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Assessment of Physico-Chemical Parameters of Awetu River, Jimma, Oromia, Ethiopia

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ABSTRACT

Water is an essential part of this environment. Water quality is the great public health concern in developing countries and for the study area at large. Water quality assessment can be the evaluation of the physical and chemical nature of water in relation to natural quality, human effects and intended uses. Therefore the aim of this study was to assess the quality of Awetu River through analysis of some selected water quality parameters for irrigation and other domestic purposes in the Jimma town, Oromia, Ethiopia based on physico-chemical parameters. Water samples were collected along the River from four (Upstream, downstream and two points at the midstream) sampling sites and analyzed for various physico-chemical parameters. Accordingly, the results obtained show that some of the physical and chemical parameters were within the accepted range of the guideline recommended by WHO, FAO and Ethiopian standards. In addition to this, some parameters are at alarming state as compared to the standards for different purposes. Therefore, the river water was found to be unfit for human consumption and was found to be safe and utilizable for different purposes by suggesting they need for treatment measures for use of the particular surface water.

Keywords: Awetu River; physico-chemical; pollution; water quality

1. INTRODUCTION

Water is one of the most abundant compounds of the ecosystem. Water recourses have critical importance to both natural and human development. According to (Evans, 2005) the water cycle refers to the continuous exchange of water within the hydrosphere, between the atmosphere, soil water, surface water, groundwater and plants. Rivers are the main inland water resources for domestic, industrial and irrigation purposes and often carry large municipal sewage, industrial waste water and seasonal run off from agricultural land to the coastal region. Water quality is the measure of the state of water resources relative to the requirements of the biotic species and human needs. Water quality depends on the local geology and ecosystem and human activities can negatively affect water quality (Curtis and Morgenroth, 2013; Huang et al., 2014).

The most important of the natural influences are geological, hydrological and climatic since these affect both the quantity and the quality of water available. Assessment of water is not only for suitability for human consumption but also in relation to its agricultural, industrial, recreational, commercial uses and its ability to sustain aquatic life. Assessing the quality of water resources is an essential process in the development of water resources. Due to increasing urbanization, surface water is getting over contaminated and more strict treatments would be required to make surface water potable. Therefore the quality of water

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should be checked at regular time of interval, because due to use of contaminated drinking water, human population suffers from varied of water borne diseases. Water quality is now a global problem (Mahananda et al., 2005).

Around 780 million people do not have access to clean and safe water and around 2.5 billion people do not have proper sanitation. As a result, around 6-8 million people die each year due to water related diseases and disasters (UN-Water, 2013). Ethiopia is one among the lowest to have accessible quality water supply in Sub-Saharan Africa (WHO, 2015). River Awetu is one among the rivers found in Jimma city which faces such huge pollution problems. Therefore the aim of this study was to investigate some physical and chemical water quality parameters of Awetu River for different purpose.

1.1 Water quality parameters

Water quality parameters are classified in to three: such as physical, chemical and biological characteristics of water in association to the set of standards. These parameters directly connected to the safety of the drinking water to human use. Physico-chemical characteristics of water quality constitutes a number of indicators that include some of them are; pH, temperature, conductivity, BOD, COD, Nitrates, TSS and etc. are indicators used to assess water quality.

1.1.1 Physico-chemical water quality

Temperature is one of the most important water quality parameters. Water temperature is affected by air temperature, storm water runoff, groundwater inflows, turbidity, and exposure to sunlight. Temperature is an important determinants because of its direct effect on chemical reactions, rates of reaction, aquatic life and the suitability of water for uses that benefit mankind and the environment (Metcalf and Eddy, 2004).

pH is a measure of how acidic or basic (alkaline) the water is. Solutions with a high concentration of hydrogen ions have a low pH and solutions with a low concentration of hydrogen ions have a high pH. Landscape in a watershed can influence the pH of its waters.

Electrical conductivity is the ability of water to conduct an electrical current, and the dissolved ions are the conductors. The warmer the water, the higher the conductivity. Pure water have very low specific conductance and sea water will have a high conductance.

Turbidity is a measure of the amount of suspended particles in the water. Turbidity is commonly high in surface waters. Sources of turbidity include: soil erosion, waste discharge, urban runoff, eroding stream banks, large numbers of bottom feeders such as carp that stir up bottom sediments, excessive algal growth.

The chemical oxygen demand (COD) test of natural water yields the oxygen equivalent of the organic matter that can be oxidized by strong chemical oxidizing agent in an acidic medium.

Dissolved oxygen is the amount of oxygen dissolved in the water. DO is important in natural water because of many microorganisms. Levels of DO vary depending on factors including water temperature, time of day, season, depth, altitude, and rate of flow.

Nitrogen is abundant on earth, making up about 80% of our air as N_2 gas. Nitrate thus enters streams from natural sources like decomposing plants and animal waste as well as human sources like sewage or fertilizer.

Phosphorus in small quantities is essential for plant growth and metabolic reactions in animals and plants. Sources of phosphate include animal wastes, sewage, detergent, fertilizer. Phosphates do not pose a human or health risk except in very high concentrations. Orthophosphate is the simplest in a series of phosphates, and is usually just called phosphate by both non-technical people and many

chemists alike; see a separate article on phosphate for details. Orthophosphates, also known as reactive phosphates, are a main constituent in fertilizers used for agriculture and residential purposes. Orthophosphates found in natural water provide a good estimation of the amount of phosphorus available for algae and plant growth. This is the form of phosphorus that is most readily utilized by biota. Orthophosphates can be carried into streams and lakes through run off.

Hardness is correlated with total dissolved solids. It represents total concentration of Ca^{2+} and Mg^{2+} ions, and is reported in equivalent $CaCO_3$. Other ions (Fe^{2+}) may also contribute. Hardness expressed as mg/L $CaCO_3$ is used to classify waters from "soft" to "very hard".

Biological Oxygen Demand (BOD) is the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. BOD is the most widely used parameter, and it is a measure of the amount of oxygen used by indigenous microbial population in water in response to the introduction of degradable organic material. The 5-day BOD (BOD_5) is most widely used.

2. MATERIALS AND METHODS

2.1 Study area

Jimma is the largest city in south-western Ethiopia. Jimma city is Located in the Jimma Zone of the Oromia regional state at 352 km southwest of Addis Ababa at an average altitude of 1780 m above sea level as shown in Fig. 1. It has a latitude and longitude of 7°40′N 36°50′E. The town is found with abundant mean annual rainfall between 1800 and 2300 mm which makes this region one of the best watered Ethiopian highland areas. The city has a population density of about 3521 person's per km in 2015 and an average population growth rate of 4.9% per year (Central Statistical Agency, 2015). There are two major rivers flowing through the city: Awetu, which bisects the center of the city and Kito, which flows at the western end.

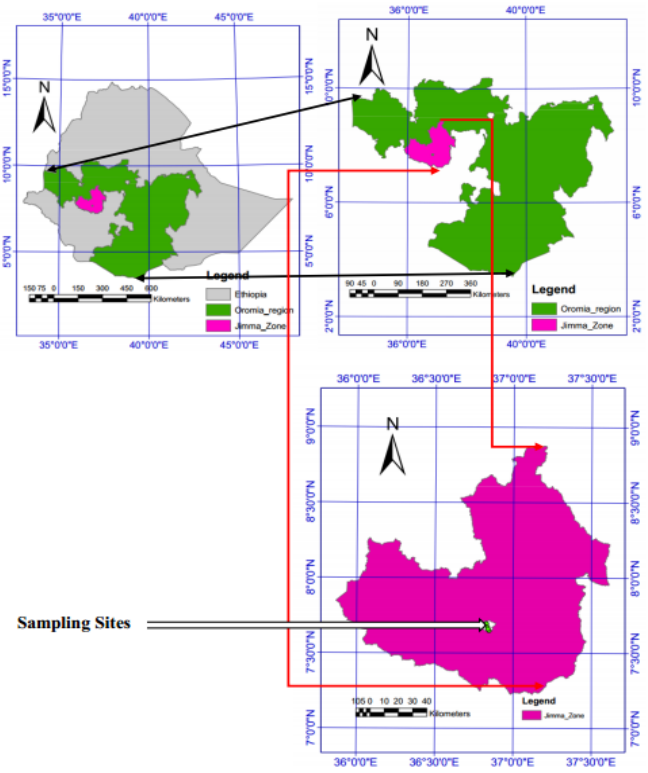

Figure 1 Map of the study area, Jimma, Oromia, Ethiopia

2.2 Sampling station

Sampling points were selected considering that the samples taken are representative of the different sources from which water was obtained. The choice of the stations were made to better represent the quality of the Awetu River water. Water samples were collected from four sampling stations. The four sampling stations (sites) in Awetu River were designated as As1, As2, As3 and As4 and they reflect different activities along the water course of the Rivers. The sampling points were depicted in Table 1 with their coordinates. The sampling sites were carefully selected to include the upstream and the downstream regions. Sampling site As1 represents the upstream where the rivers enter the town and As4 represents the downstream of the rivers ending at Jimma Town.

2.3 Sample collection

A water sample from Awetu River was collected following standard procedure as described by APHA (1998). The samples were collected during the month of June 2018 from 4 sampling sites of Awetu River. Sampling period covers summer and the samples were taken at the end of month at four stations. Water samples were collected one times from each sampling points by using polyethylene and 1 L glass bottles. The recommended minimum frequency of critical measurements in minimum sample numbers water in the distribution system (WHO, 1997). Pre-cleaned plastic bottle was used to collect water sample for physico-chemical analysis. Sample containers were labeled on the field using appropriate code and water samples were temporary stored in ice packed cooler and transported to the laboratory and stored in the refrigerator prior to analysis (APHA, 1998). At all times, fresh reagents were used and great care was taken to avoid chemical contamination.

2.4 Sample analysis

The water samples were analyzed for various physico-chemical parameters using standard methods recommended by APHA. The physico-chemical parameters such as temperature, pH, electrical conductivity, turbidity, total dissolved solids, total suspended solids, dissolved oxygen, biological oxygen demand, chemical oxygen demand, alkalinity, hardness, nitrate (NO_3^-), and orthophosphate were analyzed using the standard analytical methods. The temperature, pH, EC and turbidity were determined on site using Multimeter, turbidity also determined on site using nephelometric turbidity meter. BOD was measured based on oxygen consumed in a 5-d test period (5-d BOD or BOD_5) after arrival of sample to the laboratory. Standard laboratory methods as described by the APHA for the examination of water samples was employed for the analysis of TDS, DO, COD, NO_3^-, and orthophosphate.

3. RESULTS AND DISCUSSION

The results of various physico-chemical parameters for the water samples collected were presented and the results were summarized in Table 2.

Table 1 Water sample labels and sampling locations in Jimma town, Awetu River

S. No.	Sample Labels	Latitudes	Longitudes
1	As1	7.694694	36.8296944
2	As2	7.670917	36.83625
3	As3	7.660139	36.8395
4	As4	7.649417	36.8453611

Table 2 Physico-chemical parameters of Awetu River water samples

S. No	Parameters	Site A_s1	Site A_s2	Site A_s3	Site A_s4	WHO	FAO	Ethiopian
1	Temperature (°C)	25.6	26.1	24.3	22.2	<40	-	15
2	pH	10.06	7.26	6.89	7.5	6.5-8.5	6.0-8.5	6.5-8.5
3	EC (µS/cm)	58.5	77.9	96.6	111.8	750	3000	250
4	DO (mg/L)	5.97	6.19	6.03	1.41	5.0-7.0	>4	-
5	BOD_5 (mg/L)	1000	750	737.6	700	2.0-5.0	8.0	-
6	COD (mg/L)	1250	937.5	922	875	-	-	-
7	Turbidity (NTU)	5.15	6.47	10.03	8.12	5.0	-	5.0
8	Alkalinity (mg/L)	300	440	520	240	120	-	200
9	TSS (mg/L)	180	150	130	90	-	-	-
10	Hardness	162.3	183	362.5	224	300	-	300
11	Nitrate	2.53	2.39	2.01	1.63	45	50	50
12	Orthophosphate	0.023	0.055	0.060	0.063	0.35	0.2	-

3.1 Physico-chemical water quality parameters

3.1.1 Temperature

Temperature of water is basically important because it effects bio-chemical reactions in aquatic organisms. There is a variation of temperature along the river for all sample stations. The highest temperature is being at station 2 and the lowest at station 4. Generally, the river water temperature ranged from 22.2°C to 26.1°C with an average value of 24.15°C and is found within the permissible limit of WHO (2008).

3.1.2 pH

From onsite measurement, pH of the sampled water varied from 6 to 12 with average value of 9. The highest value of pH reading was observed at the upstream and the lowest value at the second sample station of water. According to WHO (2004) and Ethiopian guide line the permissible limit of pH is from 6.5 (lowest value) to 8.5 (highest value). It is known that pH of water (6.5 to 8.5) does not has direct effect but, lower value below 5.0 produce sore taste and higher value above 8.5 has alkaline taste. The pH values of the present investigation were within the standards set for drinking and irrigation purposes, respectively at three stations and above the standard at one station.

3.1.3 Electrical Conductivity

Electrical conductivity is an important parameter for determining the water quality for drinking and agricultural purposes. In this study, electrical conductivity values varied between 58.5 and 111.8 µS/cm. It was seen that the EC was maximum at the downstream station and minimum at the upstream station. The lower EC value is preferable for health of community if the value of conductivity is above 250 µS/cm can cause Anemia, liver, kidney or spleen damage, changes in blood. EC is lower than the permissible limit by WHO for drinking and the limit set by FAO for irrigation purposes. Thus, the result indicated that the river receives low amount of dissolved inorganic substances in ionized form from their surface catchments.

3.1.4 Dissolved Oxygen (DO)

DO an important parameter which is essential to the metabolism of all aquatic organisms that possess aerobic respiration. In the present study, maximum DO was recorded as 6.19 mg/L and minimum value of 1.41 mg/L. Concentration levels of DO below 5.0 mg/L adversely affect aquatic life. Thus in this study, DO ranged from 1.41 to 6.19 mg/L. A minimum value was recorded in Site 4 indicated that the studied Site 4 was susceptible to pollution due to the nearby market and a maximum value was recorded in Site 2 which may be due to self-purification of the water along the course of the river. DO levels are important in the natural self-purification capacity of the river. A good level of DO in sampling sites of the river indicated a high re-aeration rate and rapid aerobic oxidation of biological substances.

3.1.5 Biochemical Oxygen Demand (BOD)

BOD is the amount of oxygen required by bacteria and other microorganisms in stabilizing decomposable organic matter. BOD is a measure of the amount of oxygen used by biological and chemical processes in a stream of water over a 5-day. BOD_5 in the present study ranges from 700 to 1000 mg/L. The BOD values of the river were above the recommended values of WHO, FAO and Ethiopian standard guideline. When BOD levels are high, the oxygen that is available in the water is being consumed by the bacteria. The water sample has more BOD means the water sample is more polluted.

3.1.6 Chemical Oxygen Demand

The Chemical Oxygen Demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals. It measures the amount of oxygen required to chemically oxidize organic compounds in water. COD can be related empirically to BOD, organic carbon or organic matter. In this study the maximum COD was recorded 1250 mg/L and minimum value of 875 mg/L.

3.1.7 Turbidity

Turbidity is measured by the amount of light that is scattered by the sample. The guideline of WHO (2004) and Ethiopian drinking water standard indicate water with turbidity value greater than 5 NTU is not recommended for domestic use. Result obtained from the study showed that, the lowest turbidity value is 5.15 NTU, which was recorded at the Upstream Station. The maximum turbidity was recorded at the third station with value of 10.03 NTU. The average turbidity value of sampled water was 7.4425 NTU. The values obtained for the river were above the permissible limit set by WHO for drinking and FAO for irrigation water. This might be due to the proximity of the studied sites to the market, domestic and municipal wastes. Thus, the entire river was generally polluted posing a great danger to aquatic lives and the people using it for domestic and irrigation purposes. The higher value due to the surface runoff of rainfall.

3.1.8 Alkalinity

Alkalinity is a measure of water capacity to neutralize acids, and is important during softening. In the present investigation, the alkalinity ranged between 240 mg/L and 520 mg/L. Alkalinity at all sites was above the desirable limit of WHO and Ethiopian standard guideline. The high values of alkalinity may also be due to increase in free carbon dioxide in the river which ultimately result in the increase in alkalinity. High alkalinity may cause problems if water is used for irrigation purposes as high alkalinity leads to increase in relative proportion of sodium in soil by precipitating Ca and Mg ions.

3.1.9 Total Suspended Solids (TSS)

TSSs are solids in water that can be trapped by a filter. High concentrations of suspended solids can cause many problems for stream health and aquatic life. Water is filtered, then the residue is dried and weighed then compared to the original sample. The total suspended solids of this study values ranges from 180 to 90 mg/L.

3.1.10 Hardness

Hardness of water mainly depends upon the amount of calcium or magnesium salts or both. The hardness values of the river in the present study were found to range between 162.3 to 362.5 mg/L. The results indicate that the Awetu River is hard based on water hardness classification.

3.1.11 Nitrate

Nitrate is the most important nutrients in an ecosystem. In the present study water samples from different sampling point stations (A_S1 to A_S4) showed low concentrations of nitrate (1.65 to 2.53 mg/L) well below permissible levels as per the standards. According to this study the minimum nitrate concentration is 1.65 mg/L recorded downstream station and the maximum nitrate concentration is recorded at the upstream station with value of 2.53 mg/L.

3.1.12 Phosphate

Phosphorus in small quantities is essential for plant growth and metabolic reactions in animals and plants. Sources of phosphate include animal wastes, sewage, detergent, fertilizer, disturbed land, and road salts used in the winter. Orthophosphate (reactive) is analyzed directly on an unpreserved sample within 48 hours of sampling. The results obtained for this study were maximum and minimum of 0.063 and 0.023 mg/L respectively. The values recorded for orthophosphate were below the recommended values of WHO (2008) and Ayers & Westcot (1994) for drinking and irrigation water respectively.

3.1.13 Sources of water pollution

There are different sources of water pollution in which some of the pollutant may expose human beings and other lives to series problem. Water pollution has many sources, and the most severe is the city sewage and industrial waste discharged into rivers. The industries discharge their residuals directly into waterways, which implies that industrialization has positive relationship with increment of organic water pollution. Rapid growth of industrial capacity has resulted in tremendous increases in the pollution of stream and river water by industrial waste. Surface water can be contaminated by several sources. In urban areas, careless disposal of industrial effluents and other wastes contribute greatly to poor quality water. While industrial production can affect water quality, in turn it can also be negatively impacted by poor water quality.

3.1.14 Mitigation measures

Water pollution is a leading cause of death. It causes many deaths every day. Some of the best practices locally relevant and appropriate mitigations to sustain the water quality and pollution of the river can be: sewage treatments, prevent river water to get polluted, treatment of wastes before discharge, treatment of drainage water, keep the pond water clean and safe, public awareness, effective waste water management system. Generally, pollution could be minimized by adopting these practices by recycling, reusing, waste minimization, mitigating, preventing and compost.

CONCLUSIONS

Quality of water sources in Ethiopia is subjected to contamination and pollution resulting from human activities and natural sources. In this study, physico-chemical analysis was carried out to assess the quality of Awetu water River using a Laboratory based study design. The different water quality parameters (physico-chemical parameters) were performed using the collected samples from the four sampling stations (sites) in Awetu water River were designated as As1, As2, As3 and As4. The Sampling points were selected considering that the samples taken are better represent the different sources of the Awetu water River.

A water Sample collected from Awetu River was during the month of June 2018 following standard procedures. Some of the physico-chemical parameters were analyzed on the field (site) and the other parameters were analyzed after the samples were transported to the laboratory. The result in this study indicates that, some of the physico-chemical parameters analyzed values do not conform to either the Ethiopian Standard, FAO or WHO guideline values. The increasing value of some physico-chemical water quality parameters from the laboratory analysis was recorded as maximum value when compared with reference standards but the water may be used on limited scale for irrigation and industrial cooling and it also shows that most parameters need great care to be used even for irrigation.

In general, consuming water with above of permissible limit value could cause serious health problem. Regular investigation of the water quality parameters as well as ensuring effective use of Treatment Plant for untreated discharge and proper sewerage system would be helpful to improve water quality and ensure water health. Therefore, the local water authority shall strengthen local water quality monitoring and control system as well as risk assessment and management mechanisms.

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