Available online at www.elixirpublishers.com (Elixir International Journal)

Applied Chemistry

Elixir Appl. Chem. 127 (2019) 52664-52669

ISSN: 2229-712X

Analysis of Physicochemical Properties of Gilgel Gibe I Hydroelectric Dam Water of Ethiopia

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ARTICLE INFO

Article history:

Received: 13 July 2018;

Received in revised form: 07 February 2019;

Accepted: 18 February 2019;

Keywords

Physicochemical Properties,
Gilgel Gibe I,
Hydroelectric Dam,
Water.

ABSTRACT

In this study, physicochemical properties of Gilgel Gibe-I hydroelectric Dam water were investigated. Water samples were collected three times per day, from six sampling sites of the Dam. Physicochemical parameters including pH, dissolved oxygen (DO), electrical conductivity (EC), Temperature and Turbidity were determined in situ, whereas, other parameters such as alkalinity, total dissolved solids (TDS), total hardness (TH), total suspended solid (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate, nitrate, chloride, fluoride and heavy metals like Fe, Cu, Zn, Co and Cd were analyzed by FAAS in the laboratory. The finding of the study revealed that some physicochemical properties such as pH, EC, turbidity and nitrate of the studied water samples were exceeding WHO permissible limit for surface water and only Fe were investigated in the sample and within permissible limit domestic purposes. But, the remaining studied parameters are below the permissible range prescribed in WHO guideline for the surface water.

1. Introduction

Water is one of the most basic and prime need of life. It is a vital requirement for all life processes and life supporting activities. Surface water is generally available as ponds, rivers, lakes and Dams which is used for drinking, aquatic life, irrigation, industrial development, hydro-electrical generations, fisheries and so on [1]. In human body, water is also used transporting, dissolving organic matter and replenishing nutrients while carrying away waste materials [2]. Know a day water pollutions increase in alarming. It can be polluted by different contaminants emanating from indiscriminate disposal of sewerage, industrial waste and other human activities. Polluted waters have undesirable physicochemical properties and leads to various deleterious effects on human beings as well as aquatic organisms. Hence, investigation of physicochemical properties of different water sources is crucial to know their pollution load and to safely consume them.

Streams, rivers, wells and boreholes are the most commonly used water source without making any pretreatments [3]. Safe (quality) water physicochemical properties which are suitable for human consumption as well as growth of aquatic organisms. Dam or pond is usually formed from river, spring or rain for the sake of control farming, hydroelectric power generation, and recreation [4].

The quality of water depends on its physical, chemical and microbiological properties and thus, affects all water beneficiaries such as fish survival, fish migration, productivity of fish; recreational activities such as boating and swimming, industrial and private water supplies; agricultural activities [5, 6].

Several physicochemical features of water either directly or indirectly have some impact on the quality, production, distribution and growth of fishes. Fish and agricultural production of water also mainly affected by physicochemical properties such as dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), turbidity, pH, temperature, electrical conductivity (EC),alkalinity, total suspended solid (TSS), total hardness (TH), heavy metals and others [3, 7, 8]. In addition, fluoride (F^-), acidity, nutrients (NO_3^-, PO_4^{3-}, organic matter (OM) also indicate pollution level of a given water body [9, 10].

The leachate from open dumps and landfills contain wastes, OM and inorganic particles that can undergo degradation process into simple substances through various biochemical reactions including dissolution, hydrolysis and redox processes could influence physicochemical properties of water [11, 12]. Gilgel Gibe-I Dam was constructed by Ethiopian government for generation of hydroelectric power and surrounded by intensified farmlands, which utilize fertilizers and a range of pesticides for various purposes. The Dam was constructed in close-proximity to hamlet such as Asandabo, Denaba and Sokoru and population dense town called Jimma as well as residential villages which could directly or indirectly disseminate bulk waste to the main tributaries of the dam like Nada, Nadi, Yedi and Gibe river. Besides, people of the area are also using the Dam for fish production and other domestic purposes. However, no study has been conducted on the physicochemical properties of the Dam water. Therefore, in this study the physicochemical properties of the Gilgel Gibe I hydroelectric Dam water were investigated to check whether the Dam water is safe or not for fishery and other domestic consumption.

2. Materials And Methods

2.1. Study area

Gilgel Gibe-I hydroelectric Dam is found between latitude 07^o 48’51.4’’ to 07^o 49’08.0’’ N, longitude 37^o 19’21.6’’ to 37^o 19’57.2’’ E and with altitude ranges of 1660-1670 m. It is

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located in the South West of Ethiopia close to Denaba hamlet at a distance of 211 Km from the capital.

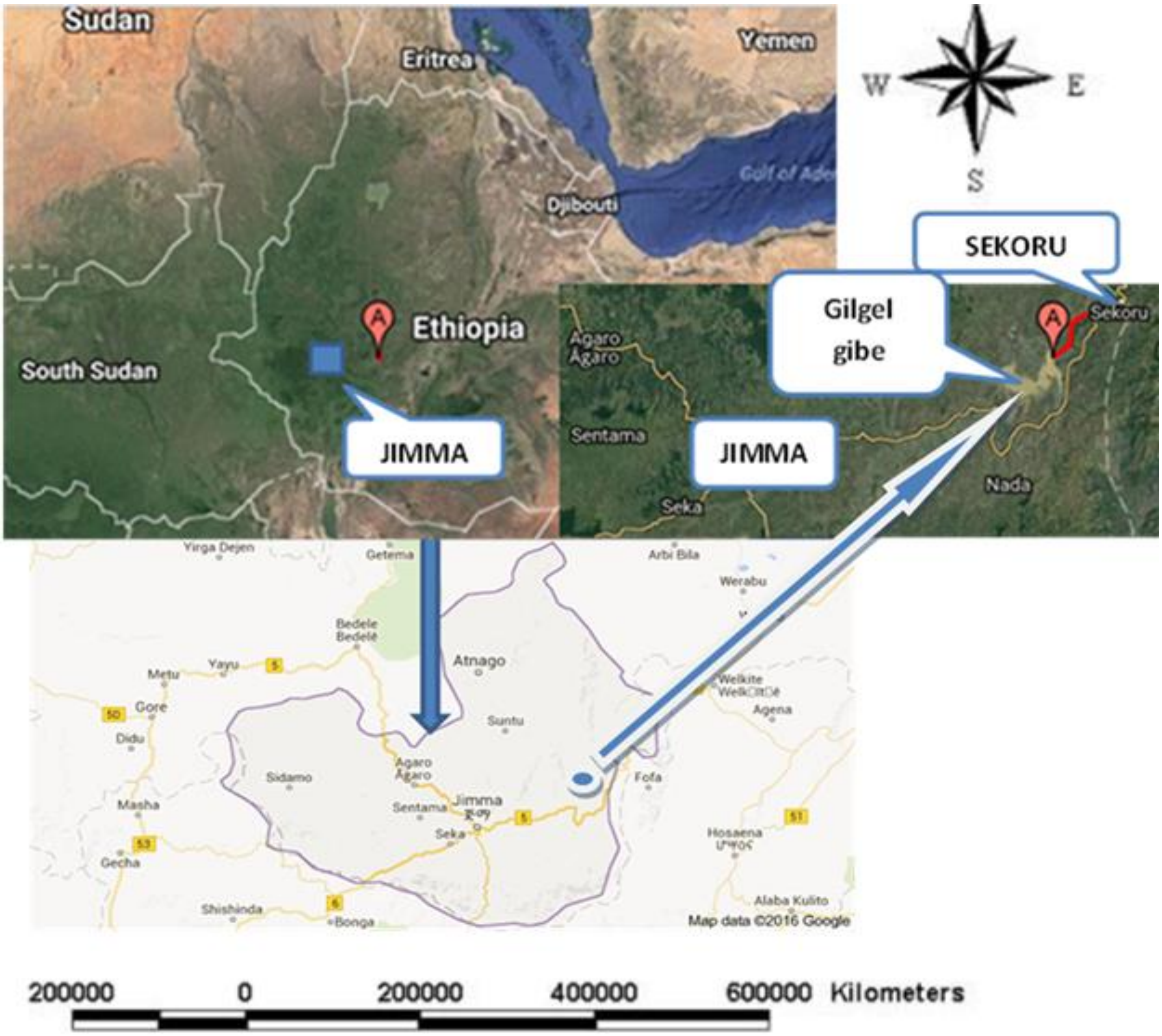

Figure 1. Map of Gilgel Gibe I hydroelectric Dam.

2.2.Sampling site

Geographical coordinates of the sampling points that taken via Global Positioning System (Garmin GPS) is presented in Table 1

2.3. Sampling method and strategy

Water samples were collected by Judgmental (purposive) sampling method. Judgment sampling is non-probability sampling that involves using knowledge about the material to be sampled and reason for sampling, to select specific samples. Such samples are collected from population on the basis of experience, intuition and knowledge of the history or properties of sample that may be termed as “representative” to connote that it is expected to exhibit the average properties of the population [13].

Accordingly, six samples were collected from the Dam water. Three samples were collected at the inlet point of three major tributaries (Gibe, Nada and Nadi rivers) of the Dam. The remaining three samples were taken from the Dam get (where people use for recreational, sanitation and washing vehicles), middle (center) of the Dam (where the bulk water is found) and the out late of the Dam. Sample collection and sample treatment were carried out with the standard technique described by APHA [**14**].

2.4. Sample collection and preservations

Water samples were collected in duplicate from each sampling site three times per day: in the morning, afternoon and evening time of March 2017 [15, 16, 17]. The samples were collected using polyethylene plastic bottles (PEPB) which were washed by socking overnight in 10 % HNO_3 followed by deionized water followed by sterilization for 20 min in autoclave at 121°C. From each site 0.9 L sample was collected. Then, they were acidified with ultra-pure 10% HNO_3 (pH < 2) and transported to the laboratory in ice box and it was kept below 4 $^{\circ}$C until the analysis was carryout [15, 16].

2.5. Chemicals and reagents

Chemicals and reagents used in this paper were analytical graded.

2.6. Water sample preparation

For the analysis of metals, water samples were digested by using the procedure [16, 17]. accordingly, 100 mL water was taken in to the beaker and then 5 mL conc. HNO_3, 3 mL H_2O_2 and 1 mL HCl were added. The content was then digested on a hot plate at 95°C by capping the beaker with the lid (watch glass) until the whole content of the sample is reduced to 10–20 mL. Afterwards, the beaker wall and the lid (watch glass) were washed with deionized water and mixed to the content[18].The obtained digest solution was filtered using Whatman N<u>o</u> 42 filter paper into a 25 mL volumetric flask and topped to the mark. Finally, the prepared sample was transferred to clean polyethylene plastic bottles and kept under 4 ^{o}C until analysis. All digestions were performed in triplicates.

Table 1. Geographical coordinates of sampling sites.

Code	Sampling site/points	Latitude (N)	Longitude (E)	Altitude (m)
GGI-A	Dam get	07° 49'04.6''	37° 19'57.2''	1660
GGI-B	Center	07° 49'05.9''	37° 19'44.7''	1670
GGI-C	Outlet	07° 49'07.2''	37° 19'30.5''	1669
GGI-D	Gibe river inlet	07° 49'08.0''	37° 19'21.6''	1660
GGI-E	Nada guda inlet	07° 48'51.4''	37° 19'38.1''	1661
GGI-F	Nadi inlet	07° 49'02.3''	37° 19'53.7''	1661

Key; GGI= Gilgel Gibe I hydroelectric Dam, A = Dam get, B = Center of the Dam C =Outlet D = Gibe river inlet, E = Nada guda river inlet and F = Nadi river inlet.

2.7. Method of analysis

Physicochemical parameters were analyzed following the method reported by APHA [14]. Accordingly, digital multi meter was used for the pH, conductivity, temperature and DO measurements. Fluorides was determined by using ion selective electrode (ISE).Turbidity was measured by Turbid-Meter, Alkalinity, Chloride and total hardness were determined by titration. COD, $PO_4^{3-}$and NO_3^- were determined using spectrophotometric technique. The heavy metals (Fe, Cu, Zn, Co, and Cd) were analyzed by using FAAS.

The operation condition of FAAS according to guideline of manufacturer industries (Table 2). Parameters such as DO, pH, temperature, conductivity and turbidity were measured at sampling sites.

Table 2. Flame atomic absorption spectrophotometer operating condition.

Elements	Fe	Cu	Zn	Co	Cd
Lamp current (mA)	3	1.5	4	4.5	5
Fuel	Acetylene				
Oxidant	Air	Air	Air	Air	Air
Wave length (nm)	248.3	324.7	213.9	240.7	228.8
Slit width (nm)	0.2	0.7	0.7	0.2	0.7
Manual LOD (ppm)	0.05	0.005	0.005	0.05	0.01

2.8. Statistical analysis

One-way ANOVA and Pearson correlation coefficient ($p \leq 0.05$) were employed to evaluate whether the studied water samples collected from six sampling sites have significant differences in terms of their physicochemical properties or not.

3. Result and discussion

3.1. Calibration curve

For the quantitative determination of the studied metals, external calibration curves were constructed by using five series of standard solutions for the metals. Standard solutions for each of analytes were prepared based on the instrumental manual detection limits (**table 3**). The obtained curves were exhibited good linearity with coefficient of determination, r^2, 0.9987 which is very good correlation. The limit of detection (LOD) and limit of quantification (LOQ) of the employed methods for metals analysis were determined from standard deviations of five blank samples prepared [19].

3.2. Recovery Test

The efficiency of the utilized analytical procedures was evaluated by spiking water sample with known concentration of the studied analytes. With the exception of Cu, which was found to be 52%, the %R of the studied analytes were ranging from 95-113%, which is laying acceptable range for metals as table 4 below [20].

Table 4. Percentage recoveries of the analytes.

Analyte	Fe	Cu	Zn	Co	Cd
%R	99	52	109	113	106

Physical parameters

Physicochemical properties of Gilgel Gibe I hydroelectric Dam water of six sample sites were presented in Table 6. The results of temperature, EC and turbidity were given in °C, μS/cm and NTU respectively, whereas, for the remaining parameters mg/L was used (Table 5).

Table 3. Details of calibration curves of the studied metals.

Analyte	Fe	Cu	Zn	Co	Cd
R^2	0.9987	0.9987	0.9987	0.9987	0.9987
LOD	0.052	0.0055	0.005	0.0535	0.01
LOQ	0.53	0.051	0.051	0.53	0.1
Regression equation	y = 0.0234x - 0.0013	y = 0.0234x - 0.0013	y = 0.0234x - 0.0013	y = 0.0234x - 0.0013	y = 0.0234x - 0.0013

LOD: Limit of detection; LOQ: Limit of quantification;

Table 5. Result of each parameter from all sample sites with WHO limit.

**	GG-1	GG-2	GG-3	GG-4	GG-5	GG-6	WHO*
Tem.	26.93 ± 0.06	26.90 ± 0.20	28.36 ± 0.35	30.10 ± 0.00	30.00 ± 0.00	30.93 ± 0.47	26-32
pH	9.34 ± 0.01	9.55 ± 0.02	9.43 ± 0.04	9.64 ± 0.01	9.53 ± 0.06	9.43 ± 0.03	6-8.5
EC	94.90 ± 0.52	94.80 ± 0.00	95.13 ± 0.15	94.36 ± 0.25	95.10 ± 0.52	95.26 ± 0.06	15-50
Turb.	49.43 ± 1.15	39.46 ± 1.50	32.13 ± 0.15	34.56 ± 0.12	31.93 ± 0.29	37.03 ± 0.06	5-10
DO	5.90 ± 0.07	6.30 ± 0.07	6.66 ± 0.01	6.74 ± 0.03	6.67 ± 0.03	6.62 ± 0.01	4-6
TSS	6.26 ± 0.03	5.41 ± 0.58	9.71 ± 0.28	23.10 ± 0.01	12.16 ± 0.02	17.21 ± 0.02	100
COD	52.46 ± 0.06	29.34 ± 0.06	60.48 ± 0.07	39.06 ± 0.06	29.70 ± 0.00	28.31 ± 0.06	255
BOD	3.89 ± 0.02	2.37 ± 0.01	2.65 ± 0.01	1.39 ± 0.02	0.99 ± 0.03	1.12 ± 0.01	20-30
TDS	64.49 ± 0.72	71.64 ± 2.33	45.55 ± 1.20	83.31 ± 0.68	70.90 ± 0.11	102.79 ± 0.92	450
Alka.	32.01 ± 0.02	28.07 ± 0.11	20.36 ± 0.31	32.83 ± 0.67	16.80 ± 0.35	24.14 ± 0.35	120
TH	32.02 ± 0.02	36.08 ± 0.02	30.42 ± 0.02	30.39 ± 0.53	29.93 ± 0.06	31.43 ± 0.20	200
Cl^-	21.18 ± 0.09	28.37 ± 0.02	21.27 ± 0.01	35.49 ± 0.01	35.28 ± 0.03	42.54 ± 0.01	250
NO_3^-	2.38 ± 0.34	1.56 ± 0.67	2.67 ± 0.06	2.39 ± 0.28	2.10 ± 0.26	2.68 ± 0.18	0.5
PO_4^{-3}	3.48 ± 0.46	2.04 ± 0.42	1.63 ± 0.26	1.97 ± 0.28	2.69 ± 0.03	2.82 ± 0.08	10
F^-	BQ	BQ	BQ	0.62 ± 0.03	0.61 ± 0.051	BQ	1.5
Fe	2.51 ± 0.06	1.57 ± 0.28	01.96 ± 0.02	2.49 ± 0.41	02.24 ± 0.43	2.01 ± 0.43	10

*BQ: Below quantification limit; ND:not detected; *Permissible limit in mg/L; **parameter*

Temperature

In the present study, water temperature was ranged between 26.90 - 30.93 °C. The variation in temperature may be due to different timing of collection and influence of season [21]. This was found to be within the permissible limit of the WHO standards.

pH

The pH is a measure of the hydrogen ion concentration in water. The pH value of Dam water was ranged between 9.34 - 9.64 with the average value of 9.48. Maximum pH was recorded from GGI-D sample; this may be due to the incoming of wastes through the gibe river. The alkalinity of the Dam might be due to the anthropogenic activity observed during sampling and the various ionic species that contribute mainly to alkalinity includes bicarbonates, carbonates, hydroxides, phosphates, borates, silicates are accountable to alkalinity [21].

Electrical conductivity

Conductivity of Dam water across the surface sampling sites varies between 94.36 - 95.26 µS/cm. The source of EC may be an abundance of dissolved salts due to poor irrigation management, minerals from rain water runoff, or other discharges [22]. This value reveals within the range recommended by WHO indicating safe for aquatic environment [23].

Turbidity

The turbidity values ranges from 31.93 - 49.43 NTU. The turbidity was due to improper disposal of sewage, surface runoff and wastewater from different domestic activities [24, 10]. Turbidity and TDS could have positive correlation and the obtained result was similar to this report [25].

Dissolved oxygen

From insitu analysis, DO is the one which indicates the conducive status of the Dam. In this investigation dissolved oxygen ranged from 5.90 - 6.74 mg/L. The value indicating that, the DO level is suitable for the aquatic life in the Dam [26]. DO is a key test in water pollution and waste treatment process control [27, 28].

Total suspended solid

The values obtained from this study ranged from 105.41 - 137.21 mg/L. The high TSS was due to the existence of carbonates, bicarbonates, chlorides, phosphates and nitrates of metals such as calcium, magnesium sodium, potassium and other particles in effluent of water [29]. Accordingly, the Dam water showed that the water doesn't cause health problem to the water product consumers [30].

Chemical oxygen demand

The amount of COD concentration obtained from the Dam water was ranged from 28.31 - 60.48 mg/L. This value might be due to the presence of chemicals that are oxygen demand in nature coming from washing of different vehicles and surface runoff.The significance difference among sites because of the presence of some chemicals coming from water runoff, car wash, fertilizers used on farm land and degradation due to nature [10].

Biological oxygen demand

BOD of Dam water was determined to be in the range of 0.98 - 3.89 mg/L. BOD values were smaller than COD in the Dam. Increased levels of BOD and COD decrease the dissolved oxygen content of the Dam water. That is why DO value is a little bit lower [28]. The entire result is optimal and normal for aquatic activities [27, 31, 32].

Total dissolved solids

The obtained TDS value was ranged between 45.55 - 102.79 mg/L. It may rise due to inorganic salts, organic matter and other dissolved material in water comes across the tributaries [33].

Alkalinity

In the present study, alkalinity of the sample was ranged between 16.80 - 32.83 ± 0.67 mg/L. This is due to the availability of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxyl (OH^-) anions in water [34].

Hardness

The Hardness of each sample was ranged between 29.93 - 36.08 mg/L. This result may be due to the existence of dissolved or polyvalent cation (Calcium, Magnesium, Iron, Barium and Manganese) concentrations in the Dam water [35]. The dam water it seems to be moderately hard water [27].

Chloride

The recorded values from six samples were in the range of 21.18 - 42.54 mg/L. The higher chloride concentration in this sample point might be due to the discharge of domestic sewage containing a large amount of chlorides or surface runoff, inorganic fertilizers, landfill leachates, septic tank effluents and animal feeds can contributes chloride content [36, 37].

Nitrate

In this study Nitrates ranged between 1.56 - 2.68 mg/L. This may be due to agricultural runoff, or from contamination by human or animal wastes [34].

Phosphate

In this study the level of phosphates was ranged between 1.63 - 3.48 mg/L. This may be due to existence of phosphate as free ion in water systems and as a salt in terrestrial environments used in detergents for water softeners.

Fluoride

In the present study concentration of fluoride was quantified at GGI-D and GGI-E as 0.61 ± 0.051to 0.62 ± 0.04 mg/L respectively. The other sample points are observed as bellow the quantification limit. When the obtained result is compared with the WHO guide line, it is found within the permissible range which can favor the life the aquatic environment [38].

Heavy metals

Heavy metals: Fe, Cu, Zn, Co and Cd were analyzed by FAAS. From the studied heavy metals only Fe was determined in all sampling points which indicate that the water is safe for domestic consumption in terms of the studied metals, as per the guideline of WHO. Cd were not detected, whereas Zn, Cu and Co concentrations were found to be below the LOQ of the method.

The observed concentrations of Fe in the Dam water samples were varying between 1.56 ± 0.28 and 2.51 ± 0.06 mg/L, with the mean value of 2.13 ± 0.43 mg/L. The variation in the concentrations of Fe in the Dam water may be due to domestic discharge and other anthropogenic activities [39]. ANOVA analysis ($p < 0.05$) also indicated that the observed concentrations of Fe are significantly different among the sampling points. The observed difference is due to temperature, water and rock interaction believed to be the main driving force behind the existence of trace metals in the Dam. However, the Dam Water Fe content is within the WHO standard limit.

3.3. Analysis of variance for physical parameters

In the comparison of the physical parameters of the Dam water samples significant differences are observed between the investigated pH, EC, DO, turbidity and temperature of the measured value. The difference among the physical properties of Gilgel Gibe I hydroelectric Dam water samples were due

Table 6. Correlation value between two variables of the water parameters.

Fe	**0.17**	**0.01**	**-0.09**	**0.16**	**-0.09**	**0.25**	**0.23**	**0.06**	**0.06**	**0.23**	**-0.55**	**0.00**	**0.15**	**0.29**	**1**
PO_4^{-3}	-0.07	-0.55	0.19	0.64	-0.54	0.32	-0.12	0.24	0.28	0.16	-0.04	0.07	0.23	1	
NO_3^-	0.38	-0.34	0.09	-0.14	0.29	0.49	0.39	-0.03	0.06	-0.07	-0.58	0.07	1		
Cl^-	0.85	-0.44	0.04	-0.39	0.57	0.71	-0.81	-0.89	0.89	-0.15	-0.19	1			
TH	-0.64	0.03	-0.09	0.44	-0.51	-0.37	-0.3	0.33	0.04	0.36	1				
Alka.	-0.33	0.06	-0.55	0.65	-0.48	0.17	0.11	0.43	0.22	1					
TDS	0.63	0.24	-0.03	0.01	0.21	0.82	-0.75	-0.61	1						
BOD	-0.86	-0.62	-0.04	0.75	-0.83	-0.42	0.71	1							
COD	-0.42	-0.49	0.01	0.19	-0.24	-0.28	1								
TSS	0.72	-0.11	0.10	0.02	0.25	1									
DO	-0.77	0.57	0.02	-0.94	1										
Turb.	0.61	-0.56	-0.06	1											
EC	0.11	-0.44	1												
pH	0.33	1													
Tem.	1														
Para.	**Temp**	**pH**	**EC**	**Turb.**	**DO**	**TSS**	**COD**	**BOD**	**TDS**	**Alka.**	**TH**	**Cl^-**	**NO_3^-**	**PO_4^{-3}**	**Fe**

to the discharges of effluents, sewage, inappropriate fertilizer usage, agricultural runoff, septic leachate, some small scale industries waste and ruminants from municipality of Jimma.

3.4.Analysis of variance for chemical parameters

Chemical properties of the Dam water samples show that the significant differences are observed between all the investigated parameters except COD of the measured value. COD have no significance difference. But the variation between the samples may not from systematic rather it is only from random error of the analysis process. The statistical difference observed at 95% confidence level among the chemical properties of Gilgel Gibe I hydroelectric Dam water sample mean might be due to the various anthropogenic activities and natural phenomenon such as minerals from discharges, effluents, sewage, poor fertilizer usage, agricultural runoff, pesticides, herbicides, septic leachate, some small scale industries waste and ruminants from municipality of Jimma hamlets that interred in to the Dam water through the tributaries.

4.5.3. Pearson correlation studies

Mutual relationships between two variables were measured by using Pearson correlation coefficient. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of the other. The correlation studies among various physicochemical parameters of water are presented in Table 6.

Strong positive correlation of temperature with (BOD, chloride and turbidity) has been obtained. This may be due to the highly related anthropogenic input and any other natural phenomenon. Moderately positive correlation of temperature with (TSS and TDS); pH with (DO), BOD with (turbidity, alkalinity and Cl) also obtained. This may be due to the common factor that arises from species having similar chemical constituents. High negative correlation of DO with Temperature and BOD were obtained this may be due to the fact that when there is increase in temperature, the amount of dissolved oxygen gas is decreased. Moderate negative correlation of temperature with TH; pH with (turbidity, phosphate and BOD); BOD with (TDS) has been obtained this may be due to the adsorbed nature of ions. The others have showed weak positive for instance: EC is positively correlated with (PO_4^{3-}, NO_3^- TSS and Cl^-) this may be due to the existence of dissolved ions in less amount when it was compared with the hugeness of the Dam. For the other parameters the positive and negative correlation indicating that the presence or absence of one parameter can affect in a weak way.

4. Conclusion and Recommendations

The present study was aimed to investigate physicochemical properties of Gilgel Gibe I hydroelectric Dam water. Various parameters including temperature, pH, EC, turbidity, DO, COD, BOD, TDS, alkalinity, TH, Cl^-, PO_4^{3-}, NO_3^- and heavy metals (Fe, Cd, Co, Cu, Zn) were studied. The observed results demonstrated that the water has higher pH, EC, turbidity and NO_3^- as compared to the permissible limit set in WHO guideline for surface water. However, the remaining studied physicochemical properties were within acceptable ranges prescribed in WHO guideline. Generally, the obtained results indicated that the Dam water is safe for aquatic life in terms of the other studied physicochemical properties except pH, EC, turbidity and NO_3^- and heavy metals: Fe, Cu, Zn, Co and Cd were analyzed by FAAS. From the studied heavy metals only Fe was obseved in all sampling points which was in permissible limit for domestic purpose as per the guideline of WHO. But, to keep the physicochemical properties of the water within the permissible ranges, regular monitoring is needed. Therefore, the concerned bodies (both governmental and non-governmental organizations) should give due attention to save the quality of the Dam water to use for different purposes.

Acknowledgements

Authors are thankful to the post graduate coordinate office, College of Natural Sciences, Jimma University, Jimma, Ethiopia for providing necessary facilities to carry out this research.

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