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Impacts of uncontrolled anthropogenic activities on the quality of Shankila River water in Addis Ababa, Ethiopia

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ABSTRACT

Pollution has become a serious threat to rivers in many cities. This study was conducted on a Shakila river, Addis Ababa. The aim of the study was to assess the level of pollution and its pollutant sources. Five sampling sites were chosen spatially along the river watercourse. A laboratory water quality test was conducted. A correlation matrix was employed using fifteen water quality parameters. Sample that was taken from the upstream was used for reference. Among studied parameters: turbidity (0.00-130 NTU), total dissolved solids (190–720 mg/L), total suspended solids (9–234 mg/L), chemical oxygen demands (40–140 mg/L), nitrite (0.012–1.12 mg/L), phosphate (0.7–35.60 mg/L), biological oxygen demand (7.6–188 mg/L), faecal coliforms (24–680 counts/100 mL) and total coliforms (1413–2134 counts/100 mL) were above the prescribed limit of WHO drinking standards. However, lower pollution status reflected in the control sample. Urbanization and industrialization processes were identified as major pollution drivers.

Key words: BOD, COD, coliforms, pollution, toxicity, anthropogenic

1. Introduction

Over 70 percent of the earth's surface material consists of water and apart from the air all living things breaths; water is the most important elements to all living things. Early civilization flourished along the Nile, Tigris and Euphrates in ancient Mesopotamian, Indus in India, Huang He in china, due to their location near to water sources (Ayoade, 1998). Water covers about 70 percent of the earth's surface, only 2.53 percent is fresh water while the remaining is salt water; in addition to this, of the 3 percent of fresh water, only 0.3 percent is found in rivers and; lake, the remaining frozen (UNESCO, 2003; World Water Council, 2005).

As declared by studies finding pollution is then introduced by the human being into the environment of substance or energy liable to cause hazards to human health, harm to living resource and ecological system, damage to structures or amenity, or interference with legitimate uses of the environment (Ibrahim, 2006). According to UNESCO report about two million tons of water per day is discharged into the receiving waters, including industrial wastes and chemicals, human wastes and agricultural wastes, such as fertilizers, pesticides and pesticide residues. Urban areas provide the economic resource to install water supply and sanitation systems but they also concentrate wastes (UNESCO, 2003). “A river may be said to be polluted when the water in it is altered in composition or condition, directly or indirectly as a result of the activities of human, so that it is, less suitable for all or any of the purposes for which it would be suitable in its natural state” (Dix, 1995).

As indicated in literature “River pollution from city-based industries and untreated sewage can lead to series human health problems in settlement downstream” Hardoy et al., 2013). Some rivers loss their quality after they have passed through cities due to a number of human and industrial activities that contribute to their pollution. Direct discharge of foreign materials from different sources, the leakages of industrial wastes from poorly designed septic tanks, discharge of effluents without detoxifying or treated the waste solid/ liquid from domestic and municipal sources, organic matter of plant and animal origin, land and surface washing and sewage effluent are among few sources pollution that changes the water quality of Shankila River. All these without care for impact on water resource eventually made much of the water across the city unfit for aesthetic value, recreational purpose, for agriculture and domestic drinking water. Discharge of domestic and municipal sewerage is not limited to Shankila River but also for other surface water bodies. There were weak policy and enforcement that couldn't successfully protect pollution of rivers. In order to strengthen the enforcement of the potential Environmental regulations and penalties for violation, understanding of the pollution trend with respect to the potential source is very important. In This study, the causes and impacts pollution of Shankila River is assessed. The physicochemical (pH, TDS, TSS, compounds of ionic form of nitrogen species, sulphate species) and Coliform are assessed to investigate the pollution sources and its impacts.

2. Materials and Methods

2.1 Description of study area

The Shankila River originates at the Gullele Mountain in the northern part of Addis Ababa and runs about 11.5 km over its border to join Little or Tinishu Akaki River. Shankila River was found near to the marketing centre of the city “Merkato” and Ehel Berenda” and the river are flows across one of highly populated sub-city of “Addis Ketema”. Due to this reason, there is an intensive activity of movement around the river course. The river pollution in this region has its origin such as discharge of solid and untreated domestic sewage wastes from residents, urban agriculture and small-scale industries. The sampling points and study area of the river is illustrated on Figure 1.

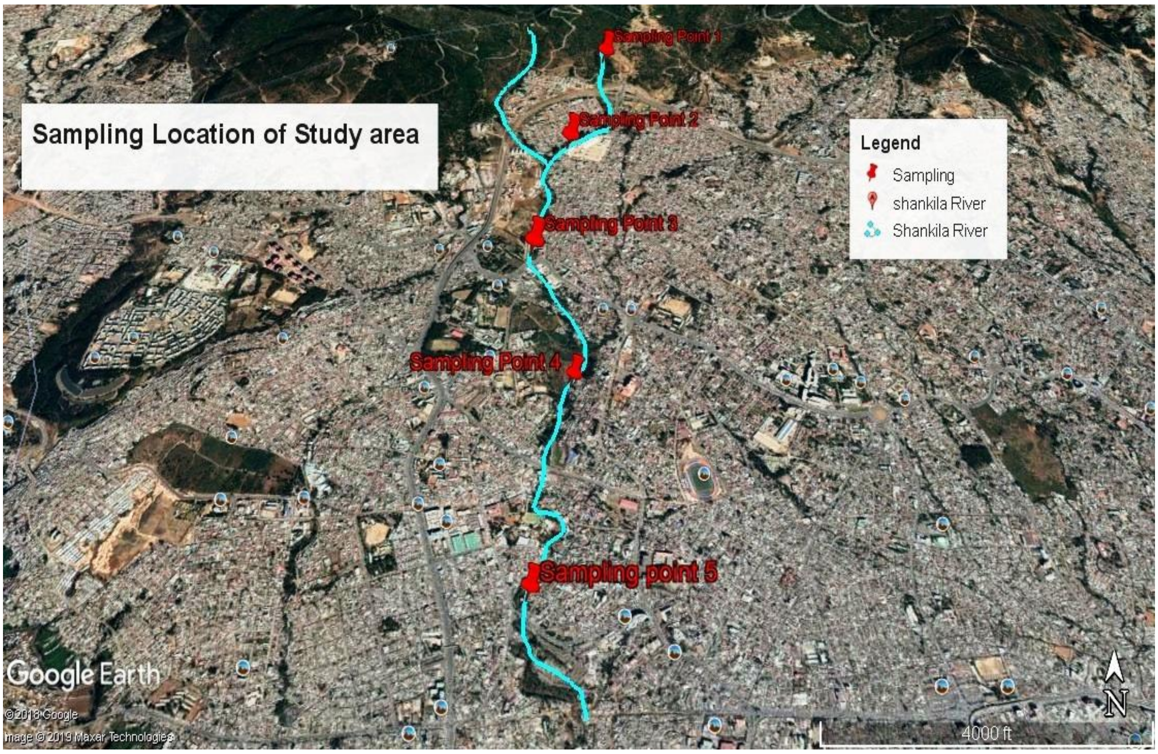


Figure 1: Location of sampling sites of Shankila River, in Addis Ababa, Ethiopia.

2.2 Methods of data collection

Primary data were obtained from field survey, observations and laboratory analysis. Water samples have been collected from different locations of the Shankila River and analysed in Addis Ababa Environmental Protection authority and Ethiopian Leather Industry Development Institute Laboratory. In addition, photographs were taken during field observation. Finally, Questionnaires were prepared and distributed to key informants of communities settled along the river corridors and expertise.

2.3 Sampling Design

2.3.1Sampling sites

Purposive sampling method was used to select sites along the river. The upper river catchment has pristine (relatively free from any human activity) clean environment; the first sampling point (S_1) was selected for background water quality data. Whereas, the other samples were taken from downstream of the river at points (S_2, S_3, S_4 and S_5) that have various residential, industrial, commercial and related human activities. The downstream river course has clear and visible land use covers so that the sampling procedures were considered accordingly. Sample 1 was taken from Gulele (pristine water quality without human intervention). The second sample was taken near to the Marble factory site, the third sample was collected from Sefereselam (which has a huge bridge & near public shower bath), fourth sample was collected near downstream of Emmanuel condominium; whereas the last water sample was collected near to the coca cola factory. All samples were taken from purposely selected sampling sites to identify source and magnitude of pollutants.

2.3.2 Analytical Procedures

Various analytical methods and instruments were used to characterize the physicochemical status of water samples collected from various points of the river course. The detail analytical procedures and methods are described below.

Turbidity

A 2100Q portable turbidity meter instrument that was made in USA was used to measure the turbidity. First the instrument was calibrated by distilled water (Zero NTU) and a standard turbidity suspension of 20, 100 and 800 NTU by choosing one of them. The thoroughly shaken sample is taken in the portable instrument and the value is recorded.

pH

A PH/MV/Conductivity/TDS/Salt/Temp Model 99720 portable pH meter instrument that was made in Taiwan was used to measure the pH. First the instrument was calibrated with two standard Buffer solutions of pH 4.0 and pH 9.0. The electrode was thoroughly rinse with distilled water and carefully wiped with a tissue paper. The electrode was dipped in to the solution swirled and waited up to one minute for steady reading. The reading was appeared after the indicated value remains constant for about a minute.

Electrical Conductivity (EC)

The cell was calibrated with standard of 0.1NKCl solution of conductivity 1413 µS/cm at 30^{o}c. and it was rinsed thoroughly with distilled water and carefully wiped with tissue paper. Then, it was dipped in to the sample solution, swirled and waited up to one minute for steady reading. The reading was taken after the reading remained constant for about a minute.

Biological Oxygen Demand (BOD)

Standard Methods for the Examination of Water and Wastewater adopted by APHA was used for this study (APHA, 2002). Distilled water was placed in a 5L flask and aerated by bubbling compressed air through water. Then, about 1 ml of phosphate buffer, 1ml of magnesium sulphate, 1ml of calcium chloride and 1ml ferric chloride solution were added for every litter. Every Sample BOD test was operated by BOD bottles. The two bottles used for blanks and two for samples. Diluted water was filled in to two bottles and necessary amount of well mixed sample was added in two bottles using pipette. The other two bottles were filled with distilled water, then the bottle was stoppered and one set of bottles (one in blank and the other with sample) were carried out with DO procedure. The other set was placed in the incubator for 5 days at 20^{o}c. Following this, the end D.O. content was determining from the incubated bottle at the end of 5 days (120h). The BOD was calculated by Equation 1.

$$BOD5, mg/l = [(D1 - D5) - (B1 - B5)]\, X \frac{f}{P} \quad \ldots 1$$

Where; D_1- 1st day D.O of diluted sample, D_5 – 5th day D.O of dilute sample, P – Decimal volumetric fraction of sample used, B_1 – 1st day D.O of control & B_5 – 5th day D.O of control

Chemical Oxygen Demand (COD)

The COD was analysed in reactor tubes. The sample was diluted about a volume of 2.5ml. Then, 1.5ml $K_2Cr_2O_7$ and 3.5 ml H_2SO_4 reagent were added consequently. A total volume of 7.5ml solution containing tube was covered and closes firmly, arrange in a steel rake and heat the oven for 2hrs at 150^{o}c. Then, the solution was cooled and titration performed. Finally, COD calculated based on formula shown in Equation 2.

$$mg/l\,COD = (blank\ value - sample\ value) X N X F X 1000/sample\ taken, mL \quad \ldots 2$$

To calculate F,

$$F = 10000/Titrant\ volume\ of\ blank \quad \ldots 3$$

Total Suspended Solids: (APHA) dried at 103 - 105°C

The sample was put in the disk with a wrinkled side up into filtration apparatus.

Following this, a vacuum and wash disk with three consecutive 20ml of distilled water was used. We carried a suction to take away traces of water, turnoff vacuum and eliminate washings. Then, the filtration apparatus was taken away, transfer to an inert aluminium weighing dish and dried in an oven at 103°C to 105ºC for 1h. Then it was cooled in desiccators to equilibrium temperature and weigh. The sample was stored in desiccators until it was cooled. Then, we assembled the filtering apparatus and filtered the sample. Procedurally, filter was wetted with a small volume of distilled water. Then, small amount of sample was measured by pipette onto the seated glass fibre filter. It was rinsed with 10 ml of distilled water for three times, following by allowing total drainage between washings and continues suction for 3 minutes after filtration. Samples with high dissolved solids may need extra washings. Then, we have removed the filter from filtration apparatus and transferred to an aluminium weighing dish as a support. The sample on the dish was dried for at least 1h at 103 to 105ºC in an oven, cooled in desiccators to balance temperature and weigh. The Total Suspended Solid was calculated by Equation 3.

$$\frac{mg}{L}TSS = (W1 - W2)(10000)/Sample\ Volume.mL \ldots\ldots\ldots\ldots \text{Equation 3.}$$

Where: W1 = weight of dried residue + filter; W2 = weight of filter

Total Dissolved Solids (TDS)

A PH/MV/Conductivity/TDS/Salt/Temp Model 99720 portable TDS meter instrument that was made in Taiwan was used to measure the TDS. First the instrument was calibrated with standard solutions of 940 mg/L, carefully rinsed with distilled water and dried. The electrode was dipped in to the solution swirled and waited up to one minute for steady reading. The reading was appeared after the indicated value remain constant for about a minute.

Total Hardness (TH)

The analysis was done by complexometric titration. During the titration Calcium and Magnesium ions reacted with EDTA and form soluble complex. Eriochrom Black T was used as complexometric indicator. A small amount of complexometerically neutral Magnesium salt of EDTA has introduced to the titter through the addition of buffer (wine red) to obtain end point (blue) by colour change of the indicator. The TH was finally determined by equation 4.

$$mg/L\,TH\ as\ CaCO_3 = (T) \times 1000/V \qquad \textbf{...4}$$

Where: T = Volume of Titrant; V= volume of sample in mL

Sulfate Test (SO_4^{-2})

Sulphate reducing bacteria use organic matter and change SO_4^{2-} to S^{2-}**.** To avoid this, the sample was stored at 42°C. Also, it was filtered through whatman No.1. Then after, the pH of a 200ml filtered sample was adjusted to pH 4.5 to 5.0 using HCl; the orange colour of methyl red indicator has been used. Procedurally, about 1.2 ml HCl was added. we have heated to boiling with gently stirring; then we added 5 to 10ml barium chloride solution slowly. The precipitated samples were digested at 80°C and keep in room temperature for 1day. Finally, filtered sample was placed and precipitated in a weighing crucible and ignite at 850°C for 30min. The SO_4^{-2} ion was determined by Equation 5.

$$mg/L\ SO_4^{\ 2-} = \mathrm{mg\ BaSO_4}^{2-} \times 411.6 \times 1000/ml\ of\ sample \qquad \textbf{...5}$$

$$411.6 = factor;\ Factor = \mathrm{Mwt\ of\ SO_4}^{2-}/\mathrm{Mwt\ of\ BaSO_4}^{2-}$$

Nitrogen (Ammonia) NH_3

A borosilicate glass flask of 500-800ml capacity was attached to a vertical condenser so that outlet tip may be underwater below the surface of the receiving boric acid solution. Instruments like pH meter, burette, 250ml conical flask, 1 ml pipette, kjeldahl flask were used. The samples were shacked and put in the distillation flask or preserved the sample with 0.8ml conc. H_2SO_4 and stored in an incubator at 20°C. Then, about 50ml of sample was taken into a distillation flask and diluted with 250ml distilled water. Following this, about 10ml borate buffer solution was added to adjust pH to 9.5 with 6N NaOH by measuring using pH meter. Then, the kjeldahl flask was transferred to the distillation apparatus and started distillation, collected the distillate in 250 ml conical flask containing 50ml of indicating boric acid. Then, we have titrated the ammonia in the distillate against standard of 0.02N H_2SO_4 until the indicator turns to a pale lavender colour and at the end, we carried out a blank through all the steps of the procedure to take the necessary correction of the result. The NH_3 was determined by Equation 6.

$$mg/L\,NH3\ \ (\mathrm{A}-\mathrm{B})\mathrm{x}\ 14\ \mathrm{x}\ 0.02\ \mathrm{x}\ 1000/ml\ of\ sample \qquad \textbf{…6}$$

Where: A = titration value; B = blank value; 14 = equivalent of ammonia; 0.02 = normality of sulfuric acid.

Phosphate (PO_4^{3-})

A 10ml of sample was taken in a 100ml volumetric flask, about 6ml of Ammonium Molybdate and 6 drops of Stannous Chloride were added and made up to the mark with distil water. Blank (B) was prepared in the same manner with distil water. Absorbance was measured at 690 nm and conc. Phosphate was calculated from the graph which was obtained by following the above procedure. A standard phosphate solution was taken in different concentrations, reading was taken before 20 minutes of makeup and used as standard measurement for our sample. The PO_4^{3-} was determined by Equation

$$mg/L\,PO_4^{\ 3-} = conc.from\ the\ graph \times 1000/volume\ of\ sample\ taken \qquad \textbf{…7}$$

Nitrate (NO_3^-)

About 50ml of sample was taken in a porcelain dish, heated and evaporated until to get the residue. The dish was cooled and the residue was dissolved in 2ml phenol disulphoinic acid and was transferred in to 50ml volumetric flask. Then, 6ml of Ammonia solution was added and yellow colour was developed. Distilled water was added to the mark to produce solution. Blank (B) was prepared in the same manner with distilled water. The concentration of nitrates was calculated from the graph which was obtained by following the above procedure; instead of using standard Nitrate solution in different concentrations and the color of sample was read at 410nm. Finally, the NO_3^- concentration was determined by Equation 8.

$$mg/L\,NO_3^{\ -} = conc.from\ the\ graph \times 1000/volume\ of\ sample \qquad \textbf{…8}$$

2.4 Data Analysis

A simple descriptive statics result was used to infer for the whole study river segments. All statistical analysis was done using the Microsoft excel software. Graphs and charts were used to present the analysis results. The interpretation was done in comparison with the WHO drinking water quality 2004 and 2006 standards and the Ethiopian surface water standards too.

3. Results and Discussion

Based on the physico-chemical and microbiological analysis result the quality of water in Shankila river is deteriorated. Pollution profiles are above the compliance limit of both Ethiopian and WHO standards. Whereas the sample analysed at the upper stream of the river showed comparatively of less pollution status. But the coliform count was investigated in this point. The detailed pollution profiles are discussed in the following sub-sections.

Electrical Conductivity (EC)

Electrical Conductivity is defined as the measure of waters abilities to conduct an electric current through dissolved ions. These ions are calcium, magnesium, sodium, potassium, iron, aluminium, chlorides, sulphates, carbonates and bicarbonate. As shown on Figure 2, the result of Electrical Conductivity (EC) of Shankila River water ranged from 276 µS/cm to 860 µS/cm. The lowest EC was measured at the upper stream (Gullele), i.e. sample point one taken from the pristine unpolluted environment. Whereas the highest EC was measured at the the sample point five (Coca Mazoriya) of EC 860 µS/cm; the place where the highly polluted part of the study sample point. In general, it is illustrated on Figure 2, the amount of EC was increased along downstream of the river. However, at sample point two (i.e. Marble factory) there was a slight increment of the result of EC = 690 µS/cm than the next two sites (i.e. Sefere Selam and Amanuel condominium sites 547 µS/cm and 600 µS/cm respectively). Conductivity increases not only with the introduction of total dissolved solids but also increasing water temperature (Davis and Simon, 1995). There are two possible reasons for increasing EC of the Shankila River at sample points.

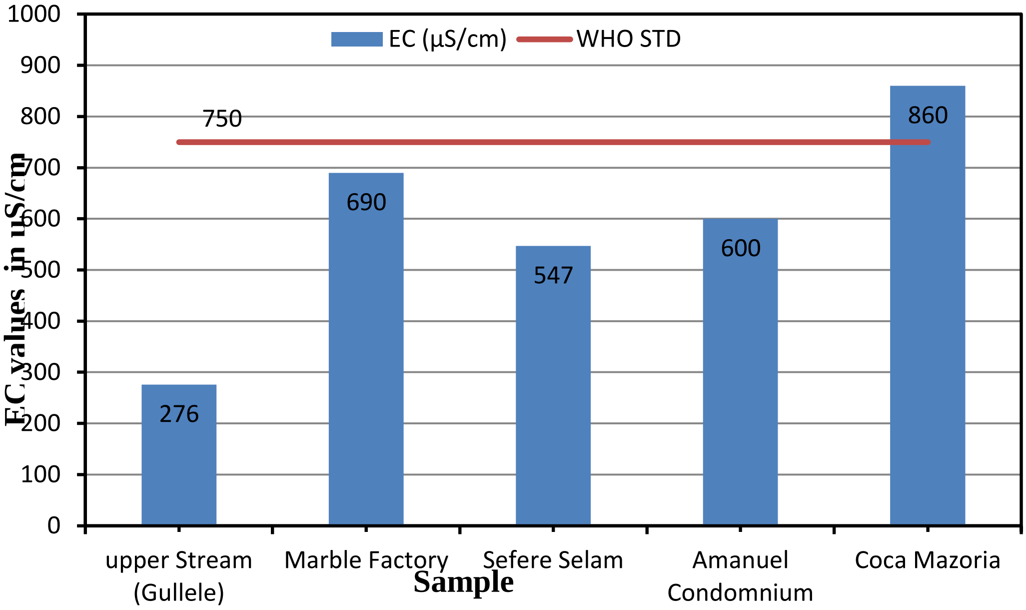


Figure 2 Electrical conductivity values of Shankila River

Potential of Hydrogen (pH)

As illustrated on Figure 3, the mean pH values of Shankila River were ranged from 6.85 to 8.04. The lowest pH value (6.85) was measured at sample point one of upper stream around Gullele and the highest value (8.05) was measured at sample point two of Marble Factory. However, the pH result was found in agreement with pH assigned by EPA as the standard of pH of water which ranges from 6.5 to 8.5 (FDRE-EPA, 2003). However, it was varied from one point to the other along the river. In general, the pH value of the water was increased slightly from 6.85 to 7.98 along downstream. However, at sample point two (Marble Factory) the pH values reached to 8.04. The marble factory emits an influent that contains Ca^{2+} and CO_3^{2-} ions; it causes to increase in EC, pH and Turbidity. Tributaries that came from other remote area outside the city have brought higher amount of dissolved salt and various ions to be a case for increasing electrical conductivity of Shankila river. Similar studies that have been conducted on Akaki river showed that different urban agriculture and industrial activities become cause for increasing pH and other pollution to surface water (Ademe and Alemayehu, 2014; Samuel et al., 2007). Overflow, sewage, geology (lime stone is associated with more alkaline condition), high nutrient levels are some of the causes to acidity or alkalinity. This was further described as high nutrient level causes excessive growth of algae and plants that increased the pH values at the receiving water bodies and this extremely low pH would result in the death of all aquatic life (Kallqvisit and Svensson, 2002; EPA, 2012).

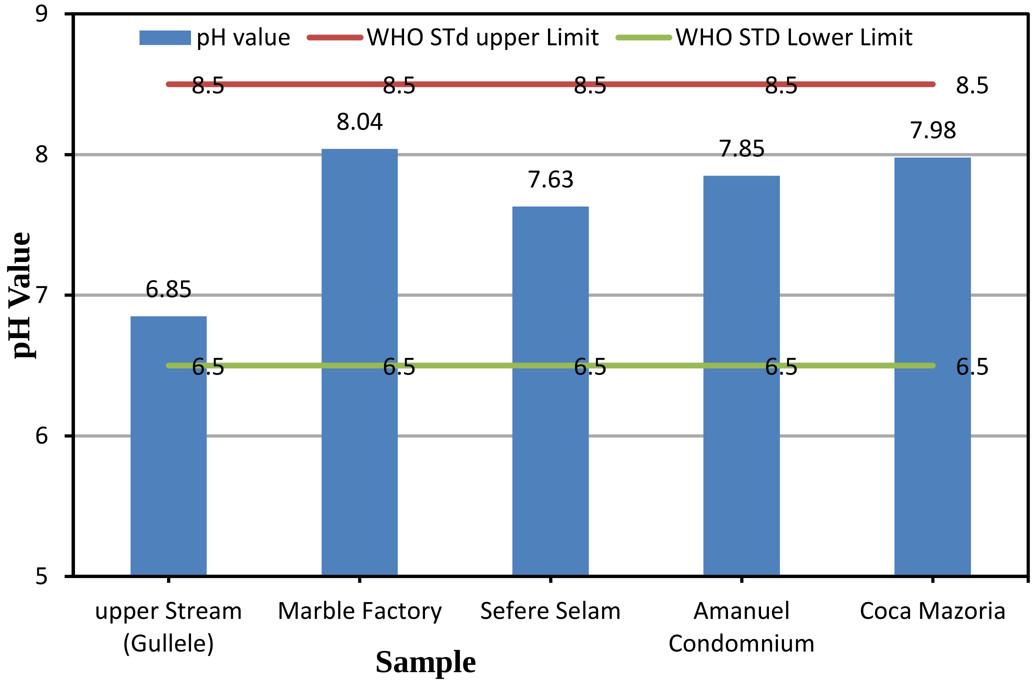


Figure 3 pH value of studied river water

Turbidity and Total Suspended Solids (TSS)

As it was shown on Figure 4, the findings of Turbidity of Shankila River water fluctuated from 0 NTU to 130 NTU. The result of Turbidity values of the Shankila River water was found in above the WHO standard limit, except sample point one (i.e. upper stream of Gullele). The level of the total suspended solids (TSS) found in the river water samples was varied from 9 mg/L to 234 mg/L. The lowest TSS value 9 mg/L was recorded at sample point one upper stream and the highest value of TSS 234 mg/L was recorded in sample point five (Coca Mazoriya).

The trends showed an increasing pattern from 0 NTU to 130 NTU due to introduction of unwanted materials to the river like suspended solid and other dissolved organic and inorganic compounds. Additionally, number of populations was increased along the river course from upstream to downstream and had a high potential to cause pollution. As turbidity is a sign of clarity of water; is a visual property; presence of colloidal particles in the river may also cause harmful or undesirable testes and odour. It may also interfere with disinfectants if in case the people along the river want to treat and use. According to certain previous study report, turbidity can indicate that water may be polluted with pathogens presenting human health concerns (Tarazona and Muñoz, 1995; Olison, 2004). So that increased level of turbidity in this river might be correlated with pathogens. Except sample point one, all sample points result of the total suspended solid were above the permissible standard limit of WHO.

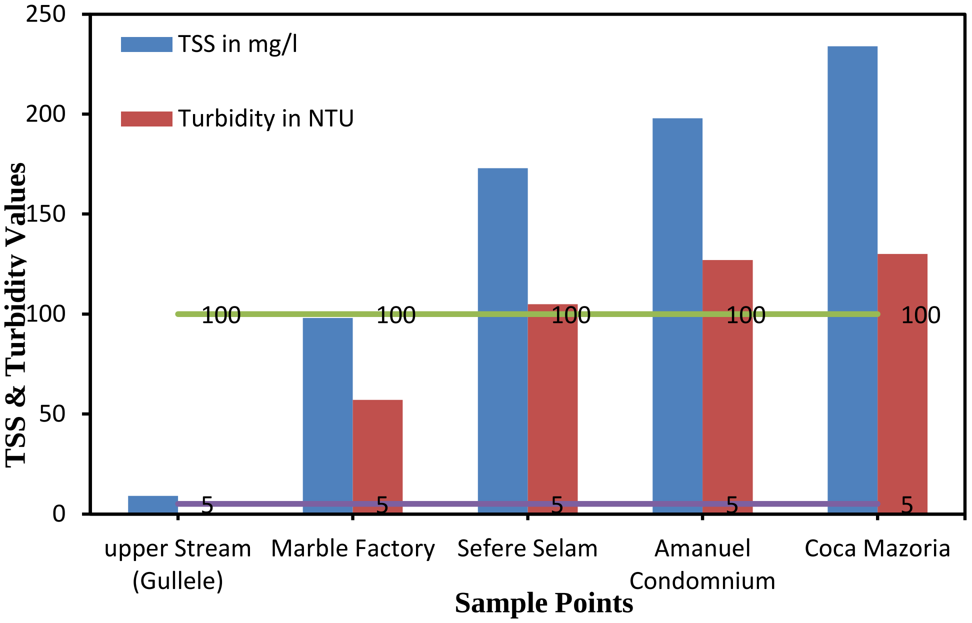


Figure 4 Turbidity and Total Suspended Solids (TSS) of the studied river water

Total Hardness (TH)

As shown in Figure 5, the maximum hardness of the river water under this study was found to 850 mg/L.The tested results of total hardness of Shankila River water indicates various results at different point; result from 200 mg/L to 850 mg/L. Increasing hardness at sample 2 was a result of a sample point two of Shankila River, there was point source of Marble factory above 200 meter from the sample point and also there was another tributary river here in the sample point two meet the Shankila River. Therefore; due to these two reasons the amount of the total hardness of the Shankila River water increased at a highest amount with compared to sample point one. Moreover, without confusion; Marble was one of the sources of water hardness due to their nature or origin of $CaCO_3$ and this is the one and the dominant causes of water hardness. The other sources of water hardness were $MgCO_3$, $MgSO_4$ and $CaSO_4$. When we come to the third sample point; Sefere Selam, the amount of total hardness was decreased to 330 mg/L, this may be due to dilution factor of the Shankila River as we compared sample point two Marble Factory with Sample point three i.e. Sefere Selam. Along the downstream, pollution profile is increased.

As described in literatures, hard water which has high hardness do not be used for household purposes such as washing, bathing and cooking and also not appropriate for industrial and agricultural use (Mitchell & Stapp, 1992; Patil et al., 2012). So that the river water under this study lost its major provisional service such as cooking, washing or bathing.

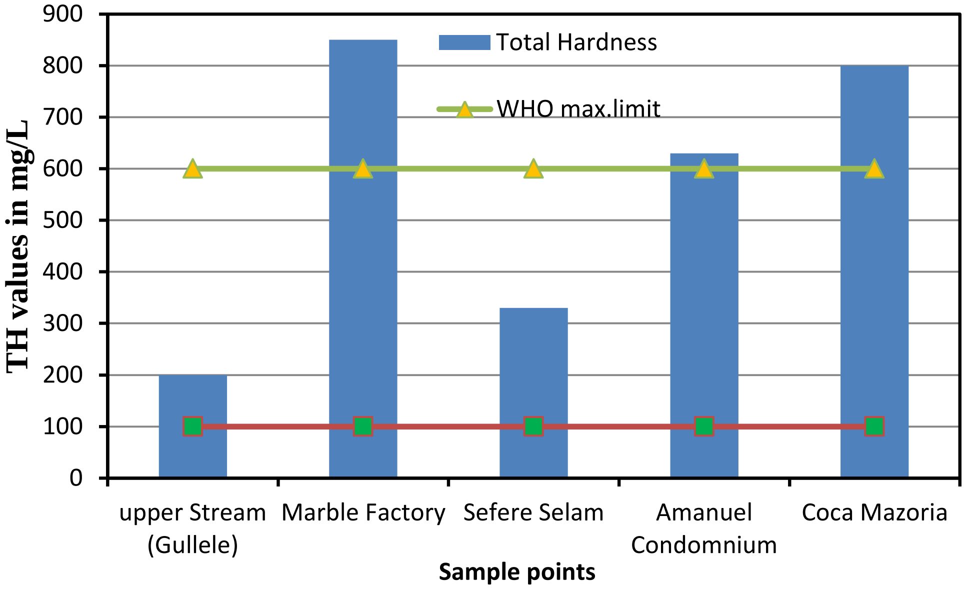


Figure 5 Total Hardness (TH)

Total Dissolved Solids/Salts (TDS)

As shown in Figure 6, the mean concentrations of total Dissolved Solids (TDS) of the selected sample points of Shankila River are ranged from upper stream of Gullele (190 mg/L) to downstream of Coca Mazoriya (720 mg/L). The highest mean value of TDS was recorded at sample point five (Coca Mazoriya) and the value was 720 mg/L. Whereas the lowest TDS value of the study was recorded at sample point one (Gullele) and had TDS value 190 mg/L. Except sample point three (Sefere Selam) the rest of the TDS measured mean values showed increasing trends along downstream.

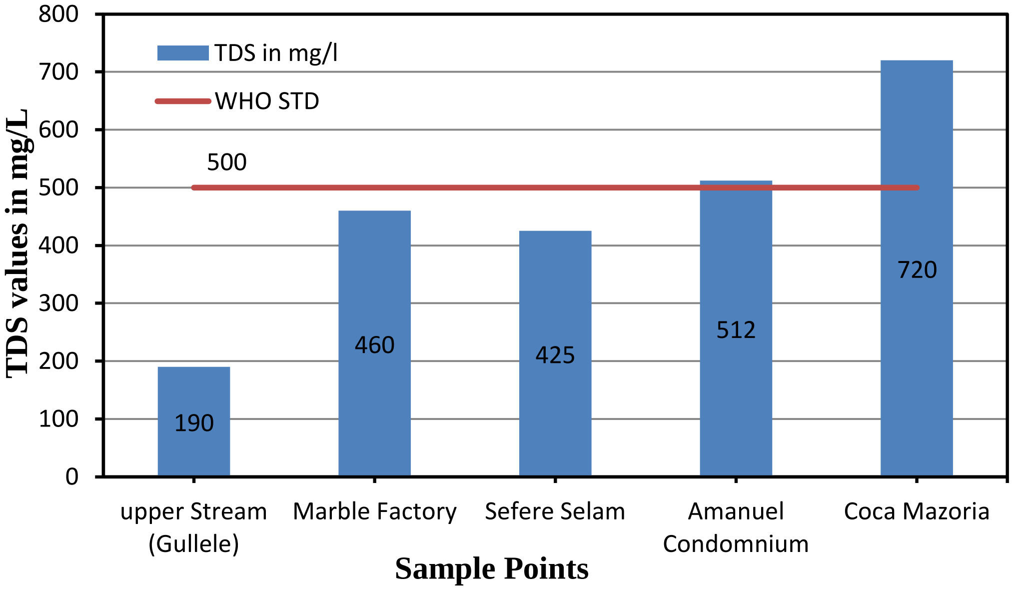


Figure 6 Mean concentration TDS values of Shankila River

Sulphate (SO_4^{2-}) and Phosphate (PO_4^{3-})

Figure 7 shows the mean calculated values of the Sulphate ions of Shankila River. The result varied in between 2.5 mg/L and 7.3 mg/L. The highest value of SO_4^{2-} was recorded at sample **point** five (Coca Mazoriya) of 7.3 mg/L and the lowest value was found in the sample point one of upper stream (Gullele) of 2.5 mg/L. The trends of both sulphate and phosphate ions show an increase pattern from upstream to downstream of the river. On both, the lower result was recorded at sample point one of Gullele 2.5 mg/L and 0.7 mg/L and the highest value was founded in sample point five of Coca Mazoriya 7.3 mg/L and 35.6 mg/L for sulphate and phosphate respectively. Sulphate is second to bicarbonate as the major ion in hard water reservoirs. The possible source of Sulphate (SO_4^{2-}) can be naturally occurring or the result of municipal or industrial discharges.

WHO suggest that the limit values of PO_4^{3-} should be less than 1 mg/L to keep drinking water and other water body from a eutrophication. But, in the present study except sample point one; the rest sample point result values of PO_4^{3-} were by far higher than the recommended value. This indicates that the level of phosphate concentration due to its disposal phosphate from domestic and industrial sewages as washing powder, intensive rearing of livestock and the use of phosphate containing particles is very high. Therefore, this means that, the effluent; basing on the results of phosphorous content which is the limiting factor to eutrophication has significant adverse effects on the receiving water body.

Eutrophication is one of fresh water impairment caused by high PO_4^{3-} and NO_3^-. Thus, they can have significant environmental impacts such as algal blooms can restricting the use of water bodies for purposes such as recreation or drinking water for the human and animal use. Deterioration of water quality and eutrophication are due to human activities including bethinks, washing of cloths, vehicles and household utensils. Rain, surface water runoff, agriculture runoff; washer man activity could have also contributed to the inorganic phosphate content (Flint, 2011). Additionally, the possible source of phosphate ion on the study includes certain soil and bedrocks, wastewater and domestic phosphate-based detergents, human and animal wastes, decomposing plants and runoff from urban lands and fertilized land areas.

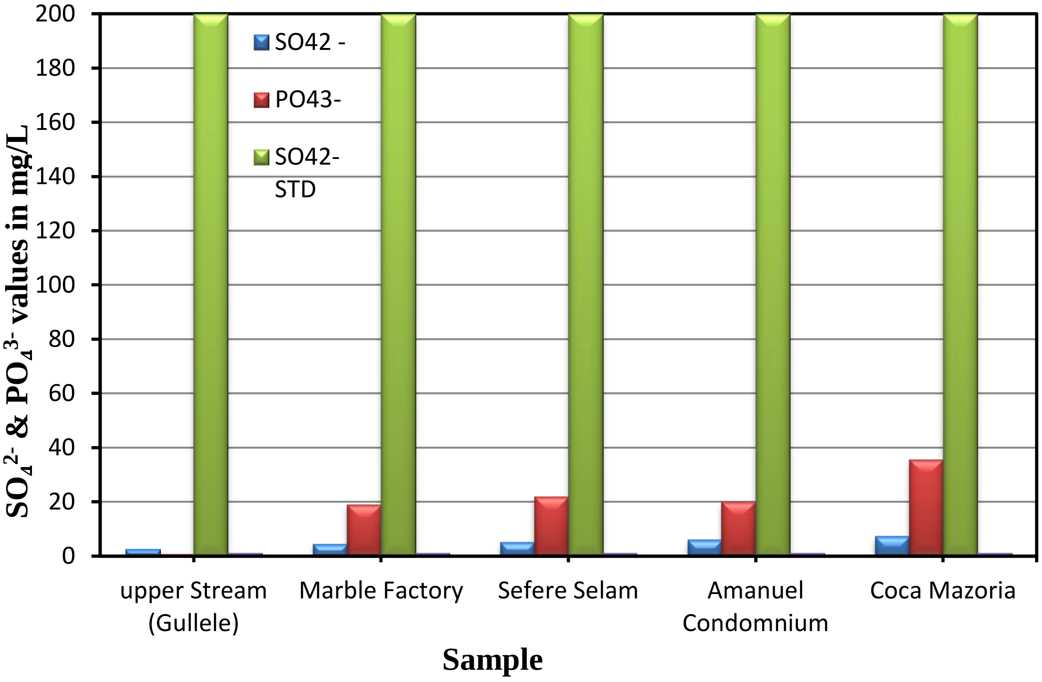


Figure 7 Mean concentration of values SO_4^{2-} and PO_4^{3-}

Ammonia

As shown on Figure 8, the mean values of NH_3 in this study were varied from a range of 0.02 mg/L to 31 mg/L. The maximum values of NH_3 was recorded at sample point five of Coca mazoriya, 31 mg/L. Whereas, the minimum value was recorded at sample point one of upper stream (Gullele) of 0.02 mg/L. As the result of ammonia on Figure 8 depicted except sample point one, the ammonia concentration was higher than the standard limit of Ethiopian surface water. The levels of Ammonia result of Shankila River Figure 10 were above the standard limit of surface water in Ethiopia. This result of ammonia is dangerous to aquatic biota like Fishes and other sensitive aquatic macro invertebrate organisms. Ammonia at high pH values (pH > 8.5), is extremely toxic in alkaline water than acidic. One of the reasons for the bad odor that can be sensed along the lake course during the field sampling could be due to presence of ammonium. High concentrations of Ammonia could indicate pollution of a water body. Ammonia and total nitrogen in wastewater results from the breakdown of proteins and amino acids in organic waste; it exerts an oxygen require in receiving waters, which can be lower or reduce dissolved oxygen, impacting the aquatic ecosystem (Pressley et al., 1972; Ramisetty, 1999; Constantine, 2001; Morrison et al., 2001). Ammonia can also contribute to eutrophication and can be toxic to sensitive aquatic biota (Pressley et al., 1972).

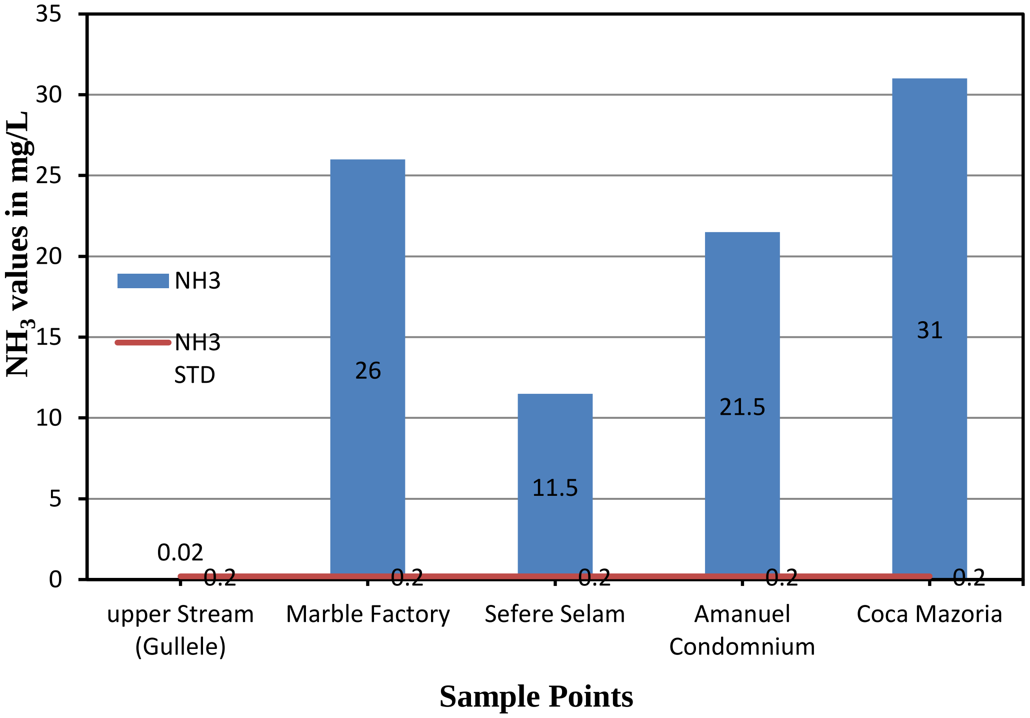


Figure 8 Mean concentration values of Ammonia (NH3)

Nitrate

Nitrate is either the end results of oxidation process of Ammonia or direct release of human activity like from fertilizers. As it was depicted from Figure 9, the result of nitrate was ranged from 0.3 mg/L to 0.4 mg/L. The obtained values of the study somewhat similar and have no significance difference among the sample points. The result was very far below the standard limit of Ethiopia to the surface water quality standard and also WHO. The maximum value of NO_3^- that were recorded at sample points four and five are 0.4 mg/L. The minimum values were recorded at sample point one, two and three; which is equal to a concentration of 0.3 mg/L. The trends of NO_3^- in downstream of the river were almost similar.

Key contributors of nitrate for surface water pollution are chemical fertilizers from cultivated land and drainage, from livestock feedlots, as well as domestic wastes and some industrial waters in the course of leakages (Jagessar and Sooknundun, 2011). Source of nitrate contamination include fertilizers, animal wastes, septic tanks, municipal sewage treatment systems and decaying plant debris. Thus, excess nitrogen, primarily in the form of nitrates, can cause the simulation of plant growth, resulting in algal blooms or overgrowth of aquatic plants, which can have serious consequences for the receiving waters such as odours, accumulation of unsightly biomass, dissolved oxygen depletion due to biomass decay, and loss of fish and selfish (Washington State DoH., 2005).

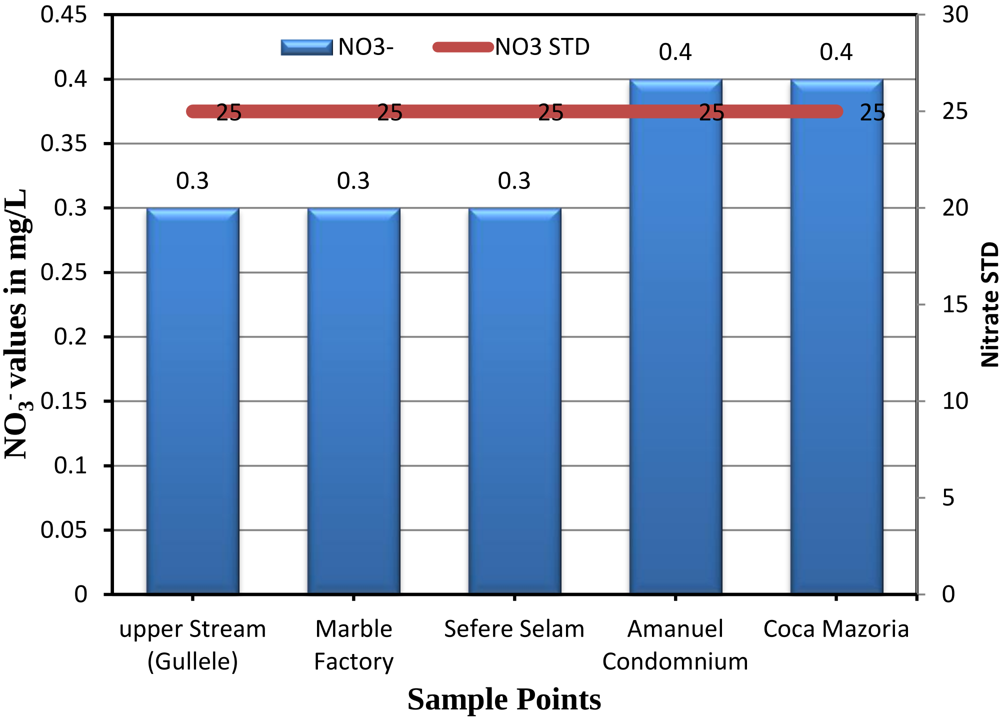


Figure 9 NO_3^- values of Shankila River

Nitrite

The obtained concentration of nitrite on Figure 10 shows that there was a slight increment of values along the river course downstream. The maximum nitrite value was recorded at sample point five (Coca Mazoriya) of 1.12 mg/L and the minimum nitrite values of the study was recorded at sample point one of upper stream of Gullele of 0.012 mg/L. Nitrate is an oxidized, inorganic form of nitrogen in water. Nitrogen is a necessary nutrient for plant growth. Too much phosphorous and nitrogen in surface waters contribute to nutrient enrichment, increasing aquatic plant growth and changing the types of plants and animals that live in a stream (Tamiru, 2007). Nitrogen-containing compounds released into environment can create series problems, such as eutrophication of rivers, deterioration of water quality and potential hazard to human health, because nitrate in the gastrointestinal tract can be reduced to nitrite ions. In addition, studies indicated that nitrate and nitrite have the potential form of N-nitrous compounds, which are potent carcinogens (Forman, 1991).

The obtained concentration of Nitrite shows that there was a slight increment of values along the river catchment from upstream to downstream. The highest result was recorded at sample point five (Coca Mazoriya) of 1.12 mg/L and the lowest result was recorded at sample point on of upper stream (Gullele) of 0.012 mg/L. The obtained study data indicates, sample point three, four and five was above the maximum standard permissible limit of Ethiopian but sample point one and two was below the standard limit of the country. Logically, the concentration of Ammonia increases; the concentrations Nitrite also increases because nitrite is the oxidation process of Ammonia in the presence of Nitrobacter bacteria. Or nitrite is generated from ammonia through oxidation process by nitrifying bacteria. Nitrite causes the formation of methaemoglobin in the blood and causes respiratory compromise as it blocks oxygen uptake by the blood.

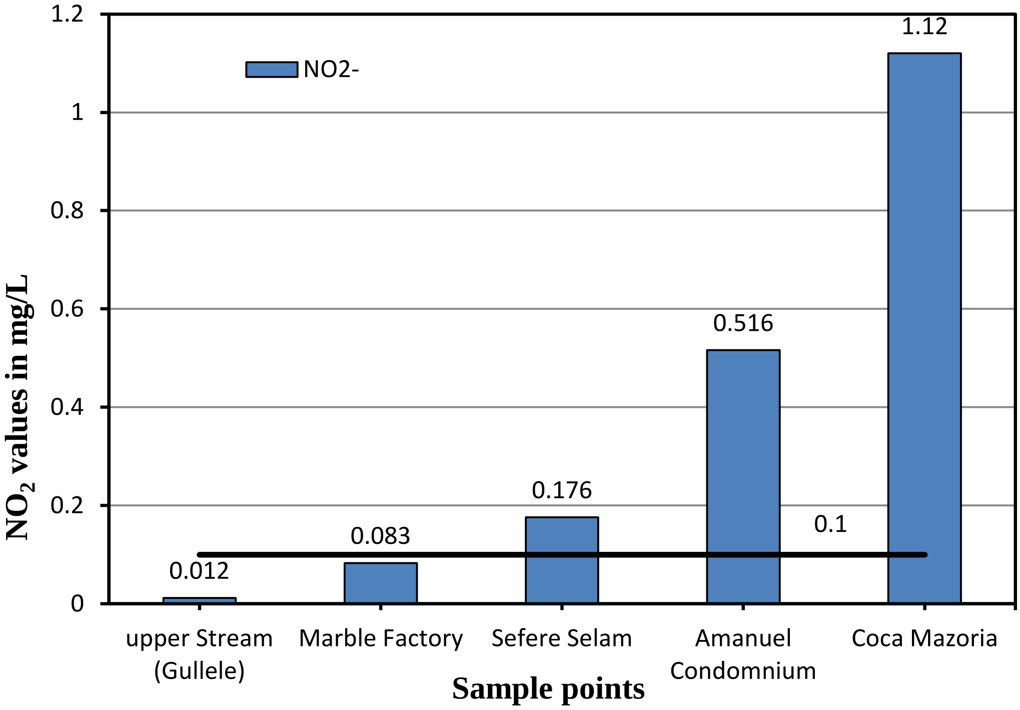


Figure 10 Nitrite values of Shankila River

Chemical Oxygen Demand and Biological Oxygen Demand

The results of laboratory analysis of BOD and COD of Shankila River are summarized on Figure 11. The maximum concentration of BOD was recorded at the sample point five of Coca Mazoriya 188 mg/L and the minimum value was recorded at sample point one in the upper stream of Gullele 7.6mg/L (Figure 11). In sample point one of the upper streams of Gullele, the BOD value 7.6 mg/L was somewhat it is closer to the standard. The other part of the river segments shows BOD/COD concentration above the compliance level of WHO and Ethiopian surface water quality standards.

The trends of BOD and COD of Shankila River water showed that an overall increasing pattern. However, at some sample point there was a reciprocal of or interchangeable of results. For example, the results of COD somewhat uniform increment from sample point one to sample point five (i.e. 40, 96, 117, 115 and 140 mg/L) respectively. Whereas the BOD results were a little bit varies from sample point one to sample point five (i.e. 7.6, 116, 62, 84, 188 mg/L) respectively. At sample point two and five, the obtained result of BOD was greater than that of COD results. Specifically, at this two sample points there was a point source of other tributary rivers meet Shankila River and at sample point five there was a lot of toilet faeces or excreta or direct discharge of effluents to the Shankila River water.

Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose organic compounds in a litter of wastewater and natural source of BOD in surface water consist of organic material from decaying plants and animal wastes (Michael et al., 2001). Human sources of BOD include faeces, urine, detergent, fat, oils and greases. The release of waste with high level of BOD can cause water quality problems such as sever dissolved oxygen depilation and fish kill in receiving water bodies. If excess biodegradable mater present in the surface or ground water it can result in reduced dissolved oxygen concentration in water and create taste and odour problems (Tamiru, 2007).

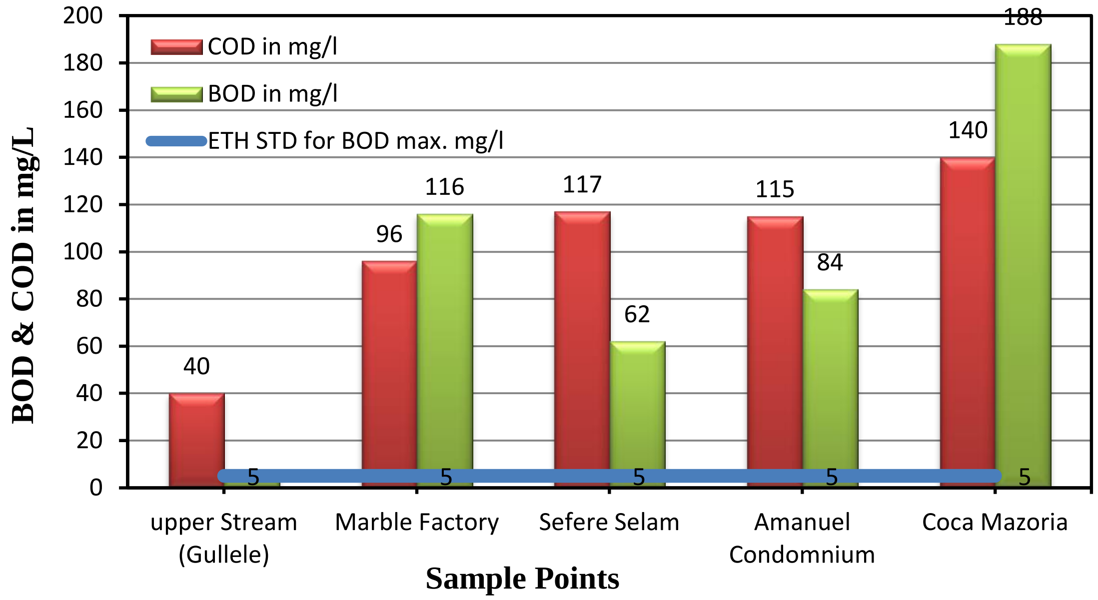


Figure 11 Chemical oxygen demand and Biological oxygen demand results of Shankila River

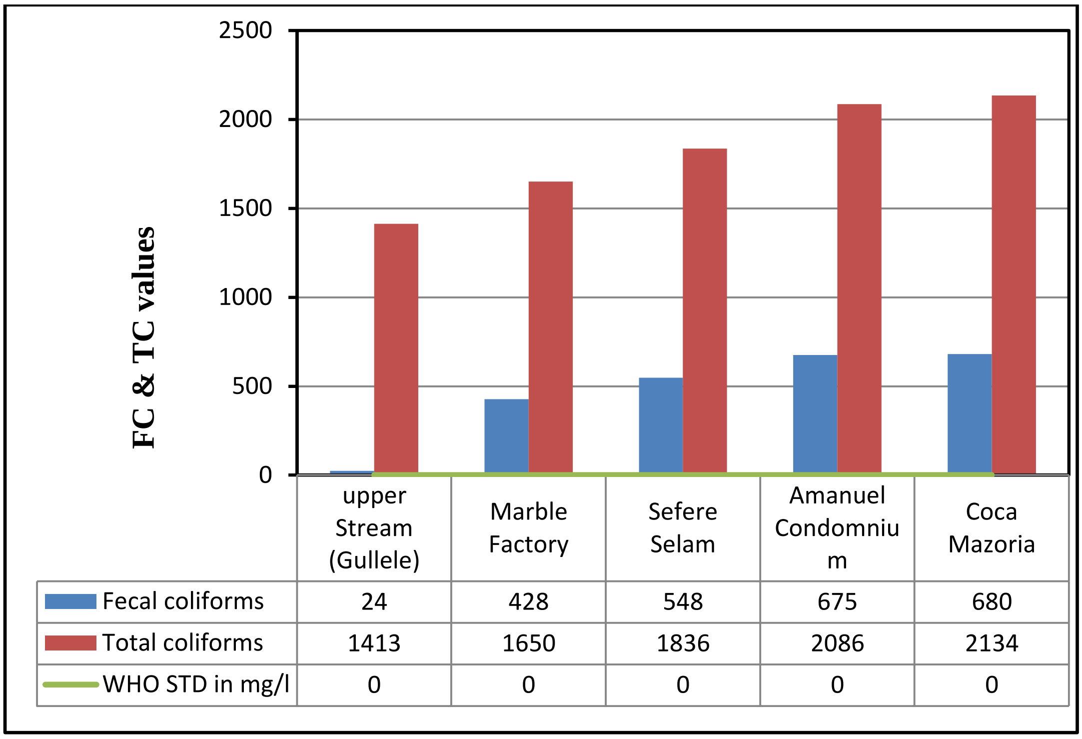
The pollution profile for COD of the Shankila River ranged from 40 mg/L to 140 mg/L (Table 1 and Figure 11). The maximum concentration of COD was recorded at sample point five of Coca Mazoriya 140 mg/L, and the minimum value of COD was recorded at sample point one of upper stream of Gullele and 40 mg/L. High COD levels implies toxic conditions and the presence of biological degradation process resistance organic substances. As reported in literatures, COD always include the inert oxygen requiring substance and its value is always greater than BOD (Barnes et al., 1998). Basically, municipal wastewater contains high level of Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS). The high level of Chemical Oxygen Demand (COD) results low Dissolve Oxygen (DO) in water and this can lead to mortality of aquatic live (Ahmad, 2009). In addition, suspended solid such as organic and inorganic material can cause dirt and odor to the water (Rangwala et al., 2007). The same report indicated that the

COD-BOD ratio is an important value in determining the biodegradability of the pollutants in wastewater.

Faecal and Total Coliforms

The result of Faecal and Total coliforms analysis of Shankila River is summarized on Figure 12. Faecal and Total coliforms count of all sample points exceeded the maximum limit of 0 per 100 ml as given by WHO. On the average Faecal and Total coliforms counts were above 471 and 1824 respectively for each sampling points giving indications of pollution through human excreta. The source of such excreta included the recurrent emptying of bucket latrines in to the river and indiscriminate open defecation along the river as well as the channelling of raw sewage in to the river. The Highest value of FC and TC 680 FC/100 ml and 2134 TC/100 ml respectively were recorded at sample point five of Coca Mazoriya. The lowest value of FC and TC was 24 FC / 100 ml and 1413 TC / 100 ml respectively recorded at sample point one of upper stream of Gullele.

The source of such excreta incorporated the regular emptying of container latrines in to the river, unsystematic open defecation along the river as well as the channelling of raw sewage in to the river. The lowest value of FC and TC 24 FC / 100 ml and 1413 TC / 100 ml was recorded at sample point one of upper stream of Gullele. Bacteriological test is noted to disclose with ease and great reliability the immediate or recent causes of water pollution. In reference with bacteriological test, the faecal and total coliforms count of the water being carried out by the river that was investigated because of the faecal and total coliforms count gives an indication of pollution being caused by human waste (Rehm et al., 1999; Rangwala et al., 2007; Ahmad, 2009).



	upper Stream (Gullele)	Marble Factory	Sefere Selam	Amanuel Condomnium	Coca Mazoria
🟦 Fecal coliforms	24	428	548	675	680
🟥 Total coliforms	1413	1650	1836	2086	2134
— WHO STD in mg/l	0	0	0	0	0

Figure 12 FC & TC values of Shankila River

4. Conclusion

The study finding has shown the different anthropogenic activities have impacted the quality of Shankila river water. The result revealed that the values of pH and Hardness, Electric conductivity, NO_3^- , SO_4^{2-} were within the standard limit but the results of Turbidity, NH_3, NO_2^-, PO_4^{3-}, BOD, COD, TSS, Faecal and Total coliforms did not fall in the acceptable range. The level of BOD, COD and other pollutant indicators such as total suspended solids (TSS), Ammonia (NH_3), Nitrite (NO_2^-), Nitrate (NO_3^-), Sulphate (SO_4^2), Phosphate (PO_4^{3-}), Faecal and Total Coliforms have been increased along downstream of the river course. According to the finding, the industrial activities, domestic liquid wastewater discharge, improper solid waste disposal practice, agriculture and other services like car maintenance *'Garaj'*, baths rooms etc. polluted the river water. Adequate mitigation measures need to be emplaced to manage the pollution sources.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

There is no conflict of interest by authors in this study.

Authors' Contributions

All authors, Mr. Amsalu Zomaneh Tiruye, Mr Mitiku Adisu Worku and Mr. Mekonnen Maschal Tarekegn have participated in the proposal development, water quality survey, analysis and manuscript preparation.

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