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Analysis of water quality of Selameko man-made reservoir using physico-chemical parameters for fishery, Debre Tabor, South Gondar (Ethiopia)

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Water quality is connected with physical, chemical and biological (including bacteriological) characteristics and these characteristics are determined the healthy status of any aquatic ecosystem. To determine whether the water quality of Selameko reservoir is good for fishing, physico-chemical parameters measurements were made. Water quality parameters, such as temperature, water transparency, water depth, dissolved oxygen, pH, total dissolved solids, phosphate, nitrate, and silicate were measured in-situ from two sites (littoral and open water zone) of the reservoir. Temperature of the water of the reservoir ranged from 18.7 to 24.2°C,water depth (only for open zone) 10.5 to 13.04 m, pH 7.01 to 8.01, DO 5.0 to 6.15 mg/l, transparency depth 32 to 97 cm, TDSs 67.1 to 137.2 ppm, NO_3-N 0.1 to 2 mg/l, PO_4-P 0.08 to 0.83 mg/l and Silicate 0.09 to 22.5 mg/l. ANOVA result of the physicochemical parameters showed presence of significance difference among seasons and between sites ($p<0.05$). The study concluded that some of physicochemical parameters such as NO_3-N and PO_4-P were indicated the presence of reservoir water pollution and not good fishing activity. The reservoir water was eutrophic (productive) throughout the year. To avoid such pollution, basin and reservoir management are recommended.

Key words: Physco-chemical parameters, fish, temperature, aquatic.

INTRODUCTION

Ethiopia has many small, medium and large reservoir dam constructed for hydropower generation, irrigation and drinking water supply (FAO, 2010). Even though dam reservoirs are providing these values, they are unable to achieve their end goal due lack of good water quality. The most important challenges are accumulation of excess sediments (Abood et al., 2009; Lee et al., 2009; Cowie, 2002; White and Bettess, 1994), eutrophication (Granit and Lindstrom, 2009; Henry et al., 2004; Little, 2004), toxicity (Holdren et al., 2001), as well as threatening factors, such as clearing of lands, application of agriculture fertilizers and pesticides for the surrounding farm land, rural and urban settlement, industrial development (Granit and Lindstrom, 2009; Mustapha,, 2008; Ostojic et al., 2005); high demographic density (Jansky et al., 2002), release of untreated wastewaters

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(Henry et al.,, 2004), land use pattern of watershed and sanitary situations of inhabitants (Bhattarai et al.,, 2008), etc. Most of the challenges are the problems of all reservoirs which are found throughout the world and unavoidable (Abood et al., 2009).

Generally, water quality is connected with physical, chemical and biological (including bacteriological) characteristics (Straskraba and and Tundisi, 1999; Nancy,, 2009) and these characteristics are determined the healthy status of any aquatic ecosystem (Venkatesharaju et al., 2010). Therefore, assessing the quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem. Once, the physicochemical characteristics of water bodies are affected then species composition, abundance, productivity and physiological conditions of aquatic organisms are badly affected (Granit and Lindstrom, 2009; Goldman and Horne,, 1983). Before the water quality is deteriorated, checking their current status of the reservoir water so crucial to give urgent resolution. Therefore, the present study was conducted to understand the physicochemical properties of Selameko man-made reservoir for fishing activity for one year from August 2009 to May 2010.

METHODOLOGY

Description of the study area

This study was conducted at Selameko manmade reservoir, Debre Tabor Town, Ethiopia. This man-made reservoir is found 2513 m above sea level (masl), specifically located at 38° 05' E and 11° 53' 24'' N (Figure 1). The reservoir was constructed in 2007 with a total of 11.6 ha of area and 20 m depth to irrigate nearly 63 ha. The catchments are extended from 2513 to 2726 masl with 879.25 ha of total areas. The reservoir water fluctuate was mainly depending on inflows: rain from the catchments and supply from Selameko river; and outflows connected with releasing for irrigation and dam crack, and due to direct evaporation of reservoir water. Because of the presence of these unbalance, the water depth was decreased by (from 13.04 m at August, first sampled month to 10.50 m at the first week of May, the last sampled month) 2.54 m in one year. Totally 6.96 m depth of the reservoir was filled by silts within three years.

Climate and hydrology

Based on the National Metrology Agency of Bahir Dar Branch Office, the study area mean annual temperature was 16.23°C (minimum 9.2°C and maximum 23.26°C) (from 1997 to 2009), and its mean annual rainfall was 1371.2 mm (minimum 1096.7 mm and maximum 1645.7 mm) (from 1999 to 2009). The climate of Selameko reservoir is characterized roughly by four seasons: (1) A main-rainy season (MRS) with heavy rains during July–September, (2) a post-rainy season (PORS) between October to November, (3) a dry season (DS) between December to April and (4) a pre-rainy season (PRS) from May to June (Tamiru, 2006; Ayalew et al., 2007).

Physicochemical samples were collected in one year, from August 2009 to May 2010 in the four seasons, that is, main rainy season /MRS/, post-rainy season /PORS/, dry season /DS/ and pre-rainy season /PRS/. The water samples were taken only from littoral (SI) and open water zone (SII) two times from each for each parameter (Figure 1).

Water temperature and pH, total dissolved oxygen (TDO), total dissolved substances (TDSs) and water transparency were determined *in-situ.* Water temperature and pH were measured with coupled pH/TDS/CON Meter (Model Tochpro II); TDO was determined by portable oxygen analyzer (JPB-607); total dissolved substances /TDSs/ was measured by cond/TDS meter (Model CE 470 Cond. Meter 01189); water transparency depth (WTD) was measured by standardized meter and transparency was measured by standardized Secchi disc (having white and black color with 25 cm in diameter). The physco-chemical parameters measurements were taken after the probes dipping down from the surface water to 50 cm down in the reservoir water. Major nutrients, nitrate (NO_3-N), phosphate (PO_4-P) and silicate (SiO_2) were measured in-situ immediately by using a portable water analyzer kit (Wagtech international, Palintest transmittance display photometer 5000, Palintest Ltd., and UK) (Palintest Ltd.,1989). The collected water samples from the two sites were first filtrate by Whatman GF/C, 0.6 to 0.7 µm pore size membrane filter.

Data analyses

Analysis of variance (ANOVA) was used to test significant differences between those like spatial and temporal variations of physico-chemical ($p<0.05$). Tukey (Honestly Significantly Differently Test) test was used to determine significance in mean catches and estimates. In general, data were calculated and organized using appropriate statistical software, such as the SPSS (2007) version 16 and SAS (2003).

RESULTS

Physicochemical measurements (in seasons and sites)

Temperature of the reservoir water ranged 18.7°C (PORS) to 24.2°C (DS) (21.5 ± 1.28°C, SI) and 19.7°C (MRS) to 24.2°C (DS & PRS) (22.23 ± 1.16°C, SII). The reservoir water depth of the open water was between10.5 m (PRS) to 13.04 m (MRS) (11.33±0.58m).The pH of the reservoir extended from 7.42 (DS) to 8.01 (PORS) (7.69±0.12, SI), and 7.01 (DS) to 7.42 (MRS) (7.26± 0.094, SII). DO range from 5.1 to 5.9 mg/l (5.47 ±0.17 mg/l, SI) and 5.0 mg/l to 6.15 mg/l (5.56 ±0.27 mg/l, SII). Both the highest (6.15 mg/l, MRS) and lowest (5.0 mg/l, DS) were recorded in open zone.

The transparency depth varied from 32 (MRS) to 67 cm (PORS) (50.25 ± 8.46 cm, SI) and from 42 (MRS) to 97 cm (PORS) (72±12.77 cm, SII). TDSs were between 67.1 to 98.4 ppm (81.8 ±6.94 ppm, SI); and between 67.1 to 137.2 ppm (102.26±15.11 ppm, SII). The maximum value of TDSs (137.2 ppm) was recorded in MRS (open zone) and the minimum was (67.1 ppm) in PORS in both sites (Table 1). NO_3-N concentration extended from 0.21 (POR) to 1.85 mg/l) (MR) (0.71 ±0.34 mg/l, SI), and 0.1 (DS) to 2 mg/l (MRS) (0.758 ±0.43 mg/l, SII). Both the highest (2 mg/l) and the lowest (0.1 mg/l) were recorded in open zone. Concentration of PO_4-P ranged from 0.12 to 0.83mg/l (0.388 mg/l±0.26, SI) and 0.08 to 0.45mg/l

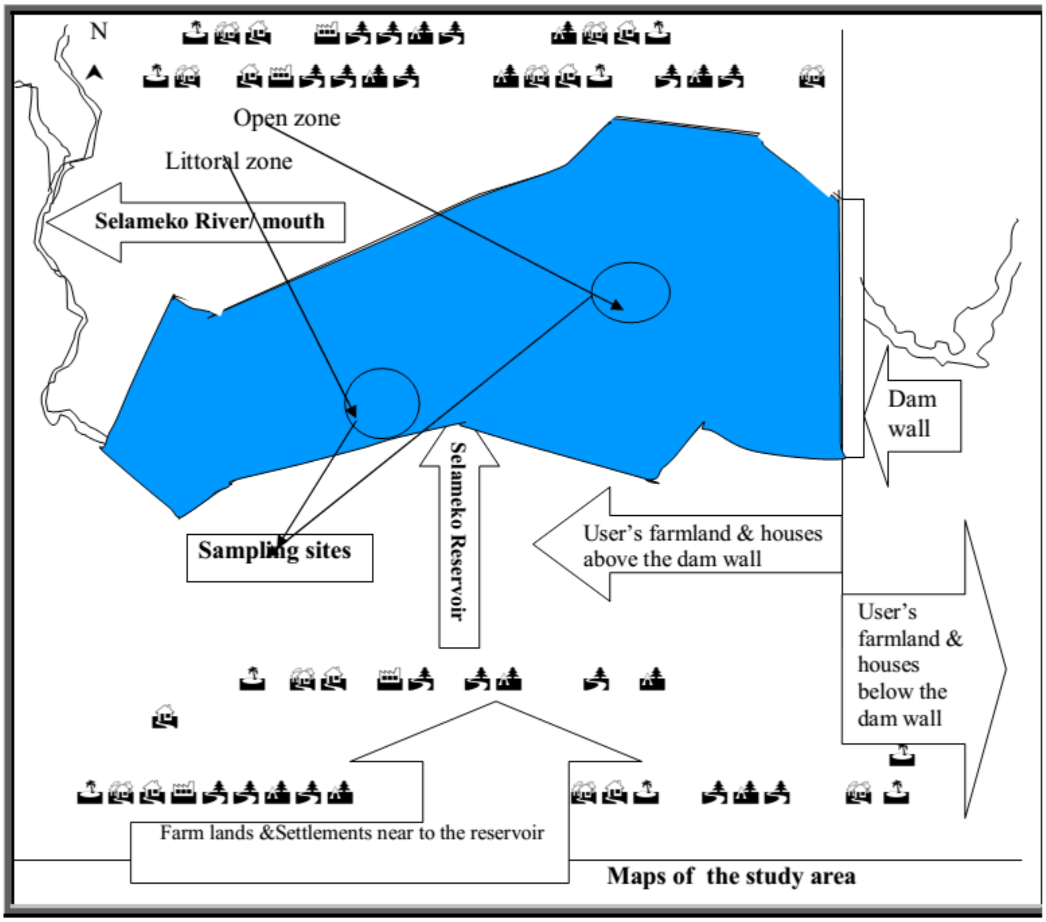

Figure 1. Map of Selameko man-made reservoir and their surrounding activities.

(0.253± 0.075 mg/l, SII). From the two sites, the highest was recorded in MRS (0.83 mg/l), and the lowest was recorded in PORS (0.08 mg/l). The SiO_2 concentration varied from 0.66 to 22.5 mg/l (8.05±4.98 mg/l, SI) and 0.09 to 22.5 mg/l (8.68±5.08 mg/l, SII). In both sites, the maximum and the minimum values were recorded in the same season (MRS) (Table 1).

The ANOVA result showed that there were highly significant difference in temperature, pH, DO, WTD, TDSs, NO_3-N, PO_4-P and SiO_2 among seasons and between sites (Table 1). The Tukey test also showed similar scenario. Additionally, the interactions of site and season with physicochemical parameters were significant, except pH (Table 2).

DISCUSSION

Physicochemical parameters

Water temperature

The recorded low temperature during the PORS (18.7°C) was probably due to the presence of cloud that reduced sun radiation (Onyema, 2007), the accumulation of runoff in the reservoir from the streams and from watershed (Oso and Fagbuaro, 2008) and the presence of high humidity and wind in the surrounding (Atobatele and Ugwumba, 2008). The higher temperature recorded in DS (24.2°C) and PRS (24.1°C) was due to clear atmosphere (the absence of rain), greater solar radiation, and low water level (Moundiotiya et al.,, 2004). Therefore, the resulted temperature (18.7 to 24.2°C) is not exactly similar to the suggested temperature ranges of by Karai et al. (2008) (22 to 31°C) for the growth of fish but in tolerable limit.

Water depth

The water depth of open zone was ranged from 10.5 Ugwumba, 2008). The higher temperature recorded in DS (24.2°C) and PRS (24.1°C) was due to clear atmosphere (the absence of rain), greater solar radiation, and low water level (Moundiotiya et al., 2004). Therefore, the resulted temperature (18.7 to 24.2°C) is not exactly similar to the suggested temperature ranges of by Karai et al. (2008) (22 to 31°C) for the growth of fish but in

Table 1. Physico-chemical parameters of Selameko Reservoir from 2009 to 2010 respect to seasons and locations. And the mean differences of (Tukey Test) Physico-chemical parameters. Means of the two columns of a particular parameter followed by the same letter (s) are not significantly different from each other (p<0.05, Tukey HSD) (Average ± SD). Abbreviations used: Average = Av, SD = standard deviation, WTD= water transparency depth.

Variable	SI					SII				
	Seasons					Seasons				
	MRS	PORS	DS	PRS	Av ± SD	MRS	PORS	DS	PRS	Av ± SD
T°C	20.0^{d}	18.7^{e}	24.2^{a}	23.1^{b}	21.5± 1.28	19.7^{d}	20.8^{c}	24.2^{a}	24.1^{a}	22.2 ± 1.16
pH	7.72^{ab}	8.01^{a}	7.42^{bc}	7.59^{b}	7.69± 0.12	7.42^{bc}	7.39^{bc}	7.01^{d}	7.22^{cd}	7.26± 0.094
DO (mg/l)	5.59^{bc}	5.9^{ab}	5.1^{d}	5.3^{cd}	5.47± 0.17	6.15^{a}	5.9^{ab}	5.0^{d}	5.2^{cd}	5.56± 0.27
WTD(cm)	32^{f}	67^{c}	62^{cd}	40^{e}	50.25± 8.46	42^{e}	97^{a}	89^{b}	60^{d}	72±12.72
TDSs (ppm)	98.4^{c}	67.1^{f}	74.3^{e}	87.4^{d}	81.8 ± 6.94	137.2^{a}	67.1^{f}	90.43^{d}	114.3^{b}	102.26±15.11
NO_3-N(mg/l)	1.85^{b}	0.21^{ef}	0.25^{e}	0.53^{d}	0.71±0.34	2.0^{a}	0.22^{e}	0.10^{f}	0.71^{a}	0.758±0.43
PO_4-P (mg/l)	0.83^{a}	0.12^{cd}	0.44^{b}	0.16^{cd}	0.388±0.26	0.45^{b}	0.24^{c}	0.24^{c}	0.08^{d}	0.253±0.075
SiO_2 (mg/l)	22.5^{a}	6.81^{c}	2.24^{d}	0.66^{e}	8.05±4.98	22.5^{a}	10.06^{b}	2.08^{d}	0.09^{f}	8.68±5.08
Chl-a (µg/l)	39.29^{a}	11.02^{e}	21.33^{c}	17.88^{cd}	22.38±6.03	31.23^{b}	23.03^{c}	15.65^{de}	12.43^{e}	20.58±4.18

Table 2. Effects (effect test) of Sites and Seasons on the physicochemical parameters.

Limnological parameter	Factors	Degree of freedom (df)	Sum of square	F-ratio	Prob. >F
	Site	1	1.96	52.27	<. 0001
Temperature	Season	3	67.98	604.27	<. 0001
	Site *Season	3	3.94	31.47	<. 0001
	Site	1	0.72	91.17	<. 0001
pH	Season	3	0.53	22.23	0.0003
	Site *Season	3	0.06	2.39	0.1440
	Site	1	0.03	2.55	0.1487
Dissolved Oxygen	Season	3	2.23	55.52	<. 0001
	Site *Season	3	0.31	7.40	0.0108
	Site	1	1892.3	630.75	<. 0001
Transparency	Season	3	5392.81	599.19	<. 0001
	Site *Season	3	236.75	26.31	0.0002
	Site	1	76.56	136.72	<. 0001
Conductivity	Season	3	1591.07	947.06	<. 0001
	Site *Season	3	363.57	216.41	<. 0001
	Site	1	1674.04	2470.90	<. 0001
Total Dissolved Substance	Season	3	5827.21	2867.02	<. 0001
	Site *Season	3	815.19	401.08	<. 0001
	Site	1	0.01	10.31	0.0124
NO_3-N	Season	3	8.05	3067.91	<. 0001
	Site *Season	3	0.07	26.09	0.0002
	Site	1	0.07	47.80	0.0001
PO_4-P	Season	3	0.65	141.99	<. 0001
	Site *Season	3	0.13	28.92	0.0001
	Site	1	1.58	146.67	<. 0001
SiO_4	Season	3	1209.20	37385.96	<. 0001
	Site *Season	3	9.33	288.57	<. 0001

tolerable limit.

Water depth

The water depth of open zone was ranged from 10.5 (PRS) to 13.04 m (MRS). The highest reservoir water depth (13.04 m) was due to the high rainfall and the high surface water inflow from upstream surrounding area (river) (Meesukko et al.,, 2007; Asriningtyas et al.,, 2005); and the lowest depth was due to the presences of high evaporation, releasing of water for irrigation and dam crack.

pH

pH of the reservoir extended from 7.01(SII) to 8.01(SI). The highest pH (8.01) was due to having much increased photosynthesis activity by phytoplanktons than the respiratory activity (Atobatele and Ugwumba, 2008; Meesukko et al., 2007) and presence of high turbulence. Low pH (7.01) was recorded due to reduced photosynthetic activity (Bellingham, 2004; Rafique et al., 2002); the absence of rain (Atobatele and Ugwumba,, 2008) and the decomposition of organic matter by microbial activity which was enhanced by high temperature, casing excessive production of CO_2 and reduced pH (Moundiotiya et al., 2004). The recorded Ph value is good for aquatic life including fish and falls (Oso and Fagbuaro, 2008) within the EPA Redbook recommended range for fresh water (6.5 to 9.0) (Schmitz, 1996) and recommended by others (Chapman, 1996; Goldman and Horne, 1983).

Dissolved oxygen

DO ranged from 5.0 (SI) - 6.15 mg/l (SII). The large concentration of DO (6.15 mg/l) during MRS was probably due to the presence of low temperature that increases DO (Schmitz,, 1996; Goldman and Horne,, 1983); released from the atmosphere (Dirican et al.,, 2009; Schmitz, 1996), as a byproducts of photosynthesis from phytoplankton blooming (Wetzel and Likens,, 1991) and due to runoff (high rainfalls). The lowest DO value in DS (5.0 mg/l) was due to decreased photosynthetic activity (Rafique et al.,, 2002), presence of high rates of decomposition of organic matter using relatively high temperature (Ayoola and Kuton, 2009) and presence of phytoplankton blooming (Ayoola and Kuton, 2009). The recorded DO amount satisfied the minimum recommended standard (> 5 ppm) set by EPA Redbook and others (USEPA, 2008; Yajurvedi, 2008) and good for fishing.

Water transparency depth

It varied from 32 cm (MRS, SI) to 97 cm (PORS, SII). The highest transparency depth was due to the absence of relatively no suspended materials (Garg et al., 2010) and presence of small number of phytoplankton density; and the lowest was due to the presences of high surface water inflow (flooding) that assisted by rainfall that contained suspended matter. These suspended cause to increased water turbidity and reduced transparency depth in the MRS (Meesukko et al., 2007; Rafique et al., 2002), again heavy rainfall leading to an increase in phytoplankton abundance and decay of organic matter in suspension as well as released heavy sand and silt into the water (Atobatele and Ugwumba, 2008; Mustapha and Omotosho, 2005). Based on the obtained result, the reservoir water is eutrophic (Horne and Goldman, 1994) and good fishing activity.

Total dissolved substances

The TDSs of the reservoir was varied 67.1 (in PORS, SI, SII) to 137.2 ppm (in MRS, SII). The highest value of TDSs was due to the presence large quantity of solid matters that carried by flooding and erosion caused by heavy rain (Meesukko et al., 2007; Onyema, 2007; Moundiotiya et al., 2004). The minimum TDSs were due to the absence of flood that brought allochthonous materials. This registered value is very conducive for the growth of aquatic organisms including fish (Mohamed et al., 2009; Karai et al., 2008).

NO_3-N

The concentration of NO_3-N ranged from 0.1 (SII, DS) to 2 mg/l (SII, MRS). The highest concentration of NO_3-N during in MRS was caused by the surface water inflow/flood carried high amounts of nutrients from the surrounding agricultural areas into the reservoir (Meesukko et al., 2007; Mustapha and Omotosho, 2005) and the leachates of municipal wastes from waste disposal sites and sanitary landfills (Bennett, 1998; Chapman,1996). The lowest value during DS was due to usages of algal species that fevered by high temperature (Szilagyi et al., 1988). Generally, this range of NO_3-N (0.1 to 2.0 mg/l) is tolerable for fish growth and satisfy surface water quality standards (< 5 mg/l) (PCD, 1997 in Chattopadhyay and Banerjee, 2007) and fulfill the minimum level of nitrate in lake to be productive (Yajurvedi, 2008).

PO_4-P

The amount of PO_4-P was between 0.08 and 0.83 mg/l. The maximum value at MRS was partly due to nutrient run-off from surrounding agricultural areas (Granit and Lindstrom, 2009; Mustapha, 2008; Oso and Fagbuaro, 2008; Chattopadhyay and Banerjee, 2007) and partly due to the entrances of municipal wastes, washing and bathing with phosphate based detergents and soaps (Davies et al., 2009) as well as washing of cow dung's into the reservoir (Mustapha, 2008; Schmitz, 1996). The lowest amount at PRS was due to usages of algal species (Stanley et al., 2003). The obtained concentration of PO_4-P is greater than as compared to other standards (0.005 to 0.020 mg/l PO_4-P) (Chapman, 1996) and (0.01 to 0.03 ppm phosphorus) (Yajurveddi, 2008; Schmitz, 1996), and an indication of the presences of pollution, and therefore, bad for fishing.

Silicate

SiO_2 concentration was between 0.09 (SII, DS) to 22.5 mg/l (SI and II, MRS). The high concentration in MRS was due the effects of runoff from the watershed (Little, 2004) and the presence of high rate of rock and soil weathering in the water body (Meesukko et al., 2007; Little, 2004; Chapman, 1996); and the lowest record at PRS was due to usages of algal species (Nirmal-Kumar et al., 2009; Stanley et al., 2003). This registered silicate concentration was normal and satisfied freshwater ranges from 1 to 30 mg/l (Wetzel, 2001 in Meesukko et al., 2007; Chapman, 1996). Therefore, it is good for growth of both aquatic organisms.

Conclusions

Based on the present observation, most of the physico-chemical parameters of reservoir were conducive for growth of aquatic organisms. However, high concentration of PO_4-P, low temperature (< 24.2°C), and presence of high altitude (2513 m above sea level) were observed which are not suitable for fishing. Based on the recorded NO_3-N and PO_4-P concentrations, the reservoir is under strong anthropogenic pressure. If the source of anthropogenic pressure is reduced, introduction of cold temperature resistant fish can be effective in Selameko reservoir. Therefore, both basin and reservoir management are recommended to solve such acute problems for sustainably use to hit the intended objective.

Conflict of Interest

The author declares no conflict of interest.

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