax breaks, import export rights, and financing, including the Dutch sugar company HVA and the British car firm Mitchell Cotts. Ethio-Italian, Ethio-Greek, and Ethio-Armenian populations, in particular, played key functions in the financial system (Sarah and Mesfin, 2011).

Hence, accordingly, this study was based on industry data to come across the attributes of space-based distribution and clustering across 8 industries and emphasize the disparities between them in Oromia Special Zone Surrounding Finfinne, Ethiopia. Afterward we additionally look at the discrepancy of industrial concentration resultant from establishment magnitude. This study is supportive to recognize the industrial site in the intra-metropolitan vicinity for regional development

2.2.2. Economic Impacts of Industry

Regional and local governments have been essential in driving economic growth in emerging and, to some extent, industrialized nations in recent years (Tucek, 2016; Rajnoha & Lesnikova, 2016; Povolna Svarcova, 2017). To support fiscal development, there has been a greater reorganization of the manufacturing sector as a result (Szalavetz, 2017; Eurostat, 2017). Ethiopia's government has highlighted this growth by providing significant funding to regional administrations to assist local initiatives (MOFED, 2020).

Through organized and well watched reviews, these resources are meant to boost fiscal growth (Ermias et al., 2011).

The growth of other industries, instant and positive effects on employment levels, increased capacity for innovation, expanded supply chain, and increased local trade with service industries are some of the benefits of promoting the manufacturing sector. However, these benefits are not without problems. In certain instances, the efforts have not benefited the locals because of an influx of immigrant workers, which has caused social unrest (Tiwari and Rawani, 2012). In addition, new projects seeking financial backing have received government support and have misused a fund, which has created a culture of distrust and corruption (Mestres, 2017).

In the instance of China throughout its restructuring era of 1979–2004, Jeon (2006) empirically tested the notion that the industrialized section is measured as the steam locomotive of fiscal augmentation. Additionally, predicted outcomes from both data sets confirmed the Kaldorian hypothesis on the industrialized sector's contribution to fiscal development in China during its transitional period. Felipe et al. (2007) conducted a study on the structural transformation of Asia's augmentation practice during the 1970s, 80s, and 90s. The most well-known aspect of this change was discovered to be a notable decline in the distribution of farming income accompanied by a corresponding increase in the distribution of services in GDP. The expected outcomes show that both the firm and the services contributed to fiscal growth. In the case of developing Asia, several substantiations of endogenous growth-induced scientific improvement were also useful.

Moreover, Chakerwari and Mitra (2008) found that the manufacturing sector's responsibility as an engine of development and depicted the interconnection between numerous manufacturing activities. Based on the consequences, the manufacturing segment emerged to be one of the burly determinants of general fiscal intensification besides production and services sectors.

The purpose of this study was to evaluate the derived or indirect financial consequences of manufacturing industries in addition to their direct financial outcomes. Manufacturing continues to be the option that societies seeking financial expansion and diversification most frequently believe in, despite the fact that the fiscal restructuring that has occurred

over the past ten years has caused some locals to closely examine foreign goods (Martin and Diaz-Garrido, 2008). Furthermore, modern Sululta practices indicate that manufacturing might still be a practical foundation for development in both rural and urban locations. In Sululta manufacturing employment increased by 16 percent (237 works) between 2012 and 2018, with significant increases seen in almost all of the city's villages (ORSAB, 2020).

Further, several studies have dealt with growth incentives to shape industry start-ups and extensions or capability replacements (Lamastra et al., 2018). Merely a little has dealt with the direct impacts of skill growth or extension, plus less up to now be scrutinized the indirect outcomes of industries of diverse sorts. The findings of this research indicated that economic impact was extensively dispersed throughout the existing sectors. The urban centers of the Shaggar city are experiencing rapid urbanization and industrialization resulted in positive or detrimental impact on economic development. Most of them are planted nearby water bodies, and it is easy to discharge wastes into water bodies. In particular, water bodies that receive industrial wastes will deteriorate water quality and affect human health. However, the previous studies were not comprehensively analyzed the spatial variability effects and concentration of physicochemical characteristics from industrial wastes emission to nearby water bodies in the urban centers of Shaggar city. The main of this study is to analyze the spatial variation effects of industry wastewater on the physicochemical characteristics of Rivers in selected areas of Sheger city (Sululta, Laga Tafo Laga Dadi, Galan, Sabata and Burayu).

Lastly, this study employed input-output model to capture the indirect economic impacts of manufacturing industries and descriptive statistics was used to describe the existing situations in the study area. The rest of this study is prearranged as follows. In part two, the method is presented with the processes of input-out model that are used in capturing indirect economic impacts. In part three, an experimental inquiry, results, discussion and recommendation are carried out on study vicinity.

Numerous empirical studies have examined the role of manufacturing in developing countries as an engine of economic expansion. Szirmai and Verspagen (2015) employed

between-effects models using Hausman-Taylor estimations for an unbalanced panel of 92 countries in order to investigate the relationship between the value added share of manufacturing and GDP per capita growth. They also included fixed and random factors. Three time periods were examined for this relationship: 1950–1970, 1970–1990, and 1990–2005. The findings were compared to the outcomes of the service sector. The study by Szirmai and Verspagen looks at how manufacturing affects GDP per capita growth in relation to education and development stage, with a lot of attention paid to the outcomes of conservative Hausman-Taylor estimations.

They find that, in low- and middle-income nations with sufficient levels of human capital, manufacturing serves as a catalyst for economic growth. The service industry does not exhibit these growth engine characteristics. It's interesting to note that data from more recent times suggest that manufacturing in developing nations cannot function as the engine of development without a higher degree of human capital, or at least 7-8 years of education.

Using an instrumental variable econometric technique, Necmi (1999) examined 45 primarily developing countries between 1960 and 1994 to see whether Kaldor's findings held true in the wake of the industrialization and catch-up boom of the 1970s. The results confirmed Kaldor's assertion that "industry is an engine of growth" in most of the developing countries examined, maybe with the exception of Sub-Saharan Africa. According to McCausl and Theodossiou (2012), developed countries from 1992 to 2007 also experienced the same trends as supported by Kaldor's thesis.

Rodrik discussed the driving nature of manufacturing (2013), how successful regions have changed their structure to benefit from this driver of economic growth (McMillan, Rodrik, and Verduzco-Gallo, 2014), and whether this path of economic development is still open to currently developing countries in a series of recent publications (2015).

This series shows how labor productivity climbed quickly and universally in the formal manufacturing sector, and how worker migration from low-productivity to high-productivity sectors—particularly manufacturing—helped Asian countries grow quicker than other areas. Rodrik, however, is pessimistic about the way developing nations' economies are currently developing as a result of early deindustrialization.

2.2.3. Physicochemical Concentration

Water is vital resource for the human beings wellbeing and ecosystems services. However, the anthropogenic activities of urbanization, industrialization, and environmental disruption have affected environment lead to human health malfunctions. The discharge of industrial wastewater into nearby water bodies was the point source of environmental pollution (Kaur et al., 2010).The degradation of environmental quality by the discharge of industrial wastewater has become an environmental problem developing countries, such as Ethiopia (Ohioma et al., 2009).In the recent decades, the industrialization has resulted an augment in the complexity of toxic wastewater (Sewvandi and Adikary, 2011). Emission from the industrial wastewater into the environment has a significant impact on the recipient water bodies (Ranade and Bhandari, 2014).

Sustained economic growth, urbanization, and high population growth have contributed to the rapid increase in the amount of industrial waste in urban areas of developing countries (Fakayode, 2005). In Ethiopia, industrial enterprises are situated nearby water bodies, and thus easy to discharge wastewater directly into rivers without treating that a decline in water quality services for aesthetic value, recreation, agriculture, and household uses (Ferezer Eshetu, 2012). According to Tamiruet al. (2005), industries exist in Ethiopia, 90 % to 96 %of waste is dumped in nearby waters and open spaces without treatment.

Industrial Wastewater effluents are the main contributor to an assortment of water, soil, and vegetable contamination tribulations. Most cities of developing countries spawn an average of 30–70 mm³ of wastewater per person per year as a result of not having or reprehensible wastewater treatment facilities often discharged into surface water sources of vessels for domestic and industrial wastes, resulting in pollution (Edokpayi et al., 2017).

The values of Zn, Pb, and Cr in spinach were above the safe limit of WHO standard signifying a health risk hazard for consumption of such vegetables in urban streams in Machakos municipality of Kenya (Tomno et al., 2020). The EC exceeded the set limits of WHO acceptable limits for surface water in urban streams in Machakos municipality

of Kenya (Tomno et al., 2020). The TDS, BOD₅, EC, Turbidity, DO, and Cl exceeded the permissible limit resulting from the high concentration of industrial wastes and toxicological compounds (Arafat et al., 2021)

The mean concentrations of pH, Cu, Cr, and Cd plus pH, EC, HCO₃⁻, Cu, Cr, Cd, and TDS were above the safe limit of FAO irrigation water quality standard at downstream and downstream irrigated farm soil samples in Kombolcha town of Ethiopia, respectively (Mohammed et al., 2021). The amount of COD, BOD, TSS, cadmium, and zinc were depicted as a heavy contamination load in textile wastewater at Sri Sulong, BatuPahat, Johor of Malaysia (Abu Bakar et al., 2020).

Furthermore, the physicochemical of water and fatty acid profile of fish, *Labeorohita* (Hamilton) collected from the Ramsar sites of Punjab of India showed poor water quality as per water quality index (WQI) of Harike Wetland and heavy load of heavy metal pollution as per heavy metal pollution index (HPI) for Harike Wetland and Nangal Wetland signifying (Kaur and Brraich, 2022). The contamination of the Akaki River of Addis Ababa city in Ethiopia had resulted in disruption of the environment and potential usability turn down for urban agriculture, livestock drinking, and recreational purposes (Deshu et al., 2021)

According to Hillary et al (2015), industrialization was deep-seated to economic development. However, its adverse impacts were not understood this much by the policy makers about the environmental degradation bent by manufacturing industries in the region (Oromia Water Works & Design Enterprise, 2011). Furthermore, there were lack of the effective and efficient controls and monitoring system son pollutant industries in the area (Daley, 2015).Even the implementations of EIA in developing countries were plummets far behind compared to implementation of EIA in developed countries (Wood, 2003).The Environmental Cost-Benefit Analysis (ECBA) showed social evaluation of investment projects and policies that involve significant environmental impacts (dorfman, 1996; Heinzerling and Ackerman, 2002; Ackerman and Heinzerling, 2004).This analysis could help to make out the environmental impact and enables better decision making (Dornfeld 2011).

The United States generates 7,080,000 tons of industrial wastes annually in the process of manufactured goods (Twardowska et al., 2004). According to Mathew A, Cole, and et al (2003), indicates that the rapid industrial growth of china has placed in increased pressure on the country's natural environment. According to Kumar (2017) industrialization has resulted in the degradation of environment, plants, and the depletion of natural resources. M.S. Narwal, Ajit, Ram Bhoor (2014) was also indicted that the industrialization damage the environment. Olaniyi et al (2012) were also depicted that industrial activities in Nigeria contribute loads of toxic wastes to the environment. Jevancherniwchan(2012) further showed that 1 % increase in industry's share of total output is associated with an 11.8% increase in the level of emission per capita.

2.2.4. Heavy Metals

Heavy metals-induced environmental disruption has threatened the ecosystem and biodiversity services (Ali *et al.*, 2013; Hashem *et al.*, 2017). The boom of industrialization and urbanization has caused degradation of the environment by heavy metals since the 1940s (Khan *et al.*, 2004). Heavy metals are not biodegradable that affect the environment, food chains, and health malfunctioning for animals and humans (Davydova, 2005; Javed&Usmani, 2012). The exposure to heavy metals in the environment disruption is an actual threat to living organisms (Wieczorek-Dabrowska *et al.*, 2013; Javed&Usmani, 2015).

In developing countries, heavy metal contamination of farmland was rigorous and degrading environment in recent decades (Agca&Ozdel, 2014). Besides, irrigation with industrial wastewater has caused striking heavy metal toxicity in soils and crops. Owing to heavy metal absorption in soil irrigated with wastewater was resulted in patronizing in growing plants' palatable parts (Arora *et al.*, 2008). Recently, the deliberation of heavy metals in irrigation water, soil, and vegetables has been gravely escalating on farmland as a result of industrialization and urbanization.

According to Suruch (2011), in developing countries, the expansion of industries such as metal smelting, beverages, textiles, chemicals, paints, paper, cement, plastic, and tanneries have been established around the residential area and nearby riverbank. Industry wastewater has resulted in a high concentration of heavy metals such as Cadmium (Cd),

Arsenic (As), Mercury (Hg), Copper (Cu), and Lead (Pb) that caused serious environmental disruption (Bigdeli&Seilsepour, 2008; Odai et al., 2008; Yusuff&Oluwole, 2009; Ahmad &Goni, 2010; Alghobar&Suresha, 2017). The Oromia Special Zone Surrounding Finfinne towns various industry types such as textile, tannery, cement, paint, plastic, pulp and paper, food processing, metal smelting, and others were established in recent decades and emitted untreated effluents into the river, which led to heavy metal toxicity in the irrigation water. Due to soil irrigated with wastewater, heavy metal concentration will be supercilious in growing plants' edible parts (Arora *et al.*, 2008). Therefore, this study aimed to evaluate the absorption of heavy metals in water, soil, and vegetable resulting from industrial wastewater generated from the selected town of Oromia Special Zone Surrounding Finfinne (Sululta, LagaTafo, Galan, Sabata, and Burayu), Ethiopia.

The concentrations of As, Co, and Pb in the cabbage and carrot were above the safe limit of the WHO/FAO signifies exposure to health risks for people consuming such vegetables and contaminated soils in most sites of Cameroon (B.A. Fonge et al., 2021). The physicochemical properties such as temperature, pH, electric conductivity, dissolved oxygen, total suspended solids, total dissolved solids, biological oxygen demand, and chemical oxygen demand were heavily accumulated in the Shankela river of Addis Ababa city in Ethiopia (Solomon et al., 2022). The concentration of Pb was also found highest in soil, water, and plant samples during the dry season around an Electronic Waste Dumpsite in Nigeria, Alaba International Market in Lagos (Olafisoye et al., 2013)

2.2.5. Industry Development Strategy

It has long been believed that structural change and economic growth are primarily driven by industrial progress (Prebisch, 1950; Singer, 1950 as quoted in Mulu, 2013). A wise and strong government guiding the private sector, securing sufficient policy tools for industrialization, constant policy learning through concrete projects and programs, internalizing knowledge, skills, and technology as a national goal, effective public-private partnerships (PPPs), and the collection and sharing of sufficient industrial information between government and private entrepreneurs have all been made possible

by proactive industrial policy (Rodrik, 2004; Hausmann and Rodrik, 2003 as cited in Mulu 2013).

It is now widely acknowledged that industrial strategy may be effective in nations with robust meritocratic social services and political checks and balances. These mostly consist of member states of the Organization for Economic Co-operation and Development (OECD) and a number of other high-income or upper middle-income nations. It is common knowledge that Korea, Taiwan, Singapore, Brazil, and Chile are among the nations that have effectively employed industrial strategies to close the gap with the wealthier OECD members. However, most observers have a modest degree of skepticism over the effectiveness of industrial policies in low- and lower-middle-income nations.

All available superiority indicators show that these nations almost entirely trail behind in terms of government responsiveness, understandability, and efficiency. Thus, even if these nations appear to be experiencing primarily violent market collapse, it is highly doubtful that their governments will be able to intervene in markets in a way that would increase the well-being of the community (Chang, 2006).

Furthermore, Ethiopia's manufacturing sector emerged in the 1950s, far earlier than in many other Sub-Saharan African nations, whereas modern industries only started to emerge in the second half of the 1950s with the intention of implementing an import substitution strategy (MoI, 2013). Significant foreign investment participation in the nation's industrial sector has also been drawn in by the industry development policy (MoI, 2013). However, in reality, industrial policy failures abound in economic narratives. Regardless, it is improbable that the appropriate policy mix would be the same as in wealthy nations because there are considerable variations in both the necessary conditions and the capacity for collective intervention.

However, little is known about the superiority as well as the results of industrial policies in low- and lower-middle-income countries, which contrasts sharply with the aforementioned achievement cases of catch-up improvement. This article's goal is to assist in closing this gap. The assessment of industrial development policies' efficacy and

the significance of industrial policymaking in advancing industries are given particular attention. It finishes with a suggestion for industrial policy.

2.2.6. Ethiopian Industrial Policy and Development Phases

In Ethiopia, modern industry development began to take shape as an economic sector at the turn of the 20th century. The demand for imported manufacturing commodities was increased by the development of railways, urbanization, strong central government support, and expanding international links. This in turn encouraged the construction of domestic factories that replaced imports, and as a result, modern manufacturing companies started to emerge in the 1920s (Mulu, 2013). Following a brief period of disruption during World War II, industrial development began to pick up steam in the 1950s. This was also evident with the introduction of a comprehensive strategy to advance the nation's industrial and economic development (Mulu, 2013).

During this period, a number of new industries, which significantly contributed to the development of the national economy, were established. The 1950s are also spotted by the commencement of a comprehensive plan to stimulate and guide the country's industrial and economic development in general. Hence, the industry development has started to get momentum in the country afterwards.

The three successive development plans have been carried out under the Imperial administration (1958–1973). The creation of the First Five Year Plan (FFYP), which covered the years 1958–1962, the Second Five Year Plan (SFYP), and the Third Five Year Plan (TFYP), which covered the years 1963–1973, respectively, marked the beginning of a deliberate effort to encourage industrial growth in the middle of the 1950s. The country's industrial sector has been boosted by the implementation of the programs, which has attracted foreign investment (World Bank, 1985). Nevertheless, by the time the Imperial government ended, the industrial foundation as a whole was inadequate. Accordingly, over 65 percent of Ethiopia's medium- and large-scale manufacturing companies were owned by foreigners (Eshetu, 1995 as reported by Mulu, 2013).

Table 2.1: History of Industry Development in Ethiopia

| Parameters | Imperial period(pre 1974) | The Dergue regime (1975-91) | The EPRDF regime (post -1992) |
|----------------------------|--|---|--|
| Guiding policy | Market oriented | Command economy | Market oriented |
| Public private role | Private-led | State-led | Private-led but also strong state role |
| Ownership structure | Dominance for foreign owned enterprises | Dominance of public-owned enterprise | Dominance of domestic private owned enterprise |
| Target industries | Import-substituting and labor-intensive industries | Import-substituting industries and labor intensive | Export-oriented |
| visualized key actor | Far-off outlay | communal sector outlay | Home-Individual sector |
| Policy tool | Using high tariffs to protect the home market | safeguarding the home market with high tariffs and quantitative constraints | Direct assistance in the form of capacity building for certain export industries |
| The role of the government | Development of human resources and infrastructure | mostly regime possession | Development of human resources and infrastructure |

Source: Mulu, 2013

There were only 60,000 jobs produced by the modern medium- and large-scale manufacturing sector (MLSM), which employs ten or more people and uses power-driven machinery. It was primarily controlled by foreigners and dominated by light industries that replaced imports (Mulu, 2013).

Prior to declaring "a socialist economic policy" in the mid-1980s, there was no official industrial policy under the Dergue government (1974–1991). As a result, several limitations on the market and private sector were imposed, and the bulk of MLSM enterprises were nationalized. State-owned businesses began to restructure their nationalized businesses. As the manufacturing sector faded, the private sector effectively downsized to micro- and small-scale industry. The Ten Year Perspective Plan 1984/85-1993/94 has been in force for the public investment program of the indicated portfolio of projects and output targets under the regime (Mulu, 2013).

Ten years after the revolution, in 1985–86, state-owned enterprises (SOE) controlled 95% of the value contributed and 93% of the workforce of all MLSM businesses during that time. The manufacturing sector was also mostly affected by the turmoil of the period and exhibited about 40 % decline in value added in 1991 alone. The number of establishments in the MLSM sector also shrunk from about 380 in 1987/88 to 275 in 1990/91 with a corresponding decline in employments.

The first decade (1991–1999) of the Federal Democratic Republic of Ethiopia (FDRE) led government was characterized by a number of changes that reversed the command economy and carried out three stages of IMF/WB sponsored reform projects. The government implemented an export promotion strategy in 1998. In 2002–2003, a comprehensive Industrial Development Strategy (henceforth referred to as IDS) was developed. IDS has been practically implemented through a variety of sub-sector strategies and subsequent development plans, including the Growth and Transformation Plan (GTP) 2010/11-15/16 (Mulu, 2013) and the Sustainable Development and Poverty Reduction Program (SDPRP hereafter) 2002/03-2004/05 and the Plan of Action for Sustainable Development and Eradication of Poverty (PASDEP hereafter) 2005/06-2009/10 (See Table 1). Thus, industry development has got due attention recently and supported by different reform program for firms promotion.

2.2.6.1 The industrial Investment Priority Areas and Infrastructure Facilities

Ethiopia's industrial policies include specific elements such as ownership structure, regulations pertaining to industrial growth, target, and indicators of activities, principles, and market orientation. Furthermore, Ethiopia's industrial development policy was export-oriented and privately led (since 1991; Ethiopian People's Revolutionary Democratic Front, or EPRDF)); import substitution and state-led (from 1974 to 1991, the Dergue regime); and import substitution and private sector-led (from the early 1950s to 1974, the Imperial regime). Then, Ethiopia's industrial development has gone through numerous fruitful development plan processes. As a result, the industry sector has significantly contributed to the achievements of the nation's development efforts.

After the FDRE formulated the national industry policy in 2002, the industrial sector in general and the manufacturing sector in particular were accorded exceptional national

prominence. This policy was created within the framework of the free market economy and the global environment. It recognizes the private sector as the driving force behind industrial development strategies, and it emphasizes labor-intensive industries, coordinated foreign and domestic investment, agriculture-led industrialization, and export-led industrialization (MoI, 2013).

Priority sectors including the textile and apparel, leather and leather products, chemical, metal, agro-processing, and construction industries have also been identified by the industry policy of 2002 as needing special attention in order to provide the groundwork for these sectors to assume their pivotal leadership roles in the economy. Furthermore, industry policy serves as the foundation for Ethiopia's future industrial growth (MoI, 2013).

Kenichi Ohno (2015) states that under developed areas, inadequate infrastructure, a lack of effort to enhance the business climate, and other issues necessitate additional reform in Ethiopia's industry strategy. Consequently, industry development policies require careful consideration in both their implementation and the elements and tools used in their preparation.

Because of the program, the percentage of people who can access infrastructure services—particularly electricity—that help industrialists has gone from approximately 8% in the 1990s to 47% in 2011. 6000 cities and rural regions were electrified during the same period, and the per capita electricity usage increased from 20KW to 100KW (The Ethiopian Herald, May 22, 2012). By 2015, the estimated electricity mix will consist of 30 MW of solar, 890 MW of wind, 70 MW of hydropower, and 9000 MW of hydropower. Ethiopia is now exporting 35 MW to Djibouti, 100 MW to Sudan, and 400 MW to Kenya in the near future (Addis Zemen Daily, April 24, 2012 as reported in MoI, 2013).

Recently, the increased accessibility of infrastructure in the country has created an opportunities for industrial entrepreneurs to utilize the infrastructures developed in country for different purposes. Thus, industry has magnetized in country with creating different job opportunity, technology transfer, increased foreign exchange earnings and other benefit that support development effort of the country.

Table 2.2: Evaluation of industry policy

| | Evaluation of industrial policy sub-components | | | | | | | | | | |
|---------------------------------|--|-----|-----|-----|-----|-----|-----|---|-----|---|-----|
| | L | M | U | T | E | R | G | H | I | J | k |
| Policy ownership | 5 | 3 | 3 | 4 | 5 | 5 | 5 | 3 | 5 | 2 | 4 |
| Vision of top leaders | 5 | 3 | 3 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 4.1 |
| Policy drafting procedures | 2 | 1 | 2 | 2 | 3 | 4 | 4 | 1 | 3 | 2 | 2.4 |
| Capacity of policy | 3 | 2 | 2 | 3 | 3 | 4 | 5 | 2 | 2 | 2 | 2.8 |
| Mindset of individuals | 3 | 2 | 1 | 2 | 4 | 4 | 4 | 2 | 3 | 2 | 2.7 |
| Budgeting staffing | 4 | 2 | 2 | 4 | 5 | 5 | 5 | 1 | 3 | 2 | 3.3 |
| Ministerial coordination | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 2.1 |
| Involvement of stakeholders | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 2.5 |
| Monitoring & evaluating methods | 3 | 1 | 1 | 2 | 5 | 5 | 5 | 1 | 3 | 2 | 2.8 |
| Impact on real economy | 2 | 2 | 0 | 4 | 3 | 5 | 5 | 2 | 3 | 2 | 2.8 |
| Average | 3 | 1.9 | 1.7 | 3.1 | 3.9 | 4.3 | 4.4 | 2 | 3.2 | 2 | 3.0 |
| Grade | B | D | D | B | B | A | A | B | B | C | B |

Source: Kenichi Ohno, 2015

Notes:

Evaluation: 0 (non-existent or worse), 1 (little), 2 (some), 3 (moderate), 4 (good), 5 (excellent)

Evaluation of policy prepared and implemented by the government only; results obtained by the Private efforts; international cooperation or external conditions are not included

Letter grade: A+ (4.5 or above), A (<4.5), B (<4), C (<3), D (<2), F (<1)

L= Industrial Human Resource

G= Industrial Parks

M= Domestic Enterprise Development

H= Supporting Local Industries Linkage

U= Business Climate

I= Productivity Technology & Innovation

T= Power and Logistic

J= Standards and Testing

E= Export Promotion

K= Average

R= Strategic FDI Marketing

2.2.6.2. The Performance of Industrial Investment

In Sub-Saharan Africa (SSA) and Ethiopia, the average annual growth of industry from 2001 to 2011 was 9.1% and 4.2%, respectively; in SSA and Ethiopia, the average annual growth of industry from 2004 to 2011 was 10% and 4.3%, respectively (Mulu, 2013). In addition, Ethiopia's industry growth rate is low when compared to SSA's average industry growth rate, meaning that the government must focus on industry development to boost the country's industrialist participation.

The Dergue regime's 1974 revolution had a significant impact on Ethiopia's manufacturing sectors and economic disruption. When capital investments in the private sector stopped, labor's marginal productivity started to fall, going from 1974/75 to 1977/78. This indicates that from 1985/86 to 1988/89, the average annual growth rates were 8.9%, 3.1%, and 3.8% annually for the year's 1978/79 and 1979/80, 1980/81 and 1984/85, and so on.

The manufacturing sector in 1975 was characterized by several factors, including a high concentration of light industries, a heavy reliance on foreign ownership and managerial, professional, and technical staff, an inward orientation and relatively high tariffs, capital-intensiveness, underutilized capacity, minimal linkage among the different sectors, and an excessive concentration of industries in Addis Ababa. With more local and foreign private entrepreneurs expanding industry projects in the nation, the country's industrial investment has improved recently.

Ethiopia's industrial development is guided by the nation's overarching economic development policy, the ADLI. The MoI's vision and targets for the industrial sector include becoming the leading country in Africa by 2025, increasing the industrial sector's GDP contribution from 15% in 2015 to 28% by 2025, and increasing manufacturing from 5% of GDP in 2015 to 18% by 2025 (MoI, 2016). Additionally, the government has established principles, targets, activities, and other strategies for industry development in development plans like the Sustainable Development and Poverty Reduction Program (SDPRP) (2002/03-2004/05), the Plan of Action for Sustainable Development and Eradication of Poverty (PASDEP) (2005/06-2009/10), and The Growth and

Transformation Plan (GTP) (2010/11-15/16). Now, let us see the performance level of industry development in the development plans of the FDRE.

2.2.6.3 .Sustainable Development and Poverty Reduction Program (SDPRP)

The economy of Ethiopia was experiencing negative growth in the 1980s and early 1990s, with average GDP growth of 2.3% and per capita GDP growth of -0.4%. However, the 1990s and 2000s saw positive growth, with average real total and per capita GDP growth of 3.7% and 0.7% per annum, respectively (MoFED, 2002). The Sustainable Development and Poverty Reduction Program (SDPRP) of 2002/03–2004/05 was the first integrated development plan the nation implemented. After this, the economy started to perform better, with average GDP growth of 6.7% annually and average annual per capita income growth rate of 3.65%. The second and third years of SDPRP period annual economic growth, with annual rates of 11.9% and 10.6%, respectively. Since then, the country has maintained high growth rates (MoFED, 2011).

The GDP and all its subsectors have grown by 10% or more during 2003–2004, although the industry's share of the GDP has remained constant at 14%. The export of merchandise is still largely dependent on manufacturing ($\leq 9\%$). This is a result of growing reliance on imports and weak domestic ties, which limit exports even when efforts are made to remedy the low quality of inputs in the domestic market (Mulu, 2013). Because of this, it is crucial that the instruments and policies put in place focus on locating new bottlenecks. Even more crucially, the policies themselves must be designed to address obstacles along the entire value chain as well as any horizontal linkages.

2.2.6.4. Plan of Action for Sustainable Development and Eradication of Poverty (PASDEP)

In order to carry out the previous PASDEP development plans, industrial development was encouraged for small, medium, and big businesses, especially those that used agricultural inputs. The nation's five-year growth plans made clear the goals and corresponding government assistance for industrial developers. Strengthening small-scale manufacturing businesses served as the cornerstone for the construction and intensification of medium- and large-scale industries, according to the PASDEP industrial development plan. Conversely, the plan's industrial sectors' strategic priority

projects included the following: textile and apparel; leather and leather products; sugar; flowers and high-value fruits and vegetables; and cement.

During the PASDEP period, the goal for industrial development was to achieve an average annual growth rate of 11.5%, which would raise the sector's GDP contribution from 13.6% in 2004/05 to 16.5% by the end of 2009/10. However, for the years 2004–05 and 2009–10, the industry sector's PASDEP attained an average growth rate and real GDP share of 10% and 12.9%, respectively (MoI,2013).Government statistics on PASDEP shows that the real GDP is growing at an average rate of 11%, 8%, 10%, and 14% per year for agriculture, industry, and services, respectively.

Less than 820 million USD in 2007–08 and more than 2 billion USD in the first half of the 2010–11 fiscal years were invested by foreigners (IDS, 2011; MoI, 2013).On the other hand, during the five years that PASDEP was implemented, the industries generated about 1.5 million new jobs. In 2009–10, the industry contributed 11% of the GDP. Nonetheless, the nation's industrial sectors, including textile and apparel factories, underperformed during the plan period. As a result, industrial performance during the plan period fell short of expectations.

At the conclusion of the PASDEP period, textile exports actually accounted for only 8% of the USD 500 objective.25% of the USD 273 million aim is for hides and leather.3.7% of the USD 227 million goal is made up of other leather products (Mulu, 2013).In reality, there was an astonishing four-fold boom in textile exports from the base year 2004/05 to 2010 and even more by 2011. The Textile & Leather industry's export performance was inadequate. According to a recent study on Ethiopian light manufacturing (Dinh et al., 2012), the lack of competitive input industries (textiles) and inadequate trade logistics are the main challenges facing the clothing industry. The scarcity of high-quality processed leather is the main obstacle to the export of leather goods.

2.2.6.5. Growth and Transformation Plan (GTP I)

The main objective of the industrial development plan is to use industrial development to alter the economy's structural makeup. The thirteen-year plan's implementation will cost 583 billion birr in total (2013-2025). The government, in partnership with the business sector and development partner nations, chooses the most urgent and high-priority

projects to be implemented. These projects have an estimated 173 billion Birr in demand over the next three to four years. Specifically, they aim to increase the GDP share of the manufacturing sector from 4% to 17% by 2025 and the GDP share of the industry sector from 13% to 27% by 2025 (MoI, 2013).

The Growth and Transformation Plan's industrial development was concentrated on the growth of small and medium-sized businesses, the support of medium- and large-scale industry development, the creation of industry zones, the management of public enterprises, the privatization of labor-intensive industries, the use of agricultural products as inputs, industries that are import substitutes and export-oriented, and industries with faster technology transfer. In order to stimulate export-oriented and import-substituting enterprises, the industry sector development GTP I greatly boosted the vertical and horizontal connections between the agricultural and industrial sectors (MoFED, 2010).

The priority industrial projects of GTP I were agro-processing, textile and garment, Leather and leather products, metal and engineering, and chemical and pharmaceutical sectors of manufacturing industries. Moreover, taking 2009/10 as the base year, the Growth and Transformation Plan I (GTP I hereafter) sets industry target under a base case to high case scenario of 10.2% to 21.4 % (Dessalegn et al., 2016). But, the performance of industry in GTP I is below expected. This is due to ambitions plan and targets were not realistically achievable.

Table 2.3: GTP I set real GDP projections targets under base-case and high case scenarios

| Base year 2009/10 | Base year 2009/10 | Five years 2010/11-2014/15 | |
|-----------------------------------|-------------------|----------------------------|-----------|
| | | Base case | High case |
| Agriculture and allied activities | 6 | 8.1 | 14.9 |
| Industry | 10.2 | 20 | 21.4 |
| Service | 14.5 | 11 | 12.8 |
| Real GDP | 10.1 | 11.2 | 14.9 |

Source: MoFED, 2010; Dessalegn et al., 2016

The GTP seeks to transform the country's economy from one that is mostly centered on agriculture to one that is led by industry and services (Dessalegn et al., 2016). Since then, it has been essential to promote private domestic and foreign investment by providing incentives in order to accelerate the development of the industrial and service sectors of the economy. According to Dessalegn et al. (2016), the industry is expected to increase from the base year's 10.2% to a high of 21.4% under the GTP's high case scenario.

Furthermore, the nation anticipated earning USD 644.2 million in GTP I from industrial sector exports in 2011–12; however, actual revenue throughout the fiscal years was USD 255.4 million, or roughly 40% of the target, indicating below objective projected. Therefore, the government has to plan industry development projects based on the available actual financial and human capability to perform in the industry sector.

The share of industry in the GDP contribution remains low compared to the agriculture and service sector. Industry is predicted to surpass agriculture in GDP contribution by 2025, with a 32% contribution as opposed to 29% in agriculture, based on its 13.0% and 15% GDP contributions in 2000–01 and 2010–11, respectively (MoFED, GTP, 2010; FDRE, IDS, 2011). The Ministry of Industry, an independent organization established by the government in 2010–11, was established to meet these objectives. Furthermore, the green economic growth path has been pursued by the industrial development strategy.

Table 2.4: Performance of Industry development in GTP I

| Indicators | 2010/2011 performance | 2011/12 performance | GTP targets 2014/15 |
|---|-----------------------|---------------------|---------------------|
| Real GDP Growth Rate | 11.4 | 8.5 | 11.4 |
| Sugar Production(000 ton) | 0.28 | 0.26 | 2.25 |
| Leather and Leather products (in Million USD) | 104.1 | 112.1 | 496.87 |
| Textile Industries Export(in Million USD) | 62.2 | 84.6 | 1000 |
| Growth rate of industrial value added (%) | 15 | 13.6 | 23.7 |

Source: Dessalegn et al., 2016

The government had set an ambitious goal for the investment projects related to textiles and leather, expecting to produce US\$ 500 million and US\$ 1.6 billion by the end of 2009/10, respectively, while the private sector was expected to contribute US\$ 1.6 billion to the textile industry. Additionally, the government intended to invest directly in the textile industry through joint ventures with international investors in order to achieve fabric self-sufficiency. However, the objective of the leather sector was to shift the export mix toward processed and completed goods, to improve the tanneries' capacity and the finished products' ability to make finished leather products, and to discourage the export of hides and skin by imposing a tax of more than 150%.

However, the nation's growth strategy did not anticipate the same level of achievement from the lofty industry development ambitions. As a result, it is crucial to base industrial project development goals on the nation's ability for sustainable growth as well as the inputs that are available.

2.2.6.6. Industrial Policy Orientation

Since the industry development strategy was launched in 2002, the development of the industry has received the attention it deserves as a matter of national importance. This policy was created in the context of a global free-market economy, taking into account the acceptance of the private sector as the driving force behind industrial development strategies, the direction of export- and agriculture-led industrialization, the importance of labor-intensive industries, the use of coordinated foreign and domestic investment, and the mobilization of the entire society for industrial development (MoI, 2013). In order to provide the groundwork for the industry to assume its crucial leadership position in the economy, the policy has also selected priority sectors that require attention. The major priority industry sub sectors were textile and garment, leather and leather products, chemical, metal, agro-processing industry and construction industry. Moreover, industry policy has created a framework that have Conducive environment for industrial development in the country.

CHAPTER THREE: RESEARRCH METHODOLOGY

3.1. Description of the Study Area

Sheger City includes both urban and rural areas, where manufacturing companies are expanding. The studied areas' urban areas are largely favorably or negatively impacted by people migration and the economy. The study focuses on the capital city of Addis Ababa/Finfinne in all directions. These are the selected study areas, currently organized as sub city like Sululta, LagaTafo Laga Dadi, Galan, Sabata, and Burayu.

Most of the areas in Sheger City are previous under Oromia Special Zone Surrounding Finfinne, which was one of the administrative zones of the Oromia Region which was established in 2008 E.C by Regulation No. 115/2008 which was enacted by Oromia region executive council. It was created from the western direction former Burayu town, Holota and menegasha towns with their rural areas; Sululta , lagatafo and lagadadi town and Molo district from Semien (North) Shewa, Gelan town from Misraq (East) Shewa, Sabata town and sabata hawas from Debub Mirab (South west). This Zone is surrounding the capital of Ethiopia, Addis Ababa, which is called Finfinne in the Oromo language. The main reason for creating this special zone was to ease made to benefit the surrounding society and to bring an efficient use of natural resource specially land to maximum development of surrounding areas of Addis Ababa and to control the urban sprawl of Addis Ababa city over the Special zone of Oromia Surrounding Finfinne.

To realizing the necessity of establishing special administrative and development strategy for areas surrounding the capital (Finfine), the Regional State of Oromia made restructured these areas as “Urban Fringe Zone of Finfine City – named as “OROMIA SPECIAL ZONE SURROUNDING FINFINE”. The Special Zone has an estimated total area of 4,300 km². It consists of six districts/woreda (Akaki, Berek, Mulo, Sebeta – Awas, Sululta, and Welmera) and eight major towns (Burayu, Dukam, Gelan, Holata, LagaXaafoo – LagaDaadhi, Sebeta, Sendafa – Beke, and Sululta) (OWWDSE, 2011).

This special zone comprises a surface area of 4,300 Km². It is surrounding the capital city of Ethiopia, Addis Ababa, which is called Finfinne in the language. Finfinne is a name equating Addis Ababa City. Even the regional National Government of Oromia in its constitution named its capital city is Finfinne (Addis Ababa).It is situated between

latitudes 80 34' 25" and 90 34' 41" N and longitudes 380 25' 50" and 390 7' 53" E. Six weredas: Akaki, Berek, Mulo, SebetaHawas, Sultulta, and Welmera, and eight sizable towns, Sabata, Gelan, Dukam, Legetafo, Burayu, Holeta, Sululta, and Sendafa, comprise the zone. Of the eight towns, Burayu, Sabata, Sululta, and Lege tafo Laga Dadi and Gelan were selected for this investigation.

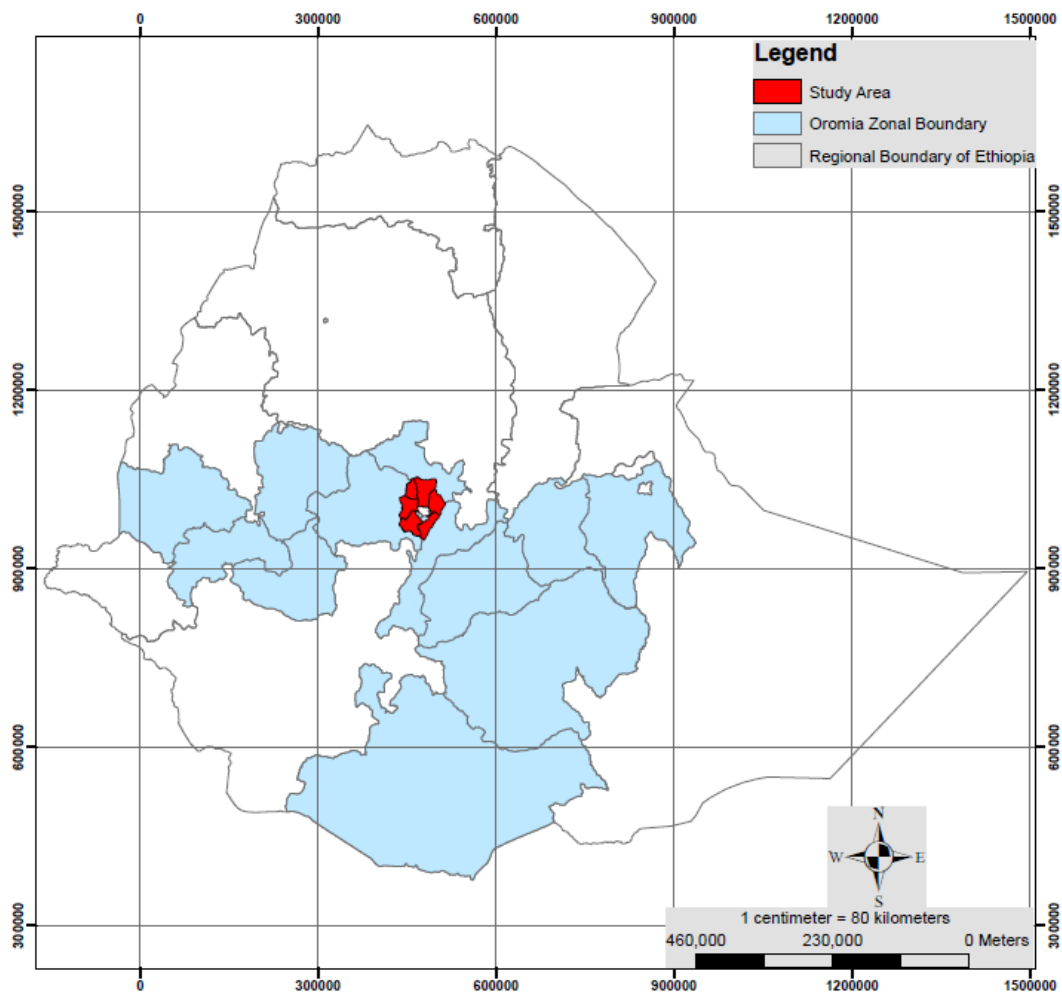


Figure 3.1: Location map of the study area

Source: Oromia Urban Planning Institute, 2022

The terrain of the Oromia Special Zone Surrounding Finfine (the Current Sheger City) is mostly classified into three categories: flat plains to undulating plains, moderate to high relief hills, and high to mountain relief hills. The heights of these areas range from 1000 to 1300 meters above sea level. The mean annual temperature of the Special Zone was in the ranges of 10-20°C and this temperature is within the ranges of physiological

requirement for agricultural production. The agro-climatic situations of the project area covers Cool Humid, Cool Per-humid, Moderately Cool Humid, Moderately Cool moist, Moderately Cool Per-humid and Moderately Cool Sub-humid. Accordingly, 67percent of the study area belongs to the moderately Cool thermal zone with mean average annual temperature of 15 – 20 °C and the remaining 33percent are in cool thermal zone.

Table 3.1: Astronomy and the sample towns Distance from Addis Ababa/Finfinne

| Study Sub cities | Astronomical site | Administrative district | Remoteness from the capital city |
|------------------|--|---------------------------|----------------------------------|
| Sululta | 9 ⁰ 30' 00" to 9 ⁰ 12'15"N latitude and 38 ⁰ 42' 0" to 38 ⁰ 46' 45'' E longitude | 44.71 sq.km | 24km |
| Sebeta | 8 ⁰ 53'38''to 8 ⁰ 59'58''N latitude and 38 ⁰ 35'11'' to 38 ⁰ 39' 33''E longitude | 99 sq.km | 24km |
| Laga tafo | 9 ⁰ 01' 29" to 9 ⁰ 06' N latitude and 38 ⁰ 53' 42" to 38 ⁰ 55' 30" E longitude | 24.3 sq.km | 21km |
| Burayu | 9°4'2.57"N latitude | 38°39'50.81"E longitude | 20 km. |
| Gelan | 8° 52' 0" North latitude | 37° 47' 0" East longitude | 28km. |

Source: Review of literature, 2022

In the context of the research area, Burayu is a less desirable location for industrial expansion than Holota in terms of manufacturing industry expansion. However, a comparison of Burayu's potential industrial growth regions shows that the aged township—presently occupied by residential properties—is a relatively better site for manufacturing expansion. However, because of its close proximity to rivers and streams, the proposed industrial area—which is situated on the upper of farming land in the southern part of Burayu—is also unsuited for industrial development. Thus, it's

imperative to prohibit further industrial development and shift the current industrial expansion gradually toward non-impurity agro-based sectors.

Next to Holota and Burayu, Sululta is a less desirable location for industrial development. The assessment of several Sululta locations for industrial expansion indicates that the aged district, which is presently largely engaged by existing residential along with other uses, is a substantially superior district for manufacturing expansion. Furthermore, due to its proximity to rivers and streams, the proposed industrial area, which is located in Sululta's southwest, is less appropriate for industrial growth. Furthermore, because the town is situated on the zone's upper stream, it would be difficult to put off pollution of streams and rivers. Thus, it is imperative to prohibit the establishment of new heavy industries and gradually shift all existing industrial development to agro-based, non-polluting industries.

The northern, south-eastern, and western portions of Sebeta Hawas are comparatively better areas for industrial development, according to an assessment of the town's several sections for industrial expansion. The town's southeast and western regions are better suited for major industrial growth because the town's northern portion is comparatively unclean. Because of its current level of heavy industry development and its ideal location near Gelan, the industrial development area proposed in the structural plan is preferred for heavy industry development, even though it is partially on upper class of farming land. Besides, new expansion on suitable areas of southeast with complete protection against contamination is also encouraged.

When comparing the two towns of Gelan's industrial growth to their land capabilities and proximity to rivers and streams, the current locations are less beneficial. Nonetheless, the towns are far more desirable than the other towns due to the investment trend, their closeness to important highways, their dry port, and other factors. Therefore, the towns can continue to serve as the region's center for industrial development as long as treatment facilities, buffer zones, and other required safeguards are provided. Furthermore, these two towns' geography and location within the downstream area may make the protection mission easier for them.

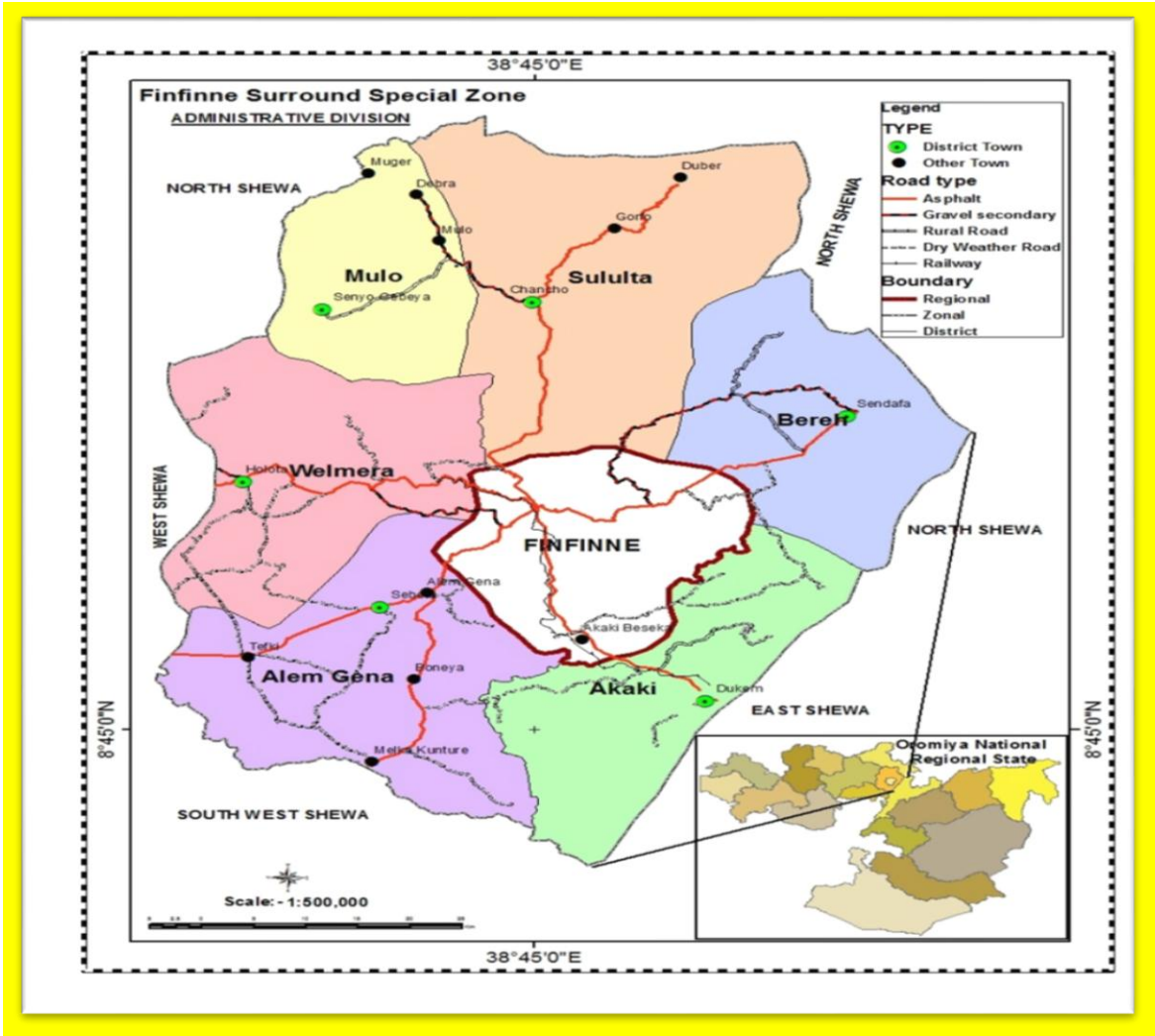


Figure 3.2: Location Map of the Sheger City.

Source: Oromia Urban Planning Institute, 2022

3.2. Research Design

This study, which was planned in compliance with the WHO Drinking Water Guidelines (WHO, 2011) and the American Public Health Association (APHA, 1999), examined the pH, EC, COD, TN, TP, TDS, water, temperature of water and wastewater samples. The American Public Health Association's (APHA, 1999) recommendations were followed in the collection and preservation of the water samples' physicochemical properties.

In order to assess the effects of industrial effluent emissions to the environment that result in heavy metal toxicity of water, soil, and vegetables from selected towns of OSZSF, five sampling sites were chosen from the towns of Sululta, Laga Tafo Laga Dadi, Galan, Sabata, and Burayu. The stresses from upper stream, middle stream, to downstream of the rivers were taken into consideration. The study also made use of secondary and primary data sources. Secondary data sources were gathered from journals, publications, and research papers in addition to primary data received through heavy metals analysis of water, soil, and vegetable samples taken from many study sites and field observation.

The American Public Health Association's (1999) guidelines for collecting water samples were adhered to. Furthermore, the techniques of Jones et al. (1991) and Kim (1995) were applied to the collection of the vegetable and soil samples, respectively. The district's several sites were sampled for water, soil, and vegetables using the composite sampling method. The Global Positioning System (GPS) was utilized to collect and map the water, soil, and vegetable sampling site points from Sululta, Laga Tafo, Galan, Sabata, and Burayu using Arc GIS.

The input-output model was employed together with survey techniques to determine the economic impacts of the manufacturing sector. Specifically, a sample of fifty-four industries was selected, examined, and polled. In order to corroborate and refute quantitative data regarding the economic impacts of the manufacturing industry, 43 stakeholders who are directly involved in its operation were interviewed. The success of the Industrial Development Strategy (IDS) was also evaluated through the use of a framework consisting of principles, criteria, and indicators (PCI) related to policy. As secondary sources of information, the PCI strategy, the industry road map for 2013–2025, and the industrial performance level from many national development plans were looked at.

3.3 Data and Methodology

3.3.1. Data-Spatial

One of the most obvious problems with distance-based approaches is data accessibility. The specific geographic coordinates of each industry, as required by the studies, cannot be obtained using these approaches. We use an uncommon fact set in our study, which is the Oromia Planning and Urban Institute's 2010 record of all industries. However, Dukem Town was specifically chosen for this investigation due to the large number of businesses in the area. The plant-level facts collection includes some basic information for business registration and market monitoring, such as the firm code, address, and service dimension. With Baidu's API, a company's address can be translated into a geographic coordinate (Application Programming Interface).

Based on the geographic coordinates of each company, a drawing comprising all industries in SHP file setup was created using Arc GIS 9.3 (Figure 1). There are 320 companies in the data collection, of which 200 are manufacturing and 171 are services. Clearly, the manufacturing sector has dominated Dukem's industrial development.

The study focuses on how different enterprises' space-based agglomerations differ from one another. Since comparing every company would take too long and be unnecessary, we have chosen eight categories of iconic businesses, including manufacturing, community services, labor- and capital-intensive manufacturing, and businesses that demand a large number of employees, resources, and expertise. In order to obtain a robust and comparable outcome, we govern the firms' bureaucrat class, as demonstrated in Figure 3.3 below.

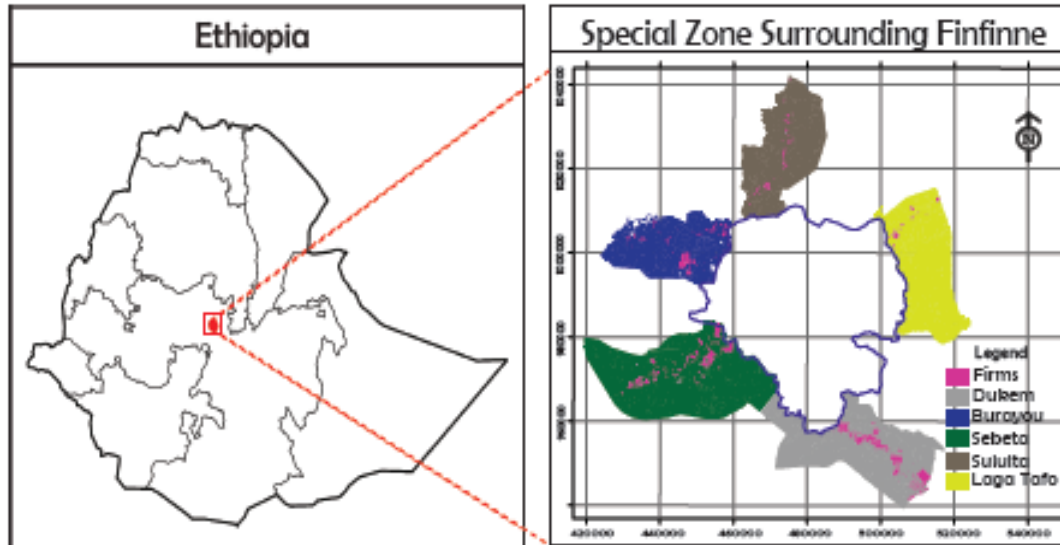


Figure 3.3: Spatial distribution of firms in Oromia Special Zone

Source: Field survey, 2022

3.3.1.1. Kernel estimate of K-density

Using Duranton and Overman's method, the space-based dispersion of each firm was estimated. To be more precise, the $n(n-1)/2$ distinct two-sided distances between each pair of firms in industry A, which has n firms, were determined. Next, an estimate of the compactness distribution of this two-sided remoteness's among the industry's firms was made. The forecaster of the density of two-sided detachments at any point d for the industry A with n firms is:

$$K(d) = \frac{1}{n(n-1)h} \sum_{i=1}^{n-1} \sum_{j=i+1}^n f\left(\frac{d-d_{ij}}{h}\right) \quad (1)$$

Where the Euclidean distance between industries i along with j is denoted by $(d-d_{ij})$. The distribution is explained using the Gaussian kernel. As validated by Silverman (1986), the bandwidth h is set to $0.9[A_n]^{(-1/5)}$. where n is the number of firms and $A = \min(\text{SD}, \text{inter-quartile interval}/1.34)$.

Table 3.2: Groups of industries and quantity of firms

| Kind of industry | Class | Sector | Industrial group | Number of firms |
|--------------------------|-----------|--|--|-----------------|
| Service industries | Education | Providing direction and teaching assistance | Producer service | 14 |
| | Healthy | providing medicinal notice | Public service | 5 |
| | Religious | Belief and conduct | Public service | 6 |
| | Municipal | Water, streets, public libraries, police, and sanitation | Public service | 4 |
| Manufacturing industries | Agro | A host of farming related material | Labor-intensive industries | 23 |
| | Cement | A cement mixture used as a building material | Capital-intensive production processes | 109 |
| | Leather | Restoring luxurious leather clothing, furniture, and interior design | labor-intensive production | 65 |
| | Metal | manufacturing equipment and apparatus | Labor-intensive Industries | 145 |

Source: Field survey, 2021

3.3.2 Economic Impacts

Information for this research was collected from Sululta sub city of Sheger which is situated about 30 kilometers north of Addis Ababa. There were 103 firms found in all, but 23 of them were purposely selected, examined, and asked questions regarding the manufacturing industries' impacts on the local economy. Only 19 of these, or 82% of the industries, offered all the data required for the analysis, though. Besides, input and output model was used to analysis the direct and indirect impacts of manufacturing.

3.3.3. Physicochemical

Shaggar city is made up of eight towns: Burayu, Dukam, Galan, Holota, Laga Tafo Laga Dadi, Sabata, Sandafa, and Sululta. Five towns with significant industrial expansion in the OSZSF—Burayu, Sululta, Laga Tafo Laga Dadi, Galan, and Sabata—were specifically selected for this research. Additionally, the population of these places is growing quickly, which raises the overall quantity of stressors in the surroundings. The OSZSF's elevations ranged from 1500 to 3443 meters above sea level. This zone is positioned among 38°25'50&39°07'53" East longitude and 8°34'25"& 9°32'41" North latitude. The range of temperatures from 10°C to 26°C. There is a range of 1043.87 mm to 1316.6 mm of rainfall every year.

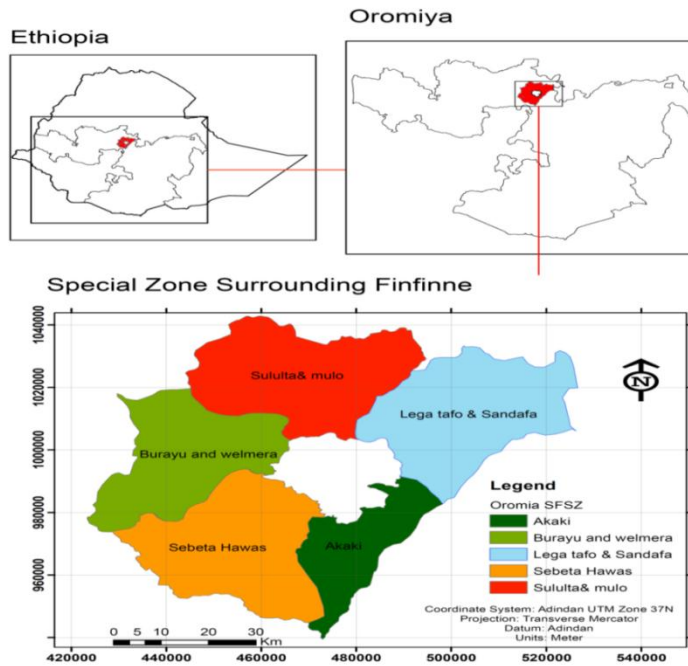


Figure 3.4: Location Map of Shaggar City
Source: Filed survey, 2022

3.3.3.1 Sampling Sites

Considering strain factors from higher stream to lower stream, five sampling points were selected for each study site in the towns of Sululta, Laga Tafo Laga Dadi, Galan, Sabata, and Burayu in order to understand the spatial variation effects of industry wastewater on the physicochemical characteristics of rivers in selected towns of OSZSF. Table 3.3 and Figure 3.4 display the study's sampling locations' and coordinates.

Table 3.3: Industry wastewater sampling points

| Sites | codes | X- coordinates | Y-coordinates | Description |
|----------------------|-------------------|----------------|---------------|--|
| Sululta | SS ₁ | 37P 0473976 | UTM 1016401 | Tap water as control site |
| | SS ₂ | 37P 0474006 | UTM 1016359 | Allied chemical factory |
| | SS ₃ | 37P 04733440 | UTM 1016793 | Around soap factory |
| | SS ₄ | 37P 0470689 | UTM 1028141 | Sibilu downstream river |
| | SS ₅ | 37P 0473024 | UTM 1015381 | Abattoir site |
| LagaTafola gaDadi | LLDS ₁ | 37P 0491810 | UTM 1004028 | Wako river pre industrial waste contact |
| | LLDS ₂ | 37P 0491473 | UTM 1004292 | Abattoir site |
| | LLDS ₃ | 37P 0491017 | UTM 1004547 | Cattle fattening site |
| | LLDS ₄ | 37P 0490832 | UTM 1004669 | MNS factory |
| | LLDS ₅ | 37P 0491827 | UTM 1003942 | Wako river after industrial waste contact |
| Galan | GS ₁ | 37P 0480382 | UTM 0977637 | Dongora stream |
| | GS ₂ | 37P 0480410 | UTM 0977340 | Plastic factory, Pulp and paper factory |
| | GS ₃ | 37P 0485780 | UTM 0974979 | Sago paper sheet factory |
| | GS ₄ | 37P 0484571 | UTM 0975470 | DHG paint factory |
| | GS ₅ | 37P 0481731 | UTM 0976147 | Sophomore (Marble production) factory |
| Sabata | SbS ₁ | 37P 0460919 | UTM 0986567 | Upper stream of Sabata River |
| | SbS ₂ | 37P 0462034 | UTM 0985605 | Ayika Addis textile factory |
| | SbS ₃ | 37P 0459635 | UTM 0985028 | Balazaf & National alcohol & liquor |
| | SbS ₄ | 37P 0457957 | UTM 0982622 | Arbaminchi textile factory |
| | SbS ₅ | 37P 0457632 | UTM 0981046 | Sabata River after industrial waste contact |
| Burayu | BuS ₁ | 37P 0458460 | UTM 0998551 | Guje upstream river farm area |
| | BuS ₂ | 37P 0458755 | UTM 0998921 | Industrial site |
| | BuS ₃ | 37P 0461058 | UTM 0998310 | Spring water used for washing cloth |
| | BuS ₄ | 37P 0460224 | UTM 0998348 | Cement factory, Electric transformer factory |
| | BuS ₅ | 37P 0460315 | UTM09988585 | Gypsum, Marble,& Food processing factory |

Source: Filed survey, 2022

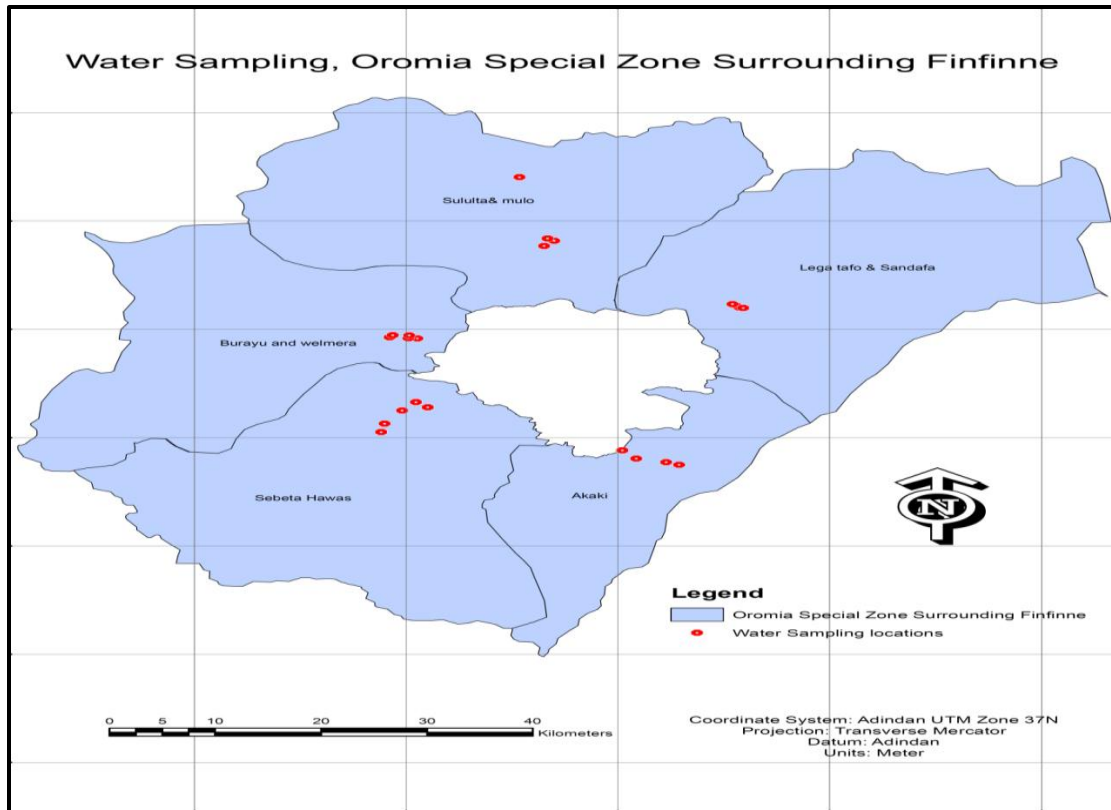


Figure 3.5: Map of industry wastewater points

Source: Filed survey, 2022

3.3.4. Study Design

This study, which was planned in compliance with the WHO Drinking Water Guidelines (WHO, 2011) and the American Public Health Association (APHA, 1999), examined the pH, EC, COD, TN, TP, TDS, and water temperature of water and wastewater samples. The American Public Health Association's (1999) recommendations were followed in the collection and preservation of the water samples' physicochemical properties.

3.3.5. Source of Data

In this study, primary and secondary data were also employed. The primary data are obtained from the physico-chemical examination of water samples collected at each study location; the secondary data are obtained from publications, journals, and research papers.

3.3.6 .Method of Data Collection and Preservation

The American Public Health Association (APHA, 1999) served as the foundation for the data collecting and preservation process used for the water sample's physicochemical parameter analysis. Thus, twenty-five (25) water samples were collected in the research region using the composite sampling approach. A sterile two-liter plastic bottle was used to collect water samples so that the physicochemical parameters could be investigated. The sample code, source, kind, date, time, and collector's name are all properly labeled on the samples. After being collected, water samples were chilled to 4°C (APHA, 1999).

3.3.7. Water sample Analysis

This study used portable conductivity and pH meters, an Aawa AD 8000 pH meter for pH, a portable ADWA TDS meter for TDS, and a 4500 Conductivity meter for EC to measure the physicochemical characteristics of wastewater. The laboratory examination was finished as soon as the sample arrived at the Oromia Environmental Laboratory Center in Burayu town in order to prevent sample deterioration. Total nitrogen (TN) and chemical oxygen demand (COD) were measured with a HACH-DR6000 UV VIS-Spectrophotometer, and total phosphorus (TP) was measured with a HACH-DR3900 UV Spectrophotometer.

3.3.8. Statistical Analysis

One-way analysis of variance (ANOVA) and descriptive statistics are used to verify the differences in the physicochemical characteristics of water at different research locations. The physicochemical variable values were analyzed and compared with the following: the Compulsory Ethiopian Standard (CES) standards for drinking water, the EPA/UNIDO Guideline Ambient Environment Standards for Ethiopia (2003), the WHO drinking water guidelines, the FAO irrigation water standard, the UNU-EHS/UNEP international guidelines for ecosystems, the USEPA, and the EU.

3.3.9 Heavy Metals

3.3.9.1. Materials and Methods

Eight major settlements compose up the Shaggar City: Buryu, Dukam, Galan, Holota, Laga Tafo, Sabata, Sandafa, and Sululta. Five towns—Burayu, Sululta, Laga Tafo, Galan, and Sabata—from the Oromia special zone surrounding Finfinne were carefully chosen to serve as the study sites. In addition to their rapidly expanding population, which has raised environmental stresses, they have rapidly expanding industries that support economic development. The surrounding areas range in elevation from 1500 to 3443 meters above sea level. The Shaggar City is situated in the latitude range of 8°34'25" to 9°32'41"N and the longitude range of 38°25'50" to 39°07'53"E.

3.3.9.2. Sampling Sites

Towns such as Sululta, Laga Tafo, Laga Dadi, Galan, Sabata, and Burayu were the five sampling locations chosen in order to assess the effects of industrial effluent emissions. The upper, middle, and downstream streams of the rivers were also selected with consideration for the stresses placed on the rivers. In addition, the research incorporated data from both primary and secondary sources. The main sources of secondary data were field observation, journal publications and research papers, and heavy metals analysis of water, soil, and vegetable samples collected from multiple study locations.

Table 3.4: Coordinate points of the sampling sites

| Sites | code | X | Y | Description of the code |
|-----------|-------------------|-------------|-------------|---|
| Sululta | SS ₁ | 37P 0473976 | UTM 1016401 | Tap water as the control site |
| | SS ₂ | 37P 0474006 | UTM 1016359 | Allied chemical factory |
| | SS ₃ | 37P 0473440 | UTM 1016793 | Around soap factory |
| | SS ₄ | 37P 0470689 | UTM 1028141 | Sibilu downstream river |
| | SS ₅ | 37P 0473024 | UTM 1015381 | Abattoir site |
| Laga Tafo | LLDS ₁ | 37P 0491810 | UTM 1004028 | Wako River before industrial |
| Laga Dadi | LLDS ₂ | 37P 0491473 | UTM 1004292 | Abattoir site |
| | LLDS ₃ | 37P 0491017 | UTM 1004547 | Cattle fattening site |
| | LLDS ₄ | 37P 0490832 | UTM 1004669 | MNS factory |
| | LLDS ₅ | 37P 0491827 | UTM 1003942 | Downstream of Wako river after industrial waste contact |
| Galan | GS ₁ | 37P 0480382 | UTM 0977637 | Dongora stream |
| | GS ₂ | 37P 0480410 | UTM 0977340 | Plastic factory, Pulp, and paper factory |
| | GS ₃ | 37P 0485780 | UTM 0974979 | Sago paper sheet factory |
| | GS ₄ | 37P 0484571 | UTM 0975470 | DHG paint factory |
| | GS ₅ | 37P 0481731 | UTM 0976147 | Sophomore(Marble production) factory |
| Sabata | SbS ₁ | 37P 0460919 | UTM 0986567 | Upstream of Sabata River |
| | SbS ₂ | 37P 0462034 | UTM 0985605 | Ayika Addis textile factory |
| | SbS ₃ | 37P 0459635 | UTM 0985028 | Balazaf& National alcohol and |
| | SbS ₄ | 37P 0457957 | UTM 0982622 | Arbaminchi textile factory |
| | SbS ₅ | 37P 0457632 | UTM 0981046 | Lower stream of Sabata River after industrial waste contact |
| Burayu | BuS ₁ | 37P 0458460 | UTM 0998551 | Guje upstream river of farm area |
| | BuS ₂ | 37P 0458755 | UTM 0998921 | Industrial site |
| | BuS ₃ | 37P 0461058 | UTM 0998310 | Spring water used for washing cloth |
| | BuS ₄ | 37P 0460224 | UTM 0998348 | Cement, electric transformer, and Marble factory |
| | BuS ₅ | 37P 0460315 | UTM 0998585 | Gypsum and food processing |

Source: Filed survey, 2022

3.3.9.3 Sampling Design

The American Public Health Association conducted a water sample after that (APHA, 1999). Nonetheless, Jones et al. (1991) and Kim (1995) served as the basis for the vegetable and soil sampling. Water, soil, and vegetable samples were gathered from various locations throughout the area using the composite sampling technique. The Global Positioning System (GPS) was used to gather the water, soil, and vegetable sampling site points from five towns. Arc GIS was then used to draw the locations (Figure 3.6).

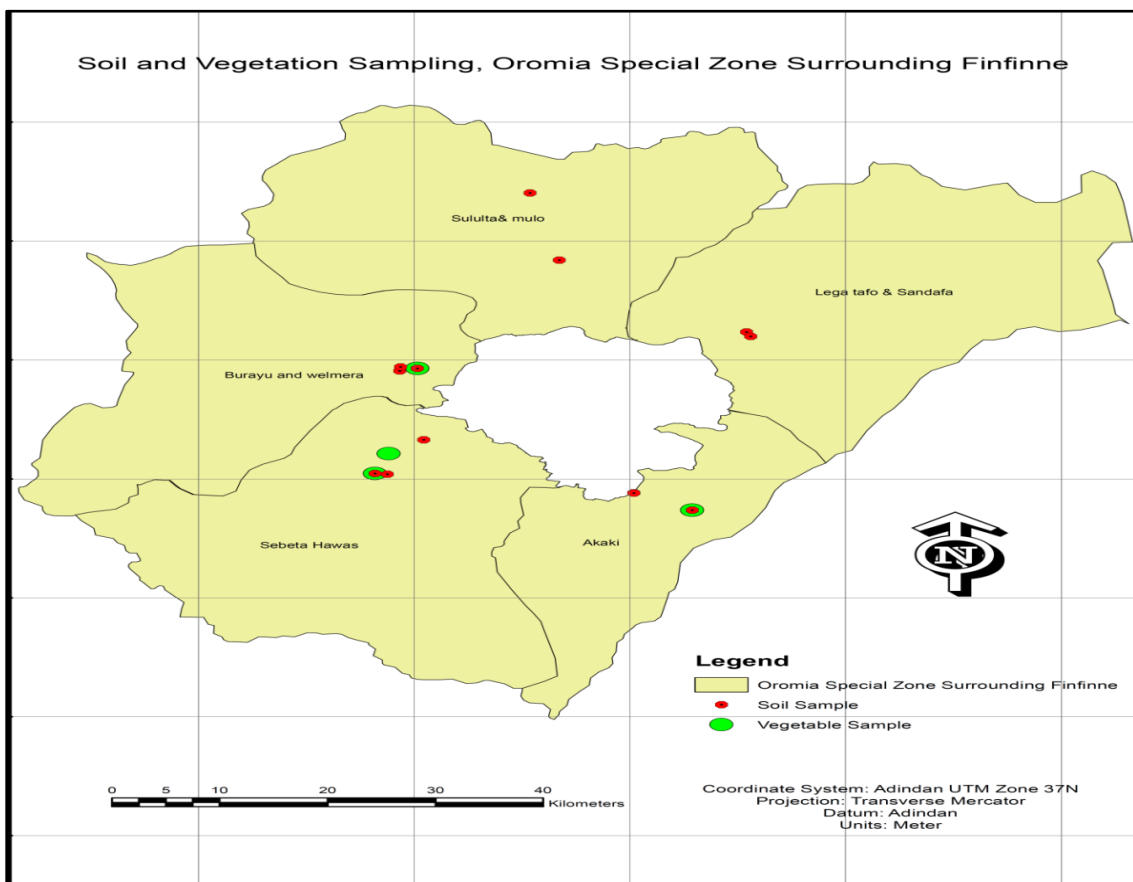


Figure 3.6: Map of soil and vegetation sampling sites

Source: Author compilation, 2022

In order to examine the accumulation of heavy metals through December 2020, samples of water, soil, and vegetables were collected, with a focus on Cu, Pb, Zn, Ni, Mn, Cr, and Cd. Within less than eight hours, soil samples in polyethylene plastic bags and water samples in polyethylene bottles were transported to the Oromia Environmental Laboratory Center of the Forest and Climate Change Authority, Burayu town. For the sake of traceability, the sample container was labeled with the sample code, date, time, source, sample type, and collector's name.

3.3.9.4 Sampling Method

Using polyethylene plastic bags that had been cleansed with distilled water and nitric acid, vegetable samples were gathered from various locations. Garden cabbage acted as the control group, while samples of cabbage, lettuce, and Swiss chard grown on soil irrigated with wastewater were classified as the treatment group. To demonstrate soil samples, the samples were plowed under a shovel. A one-kilogram sample of the surface soil was taken from the rain-fed farm, irrigated area, and wetland at a depth of 20 cm. In order to create the treatment group, water samples were taken from the midstream and lower streams where there was immediate contact with industrial waste, and from the upstream as a control group.

Through December 2020, the sample was collected once a day from 7:00 to 11:00 A.M. The aggregation of heavy metals (Cu, Pb, Zn, Ni, Mn, Cr, and Cd) in the samples was investigated. Given the availability of irrigation sites in the area, samples of water and wastewater, soil, and vegetables were taken with a merging of five, three, and one, respectively, in amounts of 25, 13, and eight. Water samples were gathered at the designated sites of Sululta, Laga Tafo, Galan, Sabata, and Burayu using sterile polyethylene plastic bags that had been washed three times with refined water prior to sample compilation. After that, nitric acid was used to seal the water samples. The attentiveness of heavy metals in water and wastewater was investigated using a UV atomic absorption spectrophotometer (NovAA 400P AAS) at the Oromia Environmental Laboratory Center of the Oromia Environment, Forest, and Climate Change Authority, Burayu town.

3.3.9.5 Digestion processes for Soil Samples

The collected soil samples were put in an oven set to 105°C for twenty-four hours, after which they were sieved and dried. Then, two to three milliliters of water were added to a 100 milliliter Erlenmeyer flask containing 1,000 grams of dehydrated earth. Subsequently, 7.5 milliliters of a mixture of nitric and hydrochloric acids were added and sealed with a stink cover. The flask was then covered with a watch glass and left at room temperature inside a fume hood for the whole night. The dirt was covered with a heated surface and cooked gradually for two hours at 100°C. After that, it was washed with 30 milliliters of water and allowed to come to room temperature.

After being cleaned using sterile, acid-resistant paper, the extract's apparent filtrate was poured into a 100 mL volumetric flask. Multiple times, the digesting container and the remaining material on the sort paper were cleaned with a tiny amount of heated ($\pm 50^\circ\text{C}$) 2MHNO₃. Following cooling, the liquid was volume-marked using a blank and a 2M nitric acid solution. For two hours, the flask was submerged in a water bath at 100°C. Finally, a UV atomic absorption spectrophotometer (AAS) was used to measure the concentration of heavy metals in the soil solutions.

3.3.9.6 Digestion Processes for Vegetable Samples

The collected vegetable samples were treated with nitric acid (HNO₃) to extract the heavy metals (Cu, Pb, Zn, Ni, Cr, and Cd). Approximately 1,000 grams of the vegetable sample were dried at 105°C before being transferred into a porcelain crucible. The samples were prepared in the furnace at 200°C or on a heated shield if the muffle furnace had an airing shaft and the catch was opened.

The samples were treated at 450°C until they got totally mineralized, which took at least two hours. The crucibles were taken out of the muffle furnace and put straight onto the hot plate using the tongs. Consequently, 5 mL of 6MHNO₃ was added, and the mixture was gradually heated until around 1 mL remained. 5 mL of 3MHNO₃ was then added, and the mixture was boiled for 30 minutes. Next, to ensure the correct amount was added, the temperate solution was transferred using a glass rod into a 100 mL volumetric flask. The residue was recovered using a cleaner after the glass rod and crucible were

repeatedly rinsed with 1% HNO₃. The cleaner was tampered with using 100 milliliters of water after being refrigerated. The flagon was closed with the stopper.

An atomic absorption spectrophotometer (Analytic Jena, German, model NOVAA 400) was used to assess the content of heavy metals in the solution prepared from the vegetable samples (Begum and Harikrishna, 2010). An HCL lamp, a 100 mm burner, and a single-beam ocular type were used to set up the analytical instrument. This analytical device was used to apply the flame technique at a concentration of 10⁻⁴ mg/L. The expected quantification boundary, NOVAA 400 10⁻⁴ mg/L, was at or above the stumpy concentration of analytic in the sample utilized to estimate the quantification border.

The validity of the soil technique was evaluated using accredited instructions from Plant Analytical Laboratories Network of Ethiopia (SPALNE) and The National Soil Research Laboratory (NSRL). Examined in the quality control technique are national average solutions of heavy metals and blank samples that are always controlled to zero. There are no analysts or zero unit concentrations in these samples. The amount of heavy metals in water, soil, and vegetable samples was measured using the flame or graphite technique, with a one part per billion (ppb) detection limits. The laboratory instrument work manual and standard operating procedure for measuring heavy metals with an atomic absorption spectrometer in environmental laboratories published by the Oromia Environment, Forest, and Climate Change Authority served as the foundation for the detection limit (MDL) and limit of quantification (LOQ) methods.

The detection limit (MDL) and limit of quantification (LOQ) methods were based on the laboratory instrument work manual and standard operating procedure for measuring heavy metals with an atomic absorption spectrometer in environmental laboratories published by the Oromia Environment, Forest, and Climate Change Authority.

3.3.9.7. Data Calculation

A) Bio concentration Factor

The ratio of heavy metal concentration in a soil sample to that of heavy metal concentration in a portion of a plant sample is known as the bio concentration factor (Rattan et al., 2005; Sharma et al., 2018). As a result, Kachenko and Singh (2004) demonstrated how to calculate the heavy metal transport from soil to plant:

$$BCF = \frac{C_{plant}}{C_{soil}} \quad (1)$$

Where:

The quantity of heavy metal in a portion of a plant is called C- plant, while the amount in soil is called C-oil. A BCF value greater than one indicates that the plant is a heavy metal receptor or accumulator.

B) Health Risk Assessments

Estimated Daily Intake of Heavy Metals

By dividing the weight of the vegetables a person consumes by their body weight, the daily intake (EDI) of each heavy metal was determined. The corresponding middling concentration in vegetable samples was used to achieve this. According to Chen et al. (2011), each heavy metal's EDI value in each type of cabbage, lettuce, and Swiss chard was calculated.

$$EDI = \frac{E_f \times ED \times FIR \times CM \times C_f}{BW \times TA} \quad (2)$$

Where:

The average life span is represented by E_f , which is the coverage incidence (365 days/year), and E.D., which is the coverage gap (65 years) (Woldetshadiket al., 2017). The WHO (2002) defined FIR as the amount of vegetables (cabbage, lettuce, and Swiss chard) an individual must consume daily in order to meet the criteria for low fruit and vegetable intake. CM stands for concentration of heavy metals (mg/kg dry weight), and C_f is the concentration conversion factor (which is 0.085) used to convert fresh vegetable weight to dry weight. (Arora et al., 2008; Harmanescu et al., 2011; Rattan et al., 2005), Woldetshadiket al. (2017) state that T.A. is the midway coverage span (65 years \times 365 days) and that B.W. is the reference body weight for adults, which is 70 kg.

C) Target Hazard Quotient (THQ)

a) Non-carcinogenic and carcinogenic risk assessment

Vegetables containing heavy metals were evaluated for their non-carcinogenic effects using the target hazard quotient (THQ). Given this, THQ values were calculated based on the same scholarly sources as Chen et al. (2011), Ezemonye et al. (2019), Zheng et al. (2007), and Khan et al. (2008) for the use of contaminated vegetables.

$$THQ = \frac{EDI}{RfD} \quad (3)$$

The estimated daily intake of heavy metals (EDI) is expressed as mg/day/kg of body weight. The reference for each heavy metal's dosage values (mg/kg/day) is called the RfD. According to Chen et al. (2011) and Antoine et al. (2017), $THQ > 1$ indicates a chance of non-carcinogenic impacts, whereas $THQ < 1$ indicates safety from non-carcinogenic effects threat.

b) Hazard Index (HI)

The health risk associated with vegetables containing heavy metals is collective and is examined using the hazard index. Next, the HI of heavy metals was computed using the formulas provided by Li et al. (2018) and Antoine et al. (2017):

$$HI = \sum_{n=1}^i THQ_n; i = 1,2,3, \dots, n \quad (4)$$

In contrast, an HI score of > 1 and < 1 indicate, respectively, no likelihood and no probability of a health impact. A depressing long-term health impact is advocated by an HI value > 10 (Antoine et al., 2017; Li et al., 2018).

c) Target Cancer Risk (TCR)

According to Kamunda et al. (2016), the target cancer risk (TCR) of heavy metal (Pb, Ni, Cr, and Cd) ingestion may increase carcinogenic effects based on the expression dose. According to Sharma et al. (2018), the following formula is used to determine the cancer risk (CR) that is attributed to a person's consumption of personage that may have carcinogenic heavy metal effects:

$$CR = EDI \times CPSo \quad (5)$$

$$TCR = \sum_{n=1}^i CR; i = 1,2,3, \dots, n \quad (6)$$

Where CPSo is the oral cancer slope factor (mg/kg/day)⁻¹, EDI displays the predicted daily heavy metal ingestion (mg/day/kg) body weight, and CR is the lifetime cancer risk by personage heavy metal intake. n is the amount of heavy metals carefully examined for cancer peril computation. The CPSo values for Pb, Ni, Cr, and Cd are 0.0085, 1.7, 0.5, and 0.38, respectively, according to Gebeyehu and Bayissa (2020).

3.3.9.8 Data Analysis

One way ANOVA and descriptive statistics were used to statistically examine the concentrated concentration of heavy metals in the soil, water, and vegetables. The changes in heavy metals along with the different sites in the area, the international standard for water, soil, and vegetable quality, and the Pearson Correlation Coefficient (PCC) were also assessed using IBM and SPSS Statistics 24 edition.

3.3.10. Industry Development Strategy

The following metrics, which are displayed in the table below, were used to assess Ethiopia's industry development strategy's efficacy:

Table 3.5: The study employed principles, criteria, and indicators (PCI) related to policy-related effectiveness.

| Principle | Criteria | Indicator |
|---|---|--|
| The goal of the industry expansion plan is to make implementation simple. | The goals of industry development policy are stated clearly. | Specific goals |
| | | Declaration and guidelines Time sequences Instruments subsidiary |
| The validity of industrial development policies must be acknowledged by stakeholders. | Interests of important stakeholders are taken into account while formulating policies. | Current policy frameworks |
| | Making policy is based on evidence. | Policy think tanks come before the process of formulating policies. |
| Industry policies need to be in line with national development policies. | National development goals are acknowledged in policy pronouncements related to industrial development. | National development was mentioned in the national industrial policy. |
| | Initiatives for industry policy are in line with strategies. | Strategy rules for national development goals and industry policy. |
| Industry policy should encourage openness. | Industry policies make it easier for mechanisms to be created and operate. | Systems and procedures are in place to promote transparency in industrial development. |

Source: Birdetal., 2013

Table 3.6: Number of respondent with proportions of participating Institutions

| No | Institution | Number of respondent | % |
|-----------|---|-----------------------------|----------|
| 1 | Oromia Investment Commission | 34 | 25.93 |
| 2 | Oromia Industry Development Agency | 20 | 18.5 |
| 3 | Oromia Environment, Forest and Climate Change Authority | 33 | 18.5 |
| 4 | Oromia Bureau of Urban Development and Housing | 29 | 14.8 |
| 5 | Oromia Industry Development and Park Development | 35 | 7.41 |
| 6 | Oromia Public Enterprises Supervisory Authority | 31 | 7.41 |
| 7 | NGO's/Civil Society | 29 | 7.41 |
| | Total | 211 | 100 |

Source: Questionnaires, 2022

CHAPTER FOUR

4. RESULTS

4.1. Findings about the Industries' Spatial Distribution

4.1.1. Comparative Analysis of Industry Trends Based on Space

Figure 2 illustrates the stark differences in the space-based dispersion between industrialized and service enterprises based on data collected from the research region. Owing to the manufacturing industry's overwhelming dominance (Figure 4.1), all firms' space-based prototypes are actually quite close to the service's prototype. Furthermore, the manufacturing sector has a higher degree of agglomeration relative to the service sector, albeit with a smaller agglomerating distance. In the manufacturing sector, the space-based clustering index is greater than 0.05, whereas in the service sector, it is roughly 0.03.

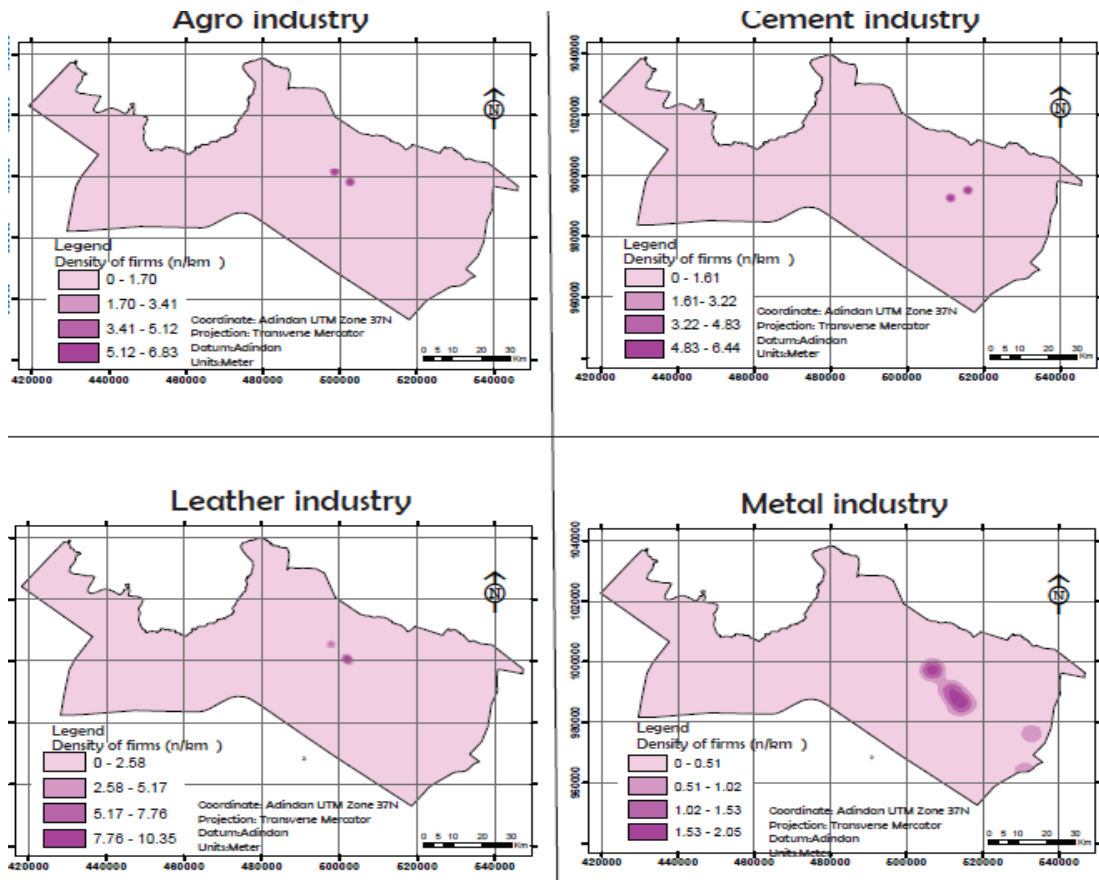


Figure 4.1: Industrialized industries' spatial distribution (n denotes the number of firms)
Source: Filed survey, 2022

According to the overall agglomeration tendency, the manufacturing industry level first rises quickly to a peak at a distance of around 0.5 km and then sharply declines. After the distance reaches 3.9 km, these changes further and falls even below the level of the service industry (Figure 4.2).

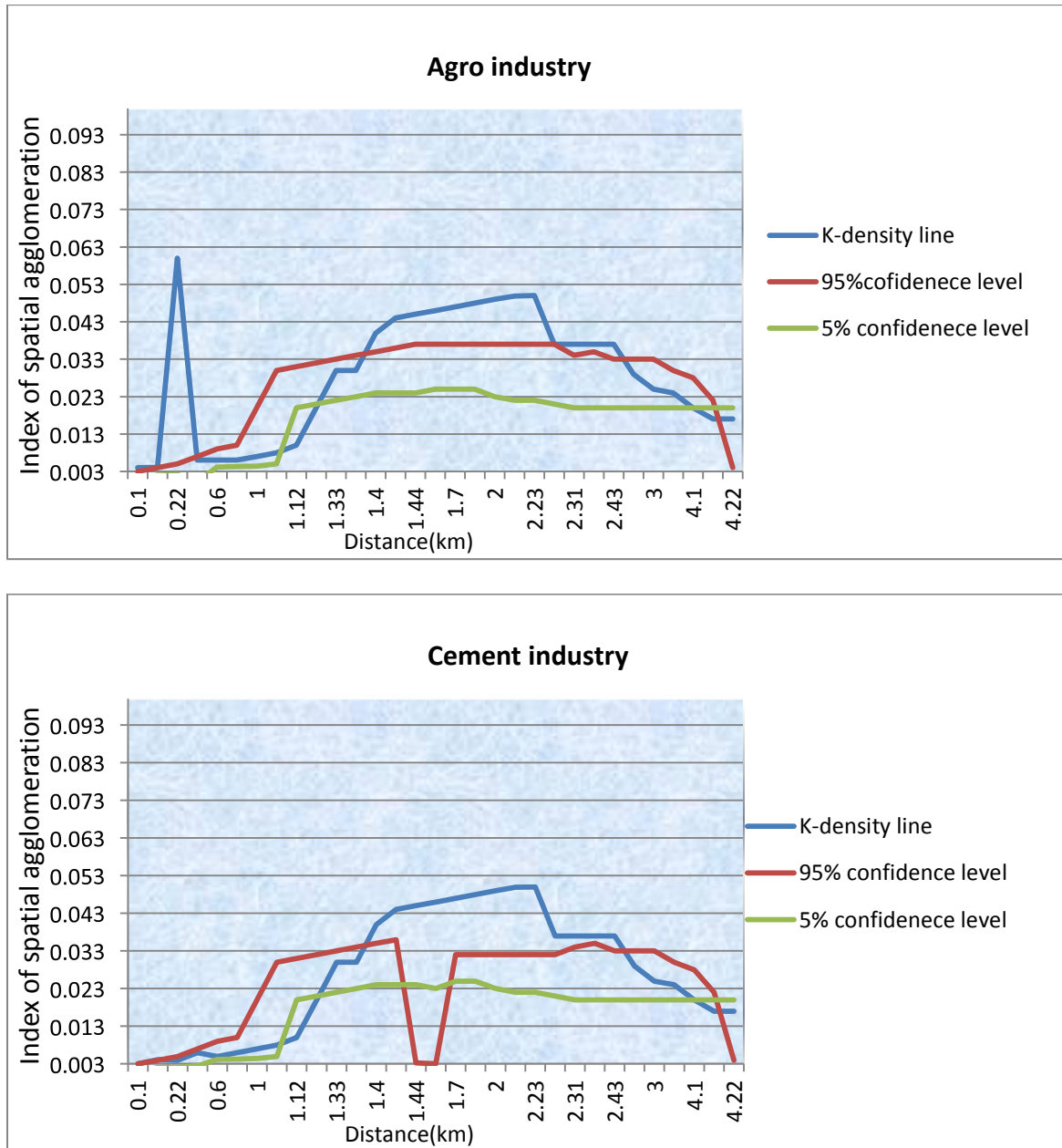


Figure 4.2: Spatial pattern of manufacturing industries

Source: Filed survey, 2022

4.1.2. Comparison between Manufacturing Industries

All four categories of manufacturing sectors share the peak agglomerating distance, which is approximately 2 km. Regardless of the firm's class, the level of manufacturing clustering area is about 2 km since the climax clustering distance is the most desired separation among industries. This result is validated by the center's concentration of manufacturing enterprises from various sectors (Figure 4.3). However, there are differences between these companies in other aspects of the space-based pattern that are apparent. The agriculture business has unquestionably the highest stage of spatial agglomeration (greater than 0.053), followed by the cement firm (Figure 4.4).

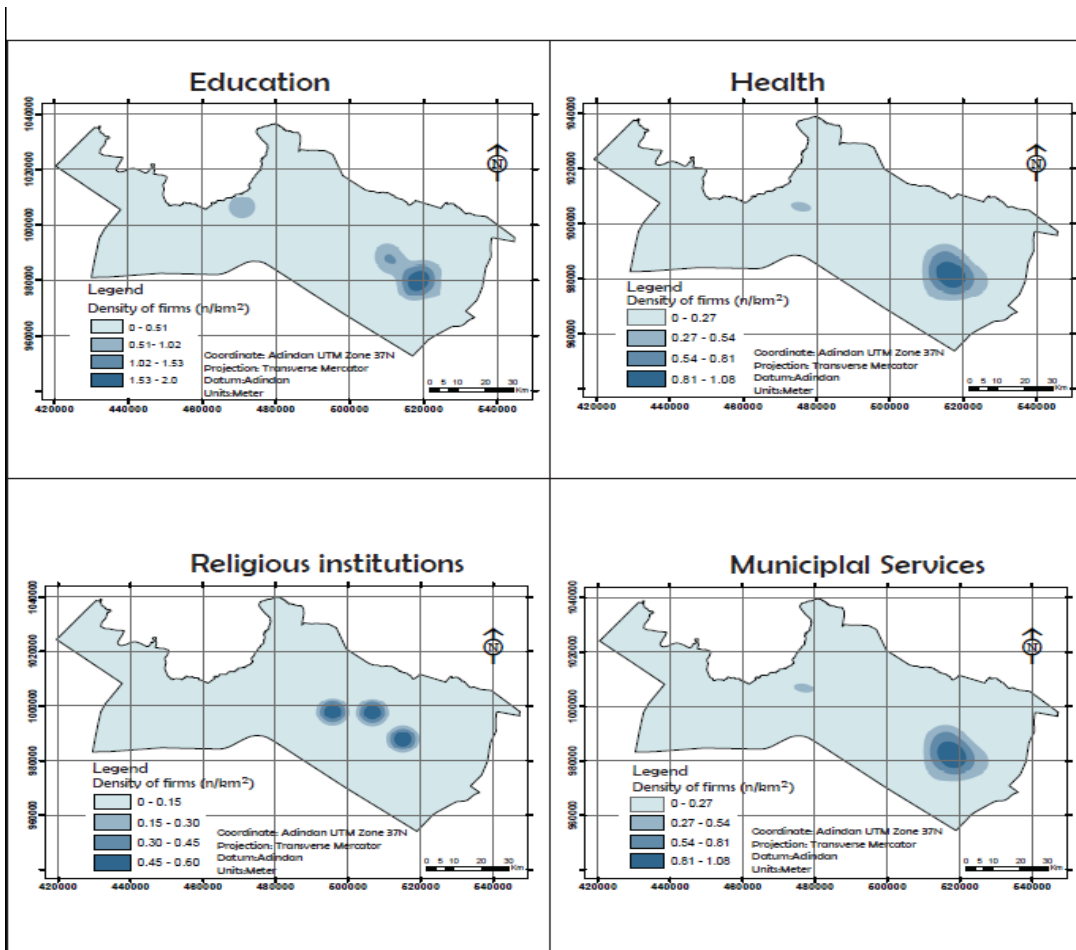


Figure 4.3: Service industry dispersion based on space (n is the number firms)

Source: Filed survey, 2022

4.1.3. Comparison among Service Industries

In the case of manufacturing industries, the difference in the climax clustering distance is not as significant as the variation in the degree of clustering among service firms. This fact suggests that we focus on the variation in clustering level.

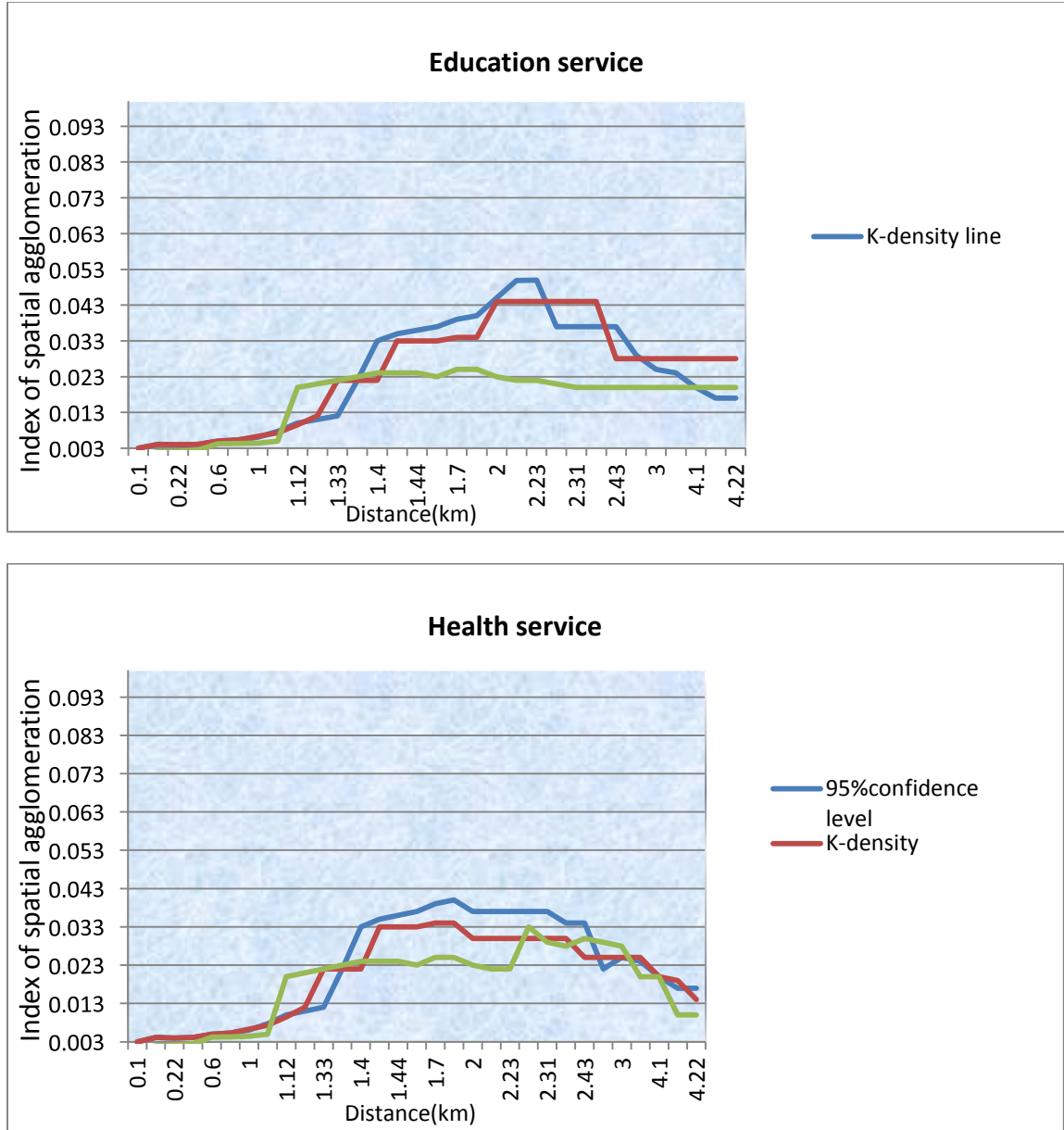


Figure 4.4 Space-based patterns of service industries

Source: Filed survey, 2022

The data analysis results show that the extent of the education service's space-based agglomeration is significantly larger (up to 0.048) than that of health services. (Figure 4.3). Additionally, a sizable cluster of service industry businesses is located in the town center (Figure 4.3). Therefore; the research region may contain a tall, concentrated industrial locality. However, there is a moderate degree of diversity in the clustering levels of the various service industries. The education service's climax aggregating distance is precisely 2 kilometers, much like the health services. This finding suggests that most service-intensive industries are located within a similar distance from one another. Stated differently, the spatial immediacy allows service-based firms to benefit more.

The space-based patterns of industries have combined to create this finale. Conversely, at a distance of less than 2 and less than 3 km, respectively, education and health exhibit a discernible clustering shape (Figure 4.4). Although there is a slight dispersion at a distance of less than 4 km, the location of educational services often appears to be grouped (Figure 4.4). The dispersion prototype is likewise clustered for healthy services (Figure 4.3).

Even while the amount of agglomeration in the service industry is slightly more than the superior at 5% confidence variety at a detachment of more than 4 km, this remoteness is also good to profit from the agglomeration economy. Figures 3 and 4 showed that, despite the fact that many businesses are located in the inner town (Figure 5), industries from these two sectors cluster in built-up area to benefit from one another. In terms of service, knowledge transfers, personnel administration, and local tax payments, the industries were concentrated but unconnected, according to data from focus groups and interviews with important stakeholders. The local development is negatively impacted by these gaps.

As a result, the study's findings largely corroborate the description of location theory provided by R. Hayter and S. Nieweler (2018), which held that proximity and connectivity were essential factors in choosing a site for industry.

4.2. Results on Economic Impacts of Industries

4.2.1. Quantitative Analysis of Industries

About 5.2% of the 23 industries were founded in 2012 or earlier, according to the field survey carried out in 2020. In addition, seven years before the poll, 55% of the industries had fewer than 25 employees and were founded before 2012. On the other hand, more than 24% of the industries were established before 2020 and had at least 25 employees seven years prior to the survey. Approximately 13% of the industry was made up of agribusiness sectors, which were comparatively unevenly distributed between producers of nondurable commodities and makers of durable goods.

Furthermore, a statistical difference ($\alpha = 0.05$) is shown by the Tukey test results between industries with less than 25 employees and those with 25 or more employees. The agriculture and other industries show a significant difference ($\alpha 0.05$) according to the Tukey test. Additionally, nearly 95% of the respondents said they started their careers in the industry within the study area. However, data collected indicated that 42.1% of the 72 million deals that took place in 2020 were carried out with steadfast dedication to businesses outside of the region (Field survey, 2020). Agribusiness and high-tech were among the participants who reported rather high average trades. A significant percentage of out-of-region trades was also recorded by the high-tech and agriculture sectors, as well as by businesses that employed twenty-five or more individuals seven years before to the start of the survey.

Besides, according to the industrial sample, labor accounted for roughly 28% of overall expenditures, with produced products accounting for 25% and unprocessed products for 27% of expenditures, respectively (Field survey, 2020). The proportion of an industry's expenditures that are made locally or, conversely, within the region directly influences the number of these districts that would be subject to indirect economic effects. The majority of the respondents reported that they received benefits from the current industry, and that nearly all of their job disbursements (97%) were made within the municipality. Additional payments and subcontracting were also made, primarily to internal town entities. On the other hand, 50% of their expenses were paid in the municipality and 69% were incurred outside the territory.

The median industrial employment was 15 at the time of the study, despite the fact that a very large industry had a considerable impact. The industries had produced twelve jobs on average over the previous seven years, with an average value of eight. Taking into account every industry, 12% of them stated that their employment had decreased over the preceding seven years, whereas 9% said there had been no change in employment. Furthermore, a small number of industries had produced a significant number of jobs. 58% of the total income was earned by the top 5% of industries in the sample based on their output (Field survey, 2020).

Based on the results of the 2020 field survey, four of the five lucrative industries operating in the research region were manufacturers of durable goods. Interviewed key stakeholders elaborated that companies launched during the last seven years have created an average of fourteen jobs per industry, whereas those developed more than seven years ago produced an average of twelve jobs. This represents the total number of jobs generated by the various industries.

Seven years before the study, a mean of 22 new jobs (or a 36 percent rise) were generated in the investigated industries with 25 or more people. Only 6.6% of all employment produced in the research zone were created in the new industry when all industries were taken into account. However, in the larger industries (those with 25 or more employees) 14% of all new employment was created, whereas up to 3% were created in the smaller industries.

The firm with the greatest rate of expenses over the prior 7 years was 69%, according to data from the selected industry. Conventional industries with fewer than 25 employees accounted for a much larger percentage of municipal expenditures seven years prior to the study than did their higher employment rate competitors. High-tech industries gave the town inside the region a far smaller portion of their earnings than other industries did. Additionally, 69 million was spent in the municipality to hire both qualified and unskillful labor. Sampled industries with 25 or more employees seven years prior to the survey's implementation likewise demonstrated a significantly higher stage of in-town disbursements per employed worker than their counterparts with fewer employees. Compared to producers of durable goods, in-town disbursements for manufacturers of

perishable commodities were significantly higher. Additionally, high-tech enterprises had very high levels of in-town purchases per direct worker, whereas the agricultural sector had very low levels.

The town's manufacturers generated an average of 138 direct jobs, or 5.2 direct works per stable job (Field survey, 2020). A compilation of data revealed that significant differences were still seen in a number of industries. There were four indirect jobs for every undeviating work in industries founded more than seven years ago, 520 indirect employment per industry, and at least 25 employees. Businesses established over the last 7 years have only 0.6 indirect jobs per direct worker (9 works per industry), compared to just 1.3 in businesses started less than 25 years ago (15 works per industry). Producers of non-durable items had much more indirect labor (4:3) per direct work than their contemporaries who produced robust products (2:5). Moreover, the proportion of indirect jobs to permanent posts in the agriculture industry was rather high.

The activities and expenditures of the manufacturers stimulated and launched the local sectors, resulting in a total of 14, 095,345 Birr per industry, or approximately 7,341,090 Birr per direct work (Field survey, 2020). The sectors that received large, regular dividends and wielded great influence were manufacturing, finance, insurance, services, real estate, and agricultural processing.

As a result, the manufacturing sector of the middle class increased the citizens' annual incomes by almost one million birr. The retail segment's overall revenue increased by about 5.5 million birr due to the functions of the intermediary manufacturer; derived outcomes accounted for nearly 87 percent of this increase. The Sululta town economic system's other sectors primarily benefited financially from manufacturing, both directly and indirectly.

4.2.2. Qualitative Analysis

Interview data substantiates the town of Sululta's extensive manufacturing activity throughout the preceding ten years, particularly from 2005 to 2012. The responders verified that the actual trade patterns found for a few particular industries had both positive and negative impacts on the community. Two respondents neatly separated the economic effects of the manufacturing sector into two groups: positive effects, which

supported regime rules and raised family earnings, and downbeat impacts, which raised livelihood costs and raised demand for handcrafted items made in the region.

All respondents acknowledged the influence on the economy, both favorable and negative, but several argued that the "window" for lucrative manufacturing businesses was brief, usually lasting from 2005 to 2012. Furthermore, several business owners in the manufacturing sector were convinced to sell despite having properly planned to support homeownership through sharply increasing product costs.

A number of experts surmised that the main driver of increased investor interest was the declaration from the manufacturing sector, which verified that over 5,000 new jobs were being hired in Sululta town. Witnesses at the event stated that since some of these community declarations, the cost of eating out had already jumped by 35% in the area. They also bemoaned the possibility of an even more hopeless chain of events leading to the economy, the kind that have left even the most isolated community awash in opulent goods.

Furthermore, information gleaned from interviews indicated that those in the manufacturing sector kept purchasing and reselling a large number of local goods, which raised the cost of those goods considerably as they developed. The survey results suggest that these plans may have been preceded by a sizable manufacturing investment based on state expenditures. After an analysis of the environment around proposed investments and trades of input and output products, it was discovered that yearly trades rose by 35% in the 7 years that pursued by the preliminary joined firm announcement (2000–2008).

Therefore, based on survey results, approximately 54% of the inhabitant's residents think that industrialized industries raise their cost of living, which has a negative impact on them. However, 30% of district communal claim that the development of district manufacturing firms helps district and provincial citizens by bringing in money and producing jobs (Field survey, 2020).

4.3 Results on Physicochemical

Table 4.7 show that the pH values varied from 4.79 to 9.28. The industrial effluents that were dumped into the water body at BuS4 of the Burayu study had the greatest pH value, while the alcohol and liquor industries at National Liquor and Balezaf's SbS3 site had the lowest pH value. Every sampling point had significantly different pH values ($P < 0.005$).

The mean electrical conductivity (EC) measured in the localities of Sabata (SbS4 and SbS5) and Burayu (BuS2) ranged from 121.00 to 1915.00 μ S/cm, respectively. The electrical conductivity between the sampling locations varied significantly ($P < 0.05$). The mean water temperatures at the Sululta (SS1) and Burayu (BuS3) locations ranged from 12.80 to 18.10, correspondingly, marking the lowly and uppermost values. Every sampling site had significantly different water temperatures ($P < 0.05$) (Table 4. 7).

Total Dissolved Dolid (TDS) values ranged from 24.33 to 3763.33 mg/L at the Laga Tafo Laga Dadi (LLD1 sample site) and Gelan (GS3 sampling site), respectively. Sago paper sheet effluent emissions resulted in the highest TDS (3763.33 mg/L) at the Gelan (GS3) location. Significant variations ($P < 0.05$) in the verified TDS value between the sampling sites are shown in Table 4.7.

The Sabata (SbS3) and Sululta (SS1 sample site) had chemical oxygen demand (COD) values ranging from 109.33 to 1078.00 mg/L, respectively. The water body in Sabata (SbS3 sample site) containing the effluents from Balezaf and National Liquor and Alcohol Factory had the highest COD (1078.00 mg/L). There is a statistically significant ($P < 0.05$) difference in the COD value between the sampling locations, as shown in Table 5.2.

Total nitrogen (TN) levels varied from 17.00 to 173.00 mg/L in the Gelan (GS1 sample site) and Sabata (SbS1) locations, respectively. The study site in Sabata (SbS1 sample site) next to the river, which receives a lot of runoff, has the highest TN (173.00 mg/L). Table 4. 7 indicate that there was a substantial variation in the TN value ($P < 0.05$) among the sampling locations.

Total phosphorus (TP) measurements ranged from 4.50 to 19.67 mg/L at the Sabata study sites (SbS3 and SbS4 sample sites) and Laga Tafo Laga Dadi (LLDS1 sampling site), respectively. Water released into the water body from the Balezaf, National wine and alcohol, and Arba Minch textile factories was the Sabata (SbS3 and SbS4) research locations with the highest TP (19.67 mg/L). Table 2 indicates a statistically significant ($P < 0.05$) variation in the TP value among the sampling locations.

Table 4.1 Analysis of physicochemical variables from industry wastewater

| Study area | Parameter | | | | | | | |
|-------------------------|------------|---------------|------------------|------------------|-----------------|----------------|-------------------|----------------|
| | Sites code | pH | EC | COD | TN | TP | TDS | Temperature |
| Sululta | SS1 | 8.250 ± 0.000 | 1148.000 ± 0.000 | 109.333 ± 0.577 | 24.333 ± 0.577 | 5.767 ± 0.404 | 683.667 ± 0.577 | 12.800 ± 0.000 |
| | SS2 | 8.790 ± 0.010 | 1330.333 ± 0.577 | 301.000 ± 1.000 | 19.667 ± 1.000 | 9.800 ± 0.000 | 1998.000 ± 1.00 | 15.400 ± 0.000 |
| | SS3 | 7.880 ± 0.017 | 1540.000 ± 0.000 | 165.000 ± 2.000 | 19.333 ± 86.048 | 5.033 ± 2.136 | 919.333 ± 1.155 | 17.000 ± 1.000 |
| | SS4 | 7.467 ± 0.058 | 133.333 ± 0.577 | 194.333 ± 0.577 | 20.000 ± 0.577 | 7.067 ± 0.153 | 969.000 ± 0.000 | 16.500 ± 0.000 |
| | SS5 | 8.747 ± 0.006 | 542.667 ± 0.577 | 174.000 ± 2.646 | 20.333 ± 2.646 | 9.467 ± 0.416 | 3206.667 ± 5.774 | 14.600 ± 0.000 |
| Gelan | GS1 | 7.957 ± 0.006 | 506.667 ± 1.732 | 151.000 ± 1.732 | 20.000 ± 1.000 | 5.967 ± 0.058 | 3033.333 ± 25.166 | 13.900 ± 0.001 |
| | GS2 | 8.900 ± 0.000 | 325.000 ± 2.646 | 455.000 ± 2.646 | 108.333 ± 2.082 | 14.000 ± 0.300 | 1978.000 ± 2.000 | 17.500 ± 0.001 |
| | GS3 | 7.540 ± 0.035 | 628.333 ± 0.577 | 147.667 ± 0.577 | 29.33 ± 0.577 | 16.333 ± 0.153 | 3763.333 ± 20.817 | 16.500 ± 0.001 |
| | GS4 | 8.203 ± 0.006 | 464.333 ± 1.000 | 252.000 ± 1.000 | 17.333 ± 0.577 | 11.667 ± 0.551 | 2803.333 ± 5.774 | 15.500 ± 0.001 |
| | GS5 | 8.857 ± 0.006 | 250.333 ± 3.000 | 145.000 ± 3.000 | 17.000 ± 1.000 | 8.633 ± 0.058 | 1571.000 ± 1.000 | 16.400 ± 0.001 |
| Sabata | SbS1 | 7.93 ± .000 | 757.667 ± 4.041 | 683.000 ± 6.083 | 173.000 ± 1.000 | 15.000 ± 0.00 | 456.333 ± 0.577 | 14.100 ± 0.010 |
| | SbS2 | 8.44 ± 0.000 | 244.000 ± 0.000 | 220.667 ± 1.528 | 42.000 ± 0.000 | 16.333 ± 0.577 | 1458.200 ± 0.173 | 13.900 ± 0.100 |
| | SbS3 | 4.793 ± 0.006 | 697.000 ± 0.000 | 1078.000 ± 1.000 | 42.667 ± 0.577 | 19.667 ± 0.577 | 4160.000 ± 0.000 | 15.600 ± 0.100 |
| | SbS4 | 8.123 ± 0.006 | 121.000 ± 0.000 | 733.000 ± 1.000 | 61.000 ± 1.000 | 19.667 ± 0.577 | 118.300 ± 0.000 | 17.100 ± 0.100 |
| | SbS5 | 7.800 ± 0.000 | 121.000 ± 1.000 | 556.667 ± 0.576 | 51.667 ± 0.577 | 17.333 ± 0.577 | 73.000 ± 0.000 | 16.000 ± 1.000 |
| Laga Tafo Laga Dadhi | LLDS1 | 8.330 ± 0.000 | 409.000 ± 1.000 | 146.333 ± 1.528 | 41.667 ± 2.887 | 4.900 ± 0.058 | 24.333 ± 0.058 | 14.800 ± 0.100 |
| | LLDS2 | 7.773 ± 0.006 | 280.000 ± 0.000 | 583.000 ± 11.533 | 91.667 ± 5.686 | 16.100 ± 0.173 | 170.700 ± 0.794 | 15.600 ± 0.000 |
| | LLDS3 | 7.997 ± 0.006 | 374.000 ± 0.000 | 182.000 ± 1.732 | 52.333 ± 2.082 | 6.700 ± 0.265 | 229.000 ± 0.000 | 17.200 ± 0.000 |
| | LLDS4 | 7.900 ± 0.000 | 1408.000 ± 0.000 | 225.333 ± 1.528 | 39.333 ± 0.577 | 4.500 ± 0.000 | 847.000 ± 0.000 | 16.100 ± 0.000 |
| | LDS5 | 8.083 ± 0.006 | 559.000 ± 0.000 | 171.667 ± 2.517 | 50.333 ± 0.577 | 15.550 ± 0.321 | 332.000 ± 0.000 | 15.500 ± 0.000 |
| Burayu | BuS1 | 7.927 ± 0.007 | 1237.000 ± 0.000 | 202.667 ± 0.577 | 34.000 ± 1.000 | 8.967 ± 0.153 | 74.300 ± 0.000 | 17.100 ± 0.000 |
| | BuS2 | 7.027 ± 0.007 | 1915.000 ± 0.000 | 575.667 ± 2.082 | 63.000 ± 0.000 | 6.467 ± 0.208 | 114.767 ± 0.231 | 16.800 ± 0.000 |
| | BuS3 | 6.623 ± 0.007 | 1268.667 ± 7.638 | 191.000 ± 2.000 | 63.333 ± 0.577 | 10.600 ± 0.436 | 75.367 ± 0.231 | 18.100 ± 0.000 |
| | BuS4 | 9.280 ± 0.007 | 386.333 ± 2.887 | 230.333 ± 2.517 | 34.333 ± 0.577 | 5.600 ± 0.173 | 227.000 ± 0.000 | 16.500 ± 0.000 |
| | BuS5 | 7.860 ± 0.000 | 319.00 ± 0.000 | 214.333 ± 0.577 | 63.667 ± 0.577 | 7.400 ± 0.000 | 189.000 ± 0.000 | 15.500 ± 0.000 |

Source: Field survey, 2020

4.4. Results on Heavy Metal

4.4.1. Validation of the Method

Method detection limits (MDL) = $10 \times SD$ and Limit of quantification (LOQ) = $3 \times SD$ were used to calculate the concentration of heavy metals analysis. Table 2 displayed the LOQ and MDL values. The samples and blank were examined using a UV Atomic Absorption Spectrophotometer (AAS). The precision and accuracy of the heavy metals were described in Table 4.1. As a result, the relative standard deviations (%RSD) of possible health risks as well as the concentration of heavy metals in vegetables and soil were evaluated for the samples that were gathered.

Table 4.2: Data specification for AAS, MDL, LOQ, and % RSD for the heavy metals

| Element | Wave length (nm) | Lamp current (mA) | MDL (mg/L) | LOQ (mg/L) | % RSD | R ² |
|---------|------------------|-------------------|------------|------------|----------|----------------|
| Mn | 279.5 | 5.0 | 0.0054 | 0.018 | 0.1-4.4 | 0.9980 |
| Ni | 232.0 | 3.0 | 0.0072 | 0.024 | 1.2-9.0 | 0.9978 |
| Cu | 324.8 | 2 | 0.0051 | 0.0170 | 1.3-7.8 | 0.9982 |
| Zn | 213.9 | 0.2 | 0.00039 | 0.0013 | 0.1-8.6 | 0.99791 |
| Pb | 283.3 | 2.0 | 0.0096 | 0.032 | 0.1-8.7 | 0.99813 |
| Cr | 357.9 | 4.0 | 0.02946 | 0.0962 | 0.5-9.7 | 0.99819 |
| Cd | 228 | 2.0 | 0.0042 | 0.0140 | 1.3-10.2 | 0.99801 |

Source: Field survey, 2020

4.4.2. The Concentration of Heavy Metal in Soil and Vegetables

The wetland in the Gelan location had the greatest concentration of Mn (27.48 mg/kg), followed by irrigated vegetables. Between the land-use groups, there was no appreciable variation in the amount of heavy metals in the soil ($P=0.06$). The lowest Zn concentration (0.00054 mg/kg) is found in the farming site at Sabata (Table 3). variable sections of a vegetable were found to have variable quantities of heavy metals, according to a spatial study (Table 2). The highest concentration of heavy metals in Pb was discovered in lettuce grown on irrigation land in Gelan. This was followed by Swiss chard at the Burayu site (34.91 $\mu\text{g/Kg}$), which was statistically significant ($P=4.13\text{E-}20$); in the

Sabata sites, $P = 1.26E-28$, lettuce (29.13 $\mu\text{g}/\text{Kg}$) and cabbage (27.21) were reported to have the highest concentration of heavy metals. Ni had the lowest mean heavy metal concentration (0.01 $\mu\text{g}/\text{Kg}$) in Swiss chard at the Sabata location.

4.4.3 Pearson Association Coefficient for Soil and Vegetables

Pearson correlation was used to create a relationship between the concentrations of heavy metals in various soil spatial regions. Consequently, the correlation between the concentrations of heavy metals varied (Table 4). Zn and Ni concentrations showed a significant positive association, while the concentrations of Cd and Cu showed strong positive correlations. On the other hand, a slight correlation was observed when Cu was mixed with Ni, Mn, and Zn between the Mn concentration and the Pb, Cr, and Cd concentrations and the Zn concentration and the Pb and Cd concentrations.

Furthermore, Table 4.2 shows how heavy metal aggregation is distributed spatially in plants. Thus, there was a strong positive association between the concentrations of the other heavy metals and those of Cd with a Pb concentration, Mn with a Pb and Cr concentration, and Zn with the exception of Ni concentration.

Table 4.3: Result of heavy metals analyzed for soil and vegetable samples (Mean \pm S.D.)

| Study Site | Vegetable | Parameter | | | | | | |
|------------|----------------|-------------------------|--------------------|--------------------|-------------------|-------------------|-------------------|--------------------|
| | | Pb ($\mu\text{g/Kg}$) | Cr (mg/Kg) | Cd(mg/Kg) | Ni (mg/Kg) | Mn (mg/Kg) | Zn (mg/Kg) | Cu (mg/Kg) |
| Sabata | Cabbage | 27.21 \pm 0.009 | 0.211 \pm 0.000 | 0.19 \pm 0.002 | 0.034 \pm 0.001 | 0.134 \pm 0.012 | 0.015 \pm 0.007 | 0.113 \pm 0.007 |
| | Garden Cabbage | ND | 0.217 \pm 0.000 | 0.016 \pm 0.005 | 0.013 \pm 0.000 | 0.013 \pm 0.008 | 0.013 \pm 0.008 | 0.132 \pm 0.005 |
| | Swiss Chard | ND | 0.275 \pm 0.000 | 0.031 \pm 0.009 | 0.012 \pm 0.003 | 0.034 \pm 0.002 | 0.021 \pm 0.009 | 0.12 \pm 0.001 |
| | Lettuce | 29.13 \pm 0.019 | 0.297 \pm 0.000 | 0.21 \pm 0.000 | 0.032 \pm 0.007 | 0.212 \pm 0.005 | 0.141 \pm 0.003 | 0.212 \pm 0.002 |
| Burayu | Cabbage | ND | 0.317 \pm 0.000 | 0.017 \pm 0.006 | 0.013 \pm 0.004 | 0.012 \pm 0.002 | 0.029 \pm 0.012 | 0.172 \pm 0.003 |
| | Lettuce | 34.91 \pm 0.048 | 0.317 \pm 0.000 | 0.34 \pm 0.009 | 0.042 \pm 0.002 | 0.121 \pm 0.002 | 0.19 \pm 0.008 | 0.121 \pm 0.010 |
| Gelan | Lettuce | 40.14 \pm 0.002 | 0.316 \pm 0.000 | 0.067 \pm 0.0089 | 0.013 \pm 0.007 | 0.11 \pm 0.003 | 0.211 \pm 0.001 | 0.310 \pm 0.007 |
| | Cabbage | 34.09 \pm 0.023 | 0.5693 \pm 0.000 | 0.27 \pm 0.00153 | 0.023 \pm 0.010 | 0.34 \pm 0.001 | 0.213 \pm 0.006 | 0.131 \pm 0.004 |
| | Soil | Pb ($\mu\text{g/Kg}$) | Cr (mg/Kg) | Cd(mg/Kg) | Ni (mg/Kg) | Mn (mg/Kg) | Zn (mg/Kg) | Cu (mg/Kg) |
| Sabata | Irrigated land | 3.91 \pm 0.001 | 10.79 \pm 0.006 | 0.19 \pm 0.03 | 4.88 \pm 0.003 | ND | 0.004 \pm 0.006 | 1.8 \pm 0.004 |
| | Wet land | 2.76 \pm 0.001 | 2.02 \pm 0.004 | 0.13 \pm 0.0008 | 1.73 \pm 0.001 | ND | 0.003 \pm 0.001 | 0.485 \pm 0.001 |
| | Farm land | 3.09 \pm 0.001 | 3.27 \pm 0.000 | 0.17 \pm 0.002 | 4.62 \pm 0.003 | 27.04 \pm 0.001 | 0.001 \pm 0.004 | 1.215 \pm 0.003 |
| Sululta | Wet land | 2.18 \pm 0.001 | 4.612 \pm 0.001 | 0.17 \pm 0.004 | 1.61 \pm 0.001 | 26.82 \pm 0.002 | 0.001 \pm 0.005 | 1.943 \pm 0.005 |
| | Farm land | ND | 0.559 \pm 0.001 | 0.12 \pm 0.0001 | 4.62 \pm 0.001 | 25.53 \pm 0.002 | 0.004 \pm 0.017 | 0.030 \pm 0.002 |
| Laga Tafo | Wet land | 4.56 \pm 0.004 | 4.53 \pm 0.001 | 0.22 \pm 0.004 | 8.83 \pm 0.001 | 26.97 \pm 0.001 | 0.004 \pm 0.001 | 1.916 \pm 0.004 |
| | Farm land | 2.21 \pm 0.006 | 3.73 \pm 0.003 | 0.15 \pm 0.004 | 7.85 \pm 0.007 | 23.52 \pm 0.005 | 0.005 \pm 0.009 | 1.85 \pm 0.005 |
| Gelan | Farm land | 5.04 \pm 0.000 | 5.128 \pm 0.000 | 0.26 \pm 0.0007 | 9.95 \pm 0.007 | 25.53 \pm 0.002 | 0.005 \pm 0.000 | 1.944 \pm 0.006 |
| | Wet land | 2.26 \pm 0.001 | 7.56 \pm 0.005 | 0.11 \pm 0.0005 | 14.36 \pm 0.01 | 27.48 \pm 0.001 | 0.031 \pm 0.005 | 0.9802 \pm 0.002 |
| | Irrigated land | 4.32 \pm 0.001 | 2.53 \pm 0.006 | 0.076 \pm 0.0004 | 10.74 \pm 0.006 | 27.09 \pm 0.001 | 0.005 \pm 0.007 | 0.5141 \pm 0.001 |
| Burayu | Farm land | 4.45 \pm 0.000 | 5.277 \pm 0.000 | 0.22 \pm 0.001 | 3.78 \pm 0.002 | ND | 0.003 \pm 0.004 | 2.018 \pm 0.005 |
| | Irrigate land | 2.27 \pm 0.001 | 3.35 \pm 0.001 | 0.14 \pm 0.0003 | 2.89 \pm 0.001 | 23.64 \pm 0.015 | 0.002 \pm 0.006 | 1.189 \pm 0.004 |
| | Wet land | 3.33 \pm 0.000 | 3.29 \pm 0.001 | 0.18 \pm 0.001 | 4.2 \pm 0.001 | 26.71 \pm 0.003 | 0.003 \pm 0.008 | 1.554 \pm 0.004 |

Source: Field survey, 2020

Table 4.4: Pearson Correlation Coefficient (r) for soil and vegetable

| Soil | | | | | | | |
|------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| <i>Soil</i> | <i>Pb</i> | <i>Cr</i> | <i>Cd</i> | <i>Ni</i> | <i>Mn</i> | <i>Zn</i> | <i>Cu</i> |
| Pb | 1 | | | | | | |
| Cr | 0.394 | 1 | | | | | |
| Cd | 0.574 | 0.347 | 1 | | | | |
| Ni | 0.266 | 0.266 | -0.125 | 1 | | | |
| Mn | -0.218 | -0.348 | -0.179 | 0.423 | 1 | | |
| Zn | -0.150 | 0.363 | -0.321 | 0.727 | 0.189 | 1 | |
| Cu | 0.556 | 0.550 | 0.791 | -0.030 | -0.089 | -0.183 | 1 |
| Vegetable | | | | | | | |
| <i>Vegetable</i> | <i>Pb</i> | <i>Cr</i> | <i>Cd</i> | <i>Ni</i> | <i>Mn</i> | <i>Zn</i> | <i>Cu</i> |
| Pb | 1 | | | | | | |
| Cr | 0.398 | 1.000 | | | | | |
| Cd | 0.737 | 0.439 | 1 | | | | |
| Ni | 0.595 | 0.013 | 0.892 | 1 | | | |
| Mn | 0.717 | 0.762 | 0.732 | 0.451 | 1 | | |
| Zn | 0.842 | 0.670 | 0.621 | 0.324 | 0.687 | 1 | |
| Cu | 0.392 | 0.020 | -0.249 | -0.289 | 0.024 | 0.466 | 1 |

Source: Field survey, 2020

4.4.4 The Concentration of Heavy Metal in Water

Table 5 indicated the average heavy metal concentration for water samples from various locations. Different heavy metal aggregations were found in water samples at different places based on spatial observations (Table 5). The heavy metal concentration at the Sabata site was found to be highest for Mn (10.65, 14.76, and 16.17 mg/L) at the SbS5, SbS3, and SbS4 sampling sites, respectively; this was statistically significant ($P = 2.8968E-22$). The second-highest concentration of heavy metal was discovered to be Mn (5.83 and 11.77 mg/L) at the GS3 and GS1 for the Gelan site ($P = 3.26416E-27$). With a mean value of 0.0009 mg/L, Mn had the lowest heavy metal content at the LLD5 site for the Laga Tafo Laga Dadi site. $P = 8.89847E-10$ indicates that this finding was statistically significant.

Table 4.5: The concentration of heavy metals of water samples collected from different study sites (Mean ± S.D.)

| Study Area | Sample Site | Heavy Metal | | | | | | |
|------------|-------------|---------------|---------------|---------------|---------------|--------------|---------------|---------------|
| | | Cr (mg/L) | Zn (mg/L) | Cu (mg/L) | Cd (mg/L) | Ni (mg/L) | Pb (mg/L) | Mn (mg/L) |
| Sabata | SbS1 | | | | | | | |
| | SbS2 | 0.19 ± 0.001 | 0.081 ± 0.002 | 0.07 ± 0.001 | 0.02 ± 0.001 | 0.03 ± 0.001 | 0.010 ± 0.015 | 0.90 ± 0.002 |
| | SbS3 | 0.37 ± 0.001 | 0.91 ± 0.001 | 0.15 ± 0.006 | 0.08 ± 0.005 | 0.53 ± 0.001 | ND | 14.76 ± 0.015 |
| | SbS4 | 0.40 ± 0.006 | 0.004 ± 0.002 | 0.09 ± 0.000 | 0.07 ± 0.001 | 0.38 ± 0.001 | ND | 16.17 ± 0.018 |
| | SbS5 | 0.30 ± 0.008 | ND | 0.08 ± 0.001 | 0.03 ± 0.005 | 0.06 ± 0.001 | ND | 10.65 ± 0.011 |
| Gelan | GS1 | 0.34 ± 0.002 | ND | 0.31 ± 0.003 | 0.05 ± 0.005 | 0.09 ± 0.002 | 0.028 ± 0.061 | 11.77 ± 0.007 |
| | GS2 | 0.41 ± 0.001 | 0.008 ± 0.006 | 0.69 ± 0.001 | 0.04 ± 0.001 | 0.12 ± 0.001 | 0.50 ± 0.003 | 0.85 ± 0.001 |
| | GS3 | 0.54 ± 0.002 | 0.005 ± 0.001 | 0.012 ± 0.006 | 0.08 ± 0.0006 | 0.21 ± 0.001 | ND | 5.83 ± 0.007 |
| | GS4 | 0.47 ± 0.001 | 0.003 ± 0.01 | 0.016 ± 0.005 | 0.05 ± 0.006 | 0.21 ± 0.000 | ND | 1.38 ± 0.001 |
| | GS5 | 0.46 ± 0.001 | ND | 0.02 ± 0.001 | 0.04 ± 0.001 | 0.15 ± 0.001 | ND | 0.25 ± 0.000 |
| Sululta | SS1 | 0.004 ± 0.02 | 0.002 ± 0.008 | 0.006 ± 0.004 | 0.09 ± 0.004 | 0.65 ± 0.000 | 0.011 ± 0.02 | 0.008 ± 0.005 |
| | SS2 | 0.45 ± 0.004 | ND | 0.009 ± 0.007 | 0.16 ± 0.002 | 0.48 ± 0.004 | ND | 0.013 ± 0.00 |
| | SS3 | ND | 0.005 ± 0.006 | 0.007 ± 0.004 | 0.10 ± 0.001 | 0.25 ± 0.000 | ND | 0.023 ± 0.001 |
| | SS4 | 0.008 ± 0.01 | 0.004 ± 0.001 | 0.009 ± 0.002 | 0.07 ± 0.001 | 0.24 ± 0.001 | ND | 0.016 ± 0.008 |
| | SS5 | ND | 0.056 ± 0.004 | ND | 0.07 ± 0.002 | 0.43 ± 0.009 | 0.008 ± 0.10 | 0.012 ± 0.001 |
| Laga Tafo | LLD1 | 0.023 ± 0.05 | ND | ND | 0.06 ± 0.001 | 0.36 ± 0.002 | 0.033 ± 0.05 | 0.054 ± 0.004 |
| | LLD2 | 0.004 ± 0.43 | 0.005 ± 0.003 | 0.065 ± 0.002 | 0.10 ± 0.009 | 0.55 ± 0.001 | 0.039 ± 0.43 | 0.017 ± 0.007 |
| | LLD3 | 0.36 ± 0.001 | 0.07 ± 0.001 | 0.029 ± 0.001 | 0.12 ± 0.004 | 0.37 ± 0.000 | 0.47 ± 0.003 | 0.021 ± 0.005 |
| | LLD4 | 0.27 ± 0.003 | 0.14 ± 0.000 | 0.055 ± 0.004 | 0.13 ± 0.001 | 0.43 ± 0.001 | ND | 0.02 ± 0.003 |
| | LLD5 | 0.14 ± 0.001 | 0.039 ± 0.006 | ND | 0.09 ± 0.001 | 0.32 ± 0.001 | ND | 0.001 ± 0.002 |
| Burayu | BuS1 | 0.027 ± 0.05 | 0.007 ± 0.006 | 0.013 ± 0.007 | 0.13 ± 0.003 | 0.55 ± 0.000 | 0.022 ± 0.003 | ND |
| | BuS2 | ND | 0.002 ± 0.007 | 0.000 ± 0.000 | 0.11 ± 0.000 | 0.46 ± 0.001 | 0.50 ± 0.001 | ND |
| | BuS3 | ND | 0.007 ± 0.007 | 0.004 ± 0.02 | 0.13 ± 0.001 | ND | 0.05 ± 0.003 | ND |
| | BuS4 | ND | 4.31 ± 0.000 | 0.023 ± 0.001 | 0.15 ± 0.008 | 0.52 ± 0.001 | 0.23 ± 0.004 | ND |
| | BuS5 | 0.029 ± 0.003 | 0.005 ± 0.005 | ND | 0.12 ± 0.001 | 0.73 ± 0.006 | 0.25 ± 0.0001 | ND |

Source: Field survey, 2020

4.4.5. Pearson association Coefficient for Water

The Pearson connection was used to show the spatial association between the concentrations of heavy metals in water at different places (Table 6). The concentration of Ni and the concentration of Cd have a high positive association, as Table 4.5 demonstrates. Furthermore, a little negative correlation was discovered between Zn and Zn, Cd and Cr and Cu, Ni and Cr and Cu, Pb and Cr and Mn, and Zn, Cd, Ni, and Pb concentrations. On the other hand, the concentrations of Cu with Cr, Cd with Zn, Ni with Zn, Pb with Zn, Cd, and Ni, and Mn with Cr and Cu showed a slightly positive correlation.

Table 4.6: Pearson Correlation Coefficient (r) for water

| | <i>water</i> | | | | | | |
|--------------|--------------|-----------|-----------|-----------|-----------|-----------|-----------|
| <i>Water</i> | <i>Cr</i> | <i>Zn</i> | <i>Cu</i> | <i>Cd</i> | <i>Ni</i> | <i>Pb</i> | <i>Mn</i> |
| Cr | 1 | | | | | | |
| Zn | -0.389 | 1 | | | | | |
| Cu | 0.339 | -0.170 | 1 | | | | |
| Cd | -0.352 | 0.338 | -0.417 | 1 | | | |
| Ni | -0.345 | 0.132 | -0.386 | 0.614 | 1 | | |
| Pb | -0.074 | 0.468 | 0.344 | 0.190 | 0.140 | 1 | |
| Mn | 0.461 | -0.170 | 0.237 | -0.345 | -0.145 | -0.242 | 1 |

4.4.6 Bio Concentration Factor (BCF)

The bio concentration factors for a number of heavy metals at different locations were shown in Table 4.6. At the Burayu site, where the zinc content of lettuce was 39.167, the highest reported value of the bio concentration factor was 95.000 for zinc. The next highest zinc values were found in lettuce at Sabata and cabbage at the Gelan site, respectively, at 45.870 and 46.304. However, it was discovered that the minimal value of the bio concentration factor for Pb in garden cabbage, Swiss chard, cabbage, and Mn in garden cabbage was 0.000 at the Sabata and Burayu locales.

Table 4.7: Bio concentration Factor (BCF)

| | | BCF of Metal | BCF of Metal | BCF of Metal | BCF of Metal | BCF of Metal | BCF of Metal | BCF of Metal |
|--------|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Site | Vegetable | Pb | Cr | Cd | Ni | Mn | Zn | Cu |
| Sabata | Cabbage | 6.959 | 0.020 | 1.000 | 0.007 | 1.000 | 4.167 | 0.063 |
| | Garden cabbage | 0.000 | 0.066 | 0.094 | 0.003 | 0.000 | 23.704 | 0.109 |
| | Swiss chard | 0.000 | 0.025 | 0.163 | 0.002 | 0.254 | 5.833 | 0.067 |
| | Lettuce | 7.450 | 0.028 | 1.105 | 0.007 | 1.582 | 39.167 | 0.118 |
| Burayu | Cabbage | 0.000 | 0.095 | 2.429 | 0.005 | 0.001 | 14.500 | 0.145 |
| | Lettuce | 0.0193 | 0.060 | 0.118 | 0.015 | 0.005 | 95.000 | 0.102 |
| Gelan | Cabbage | 7.891 | 0.225 | 3.553 | 0.002 | 0.013 | 46.304 | 0.255 |
| | Lettuce | 9.292 | 0.125 | 0.882 | 0.001 | 0.004 | 45.870 | 0.603 |

Source: Field survey, 2020

4.4.7 Estimated Daily Intake (EDI) of Heavy Metals

Table 4.7 displayed the EDI values for heavy metals at various locations. At the Gelan site, the highest EDI for lead in lettuce was found in adults and children, respectively, to be 0.0222 and 0.0242. Additionally, at the Burayu location, EDI values for lead (Pb) in lettuce for children and adults were recorded at 0.0211 and 0.0193, respectively. At the Gelan site, Pb in cabbage for children and adults was reported at 0.0188. At various locations with varying heavy metal concentrations, the lowest EDI value was observed (Table 4.7).

Table 4.8: EDI of heavy metals in different sites

| Site | Vegetable | Human | EDI | EDI | EDI | EDI | EDI | EDI | EDI |
|--------|----------------|-------|--------|--------|--------|--------|--------|--------|--------|
| | | | Pb | Cr | Cd | Ni | Mn | Zn | Cu |
| Sabata | Cabbage | Adult | 0.0150 | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0000 | 0.0001 |
| | | Child | 0.0164 | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0000 | 0.0001 |
| | Garden cabbage | Adult | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| | | Child | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| | Swiss chard | Adult | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| | | Child | 0.0000 | 0.0002 | 0.0002 | 0.0000 | 0.0002 | 0.0000 | 0.0001 |
| | Lettuce | Adult | 0.0161 | 0.0002 | 0.0001 | 0.0000 | 0.0001 | 0.0001 | 0.0001 |
| | | Child | 0.0176 | 0.0002 | 0.0001 | 0.0000 | 0.0001 | 0.0001 | 0.0001 |
| Burayu | Cabbage | Adult | 0.0000 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| | | Child | 0.0000 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| | Lettuce | Adult | 0.0193 | 0.0002 | 0.0002 | 0.0000 | 0.0001 | 0.0001 | 0.0001 |
| | | Child | 0.0211 | 0.0002 | 0.0002 | 0.0000 | 0.0001 | 0.0001 | 0.0001 |
| Gelan | Cabbage | Adult | 0.0188 | 0.0003 | 0.0001 | 0.0000 | 0.0002 | 0.0001 | 0.0001 |
| | | Child | 0.0188 | 0.0003 | 0.0002 | 0.0000 | 0.0002 | 0.0001 | 0.0001 |
| | Lettuce | Adult | 0.0222 | 0.0002 | 0.0000 | 0.0000 | 0.0001 | 0.0001 | 0.0002 |
| | | Child | 0.0242 | 0.0002 | 0.0000 | 0.0000 | 0.0001 | 0.0001 | 0.0002 |

Source: Field survey, 2020

4.4.8 Target Hazard Quotient (THQ)

Using equation 3, the Target Hazard Quotient (THQ) is computed. A kid who eaten lettuce exposed to a high level of lead at the Gelan site had a THQ value of 6.0517; this was followed by values of 5.5451 and 5.2632 for a mature man and a teenager who ate lettuce exposed to a high level of lead at the Gelan and Sabata sites, correspondingly (Table 4.8).

Table 4.9: THQ values of heavy metals in different vegetables

| Site | Vegetable | Human | THQ of Heavy Metals | | | | | | | |
|--------|----------------|-------|---------------------|--------|--------|--------|--------|--------|--------|---------|
| | | | Pb | Cr | Cd | Ni | Mn | Zn | Cu | HI |
| Sabata | Cabbage | Adult | 3.7589 | 0.0387 | 0.1050 | 0.0008 | 0.0005 | 0.0000 | 0.0015 | 3.9054 |
| | | Child | 4.1023 | 0.0422 | 0.1146 | 0.0009 | 0.0006 | 0.0000 | 0.0017 | 4.2623 |
| | | Total | 7.8612 | 0.0809 | 0.2196 | 0.0017 | 0.0011 | 0.0001 | 0.0032 | 8.1677 |
| | Garden cabbage | Adult | 0.0000 | 0.0405 | 0.0111 | 0.0003 | 0.0002 | 0.0000 | 0.0018 | 0.0539 |
| | | Child | 0.0000 | 0.0442 | 0.0121 | 0.0003 | 0.0000 | 0.0000 | 0.0020 | 0.0586 |
| | | Total | 0.0000 | 0.0847 | 0.0231 | 0.0006 | 0.0002 | 0.0001 | 0.0038 | 0.1124 |
| | Swiss chard | Adult | 0.0000 | 0.0497 | 0.0166 | 0.0003 | 0.0001 | 0.0000 | 0.0017 | 0.0684 |
| | | Child | 0.0000 | 0.0553 | 0.1628 | 0.0003 | 0.0012 | 0.0000 | 0.0018 | 0.2214 |
| | | Total | 0.0000 | 0.1050 | 0.1794 | 0.0006 | 0.0013 | 0.0001 | 0.0035 | 0.2898 |
| | Lettuce | Adult | 4.0241 | 0.0553 | 0.1160 | 0.0012 | 0.0008 | 0.0003 | 0.0029 | 4.2006 |
| | | Child | 4.3918 | 0.0603 | 0.1266 | 0.0000 | 0.0009 | 0.0003 | 0.0032 | 4.5831 |
| | | Total | 8.4159 | 0.1156 | 0.2427 | 0.0012 | 0.0017 | 0.0005 | 0.0061 | 8.7837 |
| Burayu | Cabbage | Adult | 0.0000 | 0.0589 | 0.0111 | 0.0003 | 0.0000 | 0.0001 | 0.0023 | 0.0727 |
| | | Child | 0.0000 | 0.0643 | 0.0121 | 0.0003 | 0.0000 | 0.0001 | 0.0026 | 0.0794 |
| | | Total | 0.0000 | 0.1233 | 0.0231 | 0.0006 | 0.0001 | 0.0001 | 0.0049 | 0.1521 |
| | Lettuce | Adult | 4.8226 | 0.0589 | 0.1879 | 0.0011 | 0.0005 | 0.0003 | 0.0017 | 5.0730 |
| | | Child | 5.2632 | 0.0643 | 0.2050 | 0.0012 | 0.0005 | 0.0004 | 0.0018 | 5.5365 |
| | | Total | 10.0858 | 0.1233 | 0.3929 | 0.0023 | 0.0010 | 0.0007 | 0.0035 | 10.6094 |
| Gelan | Cabbage | Adult | 4.7093 | 0.1050 | 0.1492 | 0.0006 | 0.0013 | 0.0004 | 0.0018 | 4.9676 |
| | | Child | 4.7093 | 0.1146 | 0.1628 | 0.0006 | 0.0015 | 0.0004 | 0.0020 | 4.9912 |
| | | Total | 9.4186 | 0.2196 | 0.3120 | 0.0012 | 0.0028 | 0.0008 | 0.0038 | 9.9587 |
| | Lettuce | Adult | 5.5451 | 0.0589 | 0.0387 | 0.0003 | 0.0004 | 0.0004 | 0.0043 | 5.6481 |
| | | Child | 6.0517 | 0.0643 | 0.0422 | 0.0003 | 0.0005 | 0.0004 | 0.0047 | 6.1641 |
| | | Total | 11.5967 | 0.1233 | 0.0809 | 0.0006 | 0.0009 | 0.0008 | 0.0090 | 11.8122 |

Source: Field survey, 2020

4.4.9 Target Cancer Risk (TCR)

Equation 5 is the basis for computing the TCR. Table 10 displays the results of Ni in cabbage and lettuce and TCR for Pb, Cr, Cd at Sabata sites: 1×10^{-4} and 1×10^{-4} (Cr), 1×10^{-4} and 1×10^{-4} (Cr), Burayu site 0 and 2×10^{-4} (Pb), and Gelan 2×10^{-4} and 2×10^{-4} (Pb), 2×10^{-4} and 1×10^{-4} (Cr), 1×10^{-4} , 0 (Cd) and 0 (Ni). 1×10^{-4} and 1×10^{-4} (Pb), 0 and 1×10^{-4} (Cd) and 0 (Ni) and 0 (Cd and Ni),

Table 4.10: TCR of heavy metals in vegetables at different study sites

| Site | Vegetable | Human | CR of Pb | CR of Cr | CR of Cd | CR of Ni | TCR |
|--------|----------------|-------|----------|----------|----------|----------|--------|
| Sabata | Cabbage | Adult | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0003 |
| | Garden cabbage | Adult | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 |
| | Swiss chard | Adult | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 |
| | Lettuce | Adult | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0003 |
| Burayu | Cabbage | Adult | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 |
| | Lettuce | Adult | 0.0002 | 0.0001 | 0.0001 | 0.0000 | 0.0004 |
| Gelan | Cabbage | Adult | 0.0002 | 0.0002 | 0.0001 | 0.0000 | 0.0004 |
| | Lettuce | Adult | 0.0002 | 0.0001 | 0.0000 | 0.0000 | 0.0003 |

Source: Field survey, 2020

4.5. Findings Regarding the effectiveness of the Industry Development Strategy

Key stakeholders were interviewed, and the information gathered showed that Ethiopia's goal of becoming a middle-income nation by 2025 can be achieved in part through the expansion and development of the chosen industrial sectors. Similar to this, Ethiopia's manufacturing road map has been developed over the course of 13 years, with a strategic plan that includes phases 1 and 2 for increasing productivity in priority sectors (textile, leather, agro-industry, electronics), diversifying and emerging new key industries (2016–25), and building up high-tech industry (2021–2025).

Ten major industries are included in these phases, divided into three categories: basic & import substitution manufacturing (steel, equipment, chemical, and pharmaceutical); light manufacturing (textile, leather, agro-industry, electronics); and strategic industries (energy, ICT, and biotechnology) (MOI, 2016). Based on information obtained from significant stakeholders, the government has additionally established seventeen Integrated Agro Industry Growth Corridors and eight industrial parks (MOI, 2016).

Consequently, it is anticipated that the manufacturing sector will account for 37% of the industry by 2021; yet, current data only indicates that 23% of the industry falls into this group. Moreover, studies indicate that the country's structural transformation from agriculture-driven to industry-driven development stems from the expansion of the industrial sector. Thus, the following guidelines, standards, and measure (henceforth called the PCI) are simple to apply in order to discern between the gaps; the validity, consistency, and openness of the country's industrial development plan were assessed in the manner described below:

4.5.1. Effectiveness of Implementation

Five strategic goals have been established by the government to guide the implementation of plans and initiatives for industrial expansion, according to a review of policy papers. Moreover, there is an increase in public, private, and foreign investment, the establishment and management of industrial zones and cities, the growth and development of new industries, and the manufacturing sector.

Table 4.11: Industry development policy evaluation

| Criteria | Indicators | Rating effectiveness of the policy (%) | | | | |
|------------------------|---|--|------|------|------|------|
| | | 1 | 2 | 3 | 4 | 5 |
| Ease of implementation | Embattled objective | 3.3 | 2.3 | 47.5 | 33.2 | 13.7 |
| | Time lines | 5.2 | 8.3 | 30 | 47.2 | 9.3 |
| | The method for mobilizing financial resources | 12.6 | 14.3 | 40.3 | 30.7 | 2.1 |
| Subsidiary instruments | Subsidiary instruments | 17.4 | 16.1 | 23.7 | 34.7 | 8.1 |
| | Appropriate subsidiary | 61.2 | 17.3 | 12 | 8.3 | 1.2 |
| Average | | 19.9 | 11.6 | 30.7 | 30.8 | 7.84 |

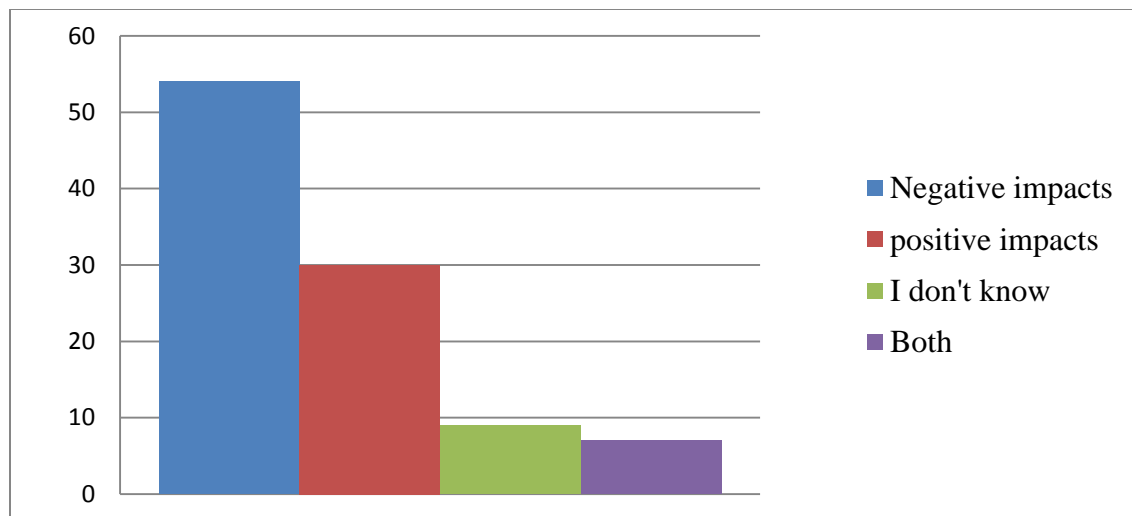
Source: Field survey, 2020

Note: 1. Very low (<30%) 2.low (30-50%) 3. moderate (50-70%) 4. high (70-90%) 5.very high (> 90%).

Yet, due to budgetary limitations, a lack of knowledge, and explicit regulations, the rate of industrial development fell by 25%. Furthermore, the findings of MOI (2013) disseminated the information that crucial implementation strategies encompass establishing a business-friendly atmosphere, securing skilled labor, procuring superior industrial inputs for value addition, broadening and diversifying local, regional, and global markets, enhancing technology transfer, and establishing and providing institutional support.

In addition, data collected for the reason of assigning grades to industrial expansion strategies reveal that the midway value is 7.84% (refer to Table 4.11), which is fairly beneficial in addressing present problems. Consequently, it is not shocking that, according to survey responses, 54% of the community believes that industrial policies harm people by increasing living expenses. However, as indicated by 30% of neighborhood stakeholders, local industrial strategy implementation generates revenue and creates jobs for local and regional inhabitants (see Figure 1).

Figure 4.5: Responses from respondents' regarding effectiveness of industrial strategic plan



Source: Source: Field survey, 2020

4.5.2. Legality of the Policy

In order to determine whether the decision was supported by evidence and whether the interests of important stakeholders were considered during the policy-making process, we examined the IDS. Table 8's results demonstrate how legally involved stakeholders were (11.95). This outcome suggests that the legitimacy of the policy has decreased.

Table 4.12: The legitimacy of Industry development policy shall be recognized by stakeholders

| Criteria | Indicator | Rating effectiveness of the policy (%) | | | | |
|---|--|--|-------|------|------|------|
| | | 1 | 2 | 3 | 4 | 5 |
| Stakeholders participation | There are proposals for strategies. | 22.7 | 20.7 | 30.3 | 12.2 | 14.3 |
| | Relevance of the key stakeholders | 23.1 | 17.2 | 28.2 | 18.3 | 13.2 |
| | Method of developing a plan of action | 6.4 | 19.3 | 30.1 | 36.1 | 8.1 |
| Developing a strategy and providing proof | The process of coming up with a plan | 28.3 | 22.1 | 26.2 | 15.3 | 5.2 |
| | Think tanks for strategy and research institutions | 17.2 | 13.4 | 36.8 | 30.1 | 3.5 |
| | Strategic file | 2.3 | 1.3 | 40.3 | 28.7 | 27.4 |
| Average | | 16.6 | 15.66 | 31.9 | 23.4 | 11.9 |

Source: Field survey, 2020.

Note: 1.Verylow (<30%); 2.low (30-50%); 3.moderate (50-70%); 4.high (70-90%); 5.very high (> 90%)

4.5.3. Industry Progress Strategy and Consistency

The combined data, as presented in Table 8.9, demonstrates how little the national development goals and the IDS align.

Table 4.13: Coherence in Industry development strategy

| Criterion | Pointer | Rating effectiveness policy (%) | | | | |
|--|---|---------------------------------|-----|-------|------|-------|
| | | 1 | 2 | 3 | 4 | 5 |
| The coherence of the industrial development strategy | Acknowledgment of national development goals | 4.6 | 1.7 | 12.7 | 47.7 | 34.8 |
| | Alignment of industrial development strategy documents with national development objectives | 9.6 | 3.7 | 19.6 | 35.4 | 32.1 |
| Average | | 7.1 | 2.7 | 16.15 | 41.5 | 33.45 |

Source: Field survey, 2020

Note: 3.moderate (50-70%); 4.high (70-90%); 1.Very low (<30%) ; 2.low (30-50%)

4.5.4. Transparency in the Financing of Industry Development

Mulu's (2013) study and the policy document's achievement ratings (see Table 10) indicate that Ethiopian industrial strategy distinguished between the "developmental" and "rent-seeking" private sectors. To enhance the capacity of the private sector, the government provides generous subsidies and assistance initiatives (carrots). Several policies (sticks) have been put in place more lately with the goal of "disciplining" the "rouge" private sector. Moreover, others contend that authorities "patronize" the private sector and lack openness on the tools (carrot and punishment) rather than heartening competition and improvement. There is also rising worry about the growth of communal outlay dwarfing that of the private sector. Therefore, in order to enable manufacturers to successfully and efficiently support the country's development goals, assistance is needed.

Table 4.14: Openness in the provision of industry development financing

| Decisive factor | indicator | Rating effectiveness of the policy (%) | | | | |
|---|---|--|-----|------|-----|------|
| | | 1 | 2 | 3 | 4 | 5 |
| The transparency of the industrial expansion strategy | The presence of any policies or frameworks designed to promote directness | 16 | 4.3 | 15.2 | 35. | 29.4 |
| Average | | 16 | 4.3 | 15.3 | 35. | 29.4 |

Source: Field survey, 2020

Note: 2.low (30-50% 4.high (70-90%); 1.very low (<30%) ; 3.moderate (50-70%)

CHAPTER FIVE

5. DISCUSSION

5.1. Spatial

Thus, the study's findings partially support the theory of location as presented by R. Hayter and S. Nieweler (2018), which states that proximity and connectivity were important considerations when deciding where to locate industry in a diversified area.

5.2. Economic Impact of Manufacturing Industry in Sululta Town

The industries had produced an average of twelve jobs over the previous seven years, with an average value of eight jobs. Considering everything, 12% of the selected industries stated that labor employment had fallen during the preceding seven years, while 9% stated that it had stayed constant. Furthermore, a small number of industries had produced a significant amount of work. 58% of the total results were produced by the top 5% of industries in the sample, based on their output (Field survey, 2020). These results are similar to those of Povolna Švarcová (2017), who found that in clusters of small businesses in northern England, 6% of industries created 34% of all jobs.

5.3. Physiochemical

Sululta (SS2 (8.79) and SS5 (8.75), Gelan (GS2 (8.9) and GS5 (8.86) and Burayu (BuS4 (9.28) had pH levels that were higher than those recommended by the EU (1998), USEPA (2009), CES (2013), WHO (2011), and FAO (2013). Furthermore, UNU-EHS/UNEP (2013) reported that the pH values of all other sampling sites, with the exception of the Burayu site of BuS4 (9.28), fell between 6.5 and 9.0. This suggests that the alkalinity of the wastewater is caused by the release of contaminated industrial effluents that contain ammonia, calcium carbonate, iron oxide, and titanium dioxide.

In contrast, the alcoholic and liquor sectors of Balazaf and National were found to exhibit the low mean pH value (SbS3(4.79)) of the Sabata site. The WHO (2011) requirements, which ranged from 6.5 to 8.5, are not met by these low readings. The Balazaf and National liquor and alcoholic businesses in the research region showed low pH values of 3.60, according to Admasu (2007) and Fekede et al. (2020). The low pH values indicated levels of acidity that affect the bioavailability of the river system and water that is not

absorbed by sediments. When excessively low pH causes anti-pH algae to migrate, it can lead to algal blooms (Environmental Folly, 2013).

The assessment of a solution's ability to conduct current, known as EC, is greatly impacted by the presence of ionic particles (Julian et al., 2018). An important factor affecting water conductivity is inorganic ion content. At Sululta (sites SS1 (1148.00 $\mu\text{S/cm}$), SS2 (1330.00 $\mu\text{S/cm}$), and SS3 (1540.00 $\mu\text{S/cm}$), Laga Tafo Laga Dadi (site LLDS4 (1408.00 $\mu\text{S/cm}$), and Burayu (sites BuS1 (1237.00 $\mu\text{S/cm}$), BuS2 (1915.00 $\mu\text{S/cm}$), and BuS3 (1268.67 $\mu\text{S/cm}$), the average EC values in the study region were determined to be between 700 and 3000 $\mu\text{S/cm}$.

The organic composition of the sample, as indicated by its chemical oxygen demand (COD) or oxygen equivalent, can be oxidized with a potent chemical oxidizing agent. This analysis establishes the degree of organic material contamination in the water (Sulaiman et al., 2016). With the exception of the Sululta sites (SS1 = 109.33 mg/L), Gelan (GS3 = 147.67 and GS5 = 145.00 mg/L), and Lega Tafo Laga Dadi (LD1 = 146.33.00 mg/L), the high COD levels were found to be above the EPA/UNIDO 2003 Guideline Ambient Environment Standards for Ethiopia, which are 150 mg/L at every sampling site. Compared to the other study sites, the Sabata study sites had the highest concentration of COD, particularly in the areas of National wine and alcohol industries and Balezaf, where SbS3 (1078.00 mg/L) was detected.

The main reasons for the high COD concentration at all research sites and sampling points were uncontrolled and untreated waste output from residences, slaughterhouses, municipalities, and untreated industrial effluents. Because industrial effluent's exceptionally high amounts of organic matter reduce dissolved oxygen in water bodies to nothing, aquatic life perishes. High COD levels, ranging from 170 to 260 mg/L, are found in the Challawa River in the state of Kano (Wakawaet al., 2008). Osibanjoet al. (2011) discovered elevated amounts of COD in water samples obtained from the Ona and Alaro rivers in Nigeria.

Total nitrogen (TN) is the measurement of all types of nitrogen, both organic and inorganic. The UNU-EHS/UNEP (2013) international guideline for ecosystems, which is < 0.7 mg/L, was not met by the average TN concentrations measured in Sululta (19.33 to

24.33 mg/L), Gelan (17.00 to 108.33 mg/L), Sabata (42.00 to 173.00 mg/L), Laga Tafo Laga Dadi (39.33 to 91.67 mg/L), and Burayu (34.00 to 63.67 mg/L). Every study site exceeded the FAO (2013) permitted irrigation threshold, which is between 5 and 30 mg/L, with the exception of Sululta.

Substances with noticeable nitrogen content promote plant development, according to Liu et al. (2018). Studies on nitrogen pollution conducted in the US and the Netherlands have shown that 60–80% of nitrogen originates from scattered agricultural resources (Shepard, 2000). Moreover, crops have helped the catchment area's TN exports to treble compared to woody basins (Alvarez-Cobelas et al., 2008). The median surface water TN concentration in the Tai Lake region was 6.4 mg/L, which was lower than the previously reported usual TN values (Xie et al., 2007). The average TN concentrations from the Mueller-Warrant et al. (2012) investigation were comparable to those from the study sites at Sululta (19.33 to 20.33 mg/L), Gelan (except for GS2, which was 108.33 mg/L), Sabata (SbS2 and SbS3; 42.00 and 42.67 mg/L), Laga Tafo Laga Dadi (LLD1 and LLD4; 41.67 and 39.33 mg/L), and Burayu (BuS1 and BuS4; 34.00 and 34.33 mg/L).

Total phosphorus (TP) is an element that is commonly found in agricultural fertilizers, organic wastes found in sewage, and industrial effluent. Elevated phosphorus levels in lakes, rivers, and streams can lead to the growth of algae. Algal-covered water is not as pleasant to swim in or fish in. The main strategy for attaining agricultural output is the widespread use of raw materials, namely nitrogen and phosphorus sources like pesticides and fertilizers. The more agricultural land there is, the stronger this trend has been.

Total phosphorus (TP) is a frequent ingredient in sewage and industrial effluent, as well as organic wastes found in agricultural fertilizers. Algae can thrive in lakes, rivers, and streams with high phosphorus levels. Fishing and swimming are not as enjoyable in water that has algae on it. Using a lot of raw material, such as fertilizers and insecticides that are rich in phosphorus and nitrogen, are the main way to achieve agricultural productivity. The greater the strength of this trend, the greater the area devoted to agricultural.

Every sampling location in the study had average total petroleum (TP) readings ranging from 4.50 to 19.67 mg/L, which is greater than the TP's yearly middling content of 0.03 to 0.56 mg/L. The Shendinghe River has the maximum yearly middling TP level, 0.43 mg/L, according to Liu et al. (2018). The 2013 UNEP/UNU-EHS global ecosystem standard, which is less than 0.02 µg/L, was not met by the study's mean TP levels.

The different inorganic minerals and specific organic minerals or salts that can dissolve in water are referred to as total dissolved solids, or TDS. According to Bwalya (2015), a high TDS level indicated poor water quality. The total dissolved solids (TDS) at the study sites of Sululta (683.67 to 3206.67 mg/L), Gelan (1571.00 to 3763.00 mg/L), Sabata (1458.20 to 4160.00 mg/L), and Laga Tafo Laga Dadi (847.00 mg/L) varied. These values exceeded the water quality standards provided by the WHO, FAO, CES (2013), EU (1998), USEPA (2009), and WHO (2013). Sewage and industrial contamination are the main sources of the increased TDS concentration (Bwalya, 2015). Wastewater discharges with high TDS concentrations have damaged water networks and significantly impacted aquatic life (LVEMP, 2002).

One of the most significant physical and chemical factors influencing the quality of water that people consume and use for various reasons is temperature. The study sites' average temperature (12.80–18.10°C) fell within the safe range recommended by the WHO (2011), CES (2013), EU (1998), and USEPA (2009). Oparaocha et al. (2010) found, however, that Nigeria (28°C) and Bahir Dar town (15–20°C) had the highest water temperatures out of a variety of water sources (Milkiyas et al., 2011).

5.4. Heavy Metal

The geographical distribution of vegetables, water, and soil was first ascertained in order to estimate the concentration of heavy metals such as Pb, Cr, Cd, Ni, Zn, Mn, and Cu in the research site. In the research region, the amounts of Pb, Cr, Cd, Ni, Zn, Mn, and Cu were tested in the soil, water, and vegetables that were irrigated with industrial effluent. The results were compared to WHO/FAO and USEPA criteria.

At the Sabata, Gelan, and Burayu sites, the mean aggregations of Cr, Cd, and Cu in cabbage and lettuce were higher than the safe limit of 0.1–0.2 µg/g Cr, 0.1 µg/g Pb, 0.1 µg/g Cu, 0.1 µg/g Zn, 0.1 µg/g Ni, 0.02 µg/g Cd, and 0.3 µg/g Mn, as established by the

WHO/FAO. Furthermore, the mean aggregation of Mn in cabbage at Gelan and Zn in lettuce at Sabata, Burayu, and Gelan sites were above permissible limits, even though the levels of Ni in all sites and all vegetables, with the exception of cabbage at the Gelan site, were within the maximum permissible limit (MPL) of WHO/FAO.

A high quantity of lead can increase the risk of cancer when daily consumption of lead beyond the tolerable limit (Chaang et al., 2014; Sa'i et al., 2016; Lin et al., 2016). The results of vegetable testing indicated that the most significantly contaminated crops were lettuces (0.316, 0.317, and 0.297 $\mu\text{g/g}$ at Gelan, Burayu, and Sabata locations, respectively) and cabbages (0.569, 0.317, and 0.211 $\mu\text{g/g}$ at Gelan, Burayu, and Sabata sites, respectively).

At every study site, this also holds true for the mean concentration of Cu in vegetables. In the Akaki neighborhood of Addis Ababa city, green vegetables exhibited a significant content of lead (Pb) over the permitted limit value, according to Woldetshadik et al. (2017). The effects of irrigation with industrial effluent in the region may be related to the concentration levels of Cr and Cu in green vegetables found in the previous study.

Consuming vegetables high in lead (Pb) has a significant impact on public health since lead has a tendency to bioaccumulate in specific human tissues and cause toxicological effects. Lead (Pb) is a known single toxic element that damages kidneys and nerves when it accumulates in the blood in a stumpy manner (Assi and Hemea, 2016; Antonio et al., 2003 ; Antonio and Leret, 2000)

Nearly everywhere, aggregations of heavy metals, including Cr, Cd, and Ni, are discovered in water samples. Furthermore, Mn in the Sabata and Gelan sites exceeded the upper limit permitted by US EPA regulations (US EPA, 2004). However, the residual heavy metal concentrations were below the US EPA's allowed level. This indicates that continuous application of industrial wastewater to farms may result in an increase in the amount of heavy metals in the soil (Seema, 2016).

The BCF values for Zn and Pb in cabbage and lettuce at the Sabata and Gelan sites, Cd and Mn in lettuce at the Sabata site, and Cd in cabbage at the Burayu and Gelan sites were all more than 1.0 for every vegetable sample from every location. Zinc may be more easily transported from the soil to plants with a high BCF than lead is. As opposed to Fe,

Cd, Mn, and Cr, Gupta et al. (2010) found that the Pb transfer factor was extremely low. Intawongse and Dean (2006) and Kabala et al. (2009) state that the kind of soil, the composition of the metal parent material, the type of vegetable, and the solubility of the metals can all influence the transfer factor of heavy metals from soil to plants.

Since vegetables are good for human health and are abundant in fiber, vitamins, and minerals, it is advised that people eat more of them. Perhaps even more important than food quality is preventing the buildup of heavy metals in food to protect consumers from their detrimental consequences (WHO/FAO, 2003). Pb EDI values in Sabata were 0.015 and 0.016 for adults and children in cabbage, and 0.016 and 0.0176 for adults and children in lettuce.

Furthermore, in the Burayu site, the EDI values for lead in lettuce were 0.019 for adults and 0.021 for children, respectively. In contrast, the EDI values for lead in cabbage at the Gelan site were 0.0188 for both adults and children, and 0.022 and 0.024 for children. Therefore, the FAO/WHO's Provisional Maximum Tolerable Daily Intakes (PMTDI) were reached by the results of the EDI of heavy metals for adults and children at different study sites.

The target hazard quotient (THQ) values at the Sabata site (Pb > Cd > Cr > Ni > Cu > Mn > Zn); Burayu sites (Cr > Cd > Cu > Ni > Mn > Zn > Pb); and Gelan site (Pb > Cd > Cr > Cu > Ni > Mn > Zn) were ranked according to the non-carcinogenic individual health risk associated with using heavy metal-contaminated vegetables. This was predicated on the idea that equation "Y" would be used to compute the target hazard quotient (THQ) under the technique segment. On the other hand, the THQ values for lettuce at the research site were organized as follows: Pb > Cr > Cd > Cu > Ni > Mn > Zn at the Burayu site, and Pb > Cr > Cd > Cu > Mn > Zn > Ni at the Gelan site.

In the Sabata, Burayu, and Gelan sites, the computed THQ values for lead in lettuce were 8.416, 10.086, and 11.597, respectively. The calculated THQ values for Pb in cabbage at the Sabata and Gelan locations were 7.86 and 9.42, respectively, and these values were greater than 1. Consequently, there is no chance of exposure leading to non-carcinogenetic consequences (Chen et al., 2011; Antoine et al., 2017). With the exception

of lead (Pb), all heavy metals investigated in this research had THQ values < 1 , suggesting a normal degree of protection against non-carcinogenic effects.

Additionally, the increasing impacts of consuming many potentially harmful heavy metals from a variety of vegetables have been estimated using the Hazard Index (HI). Table 9 provided the HI for Swiss chard, cabbage, and lettuce. At the Sabata site, the values of HI larger than one for lettuce and cabbage were 8.1677 and 8.784, respectively. At the Burayu site, the HI for lettuce was 10.609, while at the Gelan site, the values were 9.9587 plus 11.8122, correspondingly. Therefore, the HI value was larger than 1, suggesting that the lettuce (> 10) grown at the Burayu and Gelan y locations may have some health effects. A HI score of more than 10 indicates a significant long-term health effect (Antoine et al., 2017; Li et al., 2018).

According to Sharma et al. (2018), the cancer risk associated with an individual's health was calculated using equation 6. As a result, the target cancer risk (TCR) for Pb, Ni, Cr, and Cd intake may increase carcinogenic effects based on the expression dose. Consequently, Table 10 demonstrates that the TCR values for lead (Pb) in lettuce in the Sabata, Burayu, and Gelan locations were 1×10^{-4} , falling within the Health of Canada-established safe range (1×10^{-4} - 1×10^{-6}) (Health Canada, 2010). Pb in cabbage at the Gelan site had TCR values that were within the threshold value, whereas Pb in cabbage at the Sabata site had TCR values of 1×10^{-4} and 2×10^{-4} .

This suggests that eating cabbage and lettuce cultivated nearby does not put adult residents in the research area at risk for Pb-related cancer. The TCR values for Cr in cabbage and lettuce at Sabata (1×10^{-4} plus 1×10^{-4}), Burayu (1×10^{-4} plus 1×10^{-4}), and Gelan (2×10^{-4} and 1×10^{-4}) correspondingly were found to be within the safe limit, suggesting that adult population members consuming cabbage and lettuce in the study area had a likelihood of being exposed to Cr-related cancer risk. Furthermore, the TCR values for Cd and Ni in these study locations were within the threshold range, and the likelihood of Cd and Ni causing cancer was associated with the use of vegetables in the study district.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

6.1.1. Spatial Distribution

Spatial agglomeration is the key factor in the dispersion of industries. From an economic and geographic point of view, the geographic range and extension surrounding the clustering quantity are equally important in the case of industrial agglomeration. This study uses a distance-based approach that views space as continuous to examine differences in the space-based patterns of various enterprises and company sizes in Dukem. Unlike previous research, we generate two sets of confidence intervals for the industrialized and service sectors, respectively, to explore the industrial space-based dispersion at the town level. The results indicate that the service industries have a minor degree of clustering but a reasonably large coverage compared to industrial firms. This suggests that compared to the service sector, the industrial sector is less clustered.

6.1.2. Economic Impacts

As local and regional governments are more involved in plans for economic growth, accurate information regarding the direct and indirect impacts of industrial start-ups and expansions is becoming more and more crucial. The results of the study demonstrated that, when both direct and indirect economic benefits were taken into consideration, there were significant disparities between different industries. Furthermore, data obtained from key stakeholder and the findings of Birch 1987; Gallagher and Stewart 1986; Bollard and Harper 1986 and Harrison 1994 demonstrated that a widely used measure of economic divergence is the quantity of jobs generated by different industries. Besides, over the period of 7 years, the industries have added an average of 12 jobs to the districts.

Of the firm owners, almost 73% reported that total employment had augmented when contrasted to 7 years earlier. Of the industries that were sampled, 9% said that nothing had changed, and 18% said that the employment rate was falling. Significant pressure was placed on overall job creation numbers by a small industry, which at its height accounted for 64% of all jobs (based on total work produced in 4% of industries).

Numerous academics have observed that there have been less opportunities for extremely small and/or new enterprises to produce jobs for local inhabitants (Dasgupta & Singh, 2005); yet, the results of this study reveal that industries that have been partially built and monitored have created (less than 20 employees) higher employment. Modern industries, on the other hand, produced 7% of all employment created collectively, but on average, they created more jobs per firm than elder ones.

The principal results overall are : 1) The Tukey test indicates that there is a significant difference ($\alpha = 0.05$) between industries with fewer than 25 employees and those with 25 or more employees; 2) there was a significant magnitude of the direct and secondary economic impacts of manufacturing industries; 3) The direct costs and total economic impact were evenly distributed among the sectors ; and 4) The manufacturing sector contributed more than one million birr annually on average to the local population.

The industries under investigation paid to other state-affiliated industries 14,095,345 Ethiopian birr (roughly 7,341 per direct job) in direct payments. The firms under investigation made direct payments to other state-affiliated companies totaling approximately 14,095,345 Ethiopian birr (roughly 7,341 per direct job). Besides, the average annual cumulative impact for each industry was 42,092.456 Ethiopian birr, or 21,000 Ethiopian per direct jobs

6.1.3. Physiochemical

The high pH values, which were beyond the permitted limit as authorized by USEPA (2009), EU (1998), CES (2013), WHO (2011), and FAO (2013), were reported in the study sites of Sululta (SS2 (8.79) and SS5 (8.75)), Gelan (GS2 (8.9) and GS5 (8.86)), and Burayu (BuS4 (9, 28)). The lone exception was the BuS4 sampling point at the Burayu site. The remaining sampling sites met the pH values proposed by UNU-EHS/UNEP (2013) for ecosystems, which ranged from 6.5 to 9. The average pH of the SbS3 sample taken at the Sabata location was 4.79, which is below the recommended level and indicates that the water is acidic and should not be consumed or used for other purposes.

On the other hand, COD levels in all samples were higher than the 150 mg/L recommendations established by the Ethiopian EPA/UNIDO in 2003, with the exception of Sululta (SS1; 109.33 mg/l), Gelan GS3 and GS5 (147.67 and 145.00 mg/l, respectively), and Lega Tafo Laga Dadi (LLD1; 146.33.00 mg/l). The National wine and liquor industries in the vicinity of Balezaf and Sabata sample location contributed to an increase in the COD value for Sbs3 (1078.00 mg/L). Therefore, concerns about excessive COD concentration in all research sites and sample points were caused by untreated and uncontrolled industrial waste.

6.1.4. Heavy Metal

Vegetables and irrigation water samples from the Sabata area of Sb4 and Sb5 revealed heavy metal aggregations that were higher than permitted. Conversely, practically all aggregations were below permissible limits in the soil of all research areas and sample locations. At every sampling and research site, the notable effects of various manufacturers on the aggregations were observed in irrigation water, but not in soil or vegetables. Vegetable heavy metal aggregations were caused by the release of untreated industrial effluents into the soil and water, which contaminated the water.

Due to their growing in contaminated irrigation water with industrial influents above permissible levels—some of which were permitted because of the high bio concentration factor of vegetables—vegetables at the Sabata research area of sample sites had heavy metal aggregations. Public or industrial wastes could not be dumped into farmlands or water bodies without first being cleaned in order to keep heavy metals out of the irrigation region. Furthermore, as a mitigating strategy to clean up the previously contaminated water bodies with harmful trace metal substrates, treating the industrial waste release to irrigation areas is required. Reducing the risk to human health and environmental disruption requires ongoing monitoring of the quality of the water, plants, and soil to keep heavy metals out of the vegetables.

6.1.5. Industry Development Strategy

The theme of manufacturing policy can cause division, particularly in low-income nations. It is universally known that these countries must implement forceful measures to make the move from knowledge-based, formalized, productive organization patterns that

provide higher output levels to resource-based, low-productivity societies with sizable informal sectors. On the other hand, deliberate interventions that allocate resources to activities that are favored carry a risk of reducing allocative efficiency and creating incentives that are adverse to investors and bureaucrats alike.

It has been demonstrated that the Ethiopian government is extraordinarily gifted of establishing the foundation for a manufacturing uprising that is both socially and market-driven. It is unwaveringly committed to investing in technological learning in order to generate fresh advantages over competitors. This is shown by the ambitious plans designed to promote the industrial and technological development system, create new industries, and support institutions for specific sectors, such horticultural, leather, and textile items. The government has established priorities for industrial development and diversification. Export promotion and demand-driven industrialization in agriculture are key tenets of its strategy.

The findings of Mulu's (2013) research and the policy document's effectiveness rating (see Table 10) support the criticism that the instruments—the carrot and stick—are opaque and that the policymakers favor the private sector over competition and innovation, despite the fact that Ethiopian industrial policy further divided the private sectors into "developmental" and "rent-seeking" categories. The government provides extensive incentives and support programs (carrots) to increase the capacity of the private sector; more recently, a number of measures (sticks) have been established with the intention of "disciplining" the "rouge" private sector.

The challenges faced by policymakers in formulating industrial policies for Ethiopia and other nations make it evident that most previous studies were unable to reach any findings on industries. Applying the methodology of this research to similar policies in other Least Developed Countries, similar to the body of knowledge for richer countries, would enable the discovery of what makes an industrial policy successful in Least Developed Countries generally and what aspects of the policy's failure are specific to Ethiopia.

6.2. RECOMMENDATIONS

6.2.1 Spatial Distribution

The neighboring administration have to establish the concept of proximity and connectedness (firms must be grouped together and interconnected) in order to improve local and regional development. Besides, employment practice, technology, resource management, skills and taxpaying experiences have to be linked each other.

6.2.2. Economic Impacts

The local government or local partners have to implement the labor-intensive rather than capital-intensive paradigm to minimize the unemployment rate and to promote regional and local development.

6.2.3 Physicochemical

The results showed that the nutrients found at each research site and sample location have been severely polluted by TN and TP. Thus, industrial environmental stresses such as declining water quality can be harmful to ecosystems and human health. Consequently, there ought to be ongoing community education campaigns, enforcement of environmental protection laws, cleanup operations for contaminated rivers and streams, establishment of treatment facilities by business owners, and long-term oversight, management, and regulation of the installation of industrial wastewater purification systems.

6.2.4 Heavy Metal

In order to reduce the elevated levels of heavy metals in water, soil, and vegetables, concerned organizations and stakeholders must establish treatment plants, raise public awareness, and employ phytoremediation techniques.

6.2.5 Industry Development Strategy

To achieve the industrialization program and restructure the economy, the Ethiopian government needs to look into and put into place aggressive measures to boost the expansion and competitiveness of the manufacturing sectors. It is recommended that the specific policy decisions and steps outlined below be taken in to consideration:

1. Promote the following measures to boost the competitiveness of the manufacturing sector: (i) reducing import tariffs on non-locally produced material inputs; (ii) decreasing the shared income tax; and (iii) lowering the cost of power for the manufacturing sector.
2. Address the skills gap and expedite the company's hiring procedure for remote professionals to contribute to the effort to increase productivity in reachable factories.
3. Evaluate and revise specific incentives to attract potential investors by improving the operations and strategies of key organizations; supplying industrial parks with gas and energy infrastructure; and launching a green lane for customs to increase the effectiveness of supporting strategic projects.
4. Quickly put the reforms mentioned in the business environment strategy into action. These include measures to intentionally evade paying taxes, a stronger enforcement of customs regulations, and requirements to guarantee fair competition between importers and domestic producers.

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APPENDICES

Table 1: Physiochemical parameters of waste water

| No | Code | Trial number | PH | EC (μ S /cm) | COD mg/L (620 nm) | Total-N mg/L (460nm) | Total -Po ₄ ³⁻ mg /L (430nm) | TDS mg/L | Temp. °C |
|----|-------------------------------|----------------|------|-------------------|-------------------|----------------------|--|----------|----------|
| 1 | SS ₁ | T ₁ | 8.25 | 1148 | 109 | 24 | 6.2 | 684 | 12.8 °c |
| | | T ₂ | 8.25 | 1148 | 109 | 24 | 5.4 | 683 | |
| | | T ₃ | 8.25 | 1148 | 110 | 25 | 5.7 | 684 | |
| 2 | SS ₂ | T ₁ | 8.78 | 1330 | 302 | 20 | 9.8 | 1999 | 15.4 |
| | | T ₂ | 8.80 | 1331 | 301 | 19 | 9.8 | 1998 | |
| | | T ₃ | 8.79 | 1330 | 300 | 20 | 9.8 | 1997 | |
| 3 | SS ₃ | T ₁ | 7.87 | 1540 | 165 | 20 | 2.6 | 918 | 17.0 |
| | | T ₂ | 7.90 | 1540 | 163 | 19 | 6.6 | 920 | |
| | | T ₃ | 7.87 | 1540 | 167 | 19 | 5.9 | 920 | |
| 4 | SS ₄ | T ₁ | 7.4 | 133 | 194 | 20 | 7.1 | 969 | 16.5 |
| | | T ₂ | 7.5 | 133 | 194 | 20 | 7.2 | 969 | |
| | | T ₃ | 7.5 | 134 | 195 | 20 | 6.9 | 969 | |
| 5 | SS ₅ | T ₁ | 8.74 | 543 | 172 | 20 | 9.6 | 3200 | 14.6 |
| | | T ₂ | 8.75 | 542 | 173 | 20 | 9.0 | 3210 | |
| | | T ₃ | 8.75 | 543 | 177 | 21 | 9.8 | 3210 | |
| 6 | C ₁ S ₁ | T ₁ | 7.96 | 510 | 149 | 20 | 6.0 | 3,010 | 13.9 |
| | | T ₂ | 7.95 | 503 | 152 | 21 | 6.0 | 3,030 | |
| | | T ₃ | 7.96 | 507 | 152 | 19 | 5.9 | 3,060 | |
| 7 | C ₁ S ₂ | T ₁ | 8.90 | 325 | 457 | 109 | 13.7 | 1980 | 17.5 °c |
| | | T ₂ | 8.90 | 325 | 452 | 106 | 14.3 | 1978 | |
| | | T ₃ | 8.90 | 325 | 456 | 110 | 14.0 | 1976 | |
| 8 | C ₁ S ₃ | T ₁ | 7.56 | 624 | 148 | 29 | 16.3 | 3780 | 16.5 |
| | | T ₂ | 7.50 | 631 | 147 | 30 | 16.2 | 3770 | |

| No | Code | Trial number | PH | EC (μ S /cm) | COD mg/L (620 nm) | Total-N mg/L (460nm) | Total -Po ₄ ³⁻ mg /L (430nm) | TDS mg/L | Temp. °C |
|----|-------------------------------|----------------|------|-------------------|-------------------|----------------------|--|----------|----------|
| | | T ₃ | 7.56 | 630 | 148 | 29 | 16.5 | 3740 | |
| 9 | C ₁ S ₄ | T ₁ | 8.20 | 462 | 253 | 17 | 11.3 | 2810 | 15.5 |
| | | T ₂ | 8.21 | 465 | 251 | 18 | 11.4 | 2800 | |
| | | T ₃ | 8.20 | 466 | 252 | 17 | 12.3 | 2800 | |
| | | | | | | | | | |
| 10 | C ₁ S ₅ | T ₁ | 8.86 | 246 | 142 | 16 | 8.6 | 1571 | 16.4 °c |
| | | T ₂ | 8.85 | 252 | 148 | 17 | 8.7 | 1572 | |
| | | T ₃ | 8.86 | 253 | 145 | 18 | 8.6 | 1570 | |
| 11 | Sbs ₁ | T ₁ | 7.93 | 753 | 690 | 173 | 15 | 457 | 14.1 °c |
| | | T ₂ | 7.93 | 760 | 679 | 172 | 15 | 456 | |
| | | T ₃ | 7.93 | 760 | 680 | 174 | 15 | 456 | |
| 12 | Sbs ₂ | T1 | 8.44 | 244 | 219 | 42 | 16 | 1458 | 13.9 °c |
| | | T2 | 8.44 | 244 | 221 | 42 | 16 | 1458.3 | |
| | | T3 | 8.44 | 244 | 222 | 42 | 17 | 1458.3 | |
| 13 | Sbs ₃ | T1 | 4.80 | 697 | 1079 | 43 | 19 | 4160 | 15.6 |
| | | T2 | 4.79 | 697 | 1077 | 43 | 20 | 4160 | |
| | | T3 | 4.79 | 697 | 1078 | 42 | 20 | 4160 | |
| 14 | Sbs ₄ | T1 | 8.12 | 121 | 734 | 60 | 20 | 118.3 | 17.1 |
| | | T2 | 8.12 | 121 | 732 | 61 | 20 | 118.3 | |
| | | T3 | 8.13 | 121 | 733 | 62 | 19 | 118.3 | |
| 15 | Sbs ₅ | T1 | 7.8 | 120 | 556 | 51 | 18 | 73.0 | 16.0 |
| | | T2 | 7.8 | 122 | 557 | 52 | 17 | 73.0 | |
| | | T3 | 7.8 | 121 | 557 | 52 | 17 | 73.0 | |
| 16 | LLD ₁ | T1 | 8.33 | 410 | 145 | 45 | 4.9 | 24.3 | 14.8 |
| | | T2 | 8.33 | 409 | 146 | 40 | 4.9 | 24.4 | |
| | | T3 | 8.33 | 408 | 148 | 40 | 4.8 | 24.3 | |
| 17 | LLD ₂ | T1 | 7.77 | 280 | 587 | 87 | 16.1 | 171.6 | 15.6 |

| No | Code | Trial number | PH | EC (μ S /cm) | COD mg/L (620 nm) | Total-N mg/L (460nm) | Total -Po ₄ ³⁻ mg /L (430nm) | TDS mg/L | Temp. °C |
|----|------------------|--------------|------|-------------------|-------------------|----------------------|--|----------|----------|
| | | T2 | 7.78 | 280 | 592 | 90 | 16.1 | 170.4 | 15.6 |
| | | T3 | 7.77 | 280 | 570 | 98 | 15.8 | 170.1 | 15.6 |
| 18 | LLD ₃ | T1 | 8.00 | 374 | 183 | 50 | 6.5 | 229 | 17.2 |
| | | T2 | 8.00 | 374 | 183 | 53 | 6.9 | 229 | 17.2 |
| | | T3 | 7.99 | 374 | 180 | 54 | 6.4 | 229 | 17.2 |
| 19 | LLD ₄ | T1 | 7.9 | 1408 | 224 | 40 | 4.5 | 847 | 16.1 |
| | | T2 | 7.9 | 1408 | 227 | 39 | 4.5 | 847 | 16.1 |
| | | T3 | 7.9 | 1408 | 225 | 39 | 4.5 | 847 | 16.1 |
| 20 | LLD ₅ | T1 | 8.08 | 559 | 169 | 50 | 15.8 | 332 | 15.5 |
| | | T2 | 8.09 | 559 | 172 | 50 | 15.3 | 332 | 15.5 |
| | | T3 | 8.08 | 559 | 174 | 51 | 15.2 | 332 | 15.5 |
| 21 | BUS ₁ | T1 | 7.93 | 1237 | 202 | 33 | 8.8 | 74.3 | 17.1 |
| | | T2 | 7.92 | 1237 | 203 | 34 | 9.0 | 74.3 | 17.1 |
| | | T3 | 7.93 | 1237 | 203 | 35 | 9.1 | 74.3 | 17.1 |
| 22 | BUS ₂ | T1 | 7.02 | 1915 | 575 | 63 | 6.3 | 114.9 | 16.8 |
| | | T2 | 7.03 | 1915 | 574 | 63 | 6.7 | 114.5 | 16.8 |
| | | T3 | 7.03 | 1915 | 578 | 63 | 6.4 | 114.9 | 16.8 |
| 23 | BUS ₃ | T1 | 6.63 | 1262 | 189 | 63 | 10.9 | 75.5 | 18.1 |
| | | T2 | 6.62 | 1277 | 191 | 63 | 10.1 | 75.1 | 18.1 |
| | | T3 | 6.62 | 1267 | 193 | 64 | 10.8 | 75.5 | 18.1 |
| 24 | Bus ₄ | T1 | 9.28 | 388 | 228 | 34 | 5.7 | 227.0 | 16.5 |
| | | T2 | 9.29 | 388 | 230 | 35 | 5.7 | 227.0 | 16.5 |
| | | T3 | 9.27 | 383 | 233 | 34 | 5.4 | 227.0 | 16.5 |
| 25 | Bus ₅ | T1 | 7.86 | 319 | 215 | 64 | 7.3 | 189.0 | 15.5 |
| | | T2 | 7.86 | 319 | 214 | 64 | 7.5 | 189.0 | 15.5 |
| | | T3 | 7.86 | 319 | 214 | 63 | 7.4 | 189.0 | 15.5 |

Table 2: Instrumental used for physicochemical parameter test in waste water sampling

| Parameter | Wavelength(nm) | Instrumental model/size/volume/ | Measuring instrument (Mass/volume) |
|--------------------------|----------------|--------------------------------------|--|
| COD | 620 | HACH -DR6000UV VIS-spectrophotometer | -witeg digital pipette(1000-5000 μ L) Its accuracy is 0.0461) |
| Total -N- TKN | 460 | HACH -DR6000UV VIS-spectrophotometer | -d/t volume of volumetric flask -d/t volume of measuring cylinder |
| Total PO_4^{3-} | 430 | HACH-DR3900V spectrophotometer | -d/t volume of curvet |
| pH | - | Aawa AD 8000 | d/t volume of conical flask |
| EC | | 4500conductivity meter | -COD Reactor digester |
| Temperature | | With PH and conductivity meter | |
| TDS | | ADWA TDS portable meter | |

Table 3: Mean concentration of metals (mean ± SD n=3) in waste water samples by AAS.

| No | code | Tested parameters in GFAAS (unit µg/L) | | | | |
|----|-------|--|-----------------|-----------------|-----------------|-----------------|
| | | Cr | Zn | Cu | Pb | Mn |
| 1 | Sbs.1 | | | | 27.90±0.016µg/L | |
| 2 | Sbs.2 | | | | 10.39±0.015µg/L | |
| 3 | GS.1 | | | | 27.55±0.061µg/L | |
| 4 | Gs.3 | | | 12.30±0.006µg/L | | |
| 5 | Gs.4 | | | 16.41±0.005µg/L | | |
| 6 | Gs.5 | | | 19.56±0.001µg/L | | |
| 7 | SS.1 | 4.35±0.02µg/l | | 6.07±0.004µg/L | 11.35±0.02µg/L | 7.97±0.005 µg/L |
| 8 | SS.2 | | | 9.12±0.007µg/L | | 13.09±0.00 µg/L |
| 9 | SS.3 | | | 6.54±0.004µg/L | | 23.01±0.001µg/L |
| 10 | SS.4 | 7.61±0.01 µg/L | | 8.59±0.002µg/l | | 15.96±0.008µg/L |
| 11 | SS.5 | | | | 7.60±0.10µg/L | 11.53±0.001µg/L |
| 12 | LLD.1 | 23.04±0.05µg/L | | | 33.04±0.05µg/L | 53.67±0.004µg/L |
| 13 | LLD.2 | 3.81±0.43µg/L | | | 38.81±0.43µg/L | 17.09±0.007µg/L |
| 14 | LLD.3 | | | | | 20.74±0.005µg/L |
| 15 | LLD.4 | | | | | 19.61±0.003µg/L |
| 16 | LLD.5 | | | | | 0.911±0.002µg/L |
| 17 | BUS.1 | 26.70±0.05µg/L | 7.34±0.006µg/L | 12.54±0.007µg/L | 21.57±0.003µg/L | |
| 18 | BUS.2 | | 21.30±0.007µg/L | 0.36±0.002µg/L | | |
| 19 | BUS.3 | | | 4.35±0.02µg/l | | |

Table 4: Mean concentration of metals (mean ± SD n=3) in waste water samples by AAS

| No | Tested parameters using FAAS and GFAAS | | | | | | | |
|----|--|-----------------|-----------------|------------------|-----------------|-----------------|------------------|-----------------|
| | Code | Cr | Zn | Cu | Cd | Ni | Pb | Mn |
| 1 | Sbs.1 | 0.26±0.003mg/L | 0.09±0.007mg/L | 0.34±0.0007mg/L | 0.05±0.001mg/L | 0.03±0.005mg/L | 27.90±0.016µg/L | 2.03±0.001mg/L |
| 2 | Sbs.2 | 0.19 ±0.001mg/L | 0.081±0.002mg/l | 0.07±0.001mg/L | 0.02±0.001mg/L | 0.03±0.001mg/L | 10.39±0.015µg/L | 0.90±0.002mg/l |
| 3 | Sbs.3 | 0.37±0.001mg/L | 0.91±0.001mg/L | 0.15±0.006mg/L | 0.08±0.005mg/L | 0.53±0.0006mg/l | ND | 14.76±0.015mg/L |
| 4 | Sbs.4 | 0.40±0.006 mg/L | 0.004±0.002mg/L | 0.09±0.0004mg/L | 0.07±0.001mg/L | 0.38±0.0009mg/L | ND | 16.17±0.018mg/L |
| 5 | SBS.5 | 0.30±0.008 mg/L | ND | 0.08±0.001mg/L | 0.03±0.005mg/L | 0.06±0.001mg/L | ND | 10.65±0.011mg/L |
| 6 | GS.1 | 0.34±0.002mg/L | ND | 0.31±0.003mg/L | 0.05±0.005mg/L | 0.09±0.002mg/L | 27.55±0.061 µg/L | 11.77±0.007mg/L |
| 7 | Gs.2 | 0.41±0.001 mg/L | 0.008±0.006mg/L | 0.69±0.001mg/L | 0.04±0.001mg/L | 0.12±0.001mg/L | 0.50±0.003mg/L | 0.85±0.0009mg/L |
| 8 | Gs.3 | 0.54±0.002 mg/L | 0.005±0.001mg/L | 12.30±0.006µg/L | 0.08±0.0006mg/L | 0.21±0.001mg/L | ND | 5.83±0.007mg/L |
| 9 | Gs.4 | 0.47±0.001mg/L | 0.003±0.01mg/L | 16.41±0.005µg/L | 0.05±0.006mg/L | 0.21±0.0004mg/L | ND | 1.38±0.0008mg/L |
| 10 | Gs.5 | 0.46±0.001mg/L | ND | 19.56±0.001µg/L | 0.04±0.001mg/L | 0.15±0.0005mg/L | ND | 0.25±0.0001mg/L |
| 11 | SS.1 | 4.35±0.02µg/l | 0.002±0.008mg/L | 6.07±0.004µg/L | 0.09±0.004mg/L | 0.65±0.0002mg/L | 11.35±0.02µg/L | 7.97±0.005 µg/L |
| 12 | SS.2 | 0.45±0.004mg/L | ND | 9.12±0.007µg/L | 0.16±0.002 mg/L | 0.48±0.004mg/L | ND | 13.09±0.00 µg/L |
| 13 | SS.3 | ND | 0.005±0.006mg/L | 6.54±0.004µg/L | 0.10±0.001 mg/L | 0.25±0.0004mg/L | ND | 23.01±0.001µg/L |
| 14 | SS.4 | 7.61±0.01 µg/L | 0.004±0.001mg/L | 8.59±0.002µg/L | 0.07±0.001mg/l | 0.24±0.0009mg/L | ND | 15.96±0.008µg/L |
| 15 | SS.5 | ND | 0.056±0.004mg/L | ND | 0.07±0.002mg/L | 0.43±0.009mg/L | 7.60±0.10µg/L | 11.53±0.001µg/L |
| 16 | LLD.1 | 23.04±0.05µg/L | ND | ND | 0.06±0.0009mg/L | 0.36±0.002mg/L | 33.04±0.05µg/L | 53.67±0.004µg/L |
| 17 | LLD.2 | 3.81±0.43µg/L | 0.005±0.003mg/L | 0.065±0.002mg/L | 0.10±0.009mg/L | 0.55±0.0007mg/L | 38.81±0.43µg/L | 17.09±0.007µg/L |
| 18 | LLD.3 | 0.36±0.001mg/L | 0.07±0.0006mg/L | 0.029±0.0006mg/L | 0.12±0.004mg/L | 0.37±0.0001mg/L | 0.47±0.003mg/L | 20.74±0.005µg/L |
| 19 | LLD.4 | 0.27±0.003mg/L | 0.14±0.0004mg/L | 0.055±0.004mg/L | 0.13±0.001mg/L | 0.43±0.001mg/L | ND | 19.61±0.003µg/L |
| 20 | LLD.5 | 0.14±0.001mg/L | 0.039±0.006mg/L | ND | 0.09±0.001mg/L | 0.32±0.001mg/L | ND | 0.911±0.002µg/L |
| 21 | BUS.1 | 26.70±0.05µg/L | 7.34±0.006µg/L | 12.54±0.007µg/L | 0.13±0.003mg/L | 0.55±0.0004mg/L | 21.57±0.003µg/L | ND |
| 22 | BUS.2 | ND | 21.30±0.007µg/L | 0.36±0.002µg/L | 0.11±0.0003mg/L | 0.46±0.001mg/L | 0.50±0.001mg/L | ND |
| 23 | BUS.3 | ND | 7.53±0.007mg/L | 4.35±0.02µg/L | 0.13±0.001mg/L | ND | 0.05±0.003mg/L | ND |
| 24 | BUS.4 | NDL | 4.31±0.0004mg/L | 23.01±0.001µg/L | 0.15±0.008mg/L | 0.52±0.001mg/L | 0.23±0.004mg/L | ND |
| 25 | BUS.5 | 29±0.003µg/L | 5.31±0.005µg/L | ND | 0.12±0.001mg/L | 0.73±0.006mg/L | 0.25±0.0001mg/ | ND |

Table 5: Linear regression equation, coefficient of determination (R^2), LOD, LOQ, RSD %, average recovery

| Parameter | Test method | LOD | LOQ | %RSD (range) | Av. recovery | R^2 |
|-----------|-------------|-------------|-------------|--------------|--------------|---------|
| Cr | GFAAS | 0.02946mg/L | 0.0982 mg/L | 0.5-9.7 | 94.5-110 | 0.99819 |
| Zn | GFAAS | 0.00039mg/L | 0.0013mg/L | 0.1-8.6 | 88-120 | 0.99791 |
| Cu | GFAAS | 0.0051mg/L | 0.0170mg/L | 1.3-7.8 | 92.5-110 | 0.9982 |
| Cd | FAAS | 0.0042mg/L | 0.0140mg/L | 1.3-10.2 | 95.2-101 | 0.99801 |
| Ni | FAAS | 0.0072mg/L | 0.024mg/L | 1.2-9.0 | 96.4-120 | 0.9978 |
| Pb | GFAAS | 0.0096 mg/L | 0.032mg/l | 0.1-8.7 | 89.1-110 | 0.99813 |
| Mn | GFAAS | 0.0054 mg/L | 0.018mg/L | 0.1-4.4 | 93-120 | 0.9980 |

Hint.

- Ni (SD blk=0.0024mg/L)
- Cr (SD blk=0.00982mg/L)
- Mn (SD blk=0.0018mg/L)
- mg/-Zn (SD blk=0.00013mg/L)
- Cd (SD blk=0.0014mg/L)
- CU (SD blk= 0.0017
- Pb (SD blk=0.0032mg/L)

Table 6: Instrumental operating conditions in water, soil and vegetable sample analysis by FAAS

| Element | Wavelength (nm) | Silt with(nm) | Current (mA) | Flame type | Energy | Instrumental model |
|---------|-----------------|---------------|--------------|---------------|--------|--------------------|
| Mn | 279.5 | 0.2 | 5.0 | Air acetylene | | NovAA 400P AAS |
| Ni | 232.0 | 0.2 | 3.0 | Air acetylene | 453 | |
| Cu | 324.8 | 1.2 | 2 | Air acetylene | 257 | |
| Zn | 213.9 | 0.5 | 0.2 | Air acetylene | 439 | |
| Pb | 283.3 | 1.2 | 2.0 | Air acetylene | 358 | |
| Cr | 357.9 | 0.2 | 4.0 | Air acetylene | | |
| Cd | 228 | 1.2 | 2.0 | Air acetylene | 387 | |

Table 7: Mean concentration of metals (mean \pm SD, n=3) Soil samples by AAS

| S.N | CODE | TEST METHOD | TEST PARAMETERS | | | | | | |
|-----|--------|-------------|-------------------|---------------------|--------------------|-------------------|--------------------|----------------------|----------------------|
| | | | Pb (mg/Kg) | Cr-total (mg/Kg) | Cd (mg/Kg) | Ni (mg/Kg) | Mn (mg/Kg) | Zn (mg/Kg) | Cu (mg/Kg) |
| 1. | GFLS | FAAS | 5.04 \pm 0.0003 | 5.128 \pm 0.00025 | 0.26 \pm 0.0007 | 9.95 \pm 0.007 | 25.53 \pm 0.002 | 0.0046 \pm 0.00025 | 1.944 \pm 0.0056 |
| 2. | GWLS | FAAS | 2.26 \pm 0.0005 | 7.56 \pm 0.0048 | 0.11 \pm 0.0005 | 14.36 \pm 0.01 | 27.48 \pm 0.001 | 0.031 \pm 0.005 | 0.9802 \pm 0.00175 |
| 3. | GILS | FAAS | 4.32 \pm 0.0007 | 2.53 \pm 0.006 | 0.076 \pm 0.0004 | 10.74 \pm 0.006 | 27.09 \pm 0.001 | 0.0046 \pm 0.0069 | 0.5141 \pm 0.00065 |
| 4. | BUFLS | FAAS | 4.45 \pm 0.0003 | 5.277 \pm 0.0001 | 0.22 \pm 0.001 | 3.78 \pm 0.002 | ND | 0.0027 \pm 0.0036 | 2.018 \pm 0.0052 |
| 5. | BUILS | FAAS | 2.27 \pm 0.0006 | 3.35 \pm 0.0007 | 0.14 \pm 0.0003 | 2.89 \pm 0.001 | 23.64 \pm 0.015 | 0.002 \pm 0.0058 | 1.189 \pm 0.00365 |
| 6. | BUWLS | FAAS | 3.33 \pm 0.0003 | 3.29 \pm 0.0006 | 0.18 \pm 0.001 | 4.2 \pm 0.001 | 26.71 \pm 0.003 | 0.00306 \pm 0.0082 | 1.554 \pm 0.0036 |
| 7. | SBILS | FAAS | 3.91 \pm 0.0005 | 10.79 \pm 0.0064 | 0.19 \pm 0.03 | 4.88 \pm 0.003 | ND | 0.0036 \pm 0.0056 | 1.8 \pm 0.00384 |
| 8. | SBWLS | FAAS | 2.76 \pm 0.001 | 2.02 \pm 0.004 | 0.13 \pm 0.0008 | 1.73 \pm 0.001 | ND | 0.0032 \pm 0.0006 | 0.4849 \pm 0.0013 |
| 9. | SBFLS | FAAS | 3.09 \pm 0.0008 | 3.27 \pm 0.0003 | 0.17 \pm 0.002 | 4.62 \pm 0.003 | 27.04 \pm 0.0012 | 0.00054 \pm 0.004 | 1.215 \pm 0.00307 |
| 10. | SWLS | FAAS | 2.18 \pm 0.0008 | 4.612 \pm 0.0013 | 0.17 \pm 0.004 | 1.61 \pm 0.001 | 26.82 \pm 0.002 | 0.0006 \pm 0.005 | 1.943 \pm 0.00467 |
| 11. | SFLS | AAS | ND | 0.559 \pm 0.0017 | 0.12 \pm 0.0001 | 4.62 \pm 0.001 | 25.53 \pm 0.002 | 0.00425 \pm 0.017 | 0.0296 \pm 0.00194 |
| 12. | LLDFLS | FAAS | 4.56 \pm 0.0038 | 4.53 \pm 0.0012 | 0.22 \pm 0.004 | 8.83 \pm 0.001 | 26.97 \pm 0.001 | 0.0042 \pm 0.00125 | 1.916 \pm 0.0035 |
| 13. | LLDWLS | FAAS | 2.21 \pm 0.006 | 3.73 \pm 0.0032 | 0.15 \pm 0.004 | 7.85 \pm 0.007 | 23.52 \pm 0.005 | 0.005 \pm 0.009 | 1.85 \pm 0.0054 |

Table 8: Linear regression equation, coefficient of determination (R^2), LOD, LOQ, RSD %, average recovery

| Parameters | Test method | LOD | LOQ | % RSD (range) | Av. recovery | R^2 |
|------------|-------------|--------------|-------------|---------------|--------------|---------|
| Cr | FAAS | 0.02946mg/L | 0.0962 mg/L | 0.5-9.7 | 94.5-110 | 0.99819 |
| Zn | FAAS | 0.00039 mg/L | 0.0013mg/L | 0.1-8.6 | 88-120 | 0.99791 |
| Cu | FAAS | 0.0051mg/L | 0.0170mg/L | 1.3-7.8 | 92.5-110 | 0.9982 |
| Cd | FAAS | 0.0042mg/L | 0.0140mg/L | 1.3-10.2 | 95.2-101 | 0.99801 |
| Ni | FAAS | 0.0072mg/L | 0.024mg/L | 1.2-9.0 | 96.4-120 | 0.9978 |
| Pb | FAAS | 0.0096 mg/L | 0.032mg/l | 0.1-8.7 | 89.1-110 | 0.99813 |
| Mn | FAAS | 0.0054 mg/L | 0.018mg/L | 0.1-4.4 | 93-120 | 0.9980 |

Hint.

Cr (SD blk=0.00962mg/L)

Cd (SD blk=0.0014mg/L)

Mn(SD blk=0.0018mg/L)

Cu(SD blk= 0.0017 mg/

Zn(SD blk=0.00013mg/L)

Pb (SD blk=0.0032mg/L)

Ni(SD blk=0.0024mg/L

Table 9: Mean concentration of metals (mean \pm SD, n=3) Soil samples by AAS

| S.N | SAMPLE CODE | Pb ($\mu\text{g/Kg}$) | Cr (mg/Kg) | Cd(mg/Kg) | Ni (mg/Kg) | Mn (mg/Kg) | Zn (mg/Kg) | Cu (mg/Kg) |
|-----|-------------|-------------------------|----------------------|----------------------|-----------------------|----------------------|----------------------|----------------------|
| | | TEST METHOD: GAAS | TEST METHOD: FAAS | TEST METHOD: FAAS | TEST METHOD: FAAS | TEST METHOD: FAAS | TEST METHOD: FAAS | TEST METHOD: FAAS |
| 1. | SBCV | 27.21 \pm 0.0087 | 0.2109 \pm 0.00007 | 0.19 \pm 0.0023 | 0.0341 \pm 0.0009 | 0.134 \pm 0.0121 | 0.015 \pm 0.007 | 0.113 \pm 0.0067 |
| 2. | SBGC | ND | 0.2171 \pm 0.00005 | 0.016 \pm 0.0047 | 0.01314 \pm 0.00013 | 0.013 \pm 0.0081 | 0.0128 \pm 0.008 | 0.132 \pm 0.00543 |
| 3. | SBRQBR | ND | 0.2745 \pm 0.00019 | 0.031 \pm 0.0089 | 0.0117 \pm 0.0031 | 0.034 \pm 0.0023 | 0.021 \pm 0.009 | 0.12 \pm 0.0013 |
| 4. | SBLV | 29.13 \pm 0.019 | 0.2972 \pm 0.00014 | 0.21 \pm 0.00034 | 0.0324 \pm 0.0073 | 0.212 \pm 0.0046 | 0.141 \pm 0.00254 | 0.212 \pm 0.0018 |
| 5. | BUGR | ND | 0.3169 \pm 0.00005 | 0.017 \pm 0.0057 | 0.0134 \pm 0.0037 | 0.012 \pm 0.0023 | 0.029 \pm 0.0124 | 0.172 \pm 0.0034 |
| 6. | BUQR | 34.91 \pm 0.0476 | 0.3174 \pm 0.0003 | 0.34 \pm 0.009 | 0.0421 \pm 0.00212 | 0.121 \pm 0.0021 | 0.19 \pm 0.0078 | 0.121 \pm 0.0098 |
| 7. | GLV | 40.14 \pm 0.00161 | 0.3161 \pm 0.00022 | 0.067 \pm 0.0089 | 0.0132 \pm 0.007 | 0.11 \pm 0.0034 | 0.211 \pm 0.0012 | 0.3102 \pm 0.007 |
| 8. | GCR | 34.09 \pm 0.023 | 0.5693 \pm 0.00008 | 0.27 \pm 0.00153 | 0.023 \pm 0.0098 | 0.34 \pm 0.00123 | 0.213 \pm 0.00654 | 0.131.0043 |

Table 10: Linear regression equation, coefficient of determination (R^2), LOD, LOQ, RSD%, average recovery

| Parameter | Test method | LOD | LOQ | % RSD (range) | Av. recovery | R^2 |
|-----------|-------------|------------------|-------------|---------------|--------------|---------|
| Cr | FAAS | 0.02946mg/L | 0.0962 mg/L | 0.5-9.7 | 94.5-110 | 0.99819 |
| Zn | FAAS | 0.00039 mg/L | 0.0013mg/L | 0.1-8.6 | 88-120 | 0.99791 |
| Cu | FAAS | 0.0051mg/L | 0.0170mg/L | 1.3-7.8 | 92.5-110 | 0.9982 |
| Cd | AAS | 0.0042mg/L | 0.0140mg/L | 1.3-10.2 | 95.2-101 | 0.99801 |
| Ni | FAAS | 0.0072mg/L | 0.024mg/L | 1.2-9.0 | 96.4-120 | 0.9978 |
| Pb | GAAS | 0.0096 μ g/L | 0.032mg/l | 0.1-8.7 | 89.1-110 | 0.99813 |
| Mn | FAAS | 0.0054 mg/L | 0.018mg/L | 0.1-4.4 | 93-120 | 0.9980 |

Hint.

Cr (SD blk=0.00962mg/L)

Cd (SD blk=0.0014mg/L)

Mn (SD blk=0.0018mg/L)

Cu (SD blk= 0.0017 mg/

Zn (SD blk=0.00013mg/L)

Pb (SD blk=0.0032mg/L)

Ni (SD blk=0.0024mg/L)