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Water quality status of a stream receiving fish pond discharge using physicochemical indicators in lake Victoria catchment, Kenya

Jonathan Masaba, Barasa Wangila and Henry Lung'ayia

Abstract
This study assessed the water quality of a stream receiving discharge from Tilapia and catfish fish ponds using some physicochemical parameters as key indicators. Measurements were done both in the field and in the laboratory using portable multi-parameter meter and standard methods by APHA (1998). Systematic sampling design was applied. Significant differences were noted among the parameters in the sampling sites up-stream, in the ponds and downstream. Temperature, Phosphate-Phosphorus, Total dissolved solids, Turbidity, Ammonia-Nitrogen, had higher values in the ponds and Sampling site 4 downstream ($p<0.05$). Spatial variations that were within acceptable water quality standards in aquaculture, corresponding with changes caused by inflow from fish ponds, were observed.

Keywords: Fish pond discharge, physicochemical parameters, water quality assessment

1. Introduction

Kenya is now among countries in the world (Nigeria, Egypt, China) depending on aquaculture for economic growth [1] The fishing industry is estimated to raise 5% of the Kenya's Gross Domestic Product (GDP), surpassing 8% in the year 2015. [2]. Aquaculture in Kenya is practiced using earthen, liner, concrete, race ways and dams whose main sources of water being small streams and springs. The major farmed species are; Nile Tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) [2]. Water quality and quantity of small streams is a key aspect in the sustenance of wildlife, aquaculture activities, domestic and livestock water needs. Currently, Sasala stream (Study site), a head stream in the Nzoia River Basin of the Lake Victoria catchment provides water for more than 18 fishponds. Similar studies have shown that uncontrolled aquaculture activities may adversely affect the stream ecosystem. The main aspects of aquaculture in focus are: Fish pond establishment and management activities such as construction, use of fertilizers, artificial feeds, hatchery management and production, introduction of exotic species and harvesting in a sustainable manner. According to the United Nations environmental program, approximately one third of the people in the world are found in countries facing moderate to high water stress [3]. Kenya is one of the countries experiencing water stress occasioned by increased population, land use changes and climate change. Currently one of the most significant environmental challenges related to water stress facing the government of Kenya is the declining quality of water [3]. It is therefore important that tests are done to ensure that aquaculture activities do not adversely affect adjacent streams. Aquaculture activities generate large amounts of organic matter, nutrients, suspended solids which lead to adverse impacts on stream water quality including turbidity, oxygen depletion and eutrophication [4-6]. Scholars and the general public are advocating for proper management of aquaculture activities to prevent adverse effects of aquaculture to the natural ecosystem in question [7].The effects of aquaculture are mainly due to the type of fish farmed, placement of fish ponds, and magnitude of activities, morphology, limnology, hydrology, trophic status and assimilative capacity of water body where the discharge is released [8-11], report that fish ponds sited in fairly virgin water sheds may change the characteristics of the receiving water bodies extensively compared to those sited in large agricultural water sheds. Fish raised in ponds do not retain all the feeds that they are fed on in their body biomass. Some fragments of the feed get lost to the pond water as faeces, uneaten or unabsorbed feed and dissolved nutrients [12, 13].

The excess feed fragments eventually cause the levels of organic matter, suspended solids and nutrients in the pond to rise. During harvesting of fish from ponds the preferred method is complete drainage of the pond releasing the wastes to adjacent streams. The receiving streams are adversely affected through high turbidity, elevated oxygen demand and eutrophication [14, 15] Have also reported that benthic production and abundance is a reflection of the effect of inorganic fertilizers. Ponds that are not cemented or lined contain large quantities of phosphorus and nitrogen which negatively affect freshwater ecosystems [16, 17]. According to [18]. Subsidy-stress reactions in rivers and streams can be triggered by elevated nutrient enrichment, the ecosystem may show short lived good biotic characteristics from species richness and diversity indicator observations. Physical and chemical parameters have been used to monitor water quality in many streams in Kenya, hence the decision to apply the same in this study. Using physicochemical indicators this study was aimed at determining the effects of fish pond discharge on the water quality of Sasala Stream to inform for proper management and sustainable aquaculture.

2. Materials and Methods

2.1 Study procedure

Sampling involved collection of triplicate water samples for analysis in the laboratory (Phosphates, Ammonia and Biological Oxygen Demand) from sampling sites selected through systematic sampling technique. While triplicate readings for Dissolved oxygen, pH, Temperature, Turbidity, Conductivity and Total dissolved solids from each sampling point were recorded in the field using a Hydrolab (DKK-TOA Hand held water quality meter WQC-24) and an Oyster conductivity/Temperature meter. Sampling was done at intervals of 14 days during the study period, March to August, 2016. (Figure 1)

2.2 Study area

The study was conducted in Sasala Stream within the Lake Victoria catchment in Western Kenya (Figure 2). The catchment is located within Longitude 34°3´ East and Latitude 34°57´ 30´ North at an altitude of between 1250 and 2000 meters above sea level. Sasala Stream is one of the streams supplying River Nzoia which eventually drains into Lake Victoria. This study was carried out on a fish farm known as Jafi Enterprises, which specializes in Tilapia (*Oreochromis niloticus*) and Cat fish (*Clarius gariepinus*) fingerlings production for supplying fish farmers in Kakamega County and beyond.

2.3 Sampling design and sites

In the study, sampling sites (marked 1 to 6) were identified along Sasala Stream using systematic sampling technique (Figure 3). Samples were collected from downstream to upstream of the stream.

Table 1: The altitude, physical characteristics and land use of the study area with riffles, pools and runs summarized from microhabitats into habitats = stations of Sasala stream during the study period.

Site	Altitude	GPS	Land Use
1	1400	$0^0$28' 34^0N 68E	Upstream
2	1376	$0^0$28' 34^0N 68E	Tilapia pond
3	1375	$0^0$28' 34^0N 68E	Catfish pond
4	1371	$0^0$28' 34^0N 68E	Downstream
5	1365	$0^0$28' 34^0N 68E	Downstream
6	1367	$0^0$28' 34^0N 68E	Downstream

2.4 Determination of selected levels physicochemical parameters of Sasala stream

Sampling was done by starting from the downstream to upstream sites moving up systematically from site six (6) and ending with the upstream site (1). This was chosen to avoid possible interference with water parameters from physical disturbances. Sampling began in the morning through the afternoon at intervals of fourteen days. At each sampling site, three triplicate readings of physicochemical parameters: Water Temperature, pH, Dissolved Oxygen (DO), Electrical conductivity (EC), Total Dissolved Solids (TDS), Turbidity were measured in situ using a Hdrolab (DKK-TOA Hand held water quality meter WQC-24) an Oyster Conductivity / Temperature meter. In addition, triplicate water samples of 500 ml each were collected from each site and transported to the laboratory while stored in a cool box containing ice cubes. Analysis of chemical parameters was conducted at the Zoology laboratory of Masinde Muliro University of Science and Technology (MMUST). In the analysis, chemical parameters (Biological oxygen demand, ammonia and total phosphorus) were determined using standard methods developed by the American Public Health Association (APHA, 1998).

2.4.1 Determination of Biological Oxygen Demand

Biological oxygen demand (BOD_5 was determined using standard methods by [19]. To get BOD_5 levels, Azide modification of the Winkler method based on the account of [19].

2.4.2 Determination of Phosphate-Phosphorus

The ascorbic acid procedure was used [19]

2.4.3 Determination of ammonia

Ammonia levels in the water samples determined by the Wagtech Ammonia Test [20]

2.5 Data analysis

Data analysis was done using Sigma Plot version 11. (USA). Non-parametric methods of data analysis were applied since both continuous and categorical data was collected. Descriptive statistics was conducted to determine the level of selected physicochemical parameters. The Spearman rank order correlation coefficient was used to determine the relationship between physicochemical parameters. The One way ANOVA was used to determine mean differences for the different physiochemical parameter factor levels.

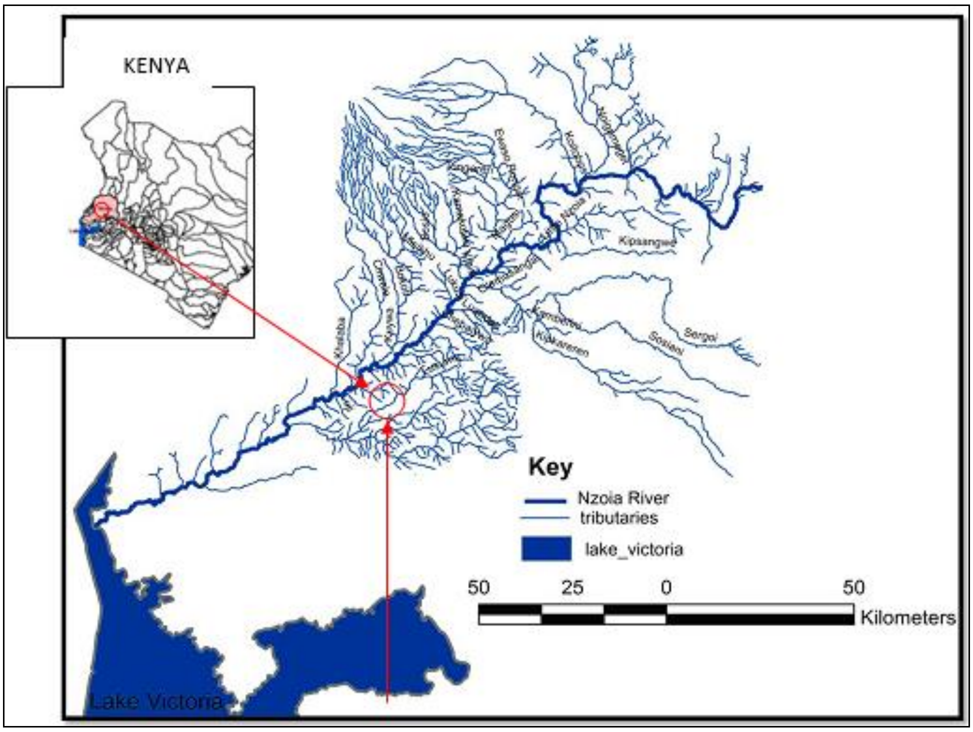

Fig 1: Lower basin of River Nzoia showing position of Sasala Stream (arrow and small circle). (See also figure 1) Source: [21]

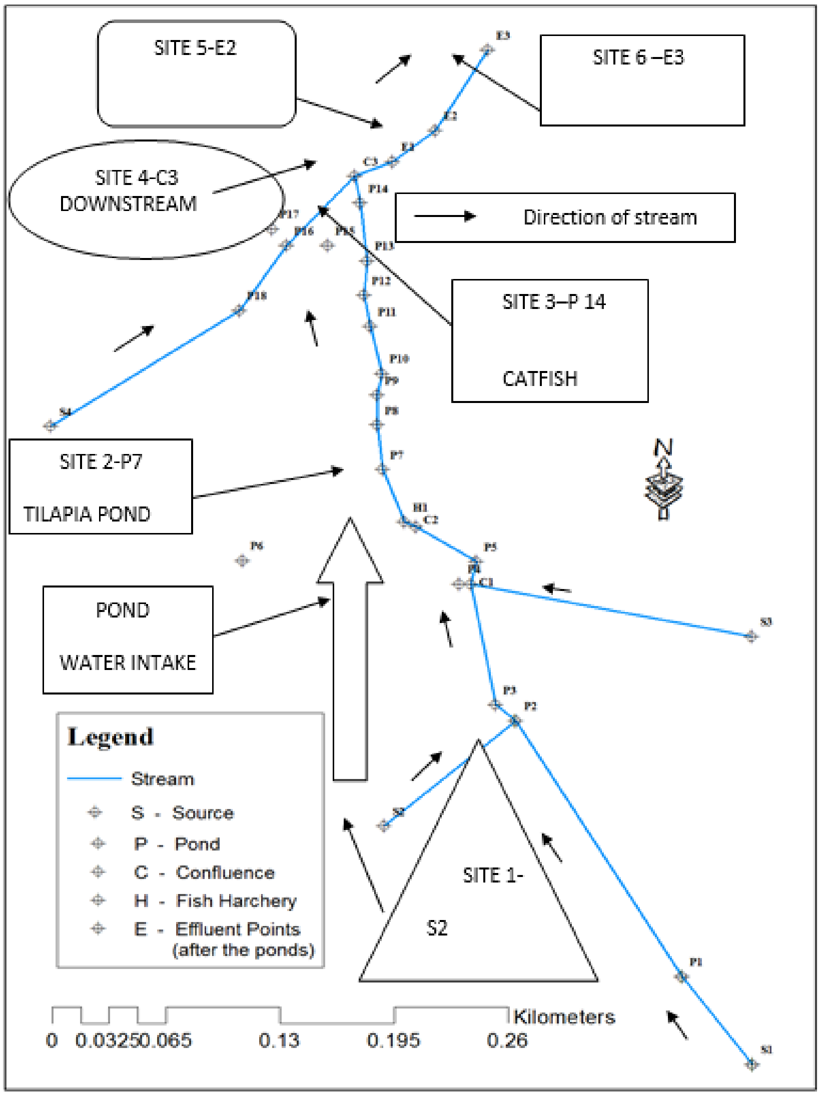

Fig 2: Diagram showing the position of study sampling points along Sasala Stream. Source: Researcher 2016

3. Results

3.1 Differences in means of physicochemical parameters

Marked differences were noted between physicochemical parameters in all the sampling sites along Sasala Stream.

Table 2: Means (+/- SE) values of physicochemical parameters of water in Sasala Stream from March to August 2016. (N= sample size)

Parameter	N	Sampling Sites						P Value
N		1	2	3	4	5	6	
pH	36	7.5±0.7	7.6±0.09	7.5±0.2	7.5±0.1	7.3±0.1	7.2±0.1	0.102
Temperature (^{0}C)	36	23.5±0.5	24.2±0.65	25.4±0.6	22.8±0.4	22.8±0.4	23.2±0.4	0.005
DO(MgL^{-1})	36	8.9±0.5	5.4±0.2	4.8±0.5	4.5±0.2	7.0±0.4	11.7±0.6	<0.001
BOD_5(MgL^{-1})	36	4.0±0.05	2.3±0.2	2.02±0.1	3.3±0.1	3.3±0.1	4.0±0.1	<0.001
Turbidity (NTU)	36	46.1±5.1	63.7±4.9	157.4±24.8	93.2±22.4	98.4±22.4	39.9±5.1	0.003
Conductivity (μScm^{-1})	36	71.4±1.8	77.5±2.9	70.9±5.6	72.9±4.0	77.6±2.6	76.4±2.5	0.657
Phos-P(μgl^{-1})	36	791.7±170	1730±32.2	1745.6±35.	1286.9±26	422.2±63.3	518.6±69.	<0.001
Ammonia-N(μgl^{-1})	36	207.2±26	330.2±12.3	427.5±11.2	260±13.4	196.4±11	150.2±11	< 0.001
TDS(MgL^{-1})	36	62.7±7.1	66.9±3.5	66.1±3.7	68.9±3.2	53.8±4.7	63.9±8.1	0.039

3.1.1 Effect of fish pond discharge on water quality of Sasala stream

The results of study showed marked differences in the values of the physicochemical parameters with higher values from site 2 and 3. (Tilapia and Catfish ponds). See Box plots below:

3.1.1.2 pH

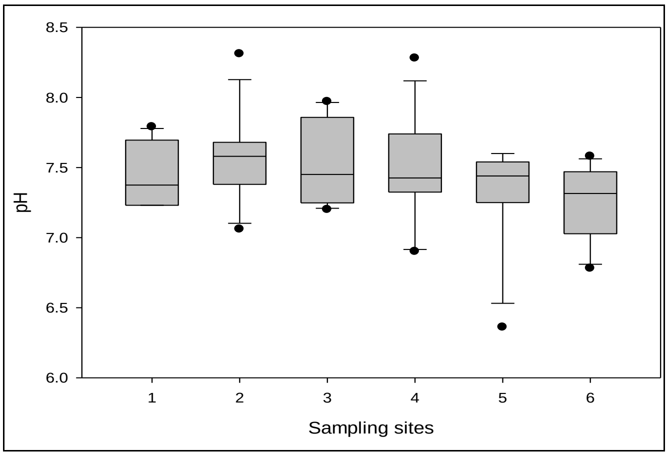

Fig 3: Box plot for variation in pH in Sasala Stream during the sampling period (March to August 2016).

3.1.1.3 Temperature

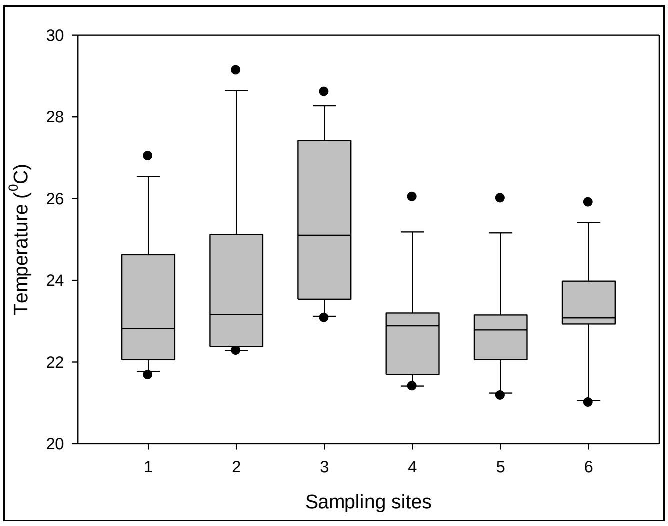

Fig 4: Box plot for variation in Temperature values in Sasala Stream during the sampling period (March to August 2016). Means bearing different symbols are statistically significant.

3.1.1.4 Conductivity

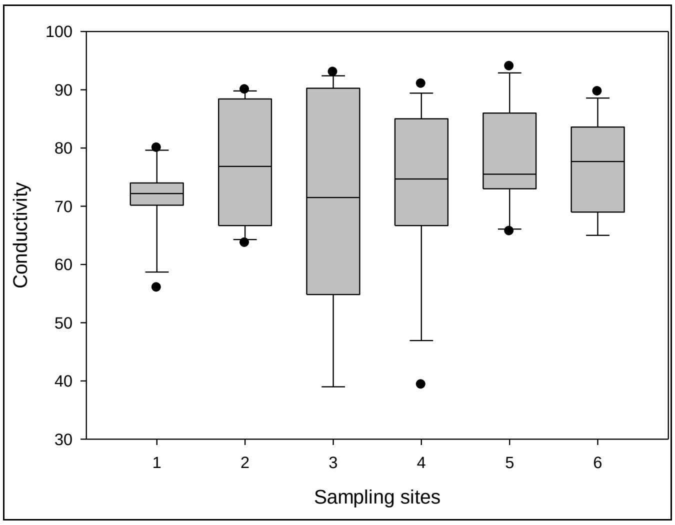

Fig 5: Box plot for variation in conductivity (μScm^{-1}) values in Sasala Stream during the sampling period (March to August 2016).

3.1.1.5 Total dissolved solids

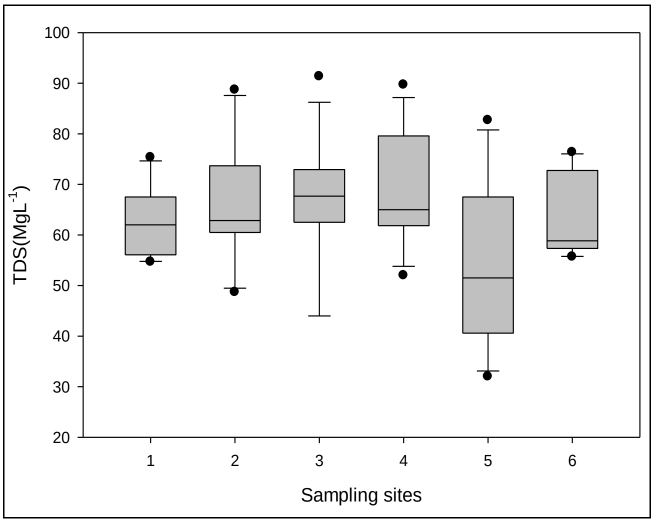

Fig 6: Box plot for variation in total dissolved solids values in Sasala Stream during the sampling period (March to August 2016).

3.1.1.6 Dissolved oxygen

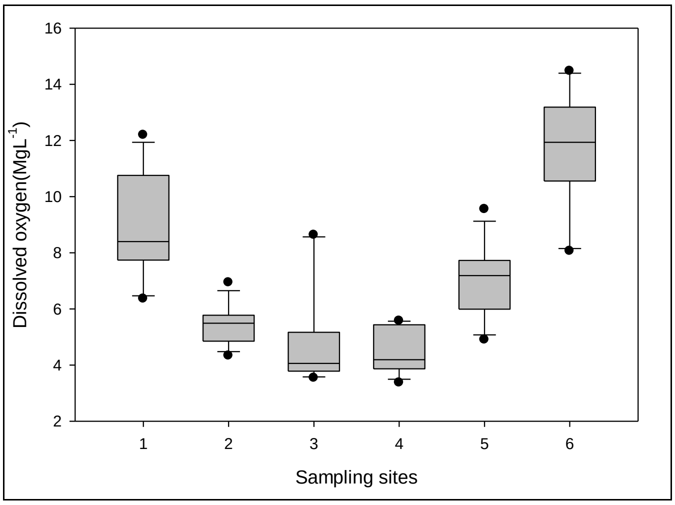

Fig 7: Box plot for variation in Dissolved Oxygen values in Sasala Stream during the sampling period (March to August 2016).

3.1.1.7 Biological oxygen demand

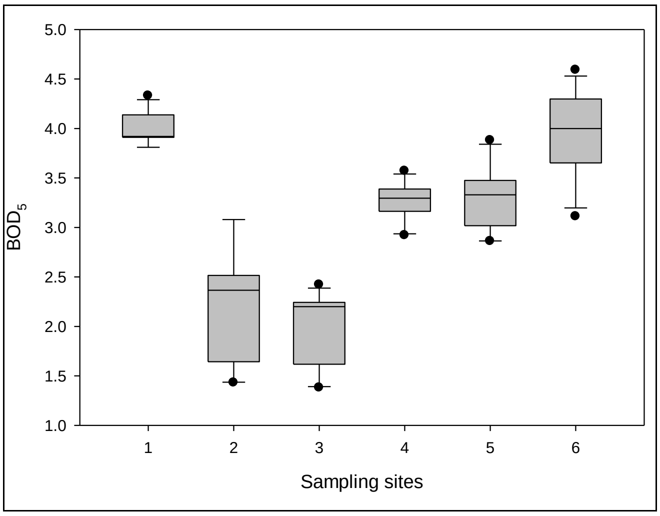

Fig 8: Box plot for variation in Biological oxygen demand (MgL^{-1}) values in Sasala Stream during the sampling period (March to August 2016).

3.1.1.8 Turbidity

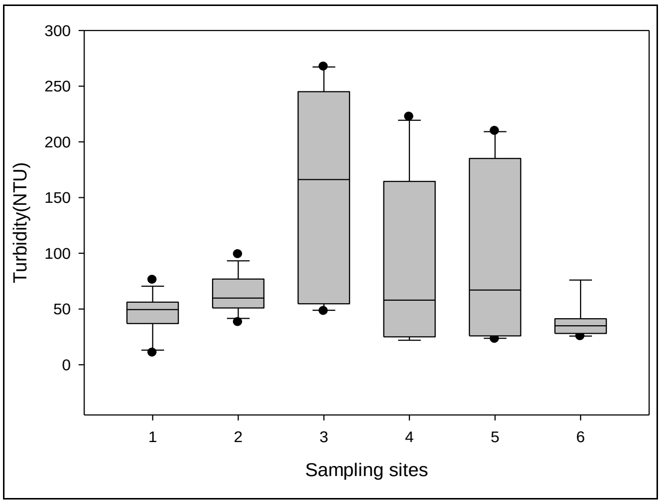

Fig 9: Box plot for variation in turbidity values in Sasala Stream during the sampling period (March to August 2016).

3.1.1.9 Phosphate-Phosphorus

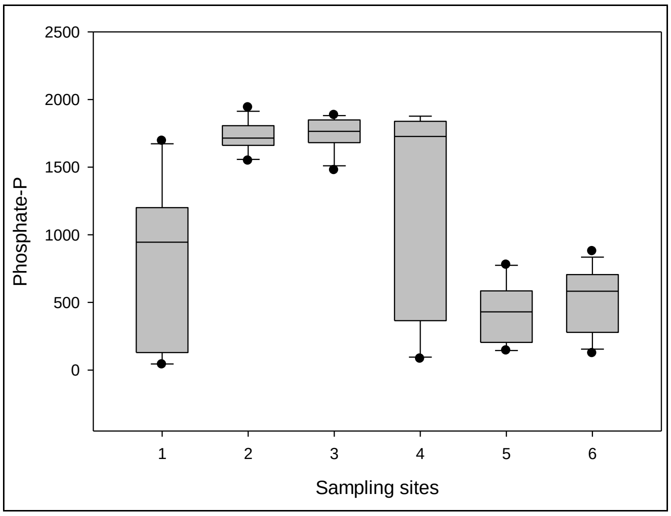

Fig 10: Box plot for variation in mean Phosphate-Phosphorus (μgl^{-1}) values in Sasala Stream during the sampling period (March to August 2016).

3.1.1.10 Ammonia-nitrogen

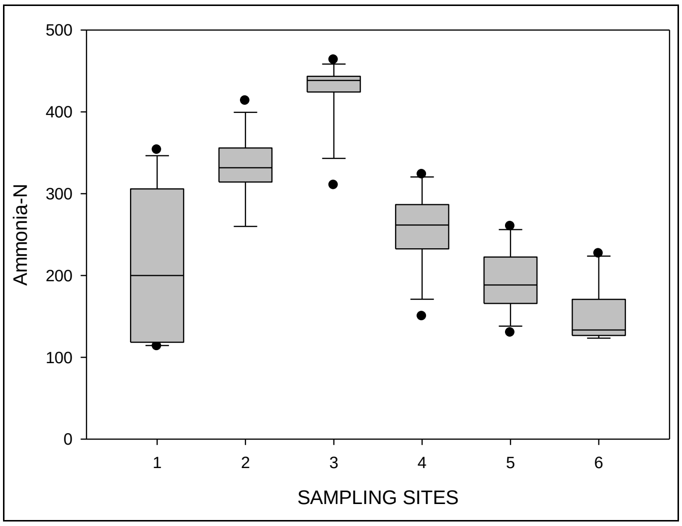

Fig 11: Box plot for variation in Ammonia-N (μgl^{-1}) values in Sasala Stream during the sampling period (March to August 2016)

4. Discussions

Higher pH values (6.4 to 8.3) were recorded in the fish ponds than the other sites, signifying minor acidic state. In the fish ponds, during feeding of fish most of the uneaten feed end up decomposing in the ponds. This is a sign of septic condition of the wastewater arising from breakdown of organic matter leading to production of acidic substances such as humic acids which reduces the pH below 7. This agrees with [22] who reported that oxidation of sulfide produced from wastewater during microbial decomposition process lead to production of sulfuric acid creating acidic condition which could harm the cultured fish species. The result also corroborates the observation of [23] in wastewater from fish ponds. Minor elevation in pH was not statistically significant (p=102). Even the pH in downstream of the fish farm was still 6.4–8.3 as anticipated suitable by different standard schemes [24-26].

Generally higher temperatures were recorded in the fish ponds when compared to sites outside the ponds. The elevated temperatures may have been due to sunlight heat absorption and retention by the more or less lentic habitat in the fish ponds and heat release by aquatic organisms like zooplankton and phytoplankton resulting from metabolic activities. Heat absorption from direct sunlight could be increased by turbidity resulting from fish feeding and swimming activities, in particular the catfish pond. Decomposition of uneaten food in the ponds may have resulted in the increase in water temperature. Fish ponds had a significant effect on water temperature(d.f =5;p=0.005).The separation of means indicated that the means of water temperature were statistically different ($p<0.05$).There were notable differences between sampling sites 3 and 6;3 and 1;2 and 6;s 2 and 1. Elevated temperatures in fish ponds can also be ascribed to sediment heaps in the ponds as reported by [27] a rise in temperature of the water leads to the speeding up of the chemical reactions in water, reduces the solubility of gases and amplifies the odors [28]. Aquatic organisms have both an upper and lower temperature limit for optimal growth.

High electrical conductivity was recorded in the sites within ponds. This is due to inputs of dissolved substances including ions and mineral salts from feeds and fertilizer used in pond management activities. The ions may have also been as a result of fish activities (construction of nests for laying of eggs, or burrowing in search of food), that disturb the surface of the pond releasing embedded substances that contain ions and minerals to the surface of the ponds. Surface overflow from agricultural actions and refuse from discarding sites close to the stream might add to the soaring electrical conductivity levels in the stream. Previous studies by [32] reported that surface runoff, effluents, minerals, and salts from town runoff during intense rainfall supply to elevated levels of electrical conductivity in receiving streams. The elevated electrical conductivity levels downstream can also be attributed to high levels of total dissolved solids, since electrical conductivity is a function of total dissolved solids (ions concentration) which determines the quality of water. [33] Conductivity gradually increased from upstream towards downstream which is similar to the findings of [34]. Electrical conductivity is a measure of the ability of an aqueous solution to carry an electric current.

Total dissolved solids followed similar patterns to those of electrical conductivity, since levels of TDS are influenced by dissolved ions and salts, in addition to micro-colloidal substances.

There was a significant difference in DO values among the sampling sites (p=<0.001). DO was higher in the sites outside the fish ponds due to water flowing through the stream causing increased absorption of Dissolved Oxygen from the air. The DO in the ponds was low due to utilization of oxygen by the fish and phytoplankton in metabolism. High temperature, re-suspension of sediments distressing phytoplankton growth and productivity, decomposition of organic matter could have also led to lower DO levels in the ponds. Oxygen is a vital parameter to the metabolism of every aquatic organism that possesses aerobic respiration. Concentration of DO indicates water quality and has a relation to the distribution and abundance of diverse algal species [35]. Its existence is fundamental to sustaining the advanced forms of biological life in the water [28]. The DO in the water samples ranged between 3.5 mg/L to 14.3 mg/L in the sampling sites during the study period that was done in the wet season. Comparable outcomes were observed in Bagmati river system by ENPHO [36] and [37]. The study uncovered that DO at all sampling sites were above 4 mg/L and consequently, the water was appropriate for drinking, bathing, aquaculture and irrigation [38].

The means of BOD_5 were significantly different (p=<0.001). These were generally low values indicating low organic waste pollution. Oxygen is required by fish and other aquatic organisms to live. The BOD_5 was found to be low during the sampling period. This may have been due to the high rainfall decreasing the concentration of organic load. Uncontaminated waters usually have BOD_5values of 2 mg/L or less [39]. The optimum BOD_5 range for fisheries and aquatic life is less than 15 mg/L [40]. A high waste discharge in organic matter and nutrients can lead to decrease in DO concentrations as a result of increased microbial activity occurring during the degradation of the organic matter. High content of BOD_5 cause oxygen depletion, which leads to the suffocation of aquatic life [41]. The values of BOD_5 during the study period in all sites were recorded within the acceptable limits thus signifying existence of decomposable organic matter in the Sasala Stream area suitable for aquaculture. Turbidity values were high high in the fish ponds. A significant difference was noted in the turbidity within the sites (p=0.003). Turbidity was high in the fish ponds due to fish activity in the ponds, increased growth of phytoplankton due to pond fertilization, fish feeds that remained unutilized, feacal matter from the fish. Silt, clay and other organic particles can suffocate larvae and clog gills of many aquatic organisms and interfere with their normal functioning or even cause death. They can also interfere with light penetration into the water column retarding growth of phytoplankton and macrophytes thereby lowering primary productivity and release of oxygen into the water, and life of other aquatic organisms. Silt, clay and other organic particles are also known to form attachment substrates for many types of bacteria and other micro-organisms. Sampling sites 3 and 4, showed poor water quality as compared to Sampling sites 1 and 6 due to receiving effluent of the fish farm as mentioned by [42]

Elevated phosphates values were recorded in the ponds. This may have been as a result of pond management activities like fertilization and feeding. Disturbance of bottom of the ponds by the fish through nest creation and feeding and burrowing by Catfish may have led to weathering of the substratum. Phosphate-P is an essential nutrient for living organism and exists in water bodies as both dissolved and particulate species. In natural waters and waste waters, phosphorous occurs mostly as dissolved orthophosphates and polyphosphates, and organically bound phosphates [43] Natural source of phosphorous in the wetland is due to the decomposition of organic matter.

Ammonia-nitrogen (NH_4-N) was high in the fish ponds. This may have been due to metabolic activities of the fish, pond fertilization and factors influencing availability of PO_4-P, and possibly through nitrogen fixation by cyanobacteria. This result resembles the study carried out by Shahi (2012) in different lakes of Pokhara. Unpolluted water contains small amounts of NH_3-N usually less than 1000 μgL^{-1} [44]. Optimal ammonical nitrogen of water for fishes is less than 3000 μgL^{-1}. Thus, Sasala Stream water is suitable for aquaculture

5. Conclusions

Based on the findings of this study, there are some spatial variations in physicochemical variables from the upstream to downstream of Sasala Stream watershed, corresponding with changes caused by discharge from fish ponds. Within the watershed, the upstream site (Site S1) and downstream site

(Site 6) showed lower values of the major physicochemical parameters with sites in the ponds recording high values. The recorded values were within acceptable limits in aquaculture and good water quality of Sasala stream. However, as aquaculture continues to grow measures must be put in place to assure sustainable production systems that focus on the interactions between the culture techniques and the environment.

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