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Assessment on the Current Water Quality Status of Walgamo River, Addis Ababa, Ethiopia

Dessalew Berihun[1*], Belina Tarfassa[2], Getachew Dagnew[1]

Department of Environmental Management, Faculty of Urban Development Studies, Ethiopia[1]

Department of Chemistry, College of Natural and Computational Sciences, Ethiopia[2]

Abstract: Urban River pollution has been one of the main issues in the world. Currently, Addis Ababa is one of the fast growing cities and concurrently the rivers in the city are vulnerable to pollution. The purpose of this study is to assess the current status of water quality of Walgamo River, which is located closer to Kotebe Metropolitan University. Water samples were collected from six sampling sites of Walgamo River and analyzed for physico-chemical parameters and fresh water elements in August 2016 and December 2016. The maximum recorded values were pH (6.64), total alkalinity (171.75 mg/L), turbidity (57 NTU), biochemical oxygen demand (72 mg/L), hardness (237.5 mg/L), total dissolved solids (283 mg/L), chloride (60 mg/L), chemical oxygen demand (177 mg/L), electrical conductivity (561 μS) Temperature 22.8^{o}C), phosphorus (1.2 mg/L), arsenic (6.22 mg/L), and mercury (14.26 mg/L). Thus results show that the quality of Walgamo River is below the expected water quality standard.

Keywords: Walgamo river, Pollution, Water quality parameters, Water quality standard

I. Introduction

Water is an essential and life-sustaining natural resource and is critical for the survival of all living organisms, food production and economic development. Surface waters are most exposed to pollution due to their easy accessibility for disposal of wastewaters. Water pollution is continuously becoming a serious problem, mainly caused by the disposal of untreated sewage and industrial waste, animal waste and chemical fertilizers [1-3]. The fresh water resources are depleted because of massive agricultural activities, urbanization, and industrialization.

Urbanization degrades streams and rivers and contributes to decreased ecological health in watersheds. Urban rivers have always been the recipient of sewage water from various sources that have different kinds of the domestic, agricultural, and industrial wastes [4]. It is commonly known that raw municipal wastewater contains a great number of pathogenic and opportunistic microorganisms as well as those antibiotic resistant including multidrug resistant, mainly of intestinal origin [5].

Urban rivers are sink that collect the municipal liquid and solid wastes with huge amount of sludge [6]. Particularly urban centers of developing countries, surface water resources, have become dump yards for waste. This is confirmed by the fact that about million tons of waste is disposed off within receiving waters daily [6]. As a result, the municipal sewage is a mixture of various organic matters, and the decomposition of these matters produces harmful gases that in fact deteriorate the environment and logically create the infection diseases [6]. The deterioration of water quality

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speedily contributes to water scarcity as a major concern. Addis Ababa is facing the relative asperity of water quality according to various types of factors, including industrialization, nonrenewable water resources, population growth and density, institutional capacity, and economic situation. Consequently, these practices have rendered most surface water resources unsuitable for both primary and/or secondary use [7].

In Ethiopia's capital city, Addis Ababa, faecal matter is discharged directly into the urban rivers or streams without any form of treatment while significant amount of solid waste also end up in surface water bodies in most areas in the city. One of the rivers in Addis Ababa City is Walgamo River. It is a river which starts from north east high lands of Addis Ababa and stream down Yeka sub-city, passes closer to and west of Kotebe Metropolitan University and down to Akaki River.

In connection to this, the most common physically observed scenario of the Walgamo River is that residential houses along the river side opened their toilets directly to the river. This fact is evidenced by the following picture (Fig. 1).

Fig. 1. Public and residential toilets directly opened to Walgamo river.

In addition to the liquid wastes, it is a common practice that residents along aside of the Walgamo River damp all sort of solid wastes they generate from homes and other activities into the River. The solid organic wastes decompose through time and result in releasing bad smell which exposes the residents along the river to many several respiratory diseases. The others are mostly used and through plastic items which remain in the environment indefinitely and it would difficult to imagine about where we are heading if the situation continues in the same trend (Fig. 2).

Fig. 2. Solid waste dumped in Walgamo river.

Even though it looks that Walgamo river is far away from of the expected fresh water natural context, communities in the river bank continued to use the river water for domestic purposes such us drinking, washing, swimming, irrigation,

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etc. Therefore, it is necessary to pave a way for restoring and protecting the Walgamo River and ultimately take care of health risk of the communities using the River (Fig. 3).

Fig. 3. A boy swimming in and a woman fetching drinking water from Walgamo river.

As a result it is worthwhile to assess the current status of the Walgamo River; the materials that contaminated the River, extent of pollution and identify the sources of pollutants with respect to agreed standard for river water quality. It is with this background that this study seeks to determine the physico-chemical and biochemical pollution status Walgamo River using different river water quality indicators.

The study tried to extract as much information as possible on the status of Walgamo River. Moreover, the result of the study may be used to design policy intervention for the mitigation of the Walgamo Rives and other rivers that have a similar scenario by arranging the contexts in other towns and the procedure and design employed in this study may be applied by researchers that may conduct studies in other cities.

II. MATERIALS AND METHODS

Study Area

The study was conducted on Walgamo River located at closer proximity to the west of Kotebe Metropolitan University, in Yeka sub-city, Addis Ababa, the capital city of Ethiopia.

Data Collection Methods

The steps that have been adopted to attain the objectives of the study were as follows:

1. Primary data were obtained from field observation and this was needed to know about the existing physical and environmental condition of the River.
2. Water Samples have been collected from different locations of the Walgamo River and water samples analyzed in the Addis Ababa Environmental Protection Authority Laboratory.
3. Live photographs were taken during field observation.
4. Questionnaires were prepared and distributed to communities settled along riverside.

Sampling Design

Sampling sites:

Sampling points in this study were selected longitudinally based on different forms of degradation and prevailing human activities along Walgamo River course. A total of six points were selected. Two sampling points (SP1 and SP2) are located up stream in the forest closer to the source which has relatively lesser population settlement to use them as reference points to look at the intensity of the contamination as the river flows downstream across Yeka sub-city where there is higher population density. Three sampling points (SP3 SP4 and SP5) were located down the course of the Walgamo River where small scale farming interspersed with agro-forestry and animal husbandry. These three sampling points were used to capture the effects of non-point sources of pollution. The effects of point source pollution was captured by selecting stations SP6 far down stream around Hillside school where semi-treated and untreated sewage is discharged into the river.

To look at the seasonal variations of different parameters, the samples from each site were collected at two different seasons; during the rainy season in August 2016 and dry season in December 2016.

Physicochemical parameters:

The water samples were collected with 1.5 liter sterilized plastic bottles and 500 mL BOD bottles for the analysis of microbial and chemical parameters from the six sampling points (SP1 - SP6) in August 2016 and December 2016. Dissolved oxygen and temperature were measured using a DO meter (Model HACH HQ 4d) while pH and conductivity were measured using a combined meter (Model HACH Eco 40). Total Suspended Solids (TSS) was determined gravimetrically and (BOD5) was determined using Winkler's method according to APHA. All other measurements were carried out within 24 hours after sampling. Water quality parameters that required immediate analyses; Ortho-phosphate, Nitrogen-Ammonia, Nitrate-Nitrogen were measured with a DR/2400 Spectrophotometer using appropriate reagent pillows at the AAEP Laboratory. Samples were preserved in an airtight ice chest at room temperature (~20 °C) before being transported to the laboratory.

Water samples for analysis of heavy metal ion concentration one liter sample was collected from a depth of 50 cm below the surface of the River and kept in acid washed polyethylene containers. The containers were rinsed thoroughly with deionized water after being washed in dilute nitric acid (HNO_3). During the collection of the Rivers water, the containers were rinsed several times with the river water. Water samples were filtered using Whatman filter paper (0.45 μm pore size) for estimation of dissolved metal. These water samples were preserved with 1 mL nitric acid to prevent the precipitation of metals.

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Biological parameters:

For assessment of Coliform bacteria water samples were collected using sterilized 500 mL glass bottles from 30 cm below the surface of the River water and transported on ice. The samples were processed within 6 hours of collection to avoid changes of bacterial count due to growth or die off. The Membrane Filtration Technique (MFT) as described in APHA (2002) was used for the analysis of the samples for the presence of indicator organisms. Three appropriate dilutions were made for each faecal indicator. Dilutions was duplicated and drained through a 0.45 µm sterile membrane filters with a vacuum pump. Filters for Total Coliforms (TC) and Escherichia *coli* (*E. coli*) were incubated on *Chromocult Coliform Agar (ISO 6222, OXOID)* at 37^{o}C for 24 hours. Typical colonies appearing pink to red and dark blue were counted as total coliforms and *E. coli* respectively. For all colonies forming units (CFU) counted, total numbers per 100 mL was expressed as APHA;

$$Total\ numbers\ (per\ 100\ ml) = (CFU's \times Dilution\ Volume\ filtered \times 100)$$

All the methodologies for field and laboratory analysis were conducted according to the Standard Methods for the Examination of Water and Wastewater. Extensive field surveys were carried out to identify the sources of pollution within the catchment areas of Walgamo River.

Data Analysis

Statistical analyses of triplicate samples were performed with the aid of Microsoft excel spreadsheet for windows 2007, MinitabTM version 14.0 for windows. Water Samples for two heavy metals (As and Hg) were analyzed using Atomic Absorption Spectrophotometry (AAS-6300, Shimadzu, Japan) according to. The mean value from the six sampling points was recorded for each metal. A comparison of the mean and range values of heavy metals concentration (mg/L) in Walgamo River with standard guidelines values for Protection of Aquatic Life and Maintenance Rivers from pollution. The obtained data was subjected to statistical analysis to test the analysis of cluster and correlation among all the parameters using SPSS statistical package.

III. Results And Discussion

Physico-Chemical Characteristics of Walgamo River

pH of Walgamo river:

During the dry season, the maximum observed pH of Walgamo River was 6.84 at downstream sampling point (SP6). However, the minimum pH of 5.51 was observed at upstream of the sampling point (SP1) in dry season. At all the sites pH values were observed within the permissible limit. The relatively high pH (6.84) at downstream of the river may be

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contributed by the local discharges which contain alkaline effluents from surrounding institutions and households. The comparison of the pH values of the six sampling points in the two seasons is summarized in Fig. 4.

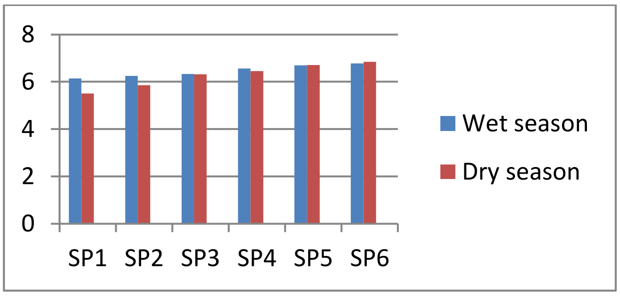

Fig. 4. Comparison of pH of six sampling points of Walgamo river in August and December 2016.

Electrical conductivity:

Electrical conductivity is important parameter of water quality for indicating salinity of water bodies. Electrical conductivity of Walgamo River varies from 101.3 μS to 552 μS during rainy season. But during dry season, the electrical conductivity of Walgamo River varies from 313μS to 561 μS. It is observed that water of high electrical conductivity values is predominant with sodium and chloride ions. This is evident at sampling sites like Sp3 during rainy season, Sp4 during both rainy and dry seasons, and SP6 during both seasons. In general, water in areas of low population settlement and with good drainage is of good quality. This is clear from the present study that in the upstream where the population settlement along the river side is low; the quality of water is relatively good whereas in the downstream areas various parameters exceeds the acceptable limits because of high population density along the riverside presumably the communities dump more solid and liquid wastes as one goes downstream of the river. The comparison of the electrical conductivities values of the six sampling points in the two seasons is summarized in Fig. 5.

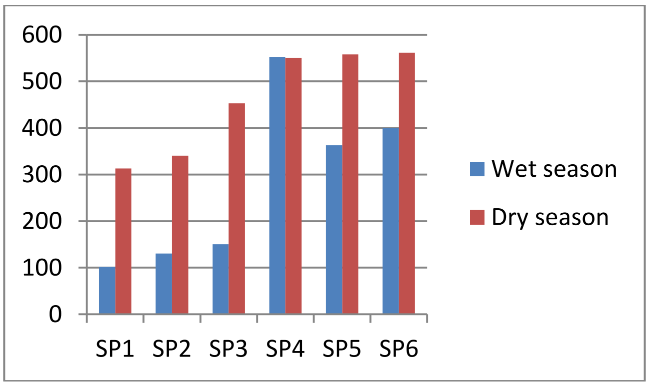

Fig. 5. Comparison of electrical conductivities of six sampling points of Walgamo river in August and December 2016.

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Total dissolved solids:

Total dissolved solids (TDS) refers to materials suspended or dissolved in water or wastewater with high content is inferior and may be polluted. The quantity of TDS in the Walgamo River water varied from 50 mg/L to 283 mg/L during the rainy season. On the other hand, the quantity of TDS in the Walgamo River water varied from 156 mg/L to 282 mg/L during dry season. Higher concentration of TDS during the dry season may be attributed to the lesser volume of the river water during this season. The maximum value of TDS was recorded at middle stream of the river during rainy season from sampling point (SP4) which is 283 mg/L and the minimum was recorded at the upstream of the river from sampling point (SP1) during rainy season. The higher values of TDS may be due to higher concentration of dissolved solids in water that causes adverse effect in taste. The comparison of the TDS values of the six sampling points in the two seasons is summarized in Fig. 6.

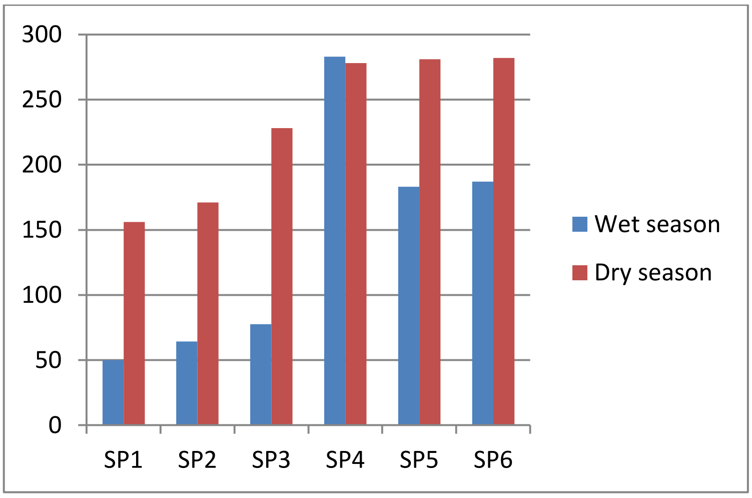

Fig. 6. Comparison of TDS (mg/L) of Walgamo river in August and December 2016.

Turbidity of Walgamo river:

The value of turbidity in the Walgamo river water varied from 8.29 NTU to 9.75 NTU during dry season but during rainy season it reached to maximum of 57 NTU in the middle stream of the river (SP4); this may be due to the fact that at the time of sampling dumping of solid and liquid waste at that point had been occurred. The results of present experiment clearly indicate that the water of Walgamo River is almost highly turbid with moderate temperature. The comparison of the turbidities values of the samples collected from six sites in the two seasons is summarized in Fig. 7.

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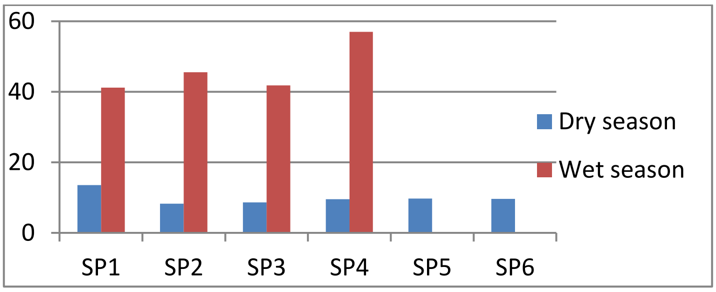

Fig. 7. Comparison of turbidity of Walgamo river in August and December 2016.

Temperature of Walgamo river:

It is observed from the figure that in river Walgamo the highest temperatures (22.8℃) and (22.6°C) were at downstream of the river during dry season at sampling points of (SP5) and (SP6); respectively whereas the lowest temperature (20.1℃) was in wet season at upstream of the river (SP2). High water temperature at downstream (SP5) may be caused by water effluent from Metal and Alcohol beverage factories near Walgamo River at Wandered Secondary school. The comparison of the temperature values of the samples collected from six sampling points in the two seasons is summarized in Fig. 8.

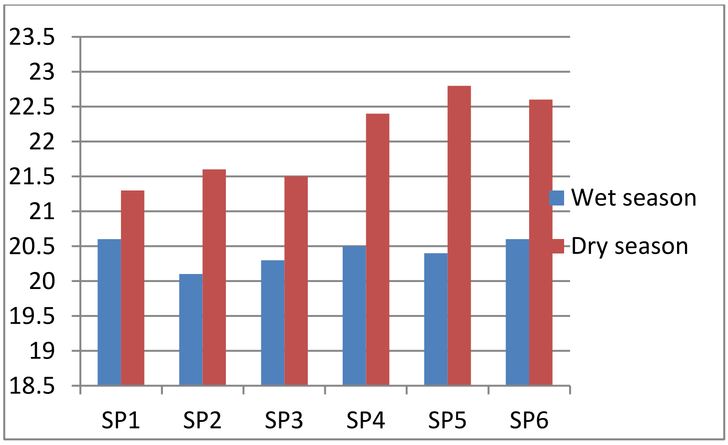

Fig . 8. Comparison of temperatures of Walgamo river in August and December 2016.

Concentration of total phosphorous:

Most researches have not prescribed any norms for phosphate in drinking water as phosphate is not considered as harmful constituent in drinking water. However, its presence accelerates the growth of algae. During the study period, phosphate concentrations in the form of total phosphorous in Walgamo river water samples were in the range of 0.2 mg/L - 1.2 mg/L during rainy season. Highest value of phosphate in the form of total phosphorous (1.2 mg/L) was found at the sampling site SP3 during rainy season while, the minimum value of phosphate (<0.0001 mg/L) was found

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at the five sampling points SP2-SP6 during dry season. The comparison of the amount of phosphorous in the samples collected from six sampling points in the two seasons is summarized in Fig. 9.

Fig. 9. Comparison of total phosphorous in Walgamo river in August and December 2016.

Total hardness of Walgamo river:

In the present study, the amount of total hardness in the Walgamo river water varied from 93.8 mg/L to 237.5 mg/L during rainy season; on the other hand the total hardness varied from 194.8 mg/L to 215.8 mg/L during dry season. Maximum value of total hardness was recorded from sampling point (SP4) and the minimum was recorded from sampling point (SP2) both during rainy season. Therefore total hardness is relatively higher at the middle stream of the river (SP4) because of the discharge of untreated domestic wastes and industrial effluents. It is important to note that there is no legal limit or standard for hardness in water. The comparison of total hardness of the samples collected from six sampling points in the two seasons is summarized in Fig. 10.

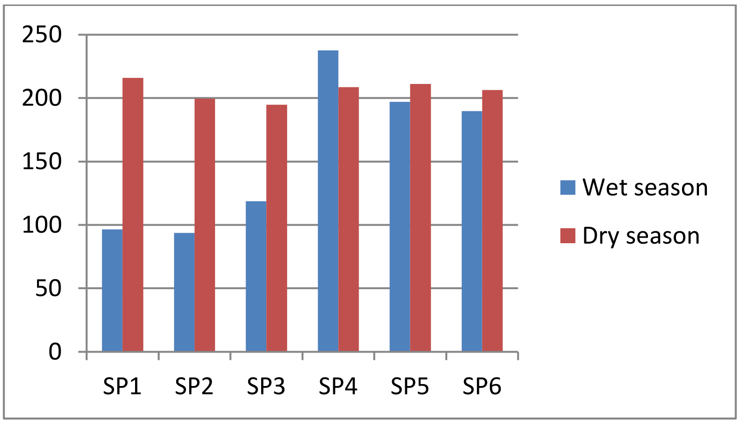

Fig. 10. Comparison of total hardness of Walgamo river in August and December 2016.

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Total alkalinity in Walgamo river:

The alkalinity of water samples at different sites ranged from 86.5 mg/L -171.75 mg/L in wet season. The maximum value of alkalinity (171.75 mg/L) was found at the sampling site (SP6) while the minimum value of alkalinity (86.5 mg/L) was found at the sampling site (SP1). In dry season, the alkalinity of water samples at different sites ranged from 176 mg/L -229.4 mg/L. The study by Pandey et al. on physicochemical analysis of ground water near municipal solid waste dumping sites in reveals that the total alkalinity was found to be in the range of 76 mg/L to 198 mg/L in ground water samples which were caused mainly due to OH^-, CO_3^{2-} and HCO_3^- ions. The comparison of alkalinity of the samples collected from six sampling points in the two seasons is summarized in Fig. 11.

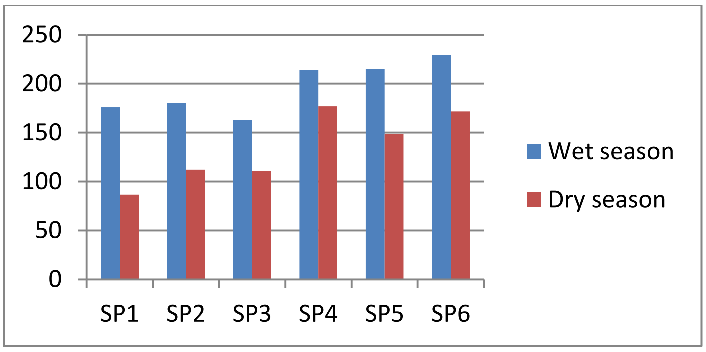

Fig.11. Comparison of alkalinity in Walgamo river in August and December 2016.

Concentration of biological oxygen demand:

The Biological Oxygen Demand (DOD) of water of the sampling points the two months were 2.6 mg/L to 21 mg/L and 7 mg/L to 72 mg/L during dry and rainy seasons respectively. As well as, the standard BOD value for inland surface water is 6 mg/L or less and if it is above this value, it can result threat to the aquatic ecosystem.

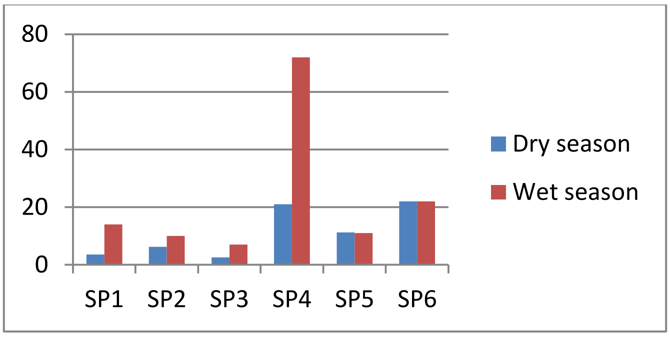

Fig. 12. Comparison of BOD in Walgamo river in August and December 2016.

The BOD at downstream of the river in both seasons is high due to the disposal of untreated sewage, such as from household latrines on the bank of the river. From graph it is visualized that the BOD values at the middle stream (SP4)

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were higher than any other sampling points during wet season. The BOD value varied from 0.61 mg/L to 9.74 mg/L across the study sites during the study period. The comparison of biological oxygen demand of the samples collected from six sampling points in the two seasons is summarized in Fig. 12.

Concentration of chemical oxygen demand and chloride:

The Chemical Oxygen Demand (COD) and Chloride concentration of water of the study area at the sampling points of Walgamo River were 16 mg/L to 177 mg/L are plotted in Fig. 13. It is observed that the highest and lowest COD 177 mg/L, 16 mg/L were observed at Middle stream of the river (SP4) and at upstream of the river (SP2); respectively. But the highest value of chloride concentration 60 mg/L was observed at Middle stream of the river (SP4) and Downstream of the river (SP5). This may be due to higher dose of chloride containing materials like human and animal urine as the population density increases downstream of the River and lowest value of chloride concentration 23.8mg/L was observed at upstream (SP1) of the Walgamo River. The comparison of COD and chloride composition of the samples collected from six sampling points in the two seasons is summarized in Fig. 13.

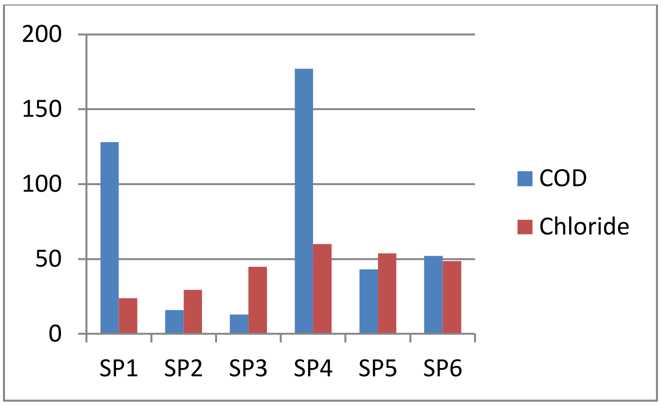

Fig. 13. Comparison of COD and chloride concentration in Walgamo river in August and December 2016.

Concentration of mercury and arsenic:

Arsenic (As) and Mercury (Hg) in water of the Walgamo river at different locations were 0.4105 µg/L to 6.22 µg/L and 2.616 µg/L to 14.26 µg/L; respectively. This shows that the highest Arsenic concentration (6.22 µg/L) was at upstream of the river (SP1) and lowest Arsenic concentration 0.4105 µg/L was observed at Middle stream of the river (SP3). The concentration of Arsenic at the sampling points in the Walgamo River was much above the proposed water quality standards (0.05 ppm). On the other hand, the highest value of Hg concentration was 14.26 µg/L at upstream of the river (SP1) and lowest value of mercury concentration was 2.616 µg/L at Middle stream of the river (SP4). The concentration of Hg at different locations in the study area was much above the accepted water quality standards (0.005

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ppm). From the data and above discussion it is clear that the water of Walgamo River in both the rainy season (August) dray season (December) were not in for domestic consumptions with respect to As and Hg concentration. The comparison of the concentrations of arsenic and mercury of the samples collected from six sampling points in the two seasons is summarized in Fig. 14.

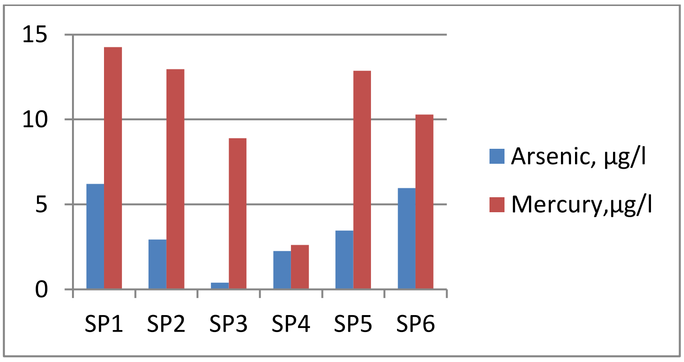

Fig. 14. Comparison of Hg and As concentration in Walgamo river in August and December 2016.

IV. CONCLUSION

The water samples were collected from different sampling points of the Walgamo River to look into the status of the physico-chemical water quality parameters and fresh water elements. The study was conducted during August and December, 2016. The results of the study revealed that the values of pH, Cl^-, and temperature, hardness, were within standard limit but the results of As, Hg, turbidity, BOD, COD and electric conductivity do not fall in the acceptable range. Therefore, Walgamo River is polluted and unsafe for domestic use.

Acknowledgments

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