IMPACTS OF METEHARA SUGAR FACTORY ON AWASH RIVER WATER QUALITY

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Declaration and Confirmation

I, the undersigned, declare that this thesis is my own original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis has been properly acknowledged.

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The thesis can be submitted for examination with my approval as institute's advisor.

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Abstract

Water quality refers the characteristic of water that influence its suitability for particular use that is how well the quality meets the needs of specific use. Good quality water has social, economical and environmental benefits and determined by its physical, chemical and biological characteristics. In our country the quality of water deteriorated through time due to various natural and anthropogenic activities. Awash River is one of the rivers found in our country and serves as a drinking source for millions of people. But it has been impaired by various types of contamination due to waste released from different socio - economic activities in its basin. This makes the lower awash community to depend on poor and unsafe water consumption that exposes them to water quality related health risks. The aim of this study was to investigate the impacts of wastewaters from Metehara sugar factory on the water quality of Awash River. Both the effluents and the river water samples at selected points were analyzed for physicochemical parameters. The results for different parameters range for turbidity (21.85-192 NTU), EC (518-17,590 518μS/cm), temperature (20.5-44.5 ^{0}c), phosphate (0.785-2.85 mg/L), COD (745-89,290 mg/L), BOD_5 (476 mg/L-71,457 mg/L) and oil and grease (30-77 mg/L) were the major drinking water quality concern in Awash River which were higher than Ethiopian (CES 58) and WHO maximum allowable limit of drinking water standard. Most of the river samples result also shown variation after dissolved with wastewaters. This clearly indicates the pollution load of wastewaters. The river is threatened by factory's wastewaters and might induce health risk. Therefore, there should be up to date treatment plant for factory wastewater and continuous monitoring and evaluation of the effluent quality before discharging into the river should be carried out.

Key Words: physicochemical parameters; drinking water; Awash River

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Table of Contents

Abstract....iii

Acknowledgment....iv

List of tables....vii

List of figures....viii

List of Acronyms & Abbreviations.... ix

Chapter 1: Introduction....1

1.1 Background....1

1.2 Statement of the problem 4

1.3 Objectives of the study 5

1.3.1 General objective 5

1.3.2 Specific objectives 6

1.4 Research questions 6

1.5 Scope of the study 6

1.6 Limitation of the study 7

1.7 Significance of the study 8

Chapter 2: Literature review 9

2.1 Industrial wastewater impact on river water quality 9

2.2 Sugar manufacturing process and wastewaters 12

2.2.1 Manufacturing process in MSF 12

2.2.2 MSF wastewaters 14

2.3 Physicochemical water quality parameters 16

2.4 Environmental policy and legislation in Ethiopia 23

Chapter 3: Materials and Methods 26

3.1 Study area & its description 26

3.2 Methods....28

3.2.1 Types of data 28

3.2.2 Source of data 29

3.2.3 Water sampling period and location 30

3.2.4 Method of analysis 35

3.2.5 Data analysis 37

Chapter 4: Results and Discussions 38

4.1 Physical and chemical parameters 38

4.1.1 pH 38
4.1.2 EC 40
4.1.3 TDS 42
4.1.4 Turbidity 44
4.1.5 Total Hardness 45
4.1.6 Alkalinity 47
4.1.7 Temperature 48
4.1.8 Phosphate 50
4.1.9 Nitrate 51
4.1.10 Chloride 52
4.1.11 Sulfate (SO_4) 53
4.1.12 COD 54
4.1.13 BOD_5 56
4.1.14 Oil and grease 57
Chapter 5: Conclusion and Recommendation 58
5.1 Conclusion 58
5.2 Recommendations 60
Appendix I: physicochemical analysis result of water samples during April 61
Appendix II: physicochemical analysis result of water samples during May 62
6. References 63

List of tables

Table 2.1: Sugar manufacturing limit value for discharges to water bodies...……………………….25

Table 3.1: Division of the Awash River basin… ………………………………………………..26

Table 3.2: Sampling point's location…… …………………………………………………….....34

Table 3.3: Selected water quality parameters and method of analysis …… …………………….36

List of figures

Fig 1.1: Schematic representation of sampling sites..7

Fig 2.1: Schematic diagram of sugar manufacturing process...14

Fig 3.1: Mean monthly annual minimum, maximum and average temperature at Metehara........27

Fig 3.2: Mean monthly precipitation...28

Fig 3.3: Map of study location and sampling site along Awash River..33

Fig 4.1: pH value of eight sample points...38

Fig 4.2: EC value of eight sample points...40

Fig 4.3: TDS value of eight sample points...42

Fig 4.4: Turbid value of eight sample points..44

Fig 4.5: Total hardness value of eight sample points...45

Fig 4.6: Alkalinity value of eight sample points..47

Fig 4.7: Temperature value of eight sample points..48

Fig 4.8: Phosphate value of eight sample points..50

Fig 4.9: Nitrate value of eight sample points...51

Fig 4.10: Chloride value of eight sample points...52

Fig 4.11: Sulfate value of eight sample points..54

Fig 4.12: COD value of eight sample points...55

Fig 4.13: BOD_5 value of eight sample points..56

Fig 4.14: Oil and grease value of eight sample points..57

List of Acronyms & Abbreviations

FAO	Food and Agriculture Organization
APHA	American public Health Authority
EPA	Environmental Protection Authority
MSF	Metehara Sugar Factory
TDS	Total Dissolved Solid
WHO	World Health Organization
EC	Electric Conductivity
MoWR	Ministry of Water Resources
m.a.s.l	Meters above sea level
UN	United Nations
WWAP	World Water Assessment Program
NTU	Nephelometric Turbidity Unit
WAE	Water Aid Ethiopia
USDPA	United State Department of Agriculture
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
ESA	Ethiopian Standard Agency
EDTA	Ethylenediaminetetra Acetic Acid

Chapter 1: Introduction

1.1 Background

Water is the most abundant, transparent and colorless chemical substance (Eran, 2012). Next to oxygen, water is the most important resource and substance for the existence of all living things. It is basic for life. No living thing can survive in this world without Fresh Water. Rivers, lakes and ground water are used to irrigate agricultural crops, drinking, cooling, cleaning, washing, processing, recreational purpose, transportation purpose, sanitation and healthy life. Early human settlement and civilization were structured along water bodies. The water bodies provide easy access for transportation and allow food security for its habitat. Ever since the beginning it is an integral part of human's life. The human body natural system normal functions mainly depends on the availability of adequate quantity and quality of water.

Around 71 % of earth's surface is covered by water, only 2.5 % is fresh and only 0.3 % of fresh water is accessible for human use. Furthermore, pressures on the resource are gowning. Currently, it is estimated that humans already used 54% of all the accessible fresh water contained in rivers, lakes and underground aquifers and by 2025, 70% of the accessible fresh water will be used by human (Holm, 2004, UN/WWAP, 2003). This estimation indicates that the growing demand of fresh water quantity with time and population growth. The earth is about to face a serious water crises in a near future (UN/WWAP, 2003). The crisis is getting worsen the available scares fresh water bodies were polluted by human socio economic activities.

Water pollution is the contamination of water bodies (Shaka, 2015). Water pollution doesn't begin in the water itself. Water pollution is all about quantity, the amount of polluting substance released to water bodies to cause physical, chemical or biological change in water quality which has harmful effects on living organisms (Chakraborty *et al*, 2013).

Water quality refers to the characteristic of a water that influence its suitability for specific use that is how well the quality meets the needs of specific use (Nancy, 2011). The quality of water is highly important component to understand the healthiness of water body and it's a critical factor affecting human health and welfare (Yasser, 2007).

Surface water pollution caused by natural process and anthropogenic activities becoming a major problem worldwide (Wang, 2018). Water pollution resulted from industrialization, urbanization, and population explosion becomes a global problem (Aymere *et al*, 2015). Rivers becoming the conduits for pollutants by collecting and carrying wastewater from catchments and ultimately discharging it into other water bodies and storm water, which can also be rich in nutrients, organic matter and pollutants finds its way into rivers, lakes and other water bodies.

Water quality alteration is among the major problems of many water use and water development activities. The most obvious source of quality alteration is the discharge of municipal and industrial waste and addition of toxic substances to natural water (Tamirat, 2003).

Ethiopia is one of the country suffer from the degradation of water quality (Aymere *et al*, 2015). Practice related with rapid population growth such as land use and modification, urbanization and human settlement are the major water quality degrading factors (Fasil *et al*, 2013). With a rapid expanding human population and growing trend of industrial development, problems related to management of industrial waste have become of considerable magnitude in Ethiopia (Getachew, 2006). Because of the huge amount of wastewater generated from industries most of the water bodies in Ethiopia exposed to pollution but the country environmental regulation clearly state that development activities that likely cause pollution or other environmental hazards shall have an obligation to install sound technologies or adopt practices that avoid or minimize the generation of waste.

The Awash River basin is one of the major twelve river basins in Ethiopia which face land and wetland degradation, soil erosion due to deforestation and over all water quality declines (Shaka, 2015). The Awash River basin is one of the most developed and most important basin in Ethiopia with relatively better infrastructure (which is the source of drinking water and irrigation for millions of people downstream), serves as home to 10.5 million inhabitants and covers a total land area of 112,696 km^2 (Mekonin *et al*, 2011). Awash River serves as drinking water supply for Adama, Metehara, Awash, Gewane Asaita and other towns, irrigation (estimated amount of 77.7% or around 160,000 ha out of 206,000 ha land suitable for agriculture in Awash River basin) and accounts for about half of the national irrigation schemes, hydropower, fishery and other water development activities (Awash Basin Authority, 2017).

Awash River is the one prone to various type of pollution. The rapid population growth and subsequent urbanization, industrial unit located in and at the outskirts of the city, exploration and exploitation of natural resources, intensive agricultural practices within the river basin and in discriminated disposal of domestic and municipal wastes are the main sources of pollution (Facil *et al*, 2013). From the total of industries located in the cities 90% of them discharge their waste without any treatment into adjoining water course (EPA, 2013). The disposal of industrial waste to Awash River is great environmental concern (Yohannes *et al*, 2017).

In addition to the effect of toxic substances, a wide range of other adverse effects can occur when wastes are disposed into the river water. As result, changes in physical, chemical and biological parameters such as infectious agents, temperature, turbidity, color, PH, salinity and oxygen concentration may occur. Changes in any of this parameter have direct environmental effects and can also produce impact by modifying other parameters (Esayas, 2005).

1.2 Statement of the problem

Globally, industrial wastewater represents the main source of water pollution (Ali, 2010). Having good quality water is common problem in developed and developing countries (Ogwo *et al*, 2002). This days in our country the water pollution from disposal of industrial wastewater becoming an environmental concern (Yohannes *et al*, 2017). Several contaminants have been known for years to be harmful to human and animal health (Wolfe, 2000).

The Awash River basin is one of the most developed and most important basins in Ethiopia with relatively better infrastructure serving 10.5 million inhabitants and covers a total land area of 112,696 km^2 (Mekonin *et al*, 2011). But the Awash River basin faces land degradation, high population density, natural water degradation, salinity and wetland degradation. Already desertification has started at lower Awash River basin. In the high land deforestation and sedimentation has increased in the past three decades (Girma, 1998).

The Awash River basin has special water quality problems to which attention need to be paid (Hiemel *et al*, 2013). It is prone to various type of pollution, with that generated in the urban conglomerate of Addis Ababa and surroundings being most pronounced. Much of the wastewater, both domestic and industrial, produced in that area reaches the Awash River untreated, seriously polluting the water coarse. Furthermore, since the downstream part of the river is used for various uses (e.g. water supply, irrigation) public health risks are high (Facil et al, 2013).

In the middle and lower Awash River basin the water related health hazards are reported to be increasing in prevalence and severity. Basic requirements such as water supply, sanitation and health facilities are poor (Girma *et al*, 2010).

Industrial wastewater considered among the major source of environmental pollution and endangering public health. In our country untreated waste from traditional and modern processing industries threatening surface waters (Beyene et al, 2009). Along the Awash River various industries are established from upstream discharging their untreated wastes to downstream, and the river receives different effluents from these industries. Metehara Sugar Factory is one of the industries carried out along Awash River. The direct discharge of the industrial wastewaters from Metehara Sugar Factory without treatment to Awash River results in increase the environmental and health impact at the discharge points and downstream user of the river in particular.

Metehara sugar factory produces more than 3,841,200 m^3 of wastewaters per day after processing, cooling, washing and disposal of waste. Sugar production is water demanding industry, requires large quantity of water for pressing, cooling, cleaning and disposal of waste. So, this study conducted with the primary objective of to evaluate the impact of these wastewaters from processing, cooling, washing and disposal of waste on the water quality of Awash River by taking samples from the sugar factory's wastewaters before and after mixed with the river.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the study was to investigate the impact of the Metehara sugar factory wastewaters on the water quality of Awash River by analyzing the physicochemical characteristics of the river water quality.

1.3.2 Specific objectives

1. to characterize the wastewaters generated by sugar factory that discharged to awash river water.
2. to characterize the quality of Awash River water after the wastewaters of MSF dissolved with the river
3. to determine the suitability of the river water for drinking purpose based on the WHO and Ethiopian drinking water quality standard.

1.4 Research questions

The study answers the following issues in line with the specific objectives.

1. What are the major water quality variations caused by the sugar industry wastewater?
2. What are the impacts caused by the wastewaters on the river?
3. Does the water quality changes are suitable for drinking purpose as compared to Ethiopian water quality standard (CES 58)?

1.5 Scope of the study

The study primarily focused on the investigation of the impacts of Metehara sugar factory wastewaters on the water quality of Awash River, by establishing the most prior physiochemical parameters that contribute for river quality variation from the source and along the river, including turbidity, temperature, pH, EC, TDS, total hardness, alkalinity, chloride, sulfate, phosphate, nitrate, oil and grease, COD and BOD_5. Based on the analyzed physiochemical parameters eight sample points were taken from the river and effluent channels around Metehara,

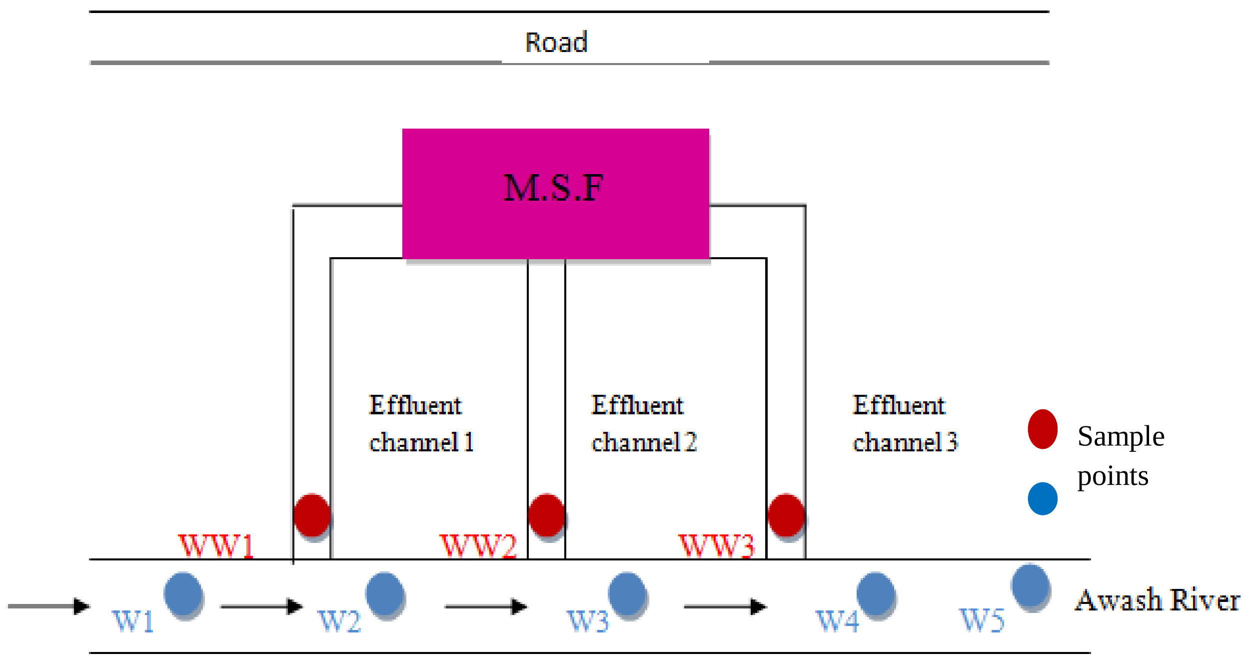

Fig 1.1: schematic representation of sampling sites

The samples were taken only on a dry season since the factory operates the production process on ten months of dry season and flooding might affect the spatial and temporal variation of water quality. The samples were collected from different location of the river before and after the wastewaters of MSF dissolved, and from the wastewaters as well in order to compare water quality variation and also to evaluate river water quality with national and international water quality standards.

1.6 Limitation of the study

Finance was the major limitation of this study while working intensively in data collection and analysis. Even though these kinds of studies required a lot of budget for data collection and analysis, the study has to be carried out with the available budget set by the institution.

1.7 Significance of the study

The study assessed the impacts of Metahara sugar factory wastewaters on the water quality of Awash River. Its hoped that Metehara sugar factory and relevant authorities will assisted by the result of this study in providing appropriate preventive measures to ensure that the quality of water in the river is improved.

Chapter 2: Literature review

2.1 Industrial wastewater impact on river water quality

The quality of water can be determined by its chemical, physical and biological characteristics. The suitability of water for designated use depends on these characteristics (Daniels, 2009). Each designated uses require a particular a specific water quality parameter composition and limit. For example the health risk of consumer increases with the level of turbidity in water. Much concentration of heavy metals like lead, iron, chromium and mercury in water produce chronic poisoning to aquatic animals. The pH range of acidic and basic water is harmful for human health. Therefore the variation of each parameter has influence on the water quality and limits the uses of water.

Water has many uses such as for drinking, cooling, fisheries, cleaning, irrigated agricultural crops, washing and processing equipment. Good quality water is very important in providing these uses. The water quality of rivers is best in the up streams, where annual rainfall amount is high. Water resources are closely related to Socio economic development, because human activities are highly interacted with water. Many activities uses water as an input; it serves essential biological functions, as a basic element of social and economic infrastructure, as a natural amenity contributing to physiological welfare (EPA, 1997).

Water quality variation of surface water can be caused by wastewaters which are produced from different activities and natural process (Edokpay *et al*, 2017). Water pollution due to discharge of untreated industrial effluents into the water bodies is a major problem in the global context (Paul, 2011). Environment has been impaired by Industrial development (Phiri *et al,* 2005). Fresh and clean water resources are continually polluted and depleted from domestic and industrial wastewater. Industries are growing as a result of urbanization and for the sake of economic development through time but this industries leave behind their pollutants to the environment.

Universally environmental pollution rose from rapid industrialization and subsequent urbanization becoming great environmental concern in recent years (Kumar *et al,* 2012). Despite the socio economic importance of this industries, there is high degree of pollution as result of waste discharging. Globally in the present day surface water is most commonly polluted by industrial waste and it increases yearly due to the fact most countries of the world getting industrialized and the number industries are increased (Gyawali *et al*, 2012). Due to the discharged wastewater from industries surface, water is one of the most influenced ecosystems on the earth (Phiri *et al*, 2005).

Water is the most important natural resource for many activities of human day to day life and all form of life. It makes up 50-97% of the weight of plant and animal and about 70 % of human body. According to WHO estimation around 20% of the world population has no access to safe drinking water (Ogwo *et al*, 2015). Both developing and developed countries experienced the problem related to water quality but the problem worsen in developing countries with the rapid growth of urbanization and newly emerged industries and lack of proper water treatment technologies (Phiri *et al*,. 2005).. In most African countries industries are rapidly grown. Most of the rivers in urban areas of these countries suffer from quality degradation from effluents discharged from the industries. The rivers receive discharged effluents directly from industries and serve as a source of drinking water and other domestic purpose to the people live near the area.

Like other African countries Ethiopia experiencing rapid urbanization and industrial growth. In different areas of the country industries are growing because the government has reinforced the policy of industrialization to develop the country's economy. However, there has been little regard to the adverse impact of industrial waste. Now a day's the wastewater disposed from industries in urban areas of the country becoming a treat for surface water quality (Abrha, 2013). With a rapid expanding human population and growing trend of industrial development, problems related to management of industrial waste have become of considerable magnitude in Ethiopia (Getachew, 2006). From the total of 2000 industries located in the capital city, Addis Ababa which comprises 65% of country's industry, most of the industries located along the river bank as much as 90 % have no any treatment plant and discharging their waste directly to the river (Yohhanes *et al*, 2017). Rivers in Addis Ababa are highly contaminated with different contaminants due to different industrial waste

Awash River basin is one of the 12 river basins found in Ethiopia which faces water quality degradation from industrialization (Fasil *et al*, 2013). The tributaries of Awash River from urban conglomerate of Addis Ababa have influence in quality degradation of water quality. Due to rapid economic and population growth the demand of water increase time to time in the basin. If the pollution rate of river and the development interest and demand of water continue like this Awash River basin will face water shortage in near future (Tajim *et al*, 2016).

The occurrence of pollution in the nearby environment increases along with the increase in industrial activity. There were a lot of industries carried out along Awash River including Metehara and other sugar industries. The wastewater generated from these industries led to a change in physicochemical characteristics of the river water. This change in physicochemical characteristics may lead to harmful effects to human and aquatic life.

2.2 Sugar manufacturing process and wastewaters

2.2.1 Manufacturing process in MSF

The first step towards the production of sugar in Metehara is the harvesting of sugar cane by the factory itself. The matured cane burned on the field to remove the bran. The bulk of burned cane is cut manually with billhook or cane knife. The cut cane collected and transported to the factory by means of special cart the so called cane carts. The cane weighted and tipped to a feed table by cane unloading crane. Horizontal cane carrier receives the cane from feed table and transported to cane cutters. The cutters break down the cane into smaller pieces to make it suitable for mill (tandems). Before subjected to mill magnetic separator picks metals coming due to some broke parts which are forbidden the mill.

The main objective of sugar milling is to extract the greatest possible juice from the cane**.** A series of horizontal mill extract the juice from the chopped cane which comprises mainly fiber. Metehara sugar factory also has one diffuser in tandem B between the mills to achieve high extraction. The extracted juice collected in juice tank and the remains of cane stack called bagasse which contains cellulose fiber used as a fuel for the boiler.

The raw sugar cane juice is composed of great number of organic and inorganic compounds, acids, salts and has color varying from greenish gray to dark green. It also caries suspended matters such as fine bagasse (bagacillo), gums, albumin, wax, particles of soil, sand, clay and has low pH.

The raw juice is viscous because of the gum, wax and albumin which cannot be filtered easily. Liming, heating and the addition of small amount of H_3PO_4 in clarification process cause many impurities in the juice to become coagulated and precipitate out. There are three stage of heating.

The juice from juice tank is pumped to the raw juice heaters and heated about 75^0C. Then it passes to lime preparation to get lime (CaO) to pH of 8 to obtain clarified juice of about pH 6.8-7.2 and SO_2 of temperature of 65 - 75^0C to clarify and remove color. After sulphitation, the sulphited juice passes to second heating or sulphited juice heaters. In this heater the juice heated about 102^0C. Then it goes to flash tank to remove non condensable gases. Then it enters to clarifier door. In clarifier door, liquid lime is added to make the mud to settle and the juice flow to clear juice tank by overflow. Then the juice pumped to the third heating heaters of temperature 115^0C. After the third heating the juice accumulated in intermediate tank. The mud can be used as a fertilizer on agricultural fields

The clear juice from the intermediate tank pumped to vapor cell which is in evaporation plant. The juice evaporated in vapor cells to reduce the water content from the juice until a thick sweet juice (syrup) is formed. The clarified juice must be evaporated further for the sugar to crystallize. In a vacuum pan heavy mixture of crystals and mother liquor, called massecute formed.

The raw sugar massecute is crystallized by cooling. Residual syrup called black strap molasses incapable of crystallizing is separated on this process and finally the batch and continuous centrifugals are used to separate the liquid and hard phase of raw sugar.

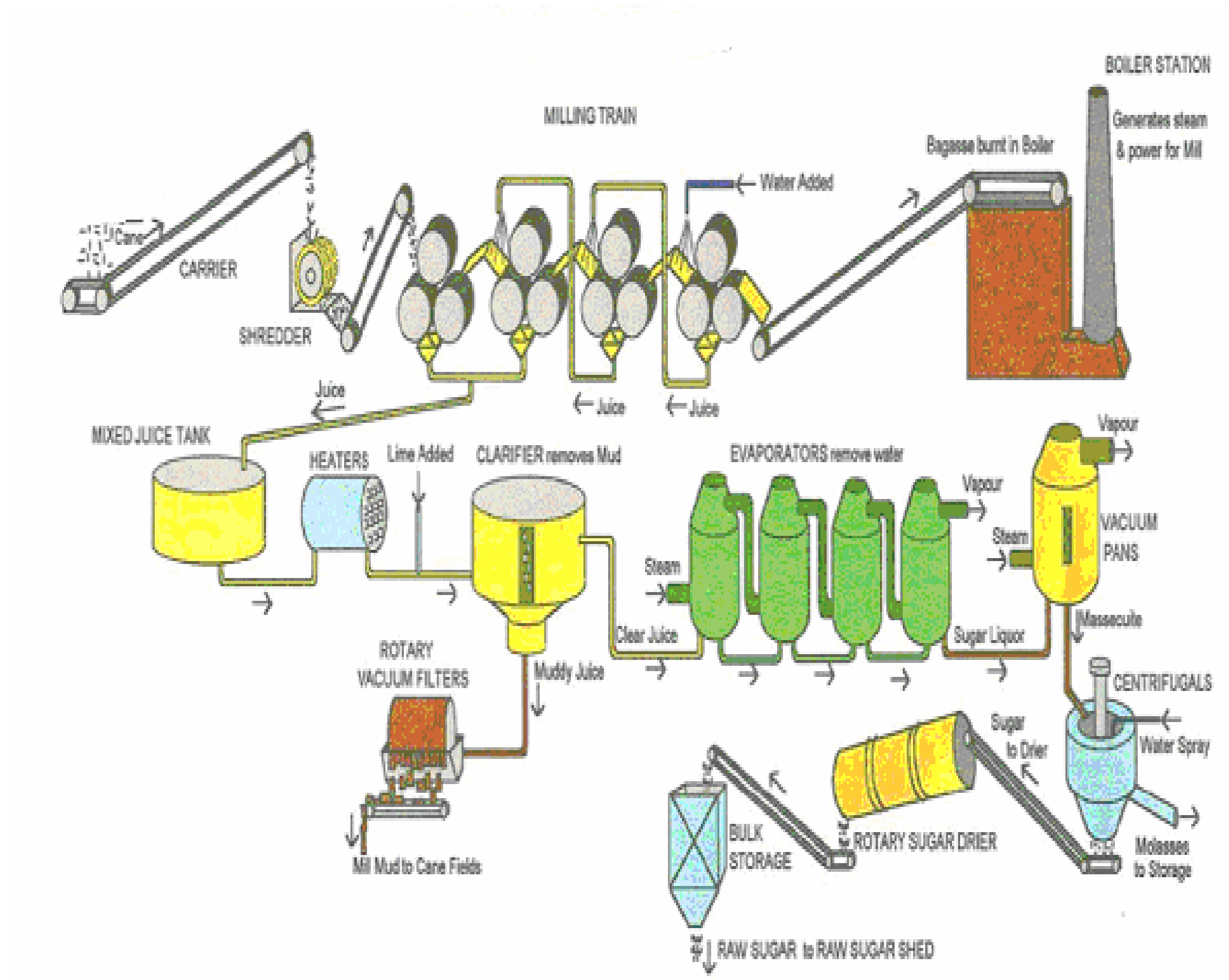

Fig 2.1: schematic diagram of sugar manufacturing process

2.2.2 MSF wastewaters

The wastewater can generate from internal and external water of sugar industries. External water is the water comes from outside canals. It is used for condensing, cooling, washing and production processing also. Internal water is the water from the cane itself which is directly involved in production process.

- ❖ Wastewater from mill house - mill plant is the plant that extracted juice from the cane. The wastewater from milling house mainly comprises the water used for cooling of roller mill bearing and water used for cleaning the floor of mill house. The juice covered floor of mill house should be cleared unless bacteria will grow. This water consists of organic matter like sucrose, bagasse, oil and grease from the bearings fitted to the mills (Kumer *et al*, 2012).

- Wastewater from factory garage house - the wastewater from garage house is the water used for vehicle body and parts washing. This water consists of diluted sulphuric acid, oil, gas, grease, naphthalene and other petroleum products.
- Wastewater from boiler house - the evaporated water from the juice in evaporation room condensed and used in boiler to produce steam. Before that the condensed water treated with different chemical (such as soda, acid and liquid oxygen) to keep the chemical composition of the water. Then the water generates the steam and the chemicals, suspended solids and dissolved solid remains in boiler pipe. The suspended solid and dissolved solid like potassium salt, calcium salt, fatty salt and soda drains as a waste when the boiler pipe cleaned (UN/WWAP, 2003).
- The leakage water from through pumps, pipelines and the water used for evaporator, juice heaters, clarification and pans washing also removed as a wastewater.
- Wastewater after composting - the molasses from centrifugal used to produce compost the remaining drain as a waste.
- Soda and acid wastes - to remove the formation of deposits on the surface of tubing the heat exchange and evaporator are cleaned with caustic soda and hydraulic acid. This chemical might goes into drains (*Kumer et al*, 2012).
- Lime residue - in clarification lime is added on the juice to settle the mud and separated the mud from the juice. The OC filter soaks up the fluid from the liquid mud and the dried mud used as a fertilizer. But in case of Metehara one of the two OC filter is malfunctioning, the remaining filter also has limited capacity so the liquid mud directly drain as a waste with aid of external water.

2.3 Physicochemical water quality parameters

Water quality can be determined by physical and chemical characteristics of water. Any undesired changes of physical and chemical properties threaten and affected the quality of water. Therefore, before using it for any activity, it is very necessary and important to taste physicochemical properties of the water. Furthermore physicochemical testing is helpful to determine the amount of chemical and treatment technique to be used to purify or treat polluted water (Shaka, 2015).

Temperature is an important parameter which determines the quality of water. It is physical quantity which measures weather the water is relatively cold or hot. Usually the water released from industry is high in temperature. Temperature can affect the chemical, biological and physical process and the concentration of many variables in water. The temperature of wastewater can affect the organism and inhabitation of aquatic medium by affecting certain chemical and biological process taking place in water. The suitable temperature for aquatic condition holding enough oxygen lies between 20 ^{0}C - 27 ^{0}C (Baraniya, 2018).

The temperature of surface water can rise from thermal discharges, usually from power plants, metal foundries and sewage treatment plants. The respiration rate increased with increasing temperature of water bodies, this increases the oxygen consumption demand and decomposition of organic matter. Such condition provides an opportunity for bacteria and phytoplankton raise their population in very short period of time leading to increased water turbidity, macrophyte growth and algal blooms, this affects fish growth and reproduction (Chitangari, 2012).

Turbidity is one of the important physical parameter and an optical property. It blocks the light not to transmit in straight line through water. It is caused by large number of individual particles that are generally invincible to the naked eye. Similar to smoke in the air it is a cloudiness or haziness of a fluid (Paul, 2011). The measurement of turbidity is a key test of water quality. The finely divided solids which cannot be filtered by regular method are the major constitutes of turbidity in water. The type and concentration of suspended matter controls the turbidity and transparency of water. The Suspended matter consists of silt, clay, fine particles of organic and inorganic matter, soluble organic compounds plankton and other microscopic organisms. The flow rate of river water, soil erosion, building and road construction, forest fire, logging and mining, urban runoff, industrial wastewater and septic system effluent, decaying plants and animal are some factors that increase the turbidity of water (WHO, 2011). As it appears visible cloudiness turbidity might not be accepted by consumers.

Higher turbidity level in drinking water increases the health risk of consumers. The reduction of the penetration of light due to suspended particles provides suitable condition for viruses, bacteria and other microorganisms to escape from ultraviolet sterilization.. These organisms may cause symptoms such as nausea, cramps, diarrhea and associated headaches and gastro intestinal diseases. Therefore drinking water should have lower turbidity, the Ethiopian and WHO limits the turbidity of drinking water to 5 NTU (CES 58, 2013; WHO 2006).

High turbidity in surface water reduces the visual range of aquatic animals and reduces the light penetrated for photosynthesis, resulting the decreasing of oxygen concentration (Nadia, 2006).

Electrical conductivity of water reflects the electric current conducting capacity of water. Conductivity determines the quality of water and expressed as micro Siemens per centimeter (µS/cm). Electric conductivity of the water is sensitive to temperature and dissolved solid variation. Electric conductivity of water increases with the increasing of water temperature. 2-3% conductivity increases per one degree Celsius of water temperature. Conductivity of water also increase with total dissolved solid known as ions concentration. Higher conductivity indicates more ions. The sudden change of conductivity of surface water indicates that there is a source of dissolved ion in the surrounding area (Paul, 2011).

The wastewater with high conductivity and ionic concentration that discharged from industries would have an adverse impact on aquatic life, the recipient becoming unfit for drinking and domestic purposes (Nadia, 2006). Therefore to determine the potential water quality problem, conductivity measurement can be used as a quick way. Waters with high conductivity are unpalatable and potentially unhealthy. WHO allowable limit of conductivity for drinking water is 500µS/cm (WHO, 2006).

pH is a scale used to determine how basic or acidic the water is. pH scale ranges 0-14, 7 represent neutral condition. The pH value of acidic and basic water is 0-7 and 7-14 respectively. The pH value of surface water helps to determine the extent of effluent plume in it. The change in pH can indicate the presence of certain effluents in the water. Industrial wastewater and domestic sewage affect the ph value of the water (Baraniya, 2018). The pH of water affects the solubility of many substances. With the increasing acidity of surface water the solubility of most metal increases. Cyanides and sulfides toxicity increases with decreasing of pH. The water having a pH value exceeding 8.5 is hard and unpalatable (Chitanageri, 2012). The Ethiopian and WHO guideline level for pH of drinking water is 6.5 - 8.5 (CES 58, 2013; WHO, 2006).

Hardness is one of the dominant physiochemical parameter. It is a natural characteristic of water which can be enhance its palatability and consumer acceptability for drinking purpose. The hardness of natural water mainly depends on the presence of dissolved calcium and magnesium salt. They are presented as carbonate and bicarbonate salt. The principal sources of hardness in water are polyvalent metallic ions from sedimentary rocks, wastewater discharging and run off from soils. Small ground water supplies often encounter significant levels of hardness but some large surface water supplies also have the same issue (WHO, 2011). Hard water can create a taste discomfort and health problem to consumers but it has an importance to minimize problems related to heart diseases. According to WHO consumers can tolerate water hardness up to 500 mg/L (WHO, 2006). Ethiopian water quality standard limits the concentration to 300 mg/L (CES 58, 2013). .

Total dissolved solid (TDS) indicates the solid amount of organic and inorganic substances present in a liquid in suspended form. These include carbonates, bicarbonates, chlorides, sulfates, calcium, magnesium, potassium, dissolved metal and substances other than pure H_2O molecule. These substances can reach to surface water through urban run-off, sewage, natural source and industrial wastewater. The presence of suspended solids in water changes physical and chemical nature of water by increasing turbidity and sediments (WHO, 2004).

Waste effluents with high TDS have adverse environmental impact. It would have adverse impact on aquatic life, becoming a cause to receiving water unfit for drinking, accelerated water system and pipe corrosion and the crop yield reduction on irrigation fields. High TDS result has undesirable taste which could be salty, bitter or metallic. It could also indicate the presence of toxic minerals (Nadia, 2006). The WHO maximum allowable limit for TDS concentration of drinking water should be 1000 mg/L (WHO, 2006). According to CES 58 Ethiopia also has the same standard for TDS concentration in drinking water.

The alkalinity of natural water acts as stabilizer for pH, due to the presence of bicarbonates (HCO^{-3}) and carbonates (CO_3^{-2}) formed in reaction in the solid through which the water percolates. Alkalinity of water reflects its inherent resistance to pH change and capacity to neutralize acids. A poorly buffered water will have a low or very low alkalinity and susceptible to pH change (patil *et al*, 2012).

By nature most natural waters are alkaline due to the presence of formed bicarbonates and carbonates from dissolved atmospheric carbon dioxide. Surface waters contain weak acid and bases naturally. The acidity of water is controlled by strong mineral acids, weak acids such as carbonic, humic and fluvic and hydrolizing salt of metals, as well as by strong acids. Until alkalinity value reach up to 200 $CaCo_3$ river water show no significant water quality. Unpatability occurs if the alkalinity value water exceeds this value. The WHO maximum allowable limit for alkalinity of drinking water should be 200 mg/L According to CES 58 Ethiopia also has the same standard.

Chloride is the anion of chlorine often soluble in water and almost all surface water contains this ions. Fresh water chloride ion concentration is mostly less than 10 mg/L, sometimes it might even lower than 2 mg/L. Industrial and sewage, paper work, galvanizing paints, softening plants effluents and agricultural and road run off are a chief contributor of chloride ion to surface water (Baraniya, 2018). Too much amount of chloride in surface waters might causes pollution and related health risk. If the concentration of Chloride ion exceeds 250 mg/L, the taste of water will become salty. It's strictly becoming intolerable for palatability as the concentration rises further. Furthermore it might cause eye and nose irritation, anemia, infants and young children nervous system effects (EPA, 2001). The maximum WHO and Ethiopian allowable limit for chloride ion is 250 mg/L (CES 58, 2013; WHO, 2006).

Chemical Oxygen Demand (COD) is the key indicator of the environmental health of surface water. It is an important parameter and rapidly measure variable for characterizing water body. It is the measure of organic matters contamination in water specified in mg/L and the amount of oxygen required to cause chemical oxidation of the organic material in to carbon dioxide and water (Patil *et al*,2012). The pollution level of domestic and industrial waste is determined by COD is experiment. The COD test surface water is useful in indicating toxicity condition and the existence of biological resistance substances (Baraniya, 2018). COD used to assess the quality of water regarding organic matter. COD positively correlated with TDS, EC, turbidity, temperature and negatively correlated with pH. The contamination level of surface water can be determined by COD value. 4 - 8 mg/L value of COD of surface water indicates low level contamination; 8 - 12 mg/l shows moderately high contamination level and 12 mg/L or more shows very high level of contamination (Omed, 2006). Therefore WHO recommended the COD value the water used for drinking purpose should not exceed 10 mg/l.

Biochemical Oxygen Demand (BOD) is measure of organic material contamination in water. It is the amount of dissolved oxygen required by microorganisms for the biochemical breakdown of organic compound and oxidation of certain inorganic materials such as iron and sulfite in water under aerobic conditions. The BOD test of water indicates the pollution amount by oxidizable organic matter. The amount of organic compounds in surface water increases with the untreated discharge of municipal and industrial wastes. The BOD value surface water increases as more organic matter dissolved. Typically the test for BOD is takes over a five-day period (Patil et al, 2012). According to Omed (2006), The water having BOD value of 1 mg/L categorized under very clean water, 2 mg/L categorized under clean water, 3 mg/L categorized under fairly clean , 5 mg/L specified as doubtful and 10 mg/l or more as bad water. Therefore WHO recommended the BOD value the water used for drinking purpose should not exceed 5 mg/l.

The concentration of Oil and grease is an important parameter to determine the water quality and safety (Sahu, 2017). It includes fats, oils, waxes, and other related constituents found in water, generally wastewater. Industrial discharges are the major contributors of oil and grease to surface water. It is immiscible in water that cause surface films and shore line accumulation leading to environmental degradation and can induce human health risk such as cholera, dysentery and hepatitis when used for drinking. The maximum recommended concentration of oil and grease for bottled drinking water is 2 mg/L. (Piscal, 2009).

Nitrate is a poly atomic anion highly oxidized nitrogen compound. At standard temperature and pressure it is soluble in water. It is the final product of nitrogenous matter. Uncontaminated surface water usually contain very small amount of nitrate. From mineral origin the amount of nitrate found in natural water is very small, organic and in organic sources, including waste discharges and artificial fertilizers can elevate the amount nitrate in surface water. In surface water, Plants can take nitrate as nutrient and assimilated in cell protein. This stimulates the growth of plants, especially algae's. This may cause eutrophication and water quality problem associated with eutrophication. The presence of nitrate in a water supply indicates on-going pollution by onsite sanitation and bacterial activity as a result of it.. High nitrate levels in water to be used for drinking will lead to several diseases such as hypertension, cancer and birth defect (Omed, 2006). The WHO and Ethiopian guide level of nitrate in drinking water is 50 mg/L (WHO, 2006).

Phosphate is the common ions in natural water. Phosphorous can be found in three forms orthophosphate, poly phosphate and organic phosphate, in aqueous solution. The dissolved phosphate level of river water should not exceed 0.1 mg/L (Omed, 2006). Run off and waste discharges are the main contributor of phosphorus to surface water. Unless it presented in very high amount phosphate has no significant impact on plant and animal. Excessive phosphate concentration in water may produce secondary pollution problem. The presence of excessive phosphorous in surface water increases euthrophication by stimulates algal production. Phosphorous Along with nitrate phosphorus in such water bodies promotes growth plants including algae. In hot climate where the dissolved oxygen is already low, it can cause the problem of taste and smell. WHO permissible limit of phosphate in drinking water is 0.1 mg/L (WHO, 2006).

Sulphate is the common polyatomic ion in natural water which has been used in different industry. The wastewater discharged from those industries also the major source of sulphate to the receiving water body. Plants can take up the normal level of sulphate in water. If the water is over loaded with organic waste and the oxygen lever reduced, sulphate as electron acceptor used for breakdown of organic matter and produce hydrogen sulphide and rotten egg smell (Sahu, 2017). Excessive concentration of sulphate and hydrogen sulphide in water can cause illness, laxative effect lead to dehydration, nausea and even death. WHO allowable limit of sulphate in drinking water is 250 mg/L (WHO, 2006).

2.4 Environmental policy and legislation in Ethiopia

According to Ethiopian Sugar Corporation, currently there are thirteen sugar industries in Ethiopia. Among those Metehara sugar factory is one of the largest industry playing a significant role in serving the demand of the people and supporting the economy of the country as well. However Ethiopian EPA specifies that the environmental pollution derived from industrial activity is the main threat to surface and ground water quality in Ethiopia.

Article 2 sub article 1 of proclamation no. 9/1995 defines environment as "the protection of land, water, air and similar other environmental resources, factors and condition which affect the life and development of all organization including human being". Federal Democratic Republic of Ethiopia (FDRE) constitution article 44 also states that all persons have the right to live in a clean and healthy environment. But according to Ethiopian environmental law 65/2000 almost all industries in Ethiopia released untreated effluents into the nearby water bodies. It further specified under 56/2000 and 57/2000, around 71.1% of country households uses unclear or unsafe source of drinking water from river/lake or spring and 49.5% of rural households get their unsafe source of drinking water from river/lake respectively. Managing the waste in an environmental sound manner is the key for the protection of land, air and water. So this can be achieve through establishment and enforcement of operational standard and guideline set to insure that one does not destroy the environment (EPA, 2003).

Ethiopian environmental law 116/2000 obligate development activities that likely cause pollution or other environmental hazards to install sound technologies or adopt practices that avoid or minimize the generation of waste and promote the re-use or recycling of effluents, discharges and waste in general.

Like other industries sugar factory must hold on to several standards and obligations. As a result public health and environment protected from pollution. By environmental law 117/2000 the responsibility to prescribe environmental standards vested to EPA. The standard set by Ethiopian EPA for sugar manufacturing wastewater limit value for discharges to water bodies are shown in the table below.

Table 2.1: sugar manufacturing limit value for discharges to water bodies

Parameter	Limit value
Temperature	40 ^{0} c
pH	6 - 9
BOD_5 at 20 ^{0} c	60 mg/l > 90% removal
COD	250 mg/l > 90% removal
Suspended solid	50 mg/l
Total nitrogen	40 mg/l > 80 % removal
Total phosphorus	5 mg/l > 80% removal
Oil and grease	15 mg/l

(Source EPA, 2003)

Moreover article 830 of criminal code of the federal democratic republic of Ethiopia (proclamation number 414/2004 E.C) strictly state that factories or industries polluting the environment specifically contaminating the cleanliness, salubrity and hygiene of water is punishable with fine or arrest.

Chapter 3: Materials and Methods

3.1 Study area & its description

Awash River basin is one of the 12 major river basins in Ethiopia. It is the most intensively utilized river basin in the country and originates and remains entirely in Ethiopia. Awash River has a total length of 1,200 km starts from the Ginchi watershed in the central highlands of Ethiopia and flows towards Djibouti. The Awash basin is the part of Great Rift Valley in Ethiopia located from 8.5^0N to 12^0N. It covers a total area of 112,696 km^2 (Mekonin *et al*, 2011). The basin includes mainly the Afar, Oromia and Amhara regions including the area of the Addis Ababa city administration and Dire Dawa council.

Traditionally Awash River basin divided into four distinct zones. These are; upper basin, upper valley, middle valley and lower valley as shown in the table below.

Table 3.1: Division of the Awash River basin

Designation	From	To
Upper basin	Head water	Koka dam
Upper valley	Koka dam	Awash station
Middle valley	Awash station	Gewane (d/s)
Lower valley	Gewane (d/s)	Lake abe

(Source: Shimelis Behailu, 2004)

The study area, Metehara lies in the upper valley of Awash River basin. It is located in east Shewa zone of the Oromia region, Ethiopia. It has a latitude and longitude of $08^0$54'N and $39^0$55'E with an elevation of 947 m.a.s.l. It is the largest town in Fentale Woreda (refer Fig 3.3).

I. **Temperature**

The study area has a semi-arid climatic condition and the average annual temperature is 25 ^{0}c. May and June are the hottest months of the year. The mean annual maximum and minimum temperature are 28.1^{0}c and 20.9^{0}c, respectively.

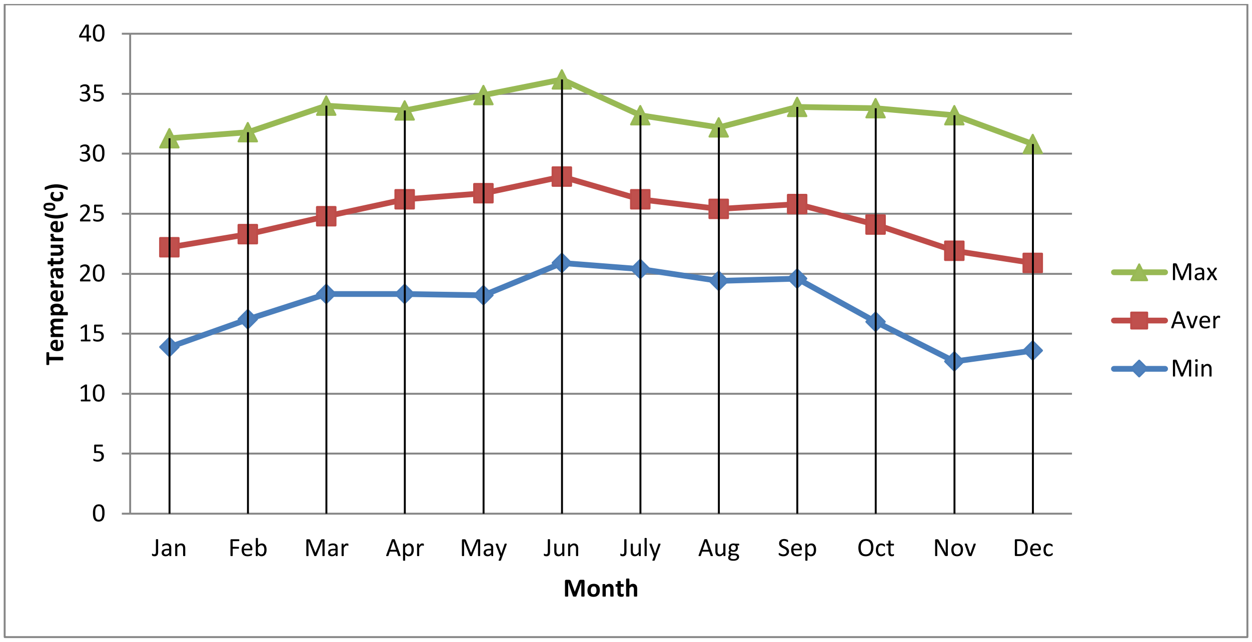

Fig 3.1: Mean monthly annual minimum, maximum and average temperature at Metehara

II. Rainfall

All year long there is no much rainfall in the study area. Throughout the year the study area got a total of 537 mm of rain. December is the driest month of the year. The precipitation is relatively higher in July and august. Since the rain (muddy field) affects the burning, cutting and transportation of cane, MSF productions months extended only from September to June.

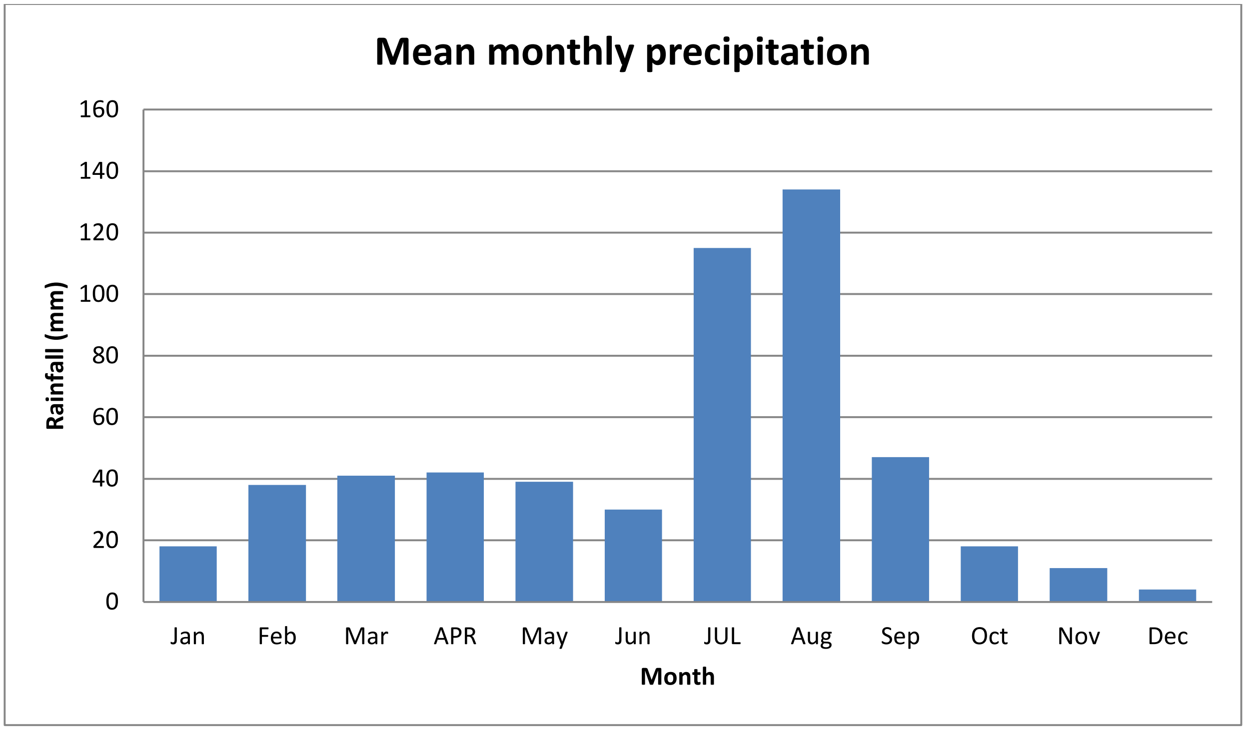

Fig 3.2: Mean monthly precipitation

Metehara sugar factory was selected as the focus of this study to determine the impacts of its effluent on the quality of Awash River. It is one of the thirteen sugar industries in Ethiopia. It produces up to 6,000 quintals of sugar per day. It discharges an average of 3,841,200 m^3 of wastewater per day.

3.2 Methods

3.2.1 Types of data

In order to achieve the objectives of the study both primary and secondary data were collected from different sources. .

3.2.2 Source of data

A. primary data

The primary data collected includes water and wastewaters samples from the study area including:

- ✓ The concentration of key water quality parameters based on the following physiochemical parameters:

Physiochemical parameters	Turbidity
	pH
	Electrical conductivity
	Total dissolved solid
	Hardness
	COD and BOD_5
	Alkalinity
	Oil and grease
	Chloride, phosphate, nitrate and sulfate,

- ✓ Field measurement of temperature in sampling site: to analyze the temperature variation of the river water before and after the effluents of Metehara sugar factory dissolved.

B. Secondary data

Secondary data were collected from both published and unpublished literatures & documents including articles, reports, books, journals and previous researches.

3.2.3 Water sampling period and location

3.2.3.1 Sampling location

Site selection decision was takes place based on the source of pollution in order to clearly understand their potential impact on Awash River. The sampling points were taken from the location of factory discharge and relative accessibility of the sample location.

The total of eight sampling sites selected to represent the water quality variations at these points. The major six sampling locations were selected based on the MSF wastewater discharging channels. The factory discharges three different types of wastewaters at three different locations. The samples were taken from each discharging point of the factory's wastewater twice before and after mixed with the river in systematic manner by which such points believed to show the amount effluents dissolved to Awash River and the possible water quality variation. The two additional sample points were taken from the river before any of the wastewaters dissolved and after all of the wastewaters of MSF dissolved, both points believed to show quality variation along the river. The sample sites are shown in the figure below.

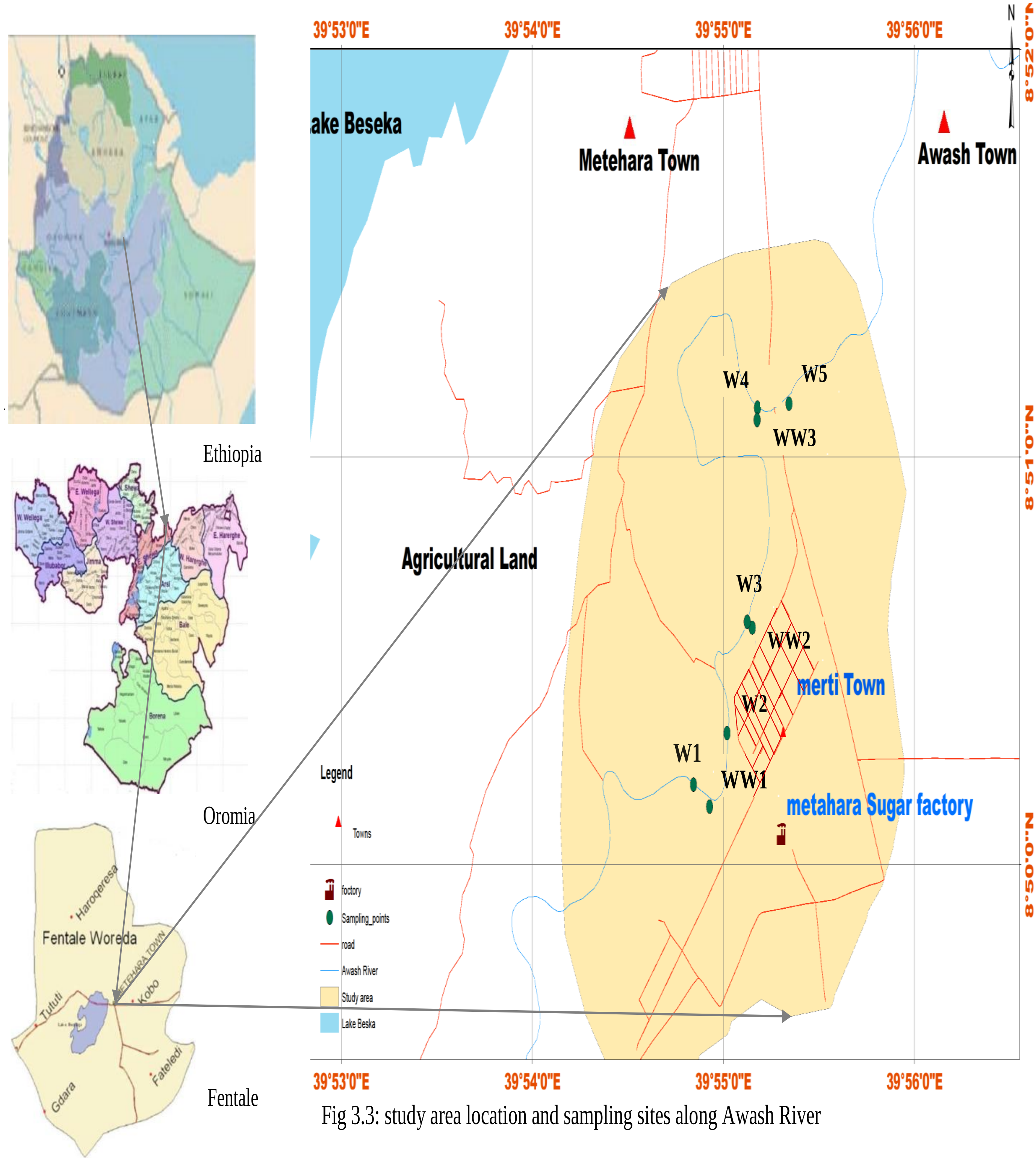

Fig 3.3: study area location and sampling sites along Awash River

The study area lies between 967 m.a.s.l at first sampling site W1 to 958 m.a.s.l last sampling site W5. Each sampling points are described as follow

1. River water sample point one (W1) - this water sample point was located 08^0.83' N and 39^0.91' E with an elevation of 967 m.a.s.l on the upper part of Awash River before any of Metehara sugar factory waste effluents dissolved. This sample point may help to evaluate the water quality of Awash River before the intrusion of any of the wastewater from the factory.

2. Wastewater sample point one (WW1) - this wastewater sample point was located 08^0.83' N and 39^0.91' E with an elevation of 966 m.a.s.l in the middle 100 m ahead of W1, on the first channel that transport waste effluents from Metehara sugar factory before dissolved to Awash River. This channel collects all the wastewater and by products of the factory after being processed in production. Analyzing this sample may help to evaluate the type and amount of effluents dissolved in Awash River at this point.

3. River water sample point two (W2) - this water sample point was located 08^0.836' N and 39^0.916' E with an elevation of 962 m.a.s.l in the middle around 6 m beyond WW1, after the wastewater of first channel dissolved with the river. Analyzing this sample may help to evaluate the impacts of the first wastewater on the quality of river water.

4. Wastewater sample point two (WW2) - this water sample point was located 08^0.84' N and 39^0.91' E with an elevation of 961 m.a.s.l in the middle 1 km to the front of W2, on the second channel that transport waste effluents from Metehara sugar factory and surrounding area before dissolving to the river. This channel collects all sewage from the factory and surrounding area. Analyzing this sample may help to evaluate the types and amount of effluents dissolved in the river at this point.

5. River water sample point three (W3) - this water sample point was located $08^0.84'$ N and $39^0.91'$ E with an elevation of 959 m.a.s.l in the middle around 6 m ahead of WW2, after the wastewater of second channel dissolved with the river. Analyzing this sample may help to evaluate the impacts of the second wastewater on the quality of river water.

6. Wastewater sample point three (WW3) - this water sample point was located $08^0.85'$ N and $39^0.91'$ E with an elevation of 959 m.a.s.l in the middle 2.5 km at the fore front of W3, on the third channel that transport waste effluents from Metehara sugar factory before dissolving to the river. This channel collects all the wastewater which had been used for cooling and washing. Analyzing it may help to evaluate the types and amount of effluents dissolved in the river at this point.

7. River water sample point four (W4) - this water sample point was located $08^0.85'$ N and $39^0.91'$ E with an elevation of 958 m.a.s.l in the middle around 6m ahead of WW3 after the wastewater of third channel dissolved with the river. Analyzing this sample may help to evaluate the impacts of the third wastewater on the quality of river water

8. River water sample point five (W5) - this water sample point was located $08^0.85'$ N and $39^0.92'$ E with an elevation of 955 m.a.s.l on the lower part of the river 2.1 km beyond the third and the final channel of waste effluent transporter. This point help to evaluate the overall impact of Metehara sugar factory and water quality variation of Awash River. The summary is presented in Table 3.2.

Table 3.2: Sampling point's location

Sampling point	Altitude (m)	Latitude	Longitude
W1	967	8.836602^0	39.914052^0
WW1	966	8.835705^0	39.915451^0
W2	962	8.836054^0	39.916225^0
WW2	961	8.843021^0	39.9919175^0
W3	959	8.843264^0	39.918740^0
WW3	959	8.851512^0	39.919601^0
W4	958	8.852013^0	39.919636^0
W5	955	8.852179^0	39.922384^0

3.2.3.2 Sampling period

Because of the possible variation of physicochemical quality of water the field investigation was take place twice within the dry season since flooding might affect the spatial and temporal variation of water quality. In addition because of the rain, the active production season of the industry restricted to the dry season only. The cane collection and transportation is not possible in wet season. The samples were collected in the morning for the period of two months (April and May, 2011 Ec.).

3.2.3.3 Sample collection

Grab sampling method were used to collect the samples because each samples has to be transported to the laboratory within 24 hours. River water and wastewater samples were collected using 1000 ml plastic bottle. All river water and wastewater samples from eight sampling point were collected by direct immersion of bottles on water sample points handled by rope. Water sampling and preservation techniques followed the standard methods of water sampling and preservation technique (APHA, 1998). Before collection bottles were washed with concentrated nitric acid and distilled water to avoid contamination. Sample bottles were preserved using ice box and transported to Addis Ababa University laboratory.

3.2.4 Method of analysis

A collected water sample at one time from each point was analyzed in laboratory for the physicochemical parameter which is listed in Table 3.3. Water quality analysis was done in accordance with standard methods for examination of water and wastewater (APHA, 1998). Turbidity of collected water samples were measured by digital turbid metric 2100 A. EC and pH were measured with a multi digital meter or using EC meter and pH meters (HI 9024 HANNA) respectively. Determination of alkalinity, total hardness, and chloride were carried out by titration methods by using 0.02N of H_2SO_4, EDTA and $AgNO_3$ respectively. Total dissolved solids measured by gravimetric method. BOD_5 determination was carried out using BOD incubator. COD, nitrate, sulfate, and phosphate amount of the collected water sample were analyzed calorimetrically using HACH DR/4000 spectrophotometer.

Table 3.3: Selected water quality parameters and method of analysis

No	parameters	Analysis method	Ethiopian standard CES 58	WHO standard	Equipment
1	Turbidity	Turbidity meter	5 NTU	5NTU	Using DR2000 spectrophotometer
2	EC	Direct measurement		500 μS/cm	EC Meter
3	pH	Direct measurement	6.5 - 8.5	6.5 - 8.5	PH meter
4	Total dissolved solids	gravimetric	1000 mg/L	1000 mg/L	Oven drying (105^0)
5	Total hardness	Titration	300 mg/L	500 mg/L	Using EDTA
6	Alkalinity	Titration	200 mg/L	200 mg/L	Using H_2SO_4 with methyl orange and phenolphthalein
7	Nitrate	colorimetric	50 mg/L	50 mg/L	Using DR 2000 spectrophotometer
8	Phosphate	colorimetric		0.1 mg/L	Using DR 2000 spectrophotometer
9	Chloride	Titration	250 mg/L	250 mg/L	Using $AgNO_3$ with dichromate indicator
10	Sulphate	colorimetric	250 mg/L	250 mg/L	Using DR 2000 spectrophotometer
11	COD	Colorimetric(digested)		10 mg/L	Atomic absorption spectrometry
12	BOD	BOD incubator		5 mg/L	
13	Oil and grease	gravimetric			

3.2.5 Data analysis

To interpret the water quality characterization, water quality criteria standards and the related legislation were used. The analyzed laboratory result of eight sampling point for each physicochemical values were evaluated based on the WHO and Ethiopian water quality standards and interpreted in accordance with maximum WHO and Ethiopian allowable limits. The reason and implication of any deviation from such standard were describe and interpreted in relation to the corresponding activities.

Chapter 4: Results and Discussions

The water samples from the Awash River water (W1-W5) and factory wastewaters (WW1-WW3) were collected and analyzed in laboratory to determine the pollution load of the factory on Awash River and the compatibility of river water for drinking purpose. The result of physicochemical analysis of the samples were listed and compared with the WHO and Ethiopian drinking water standards and guidelines. The reason and implication of the physicochemical analysis result of wastewaters and river water samples were also discussed.

4.1 Physical and chemical parameters

4.1.1 pH

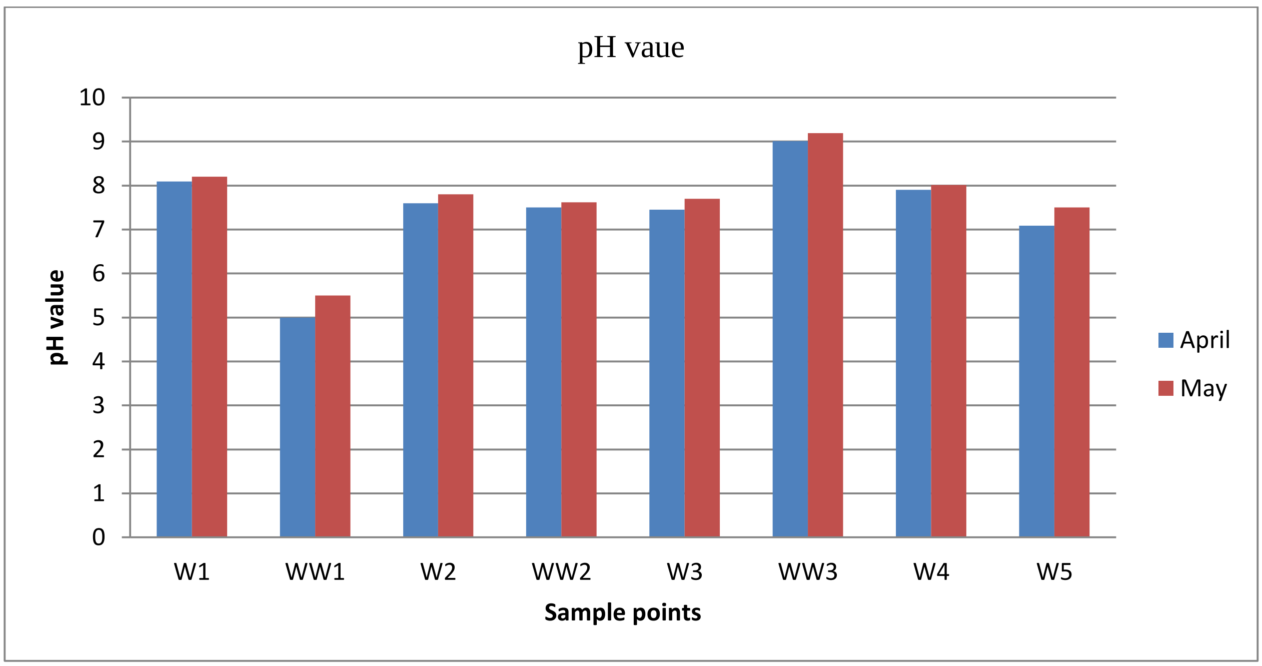

Fig 4.1: pH value of eight sample points

The result of the pH values of the samples are shown in figure 4.1. The pH value of all the samples ranged from 5 to 9.01 and 5.5 to 9.2 during April and May respectively. The higher and lower pH value of surface water usually related with receiving of waste effluent from anthropogenic activities (Paul, 2011). Likewise the pH result of wastewaters samples ranged from 5 to 9.2 and 5.5 to 9.1 during both analyses. The river water samples value ranged from 7.09 to 8.09 and 7.5 to 8.2 which was relatively neutral than wastewaters samples.

The first wastewater sample WW1 (5.0 and 5.5) was more acidic sample during both analyses and its impact further reflected on W2. The initial pH result of the river water before any effluents dissolved at W1 was 8.09 and 8.2. The pH value of the river water decreased by 0.29 and 0.6 respectively at W2 after dissolved with WW1. Similarly WW3 (9.01 and 9.19) was more alkaline sample during both analysis and its impacts also reflected on W4 (7.9 and 8.01) where it was (7.45 and 7.7) at W3 before dissolved with WW3. While comparing the first W1 (8.09 and 8.2) and the last river sample W5 (7.09 and 7.5) there were a change in terms of pH value. This change in pH indicates the overall pollution contribution of all the wastewaters from the sugar factory.

The Lowest pH values observed at WW1 was probably due to acidic waste from phosphoric acid and sulphur dioxide used for sugar cane juice clarification process. The pH value at W2 shows an improvement after the river dissolved with WW1. This indicates the dilution of river water was the reason for pH improvement. The high value of pH observed at WW3 was might be due to the basic waste from evaporator after cleaned with caustic soda (sodium hydroxide). The dilution of river water might also be the reason for the loss of alkalinity at W4 after WW3 mixed with the river.

The pH value of river samples obtained in the present study was consistent with the study conducted by Kidu *et al*. (2015). The pH value of all river samples lies within the Ethiopian and WHO guideline level for pH of drinking water i.e. 6.5 - 8.5 (refer Table 3.3). Only wastewater samples WW1 and WW3 were above WHO and below Ethiopian guideline level for pH respectively.

4.1.2 EC

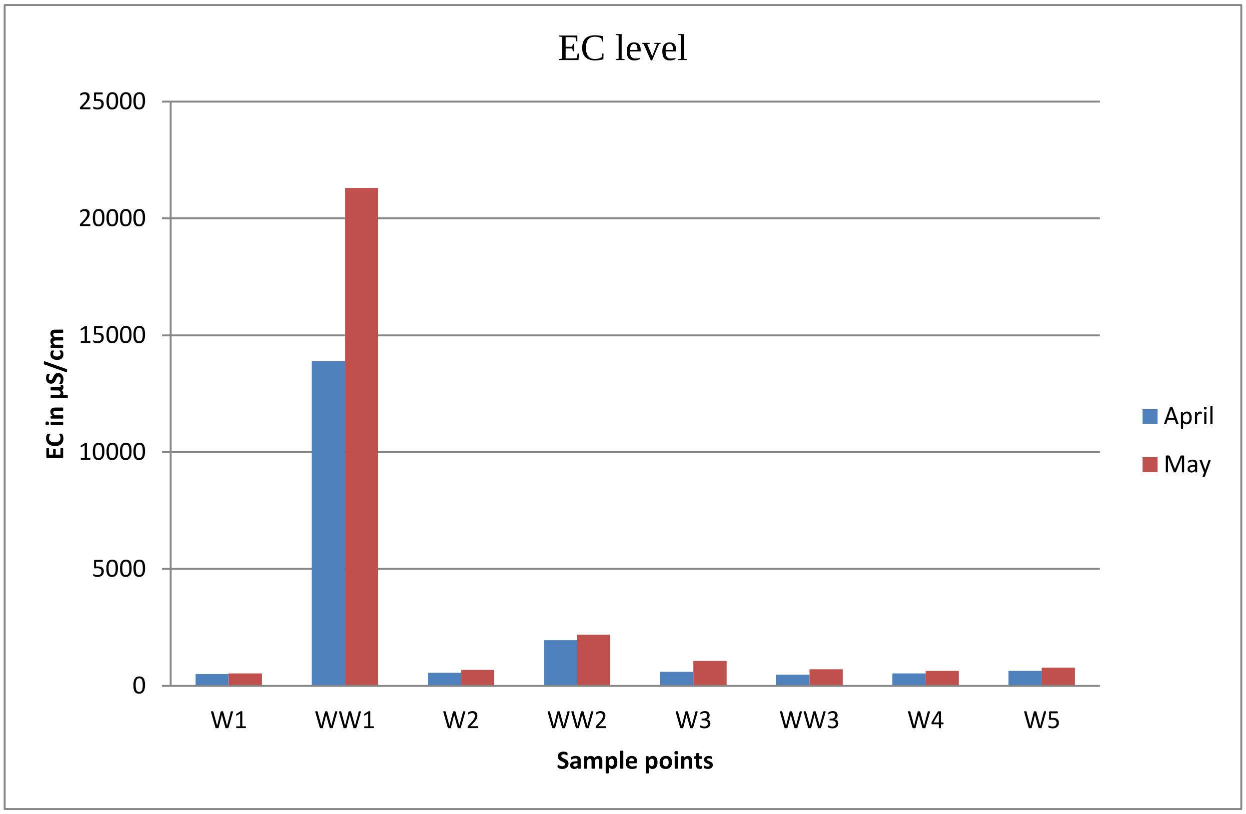

Fig 4.2: EC value of eight sample points

The results of the EC values of the samples are shown in figure 4.2. The EC value of all the samples ranged from 504μS/cm to 13,880μS/cm and 532μS/cm to 21,300μS/cm at April and May respectively. The a EC value of wastewater samples ranged from 480µS/cm to 13,880 µS/cm and 532 μS/cm to 21,300 μS/cm and river water samples 504µS/cm to 640µS/cm and 532 μS/cm to 1,060 μS/cm during both analyses respectively. Conductivity can determine the pollution level of surface water (Omed, 2006). The lowest value of conductance may indicate good quality of water and low quality water may have high value of conductance, high TDS level, high concentration of ions and high temperature. Similarly the wastewater samples recorded the highest EC value, specially the first and second wastewater during both analysis, WW1 (13,880μS/cm and 21,300 µS/cm) and WW2 (1,950μS/cm and 2,190µS/cm) respectively. This signifies the quality level and the quantity of contaminants the wastewaters could pose on the river water.

The initial electric conductivity of river water at W1 was 504μS/cm and 532µS/cm. After dissolved with WW1 it became 560μS/cm and 677µS/cm at W2 and elevated to 590μS/cm and 1,060µS/cm once again at W3 after dissolved with WW2. While comparing the first and the last river samples there was a significant change in terms of EC value. These changes signify the impacts of dissolved wastewaters. WHO allowable limit for drinking water is 500µS/cm (refer Table 3.3). But none of the sample sites result complies with the limit. This high EC value implies the availability of chemicals in the river water that may cause chronic danger on plants and animals.

4.1.3 TDS

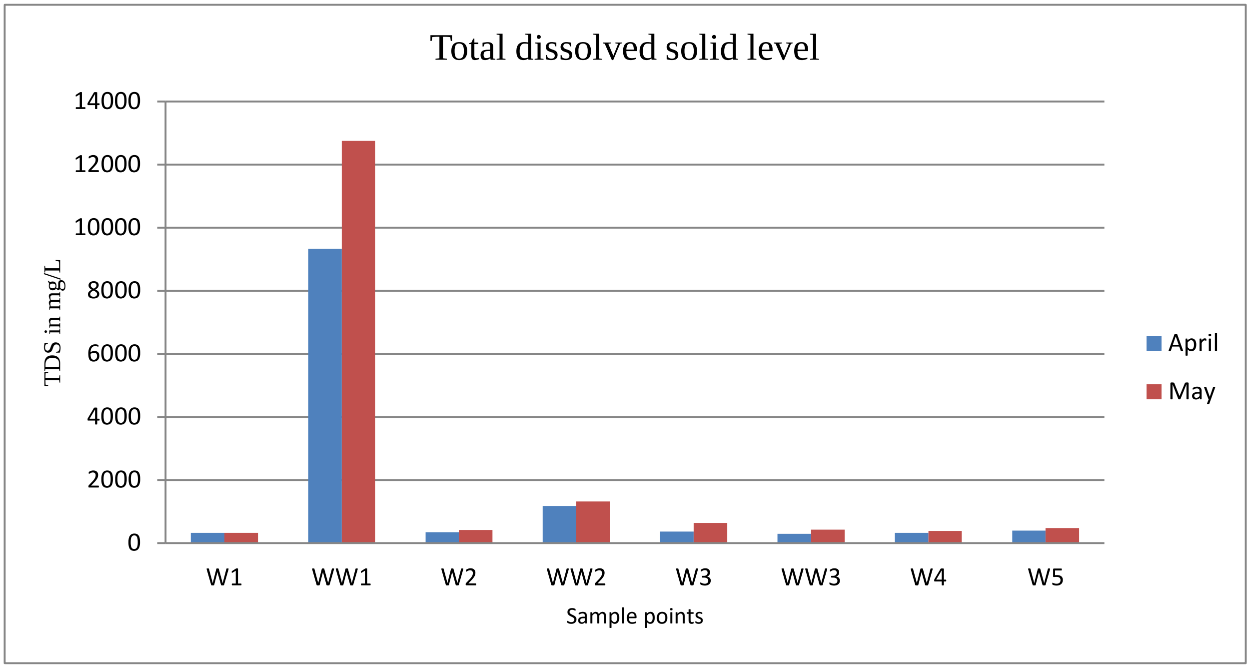

Fig 4.3: TDS value of eight sample points

The results of the TDS values of the samples are shown in figure 4.3. The TDS value of all the sampling sites ranged from 293 mg/L to 9,330 mg/L at April and 322 mg/L to 12,750 mg/L at May. The wastewater samples TDS result ranged from 293 mg/L to 9,330 mg/L and 424 mg/L to 12,750 mg/L. The river water samples TDS result also ranged from 318 mg/L to 389 mg/L and 322 mg/L to 635 mg/L. In similar fashion with EC the highest value of TDS recorded at factory's wastewater WW1 (9,330 mg/L and 12,750 mg/L) and WW2 (1314 mg/L and 1,170 mg/L) during both analysis.

The possible reason for the variations in total dissolved solid values of wastewater is due to the convent collision of the colliding particles (Baraniya, 2018). The collision aggregated process is influenced by pH of effluents. The relative pH value difference might be the reason for the TDS value variation at WW1 at April and May,.

The highest value of TDS indicates that the wastewaters were highly mineralized so that they could pose considerable amount of mineral to the river water and might cause taste change and corrosiveness to river water. Noticeable amount of TDS variation between the first W1 (319 mg/L and 322 mg/L) and last W5 (389 mg/L and 469 mg/L) river water samples might shows the pollution strength of wastewaters.

The maximum allowable limits of the Ethiopian and WHO drinking water standard for TDS is 1000 mg/L (refer Table 3.3). All the samples from river water were below the limit of WHO and Ethiopian drinking water standard. The TDS value of this study was in line with the study conducted by Amare *et al.* (2017) on water quality of Awash River. Specifically this study consistent with the result obtained from Dupti area.

The TDS values of wastewaters samples were very higher specifically at WW1 and WW2. This might be due to the wastes containing dissolved solids like calcium salt, sodium salt and fatty salt from the factory boiler house. After the dilution with the river water The TDS values of both samples reduced.

4.1.4 Turbidity

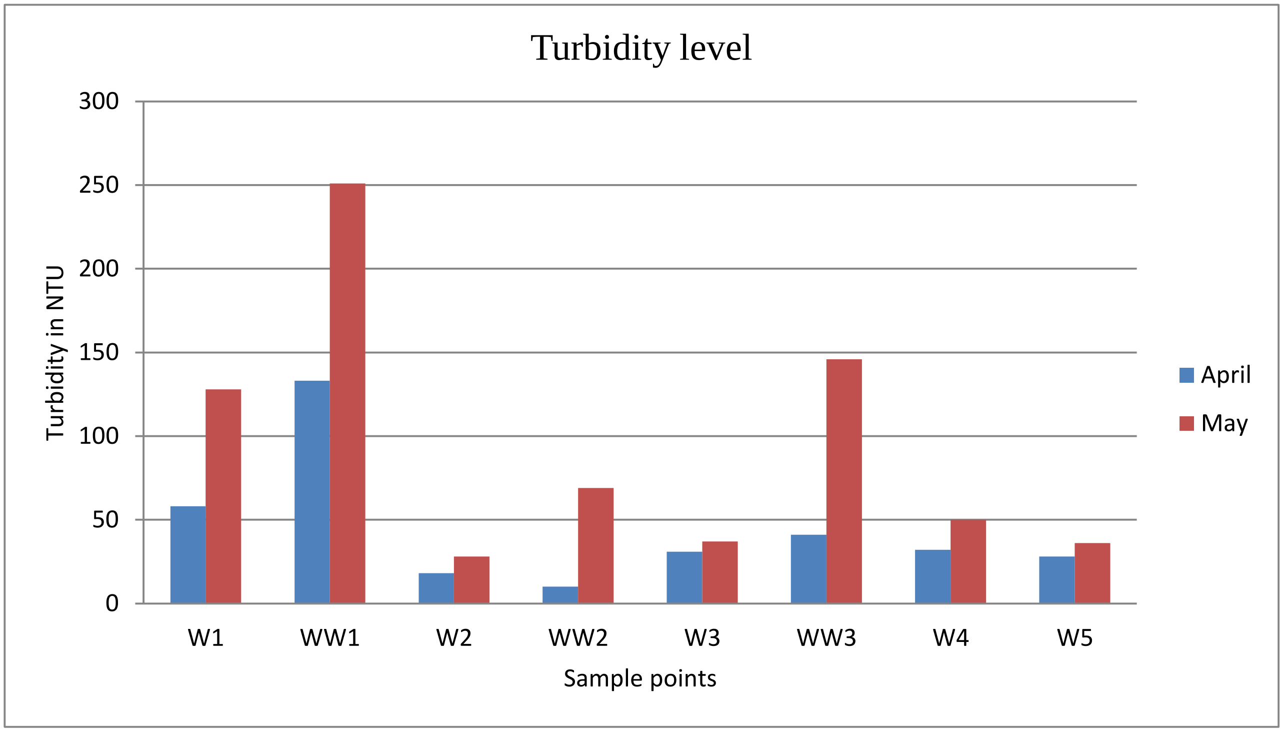

Fig 4.4: Turbidity value of eight sample points

According to the Ethiopian and WHO drinking water standard only the water supply sources with the turbid value of 5 NTU or less is acceptable to consumers (refer Table 3.3) but none of the samples were meet the requirement. As shown in figure 4.4 the result for the average turbid value of river water and wastewaters samples ranged from 23 NTU to 93 NTU and 39.5 NTU to 192 NTU during both analyses respectively. This high turbidity could provide food and shelter for microorganism in the water which causes and leading to waterborne disease outbreaks.

The turbidity of water increases with the increasing number of individual particles. WW1 (133 NTU and 251 NTU) and WW3 (41 NTU and 146 NTU) were the wastewater samples with large number of particles, potentially imposing high sediment load to the river with the huge quantity of solid matter in suspended state. These high turbid values were may be due to the waste from mill house containing organic matters like sucrose, bagacillo, oil and grease. Comparing the turbid value of river samples the first sample W1 result was relatively higher than the other samples. There was an average 61.5 NTU turbid value difference in between W1 and W5 and relatively low turbid value is also recorded at W2, W3 and W4. This is might be because of the presences of vegetation cover to both sides of the river specifically in the study area and the relatively slower rate of flow of the river water. This study river samples turbidity result was consistent with the study conducted by Kidu *et al*, (2015).

4.1.5 Total Hardness

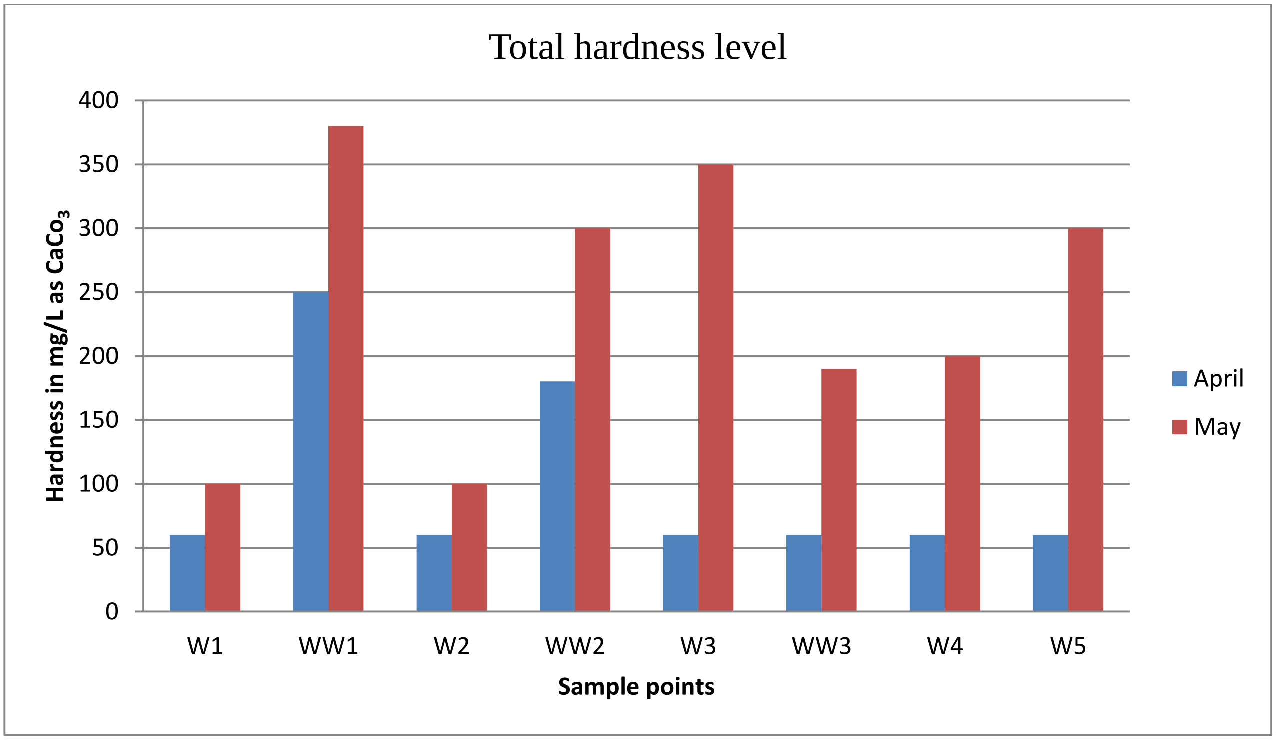

Fig 4.5: Total hardness value of eight sample points

Total hardness of water mainly depends on the presence of dissolved calcium and magnesium salt. Water with the value of hardness range from 0 -75 mg/l $CaCo_3$ classified as soft water, 75-

100 mg/l $CaCo_3$ classified as moderately hard water, 100 - 300 mg/l $CaCo_3$ classified as hard water and above 300 mg/l $CaCo_3$ classified as very hard water.

As shown in figure 4.5 the total hardness value of all samples ranged from soft (60 mg/l $CaCo_3$) to very hard (380 mg/l $CaCo_3$). The average value of wastewater samples WW3 125 mg/l $CaCo_3$, WW2 240 mg/l $CaCo_3$ and WW1 315 mg/l $CaCo_3$ were the hardest samples in sequential manner. These high hardness values were may be due to high concentration of calcium salt from boiler house wastes. While comparing the average hardness value of river water samples before and after dissolved with all the wastewaters at W1 and W5 respectively, W1 was moderately hard 80 mg/l $CaCo_3$ and WW5 was hard 180 mg/l $CaCo_3$. This might indicates the contribution of wastewaters on the hardness of river water.

The total hardness value of the river samples of this study was consistent with the study conducted by Bizualem (2015). The entire analyzed samples apart from WW1 and WW3 meet the Ethiopian drinking water guideline limit of 300 mg/l $CaCo_3$ and all the samples meet the WHO requirement for drinking water of 500 mg/l $CaCo_3$ (refer Table 3.3).

4.1.6 Alkalinity

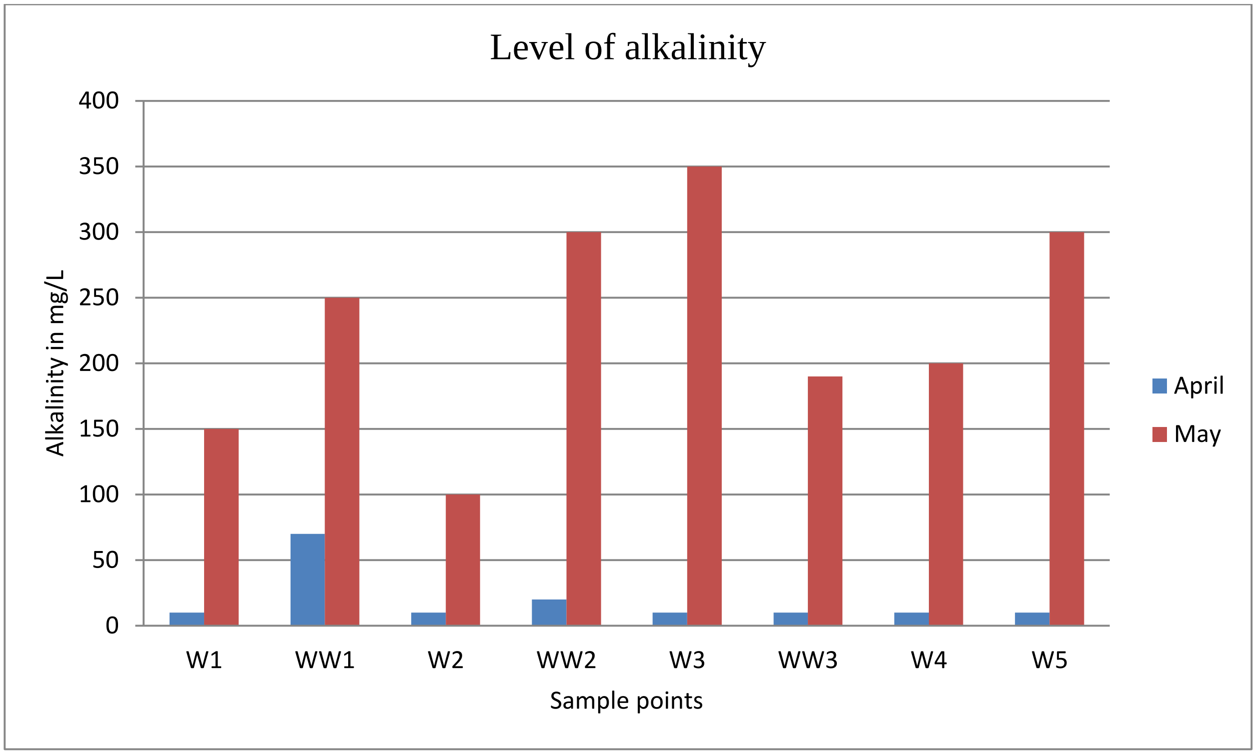

Fig 4.6: Alkalinity value of eight sample points

The result of the alkalinity values of the samples are shown in figure 4.6. The alkalinity value of all samples ranged from 10 mg/L to 70 mg/L and 100 mg/L to 350 mg/l during April and May respectively. Highly alkaline water has high concentration of calcium carbonate ($CaCo_3$) so as hard water. Soft water usually has low alkalinity and little buffering capacity. In similar manner the softest water samples W2 and W1 has the lowest alkalinity value (10 mg/L and 100 mg/L) and (10 mg/L and 150 mg/L) respectively and the hardest water samples WW1, WW2 and W3 has relatively high alkalinity value. The 75 mg/L alkalinity value variation between river water samples W1 and W5 indicates the pollution strength of the wastewater dissolved in between these sample points.

The concentration of carbon dioxide in water has a great influence on its alkalinity (Nagendra, 2012). The alkalinity value of surface water increases as the concentration of carbon dioxide increases. As the result indicates the alkalinity value of May was higher than April. This might be because of the bagasse dissolved to the river water from newly emerged bagasse disposing site at May which was very near to the river. The study conducted by Yohannes (2007) shows that the carbon content of the bagasse from MSF was as weigh as 23.7 % of its weight.

This study alkalinity value was in line with the study conducted by Ezerbem *et al* (2012). The Ethiopian and WHO maximum allowable limit for alkalinity of drinking water is 200 mg/L (refer Table 3.3). All the analyzed samples average value were complying with the limit.

4.1.7 Temperature

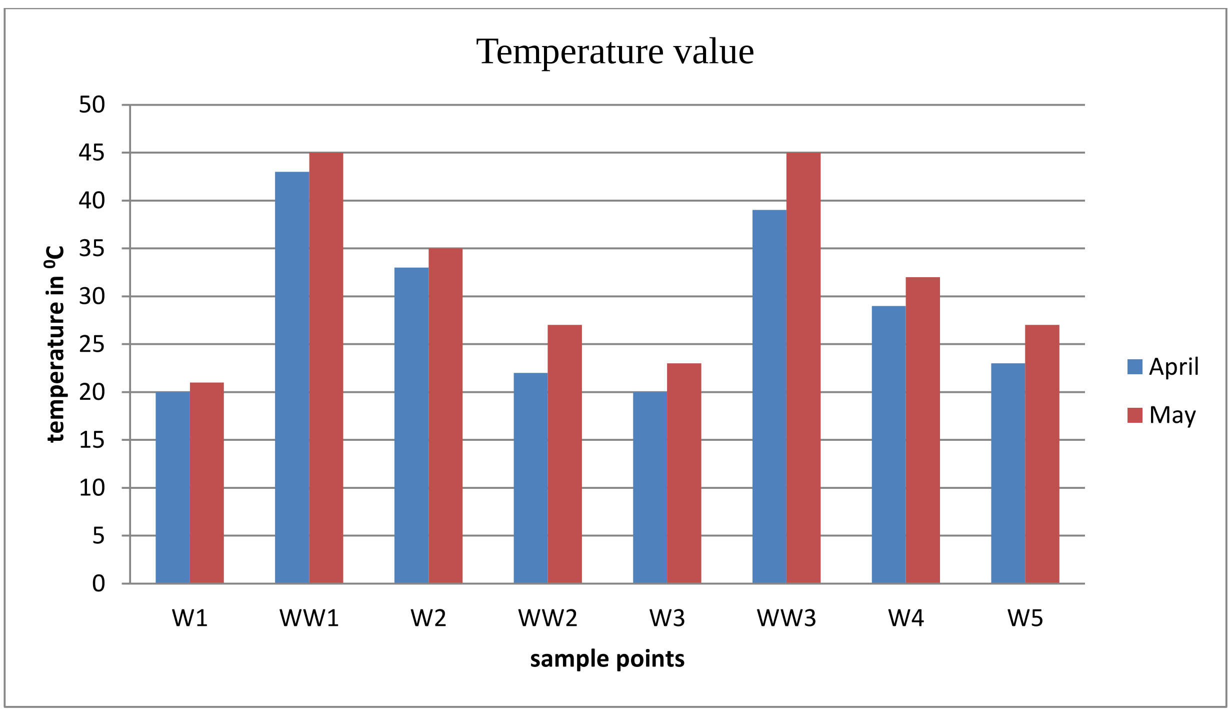

Fig 4.7: Temperature value of eight sample points

The result of the temperature values of sampling points are shown in figure 4.7. The temperature value of all samples ranged from 20 ^{0}C to 43^{0}C at April and 21^{0}C to 45 ^{0}C at May. The temperature range of river water samples (20 ^{0}C to 33 ^{0}C) and (21 ^{0}C to 35 ^{0}C) was relatively lower than the temperature range of wastewaters samples (22^{0}C to 43 ^{0}C) and (27 ^{0}C to 45 ^{0}C) during both analysis.

The first river sample recorded the lowest temperature during both analysis; this is may be because of the samples were collected at the morning during both periods and didn't contaminated with any of the factory wastewaters. As the result indicates the river samples temperature varies after dissolved with the wastewaters. The temperature value at W1 (20 ^{0}C and 21 ^{0}C) turns out to be (33 ^{0}C and 34^{0}C) at W2 after dissolved with WW1 (43 ^{0}C and 45 ^{0}C) and the temperature value at W3 (20 ^{0}C and 23 ^{0}C) became (29 ^{0}C and 32 ^{0}C) at W4 after dissolved with WW3 (39 and 45 ^{0}C). The temperature value of the last river sample is also higher than the first sample; this implies the impact of wastewaters on the temperature variation of river water and the wastewaters also loses their temperature when diluted with relatively cold river water.

The temperature value of this study was in line with the study conducted by Aregawi *et al* (2015). The Ethiopian EPA discharging temperature limit value of sugar manufacturing waste water is 40 ^{0}C (refer Table 2.1) but WW1 and WW2 were beyond this limit.

4.1.8 Phosphate

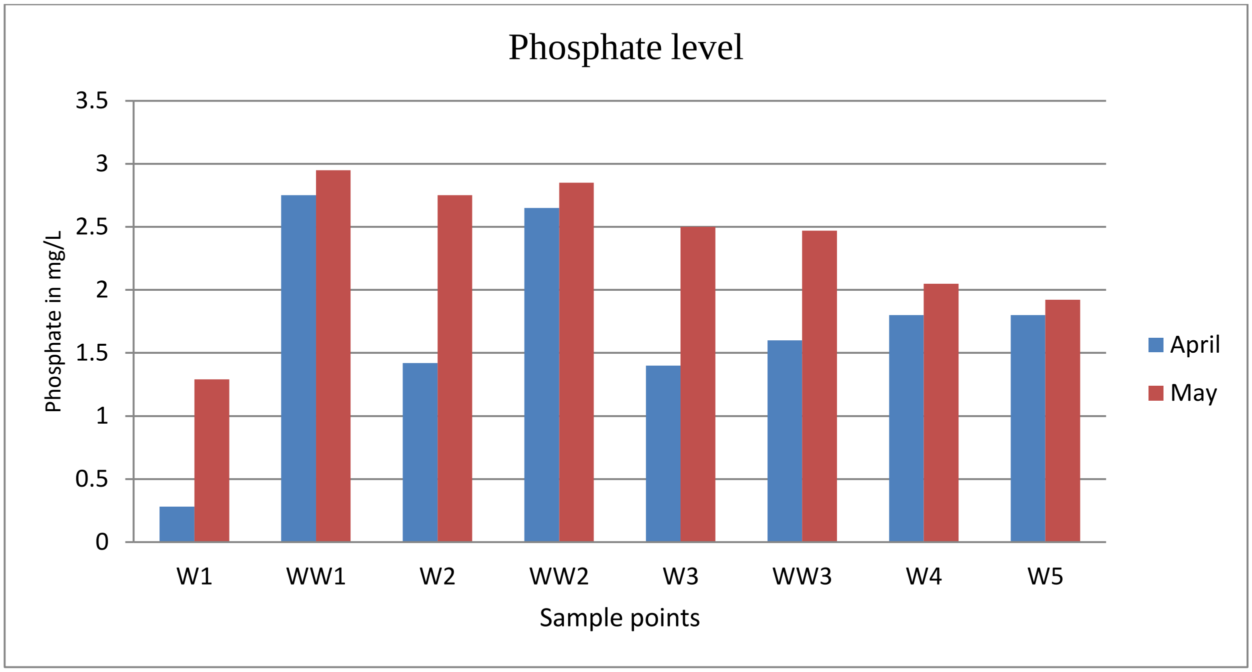

Fig 4.8: phosphate value of eight sample points

The result of the phosphate values of the samples are shown in figure 4.8. The phosphate value of all samples ranged from 0.28 mg/L to 2.75 mg/L and 1.29 mg/L to 2.95 mg/L during the first and second analysis respectively. The wastewaters samples phosphate concentration ranged from 1.6 mg/L to 2.75 mg/L and 2.47 mg/L to 2.95 mg/L and the river water samples ranged from 0.28 mg/L to 1.8 mg/L and 1.29 mg/L to 2.75 mg/L during April and May respectively.

From the eight samples the maximum reading revealed at WW1 (2.75 mg/L and 2.95 mg/L). This might be due to the waste from added H_3PO_4 to improve clarification during sugar production process. WW2 also recorded the second highest concentration (2.65 mg/l and 2.85 mg/L), this also may be due to sewage from the factory. The phosphate value of river samples W2 and W3 improved to (1.42 mg/L and 2.75 mg/l) and (1.4 mg/L and 2.5 mg/L) respectively after dissolved with WW1 and WW2 respectively while it was (0.28 mg/L and 1.29 mg/L) at W1. This indicates the pollution load of factory's wastewaters WW1 and WW2.

WHO permissible limit of phosphate concentration in drinking water is 0.1 mg/L (refer Table 3.3). But none of the samples average values were lies under allowable limit of WHO for phosphate concentration. The average phosphate concentration of this study was consistent with the study conducted by Amare *et al* (2017) on water quality of Awash River. Specifically this study in line with the result obtained from Dupti area.

4.1.9 Nitrate

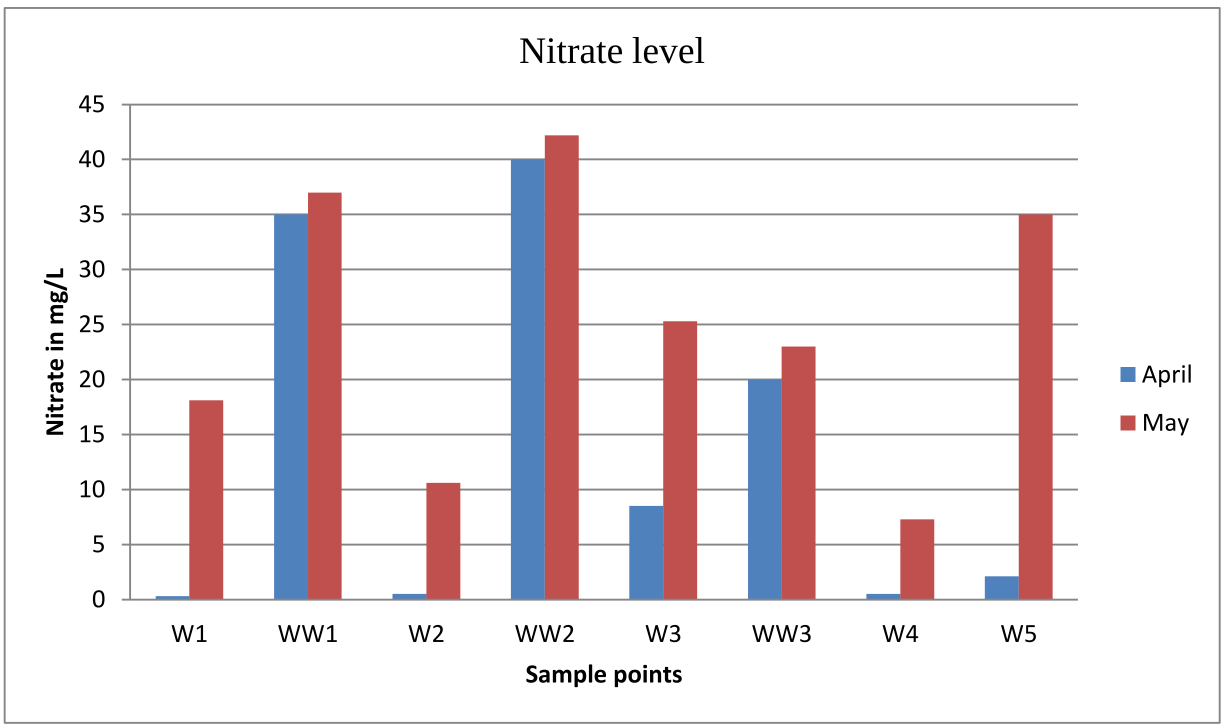

Fig 4.9: Nitrate value of eight sample points

The result of the nitrate values of the samples are shown in figure 4.9. The nitrate value of all samples ranged from 0.3 mg/L to 40 mg/L at April and 7.3 mg/L to 42.2 mg/L at May. Industrial waste and sewage are the chief sources of nitrate that can degrade the quality of surface water

(Omed, 2006). Similarly the highest nitrate concentration was registered at WW1 (35 mg/L and 37 mg/L) during both analysis and at WW2 (40 mg/L and 42.2 mg/L). Comparing nitrate concentration of river water samples, the average concentration of the first sample 9.2 mg/L is doubled at the last sample 18.55 mg/L. This concentration increment indicates the amount of dissolved contaminants.

The river water nitrate concentration of this study was consistent with the study conducted by Amare *et al* (2017) on water quality of Awash River. The Ethiopian and WHO guide level limit of nitrate concentration in drinking water is 50 mg/l (refer Table 3.3), thus the nitrate concentration of all sampling sites were within the acceptable limit.

4.1.10 Chloride

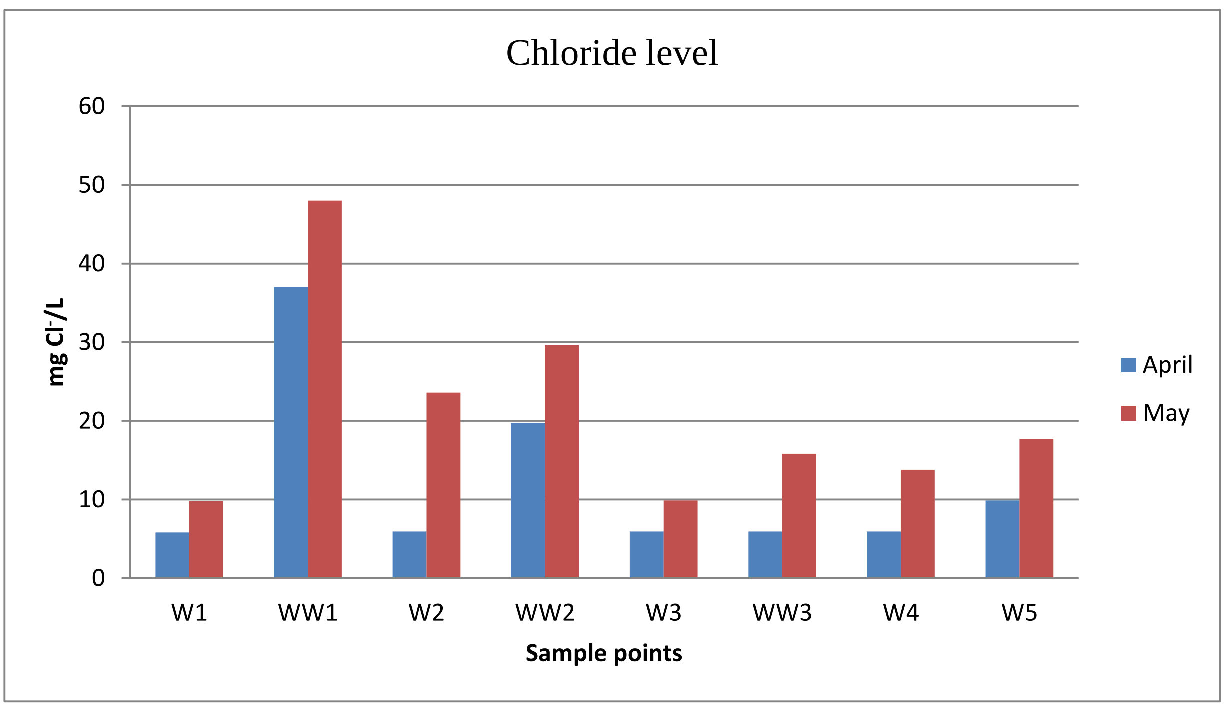

Fig 4.10: chloride value of eight sample points

Figure 4.10 shows the result obtained from the water quality laboratory analysis on the chloride concentration of both wastewaters and river water samples. The chloride value of all samples ranged from 5.8 mg/L to 37 mg/L during April and 9.8 mg/L to 48 mg/L during May. Chloride is the anion of chlorine often soluble in water and almost all surface water contains this ions. The dilution salt of hydrochloric acid as a table salt (NaCl) is the main source of chloride. Too much amount of chloride in surface waters might causes pollution.

The highest concentration of (37 and 48) milligram of chloride per liter was recorded at WW1. This might be because of the neutralization (resulting NaCl) of soda and acid waste. The lowest concentration of (5.8 mg/L and 9.8 mg/L) of chloride recorded at W1 and elevated to (6 mg/L and 24 mg/L) at W2 after dissolved with WW1. The final river sample W5 (9.86 mg/L and 17.7 mg/L) chloride concentration was higher than the first sample W1 (5.8 mg/L and 9.8 mg/L). This might show the impact of the wastewaters and loses their chloride concentration through dilution. The maximum Ethiopian and WHO allowable limit for chloride ion is 250 mg/L (refer Table 3.3). Thus all the sampling sites chloride concentration was within the acceptable limit.

4.1.11 Sulfate (SO_4)

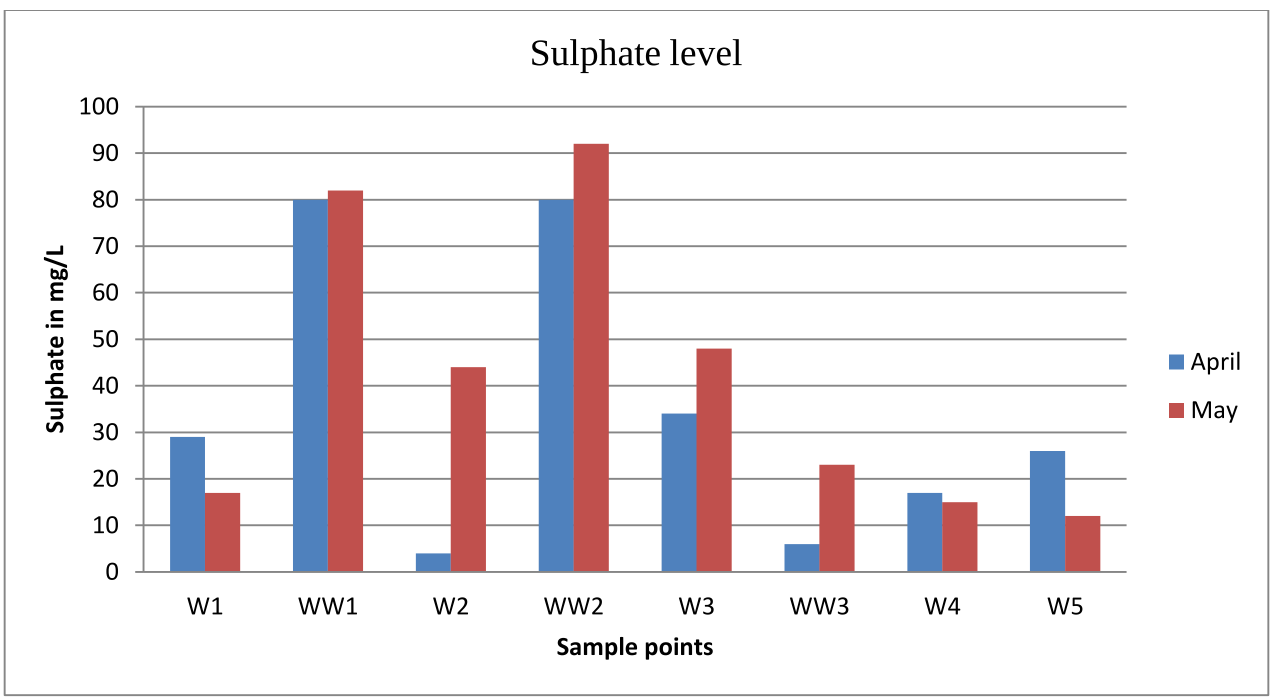

Fig 4.11: sulfate value of eight sample points

The result of the sulfate values of the samples are shown in figure 4.11. The average sulfate value ranged from 16 mg/L to 86 mg/L. Sulfur dioxide is used in sugar industries for clarification in the production process. Sulfur dioxide can be oxidized in water to form sulfate. Accordingly the sulfate concentration of factory's wastewaters WW1 (80 mg/L and 82 mg/L) during both analysis and WW2 (80 mg/L and 92 mg/L) was relatively higher than other samples. The sulfate concentration of other samples ranged from 4 mg/L to 34 mg/L during April and 12 mg/L to 44 mg/l) during May. The elevation of sulfate concentration at W3 (34 mg/L and 48 mg/L) after dissolving with WW1 and WW2 respectively whereas (29 mg/L and 17 mg/L) at W1 might indicates the contaminant contribution of both wastewaters to the river.

The Ethiopian and WHO guideline maximum limit for sulfate concentration of drinking water is 250 mg/l (refer Table 3.3). All the samples were below this limit.

4.1.12 COD

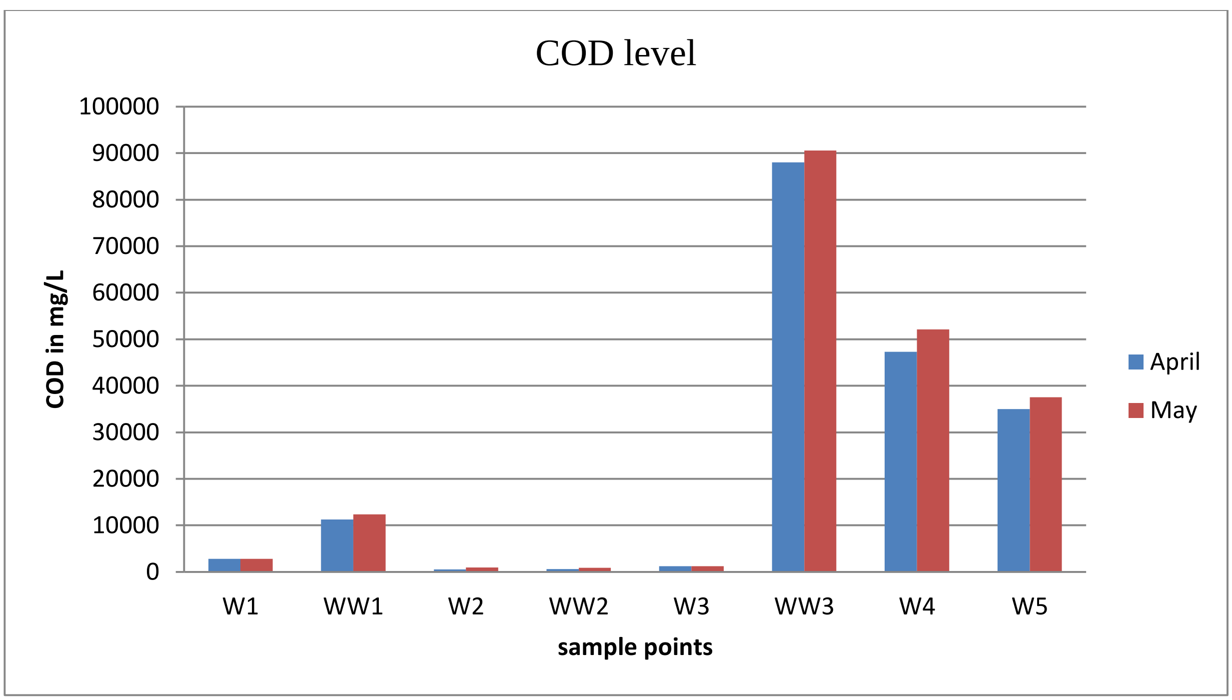

Fig 4.12: COD value of eight sample points

The results of the COD values of samples are shown in figure 4.12. The COD value of all samples ranged from 540 mg/L to 88,000 mg/L on the first analysis and 870 mg/L to 90,580 mg/L on the second analysis. The average COD value of river water samples ranged from 760 mg/L to 48,730 mg/L and wastewaters samples ranged from 745 mg/L to 89,290 mg/L. The third waste water sample WW1 recorded the highest COD value during both analysis. This might be due organic and inorganic waste and the dissolved smelly ethanol waste after preserved in pond for days. Comparing the COD concentration of river samples W4 and W5 with the first sample W1, they were 16.7 times and 12.5 times higher respectively. This indicates that huge amount of chemical oxygen demanding substances in the effluent were released from the factory into the river. Due to the dilution of river water the highest COD value of factory's wastewater WW3 tends to reduce by 40 % at the last river sample W5.

High COD level of Awash River water implies toxic condition and the presence of biologically resistant organic substances. The oxygen level in water reduced by the amount of oxidize able organic materials can lead to anaerobic conditions, which is deleterious to higher aquatic forms. The WHO limit for COD concentration of drinking water is 10 mg/L (refer Table 3.3) but all the samples were above this limit.

4.1.13 BOD_5

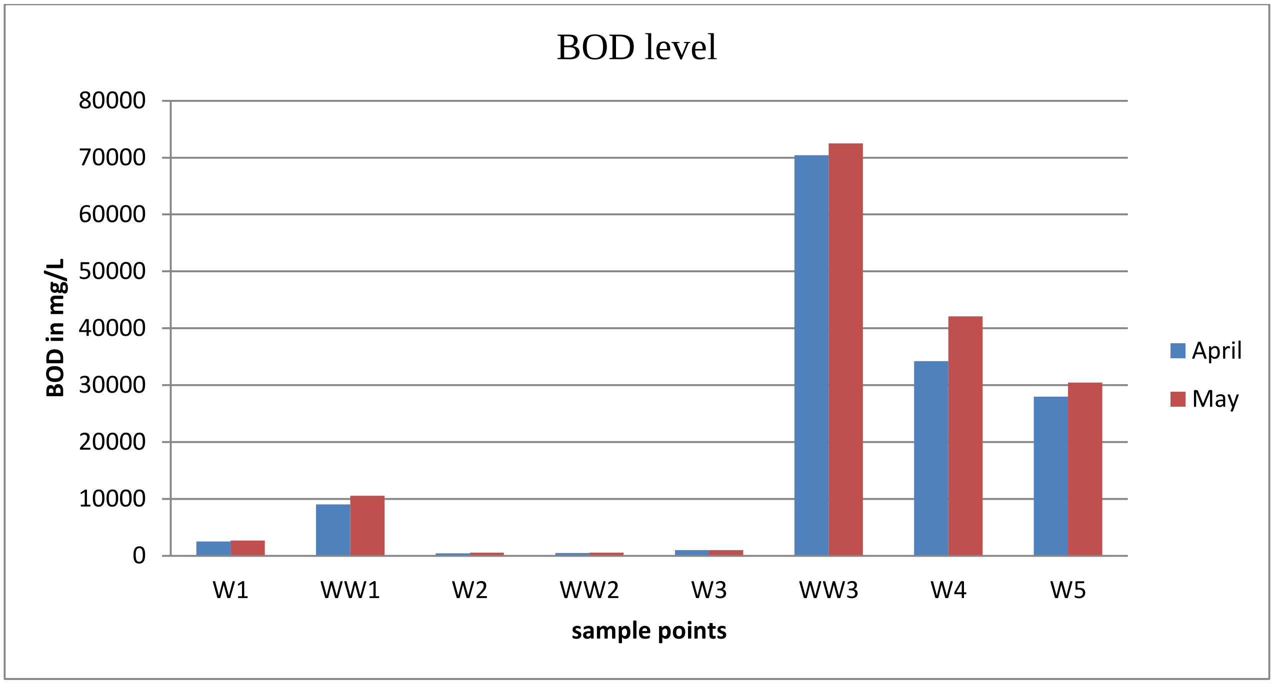

Fig 4.13: BOD_5 value of eight sample points

Because of many organisms decompose chemically that cannot be oxidized biologically; the value of COD is always higher than BOD_5. Likewise as shown in figure 4.13 the BOD value of all samples ranged from 432 mg/L to 70,400 mg/L on the first analysis and 520 mg/L to 72,513 mg/L on the second analysis which was lower than COD concentration. The average BOD_5 value of river water samples ranged from 467 mg/L to 38,150 mg/L and wastewaters samples ranged from 511 mg/L to 71,456 mg/L.

Comparing the BOD_5 value of river water samples before and after dissolving with the wastewaters there were a massive variation. The third wastewater channel was the one imposing huge amount of biological oxygen demanding substances to the river. The recipient river samples W4 and W5 pollution average concentration elevated from 982 mg/L to 38,150 mg/L and 29,225.5 mg/L respectively. This high BOD_5 levels imply the pollution strength of the wastewaters which is deadly for fishes and other aquatic organisms by decreasing the level of dissolved oxygen available in the water. The WHO limit for BOD_5 concentration of drinking water is 5 mg/L (refer Table 3.3) but all the samples were above this limit.

4.1.14 Oil and grease

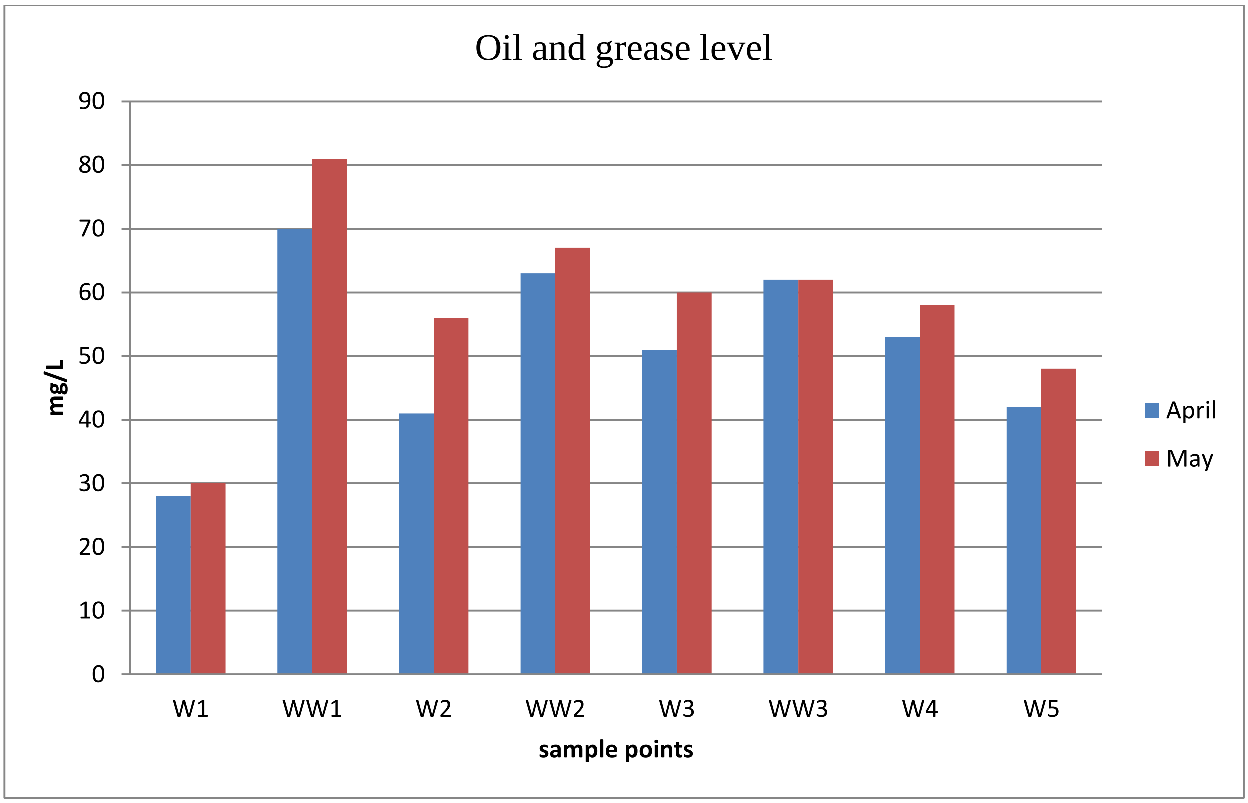

Fig 4.14: Oil and grease value of eight sample points

The results of the oil and grease values of samples are shown in figure 4.14. The oil and grease value all samples ranged from 28 mg/L to 70 mg/L during first analysis and 30 mg/L to 81 mg/L during second analysis.

The highest oil and grease concentration was recorded at WW1. This high concentration was might be because of wastewater from mill house containing organic matter including oil and grease. The oil and grease concentration of river sample W1 which was (28 mg/L and 30 mg/L) elevated to (41 mg/L and 56 mg/L) after dissolved with WW1. Comparing the first and final river sample, the final sample average concentration is 22 % higher than the first sample. This implies the pollution load of wastewater dissolved between these sampling points.

The entire factory's wastewater samples were above Ethiopian EPA discharging limit of sugar manufacturing oil and grease to water bodies which is 15 mg/L (refer Table 2.1)

Chapter 5: Conclusion and Recommendation

5.1 Conclusion

This study was conducted to assess the impacts of Metehara sugar factory on the water quality of Awash River, where the special consideration was given to wastewater.

The result of the study indicated that the release of wastewaters from sugar factory directly into Awash River without treatment. The discharged industrial wastewaters effluents were polluted in terms of electric conductivity, phosphate, TDS, turbidity, pH, total hardness, alkalinity, COD, BOD and oil and grease. These parameters extent were all above the maximum permissible limit of Ethiopian and WHO drinking water quality standards.

The study also reflected Awash River water in the study area was polluted. The pollution was indicated by electric conductivity, turbidity, temperature, phosphate, COD, BOD and oil and grease. These parameters measurement were all above the maximum permissible limit of Ethiopian and WHO drinking water quality standards. The value variation of river samples before and after dissolved with wastewaters, that are the relative highest values at W2, W3, W4 and W5 for almost all parameters than at W1 was clearly indicates the pollution load the wastewaters

From the all parameters, wastewater samples taken from the sugar factory that came out after processing WW1 had Specifically the highest record was aligned to pH, EC, TDS, temperature, turbidity, total hardness, phosphate, chloride and oil and grease. The value of sulfate and nitrate was higher at WW2, COD and BOD was higher at WW3 and only alkalinity showed a higher record at river sample W3.

Overall during both analyses wastewaters samples recorded the highest value almost in all parameters. This indicates the pollutant concentration of industrial wastewaters and the pollution load the industry bring to the river water while directly discharging in routine manner. For the developing countries like Ethiopia the development of sugar industries is an encouraging phenomenon from economic point of view. However such development prospect could have an environmental impact like this unless the wastes are managed properly.

Generally the physicochemical results of this study showed that some of the parameters measured in the river were above the discharging standards set by EPA and WHO and Ethiopian drinking water quality guideline. Therefore the water of Awash River was treated by the industry effluents and could induce health risk when used for drinking.

5.2 Recommendations

The present study presented the following recommendations which can go along with the specific objectives and results investigated in this study.

- The river is still contaminated with chemicals and toxic substances. The MSF should monitor all its effluents and take all necessary actions to transform wastewaters to environmental friendly form before discharging into Awash River as soon as possible.
- The industry should recycle and re-use wastes, thus minimize the quantity of generated waste and consequently its impact on Awash River.
- The factory should apply water pinch technology for water and wastewater minimization.
- Even though the river is contaminated with chemicals and toxic substances, it was serving as a drinking water supply for several communities and towns of middle and lower valley. The communities and towns should be aware of the potential danger of using such polluted water.
- The health risk of using Awash River water for drinking and other purposes should be noted and water quality monitoring and further treatments should be carried out in middle and lower valley.
- The industry should provide alternative potable water source for surrounding local communities.
- Environmental standards, rules and regulation should be respected and followed with strict enforcement measures.

- The study was conducted within a period of two months. It may lack comprehensiveness. Further studies should be conducted in different seasons with considering other water quality parameters.

Appendix I: physicochemical analysis result of water samples during April

No	parameters	W1	WW1	W2	WW2	W3	WW3	W4	W5
	Sample day (Ec.)	06/8/2011	06/8/2011	06/8/2011	06/8/2011	06/8/2011	06/8/2011	06/8/2011	06/8/2011
	Time (morning)	9 am	9:15 am	9:20 am	9:50 am	9:55 am	10:45 am	10:50 am	11:55 am
1	Turbidity (NTU)	58	133	18	10	31	41	32	28
2	Ec (MS)	0.504	1388	0.56	1.95	0.59	0.48	0.53	0.64
3	pH	8.09	5.0	7.6	7.5	7.45	9.01	7.9	7.09
4	Temperature (^{0}C)	20	43	33	22	20	39	29	23
5	TDS (mg/L)	319	9,330	336	1,170	357	293	318	389

6	Total hardness (mg/L as $CaCo_3$)	60	250	60	180	60	60	60	60
7	Alkalinity (mg/L as $CaCo_3$)	10	70	10	20	10	10	10	10
8	Chloride (mg/L)	5.8	37	5.92	19.72	5.92	5.92	5.92	9.86
9	Phosphate (mg/L)	0.28	2.75	1.42	2.65	1.4	1.6	1.8	1.8
10	Nitrate (mg/L)	0.3	35	0.5	40	8.5	20	0.5	2.1
11	Sulfate (mg/L)	29	80	4	80	34	6	17	26
12	COD (g/L)	2.54	11.3	0.54	0.62	1.21	88	47.33	35
13	BOD_5 (g/L)	2.5	9.04	0.432	0.496	0.968	70.4 l	34.2	28
14	Oil and grease (mg/L)	28	70	41	63	51	62	53	42

Appendix II: physicochemical analysis result of water samples during May

No.	parameters	W1	WW1	W2	WW2	W3	WW3	W4	W5
	Sample day (Ec.)	21/9/2011	21/9/2011	21/9/2011	21/9/2011	21/9/2011	21/9/2011	21/9/2011	21/9/2011
	Time (morning)	9 am	9:15 am	9:20 am	9:50 am	9:55 am	10:45 am	10:50 am	11:55 am
1	Turbidity (NTU)	128	251	28	69	37	146	50	36
2	Ec (MS)	0.532	2130	0.677	2.19	1.06	0.708	0.638	0.781
3	pH	8.2	5.5	7.8	7.62	7.7	9.19	8.01	7.5
4	Temperature (^{0}C)	21	45	35	27	23	45	32	27
5	TDS (mg/L)	322	12,750	408	1,314	635	424	383	469

6	Total hardness (mg/L as $CaCo_3$)	100	380	100	300	350	190	200	300
7	Alkalinity (mg/L as $CaCo_3$)	150	250	100	300	350	190	200	300
8	Chloride (mg/L)	9.8	48	23.6	29.61	9.87	15.8	13.8	17.7
9	Phosphate (mg/L)	1.29	2.95	2.75	2.85	2.5	2.47	2.05	1.922
10	Nitrate (mg/L)	18.1	37	10.6	42.2	25.3	23	7.3	35
11	Sulfate (mg/L)	17	82	44	92	48	23	15	12
12	COD (g/L)	3	12.35	0.98	0.87	1.24	90.58	52.13	37.51
13	BOD_5 (g/L)	2.65	10.53	0.52	0.526	0.995	72.51	42.1	30.45
14	Oil and grease (mg/L)	30	81	56	67	60	63	58	48

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