Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.21, 2015

Physico-Chemical Studies on the Pollution Level of Stream Bisnit, Gondar, Ethiopia

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Abstract
This study was carried out to assess the water quality of Stream Bisnit. The water samples were collected along the stream at five different sampling sites. Sample S1 was collected from the upstream and S5 was collected at the nearby of Keha river where it is the receiver of Bisnit water; the rest of sampling sites S2, S3 and S4 are along the stream in between S1 and S5 sampling sites. The various physico-chemical parameters studied were temperature, pH, Electrical conductivity, BOD_5, PO_4^{-3} and NO_3-N. P^H at sampling sites S1(6.4), S2 (6.35) and S3 (6.2) were not in the WHO and Ethiopian EPA surface water permissible Standard but all of the sampling sites temperature records (S1=23, S2=24, S3=24, S4=21 and S5=21) were in the mentioned standard levels, while EC (S1=1703, S2=1719, S3=1777, S4= 1661 and S5=1023), BOD_5 (S1=209, S2=350, S3=447, S4= 258 and S5=164), PO_4-3 (S1=12, S2=26, S3=32, S4=19 and S5=6) and NO_3-N (S1=133, S2=154, S3=180, S4=102 and S5=56) in all of the sampling sites were above Ethiopian EPA and WHO standards. Hence it is recommended that the water condition could be maintained by using Best Management Practices or wastewater treatment methods.
Keywords: pollution, water quality, Physico-chemical analysis, degraded ecosystem

Introduction

Water is the most vital and basic need of life. It is a vital requirement for all life processes and supporting activities. Surface water available in ponds, streams, rivers, lakes and dams is used for drinking, irrigation, power production, etc. Usually sources of drinking water are streams, rivers, wells and boreholes which are not commonly treated. Surface water quality encompasses a wide range of conditions that are part of the aquatic environment. The aquatic environment provides diverse habitat and a clean water supply for aquatic life, wildlife and humans. Rivers constitute major surface water sources for domestic, agricultural and industrial purposes and are essential for the development of human civilization. Surface waters are most exposable to pollution due to their accessibility for disposal of wastewaters (Etim and Obot, 2014).

Water pollution occurs when waste products or other substances change the physical, thermal, chemical or biological characteristics of the water that adversely affects living species and the water benefits. Pollution is becoming a serious problem caused by the disposal of untreated sewage, industrial and agricultural activities (Abdulhameed *et al*, 2014). Increasing population, urbanization and industrialization have increased pressures on water bodies in declining benefits (Clarke, 1994).

A river is polluted when substances degraded the water quality that entered the water way and alters its natural function. Environmental concerns related to health and aquatic ecosystems become global emerging issues. Due to urbanization, industrialization and agricultural activities the function of aquatic systems is disturbed by pollution. Polluted water can harm plants and animals, restrict recreation, spoil scenery, and damage economic uses (Water facts, 1997). The biological status of aquatic environment such as the abundance, biomass and distribution of various indigenous populations which largely depend on their respective physiological condition, dynamics of various life stages, productivity and growth pattern are a reflection of the water quality variables (APHA, 1992). The physical, biological and chemical characteristics of water are important parameters as they may directly or indirectly affect its quality and consequently its suitability for the distribution and production of aquatic organisms (Etim and Obot, 2014). The productivity of aquatic organisms depends on the physicochemical properties of the water body. The maximum productivity is obtained when the physical and chemical parameters are at optimum level (Gupta *et al*, 2013). There is no single or simple measure for water quality. Water may be tested for a few characteristics or numerous substances and contaminants depending on the need. This can be done using the methods by collecting representative water samples from a water body and analyzing them in laboratory or onsite by hand held electronic meters (Etim and Obot, 2014)

The imposed quality standards for surface waters/rivers and streams have to be related with the river usage type. For example, the drinking water implies higher standards than the water used for industrial or agricultural purposes. Water quality monitoring data are used in order to evaluate impacts on aquatic ecosystems. Some of the Significant physical and chemical factors that affect the natural water quality are dissolved oxygen (DO), Biological oxygen demand (BOD), temperature, pH, turbidity, alkalinity, nutrients (Nitrate-N, Phosphate-P), etc. These parameters are limiting factors for the survival of aquatic organisms (Omaka *et al*, 2014). Recently lots of works has been done on fresh water bodies to study changes in their ecological condition (Hussain, 2013 and Etim and Obot, 2014).

Water pollution is an acute problem in all the major rivers of Ethiopia. In the wake of increasing urbanization and industrialization, the pollution potential of stream Bisnit is gaining momentum day by day. The stream flows from the eastern base of Genet Mountain through the center of Gondar city to the south and end by joining river keha. The survey of the stream revealed that all sources of waste water from anthropogenic activities are discharged to the stream. This has caused pollution in the stream to the extent that its water is no more palpable and is posing threat to the survival of aquatic flora and fauna.

It is therefore, desirable to monitor the pollution level over the stretch at Church Gebriel, Mebrathail, Othoparko, Kera and near Keha by collecting and analyzing the water samples with a view to study the physical and chemical characteristics of the stream Bisnit. This study can also help in formulating remedial measure.

Objectives

General objective

The overall objective of this study is to assess the Physico-chemical status of Stream Bisnit, Gondar, Ethiopia.

Specific Objectives

To study the chemical composition of the stream

To identify the degree of pollution of the stream

To determine the Physico-chemical parameters of the stream:, PH, temperature, EC, BOD_5, NO_3-N, and PO_4^{-3} in water.

Materials and Methods

Description of the Study Area

The study area is found in the city of Gondar which is located in the North western Ethiopia, the Amhara national Regional State. Gondar city established 375 years ago. The town had served as administration center for the country. It is located about 734 km from Addis Ababa. Geographically Gondar is bounded by 120 35' 07'' North latitude and 370 26' 08'' East longitudes with an altitude range of 2000-2200m above sea level and with 20°c annual average temperature, 1172 mm average annual rain fall. The coordinate was measured using Global Positioning System (GPS). The total population of the city is about 304,818. The city is the first in terms of population size in the region, Amhara regional state. Some of the town attraction sites have been registered by UNESCO. It has more than 18 historical and natural heritages sites in the city (Gonder town administration Journal, 2006). The Bisnit Stream is a Stream in Gondar city. It raises at the base of Genet mountain and flows from the eastern base of Genet Mountain through the center of Gondar city to the south and end by joining river keha.

Stream Bisnit contribute water to river Keha that drains to River Angereb, part of the tributaries of Lake Tana. Lake Tana is the huge source of Blue Nile River. It serves as natural sewerage lines for domestic and industrial wastes. But river Keha and Anereb are used as source of water for domestic activities including drinking water and bathing.

The upstream site was Church Gebriel Site (S_1), Mebrathail Site (S_2) about 1 km distance in the downstream from site 1, Othoparko Site (S_3) about 2 kms far away from site 2, Kera Site (S_4) about 2 kms far away from site 3 and Keha Site (S_5) in the nearby of the junction point of river keha about 2 kms far away from site 4.

Sampling

The samples were collected in polyethylene bottle at depth between 0.20 to 0.50 meters of the stream. Samples were collected three times at each site (two replicates per site per sampling date, six samples per site) in May 2015 following the protocols used for wadable rivers (King *et al.*, 1996).

Water samples were taken from the five sites for water quality analysis. Water quality sampling was conducted in the dry season, May 2015 when there is no rain dilution factor.

Physico-chemical Analysis

Surface water quality data for 6 physical and chemical parameters collected from 5 different points and were analyzed during the springtime of the year 2015.

Water samples were collected for analysis of nitrate (NO_3-N), orthophosphate (PO_4^{-3}), and biological oxygen demand (BOD_5) as chemical variables and temperature, p^H and electrical conductivity (EC) included as physical variables were measured following water quality assessment protocols. Dissolved oxygen was fixed by the azide modification of the Winkler method to reduce consumption of oxygen by microorganisms after samples were taken from the site until it is prepared for BOD_5 measurement. Water temperature was measured by using a glass thermometer, pH was measured using Jenway model 3305-pH meter and electrical conductivity was measured using Jenway Model 470 conductivity meter.

PO_4 was determined with spectrophotometer (HACH DR/2010, USA) according to HACH instructions and using pillow (prepared reagents). BOD_5 and Nitrate were determined using outlined standard methods for examination of water quality manual that uses standard chemicals and measured using Jenway Model 9200 Jenway Model 6305 UV/Vis. Spectrophotometer (APHA, 1998).

The experimental analysis was made at Dashen brewery quality assurance Laboratory.

Statistical analyses

Graphs were used to evaluate differences in physicochemical parameters among the sites. physicochemical parameters were analyzed using Analysis of Variance (ANOVA) techniques to find whether significant differences existed in the different sampling sites for the parameters studied. P value less than 0.05 was considered to show significant difference. Pearson bivariate correlation analysis was used to relate physicochemical parameters each other. All statistical analysis was performed using the SPSS statistical software (Version 16; SPSS Inc, 2010) and Excel spreadsheet.

Results and Discussion

In this study, the average results for the 6 physicochemical parameters of the five sites are given in Table 1. Except Temperature; pH, EC, BOD_5, PO_4^{-3} and NO_3-N have significant difference among the sampling sites. Physicochemical variables that are modified by habitat disturbances show pollution effect in all of the sites (Green *et al*., 2000). Pond and McMurray (2002) reported that conductivity, dissolved oxygen, pH and organic load (which can be expressed in the form of BOD_5) in degraded habitat were significant factors to compare impaired sites in streams. In this study, of the six variables P^H, EC, BOD_5, NO_3-N and PO_4^{3-} showed habitat degradation in all the five sites.

The correlation among the physicochemical parameters each other is shown in table 2. A positive relationship existed between Temperature and PO_4^{-3} ($r= 0.902$, $p<0.05$) and NO_3-N ($r= 0.920$, $p<0.05$), BOD_5 and PO_4^{-3} ($r= 0.940$, $p<0.05$) and PO_4^{-3} and NO_3-N ($r= 0.893$, $p<0.05$). And a negative relationship existed between P^H and Temperature (°C), EC and NO_3-N ($r= -0.900$, $r= -0.918$, $r= -0.987$ respectively, $p<0.05$).

pH

The Sampling sites p^H range was between 6.2 and 7.1. The highest pH (7.1) was recorded at Site 5 and the lowest (6.2) p^H was recorded at Site 3 (Figure 1). The rest P^H value were S1=6.4, S2=6.35 and S4=6.7. Statistical analysis using ANOVA indicated that pH was significantly different ($p<0.05$) among the sampling sites.

The permissible pH limit for the stream water is 6-9 (EPA, 2003, World Bank Group, 2007 and FDRE EPA and UN Industrial Development Organization, 2003). WHO permissible range is 6.5 to 8.5 (WHO, 2011).

The decrease in pH value at the upstream sites might be due to use of acids in industries as sterilizer of bottles and for other purposes, in MOHA soft drink factory and others. In unpolluted water, the balance between carbon dioxide, carbonate and bicarbonate ions as well as other natural compounds controls pH. The most significant environmental effect of pH involves synergistic effect. Synergy involves the combination of two or more substances, which produces greater effect than their sum (Dodds, 2002). pH can have a direct effect on the physiology of organisms (Abowei, 2010).

Industrial activities generally cause acidification rather than alkalinization of streams and rivers. Acidification is normally the result of low-pH source from industries, such as pulp and paper and tanning and leather industries; Elevated pH values can be caused by increased biological activity in eutrophic systems. A change in pH from that normally encountered in unimpacted streams may have severe effects upon the biota. Direct effects of pH changes consist of alterations in the ionic and osmotic balance of individual organisms, in particular changes in the rate and type of ion exchange across body surfaces. This requires greater energy expenditure, with subsequent effects such as slow growth and reduced fecundity becoming apparent. Aquatic organisms, however, generally have well developed mechanisms for maintaining ionic and osmotic balance. Impacts of indirect pH changes include changes in the availability of toxic substances such as aluminium and ammonia. Gradual reductions in pH may result in a change in community structure, with acid tolerant organisms replacing less tolerant organisms. Streams with acidic pH values have different periphyton (micro flora and fauna living on solid surfaces) communities and lower overall production compared with less acidic streams (FDRE EPA and UN Industrial Development Organization, 2003).

Temperature

Water temperature was varied from 21°C at Site 4 and 5 to 24 °C at Site 2 and 3 (Figure 2). There was no significant difference ($P<0.05$) in water temperatures among all of the sampling sites.

The increment in site 2 and 3, 24 °C compared to sites 4 and 5 of 21°C, might be due to MOHA soft drink factory hot water release (thermal pollution) (Figure 2). The optimum temperature for stream water is 11-25 °C (EPA, 2003). The relative high temperature recorded for Site 2 and 3 could be attributed to discharges of hot water from the soft drink factory operation as Ekhaise and Anyasi (2005) reported similar findings. The temperature permissible limits are of < 30 ºC (World Bank Group, 2007). The temperatures of inland waters limit range is from 5 - 30 °C (FDRE EPA and UN Industrial Development Organization, 2003). WHO drinking water standard is 15 ºC (WHO, 2004).

Electrical Conductivity (EC)

The value of electrical conductivity was between 1023 µS/cm and 1777 µS/cm. The highest EC value was (1777 µS/cm) in Site 3. The lowest value (1023 µs/cm) recorded at Site 5 (Figure 3). ANOVA result showed that there was significant difference ($p<0.05$) among the sampling sites.

The lowest value (1023 µs/cm) recorded at Site 5 but the rest sites recorded highest values. It is generally known that organic loading and effluent discharge increase stream water ionic concentrations and subsequently conductivity. Tolerant species will be enhanced and intolerant species will be eliminated in this water condition. In general, domestic waste water and industrial effluent discharge contribute to this elevated conductivity (Abbasi, 2000).

The electrical conductivity provides an idea about the exchangeable elements present in the water. The source of EC might be ions from organic loading and effluent discharge. The most common quality of water measured in terms of electrical conductivity is salinity or ions. The salinity hazard is low at less than 0.75 µs/cm (Abbasi, 2000). Conductivity at 25 ºC is 0.055 µS/cm in absolute pure water. The optimum EC for stream water is 100 – 1000 µS/cm at 20 º C (EPA, 2003). The federal democratic republic of Ethiopia EPA surface water EC limit is 1000 µS/cm (20 °C) (FDRE EPA and UN Industrial Development Organization, 2003). From this, we can say that all of the sites are of poor water quality.

Biological oxygen Demand (BOD_5)

Biological Oxygen Demand (BOD_5) fluctuated between 164mg/l and 447 mg/l. The downstream Site (S_5) had lower values of mean 164 mg/l. Site 3 had high value of mean (447 mg/l) (Figure 4). Analysis of variance (ANOVA) result showed that BOD_5 was significantly different ($p<0.05$) among the sampling sites.

The key indicator for the oxygenation status of water bodies is the biological oxygen demand (BOD_5) which is the demand for oxygen resulting from organisms in water that consume oxidisable organic matter (Keshebo1, D.L. and Degefu, M. Y., 2015). In this case the result showed there is high biologically oxydisable organic load in the study sites. Mostly unpolluted streams have a BOD_5 that ranges from 1 to 8 mg/l (USEPA, 1976). The optimum BOD_5 for stream water is ≤ 5 mg/l (EPA, 2003 and FDRE EPA and UN Industrial Development Organization, 2003). Thus; the amount of BOD_5 conducted at all of sites shows that the stream was under high human impact. The increase in BOD of the downstream can be attributed to an organic loading from sewage and effluent discharges from MOHA soft drink industry and this is in accordance with the fact that high organic load is found in wastewaters of domestic and industries discharges (Ipeaiyeda and Onianwa, 2009).

Current scientific opinion is that waters with a BOD failing within the range of 0 - 4 mg/l O_2 are of satisfactory quality for sensitive species such as salmonid fish and thus for other beneficial uses. If an upper limit for BOD of 4 mg/l O_2 is adopted as a criterion of satisfactory quality then it is possible to assess the degree to which waters are polluted by reference to this datum. It is most important to remember, however that a BOD figure for receiving water indicates the maximum extent to which the oxygen level may be depleted by the organic matter present (FDRE EPA and UN Industrial Development Organization, 2003).

Phosphate (PO_4^{-3})

The values of phosphate was between 6 and 32 mg/l. Site 3 had relatively higher mean value 32 mg/l of phosphate as compared to the other sampling sites. The lowest mean value 6 mg/l of PO_4 was recorded at site 5 downstream (Figure 5). Statistical analysis using ANOVA indicated that there was significant difference ($p<0.05$) in the value of PO_4^{-3} among the sampling sites.

When excess of phosphate enters the waterway; algae and aquatic plants will grow wildly, choke up the waterway and use up large amounts of oxygen (Akin-Oriola, 2003). The standard for Phosphates should not to exceed 0.1mg/l in any stream (Hyland *et al.*, 1993) and ≤ 0.005 mg/l (EPA, 2003). The federal democratic republic of Ethiopia EPA water quality standard surface water Orthophosphate (Cations and Anions) limit is 0.03 (FDRE EPA and UN Industrial Development Organization, 2003). PO_4^{-3} concentrations all along the sampling sites of Stream Bisinit were higher than standards indicating eutrophication.

The most significant effect of elevated phosphorus concentrations is its stimulation of the growth of aquatic plants. Both phosphorus and nitrogen limit plant growth, and of these, phosphorus is likely to be more limiting in fresh water. The effect is dependent on the form of phosphorus present in the water, since not all forms are available for uptake by plants. Other factors, such as water temperature, light and the availability of other nutrients, also play an important role in limiting plant growth (FDRE EPA and UN Industrial Development Organization, 2003).

Average Summer Inorganic Phosphorous Concentration (µg/l)	*Effects*
<5	***Oligotrophic*** conditions; usually moderate levels of species diversity; usually low productivity systems with rapid nutrient cycling; no nuisance growth of aquatic plants or blue-green algae.
5-25	***Mesotrophic*** conditions; usually high levels of species diversity; usually productive systems; nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms seldom toxic.
25-250	***Eutrophic*** conditions; usually low levels of species diversity; usually highly productive systems, nuisance growth of aquatic plants and blooms of blue-green algae; algal blooms may include species which are toxic to man, livestock and wildlife.
>250	***Hypertrophic*** conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.

Source: FDRE EPA and UN Industrial Development Organization (2003).

Nitrate-Nitrogen (NO_3-N)

The values of NO_3-N fluctuated between 56 and 180 mg/l. The highest NO_3-N value (180 mg/l) was recorded at Site 3. The lowest value (56 mg/l) was recorded at site 5 (Figure 6). ANOVA result showed that there was significant difference ($p<0.05$) among the sampling sites.

The high amount of NO_3-N shown from this result might be due to the decomposition process of sewage and effluent discharges.

Nitrates react directly with haemoglobin in human blood and other warm-blooded animals to produce methemoglobin. Methemoglobin destroys the ability of red blood cells to transport oxygen (Downes *et al.*, 2002). This condition is especially serious in babies under three months of age. It causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrate levels exceeding 1.0 mg/l should not be used for feeding babies (Dodds, 2002). Under certain conditions high levels of nitrates ($\geq$10 mg/l) in drinking water can be toxic to humans. High levels of nitrates in drinking water have been linked to serious illness and even death in infants (FDRE EPA and UN Industrial Development Organization, 2003). Expected levels are < 1.0mg/l (Barbour *et al.*, 1999) and $\leq$ 10 mg/l (EPA, 2003). The federal democratic republic of Ethiopia EPA water quality standard surface water Nitrate limit is 50 mg/l (FDRE EPA and UN Industrial Development Organization, 2003). WHO maximum Nitrate permissible level is 50 mg/l (WHO, 2011). So using the study area water for household services may endanger people as indicated by Downes *et al* (2002); Dodds (2002) and Barbour *et al* (1999).

Conclusion

This study is aimed to assess the anthropogenic impacts on the stream Bisnit water quality and to check the level of pollution at the sampling sites using the selected Physicochemical parameters. From the data collected in this study the Physicochemical parameters analyzed in all of sampling sites showed comparatively high mean values of EC, BOD_5, PO_4^{-3} and NO_3-N. The high mean values were due to domestic and industrial waste discharge to the stream without treatment; while parameters mean value is less in the downstream due to flow regime natural treatment system. The result of the physicochemical parameters analyzed in all of the sampling sites were revealed that the parameters pH, BOD_5, EC, PO_4^{-3} and NO_3-N beyond surface water permissible limit set by Ethiopian EPA, WHO and World Bank and Temperature parameters were found in the safe limit.

Recommendations

From the results of the study, domestic waste, sewage and industrial effluent were affecting stream Bisnit. The water condition could be maintained by using Best Management Practices or wastewater treatment methods. Adequate waste water treatment plant should be applied to reduce the impact of waste water on the study area water bodies. The use of wastewater treatment system can reduce the pollution strength and organic content of the waste. It is also recommended that further studies also need to be conducted on the microbiological quality. Monitoring should be done for the standard parameter to be analyzed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken.

Acknowledgement

I want to thank Dashen Brewery factory for allowing me to have access to the laboratory facilities to this work.

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Table 1. Physicochemical values of the five study sites, Stream Bisnit, Gondar, Ethiopia.

Parameter	Sites					Mean + SD
	S_1	S_2	S_3	S_4	S_5	
pH	6.4	6.35	6.2	6.7	7.1	6.55+ 0.36
T^O(ºC)	23	24	24	21	21	22.60+ 1.52
EC(µs/cm)	1703	1719	1777	1661	1023	1576.60+312.25
BOD_5(mg/l)	209	350	447	258	164	285.60+113.59
PO_4^{3-}(mg/l)	12	26	32	19	6	19.00+ 10.44
NO_3-N (mg/l)	133	154	180	102	56	125.00+ 48.01

Table 1 is a table that shows the average results for the six physicochemical parameters of the five sampling sites in the study area.

Table 2. Pearson Correlation matrix of physicochemical parameters data

Parameters	PH	Temperature (ºC)	EC (µS/cm)	BOD_5 (mg/l)	PO_4^{-3} (mg/l)	NO_3-N (mg/l)
PH	1					
Temperature (ºC)	**-.900***	1				
EC (µS/cm)	**-.918***	.676	1			
BOD_5 (mg/l)	-.794	.761	.682	1		
PO_4^{-3} (mg/l)	-.817	**.902***	.631	**.940***	1	
NO_3-N (mg/l)	**-.987****	**.920***	.874	.878	**.893***	1

The above table shows the correlation among the physicochemical parameters each other of the study area.

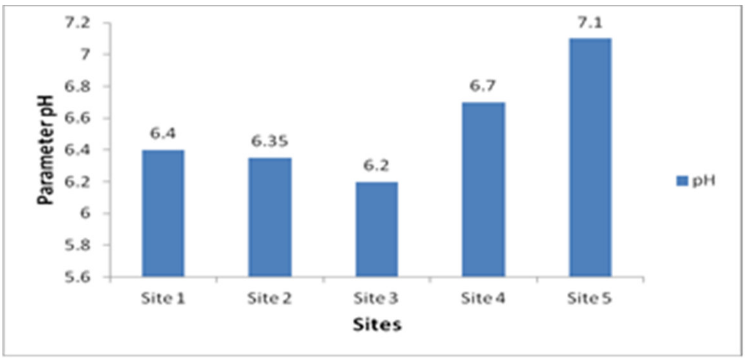

Figure 1. Variation in pH of the five sites in stream Bisnit

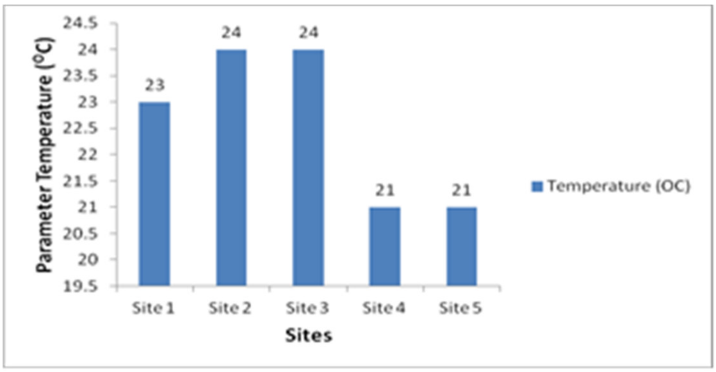

Figure 2. Variation in Temperature of the five sites in stream Bisnit

Figure 3. Variation in Electrical Conductivity (EC) of the five sites in stream Bisnit

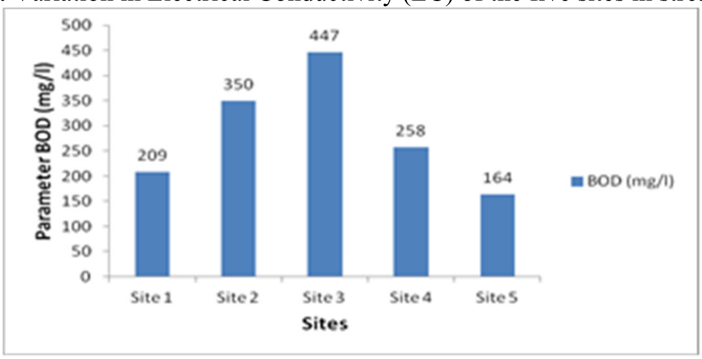

Figure 4. Variation in Biological Oxygen Demand (BOD_5) of the five sites in stream Bisnit

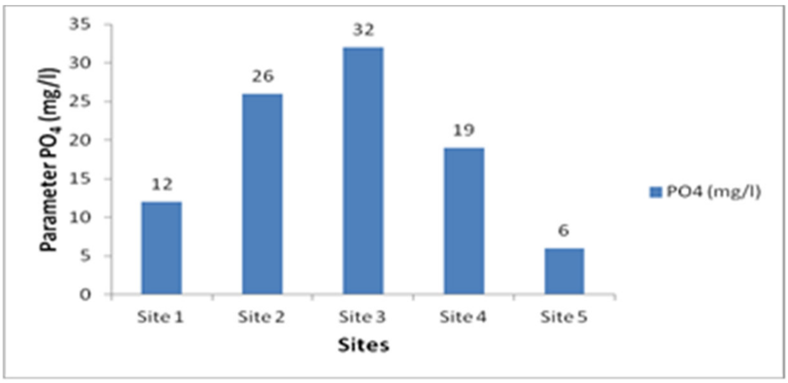

Figure 5. Variation in Phosphate (PO_4^{-3}) of the five sites in stream Bisnit

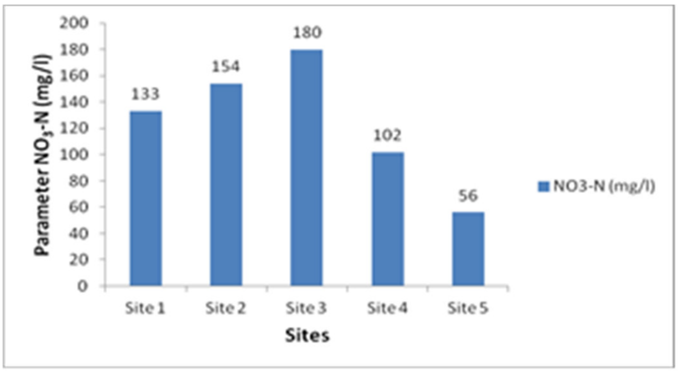

Figure 6. Variation in Nitrate- Nitrogen (NO_3-N) of the five sites in stream Bisnit