
**E-ISSN: 2347-5129**
**P-ISSN: 2394-0506**
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2019; 7(3): 121-127

www.fisheriesjournal.com
Received: 21-03-2019
Accepted: 24-04-2019

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# Assessment of water characteristics in aquaculture ponds in Tigoni, Limuru sub-county, Kenya

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**Abstract**
Aquaculture production has increased from 29.5m tones in 2010 to 37.5 million tones in 2014 in the world and 1.3 million tones in 2010 to 3.8 million tones in Africa. The study area was Tigoni in Kiambu County. Stratified random sampling design was used to select 8 sample ponds which water samples were collected twice a month for four months. Parameters measured were temperatures, pH, conductivity, dissolved Oxygen (DO), secchi depth, Biochemical oxygen demand (BOD), nitrates and phosphate. Mean temperature were in the lower range with pond D and H being below range. DO t-test, pond G had a significant difference ($t=7.500$, $\alpha=0.05$, $p=0.00$) and there was no significant difference in BOD in all ponds. In conclusion, water characteristic in the aquaculture ponds did not vary significantly from one pond to another, the characteristics in aquaculture ponds met characteristics for warm water culture but temperatures were low and in some ponds they were below range.

**Keywords:** Aquaculture, physical parameters, chemical parameters and pond

## Introduction
In recent decades, aquaculture has become an increasingly important part of the world economy (Piasecki, Goodwin, Eiras, & Nowak, 2004) [1]. According to (FAO, 2002) [2] fisheries and aquaculture are source of income for 55 million people in the world, the sectors contributes to food security and nutrition, providing more than 4.3 billion people with about 15% of their animal protein intake. In Kenyan, the production that enters international trade from the sub-sector contributed more than 0.54% to GDP of the country (FAO, 2015) [3].

Water characteristic is important for aquaculture production as it is the main factor controlling the production of the aquaculture in ponds, it affects the production in the in the aquatic body, which in turn affects the productivity of food and the health of the people (FAO, 2012) [4]. In some cases, agricultural runoff, effluents of industrial activities, and sewage effluents drain into the water bodies and sediment with huge quantities of inorganic anions and heavy metals that greatly affect water quality depending on the source (Arain, *et al*., 2015) [5]. Pollution of the aquatic environment by inorganic and organic chemicals poses serious threats to the fish (Saeed & Shaker, 2008) [6]. Water characteristic is also affected by management practices of ponds, the interventions impacts on aquifers which in turn affects fish ponds productivity (Mbugua, 2007) [7]. In aquaculture for healthy fish and high production to be enhanced, good water characteristic must be maintained and currently there is no sufficient information on aquaculture in the area.

Currently, there is insufficient information on aquaculture in Tigoni, despite the rise in aquaculture production over the years. The need to understand the dynamics of aquaculture in relation to appropriate fish production is paramount. In Tigoni area there is increase in agricultural activities which have contributed to various impacts on the quality of water resource including rivers/streams which in turn have brought about impact on water quality in aquaculture production (Odino, 2013) [8].

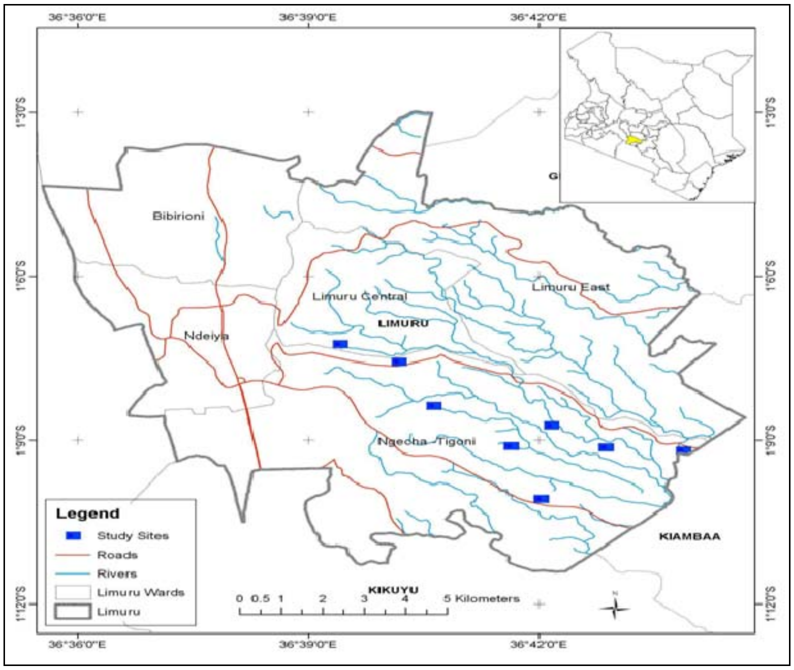
The current status has directly and indirectly contributed to low aquaculture production in the area as the poor water quality causes stress to fish affecting their growth and at times fish mortality. The aims of the study are to determine characteristic of water in fish ponds in Tigoni. It will fill the current information gap in aquaculture water characteristics in Tigoni and also inform farmers on water characteristics in ponds and suggest areas of further studies.

## Materials and Methods

### Study area

Tigoni is located in Ngecha/Tigoni ward in Limuru Sub-county, Kiambu County it is about 40 km North-west of Nairobi city center, at an altitude of 2131 masl, latitude of 1°15' S and longitude 23° 46' E (Jaetzold, Schmidt, Hornetz, & Shisanya,, 2006) [9]. It covers a total area of 41.4km$^2$.

The mean annual air temperature is 18°C ranging between 12 and 24 °C. The average annual rainfall is 1096mm with a bimodal distribution. Humidity and evaporation, the wind direction is easterly and evaporation ranges from 100 to 150mm per month while, the humidity varies between 50% and 90%. Rivers Rwaka and Ithanji are main sources of water in the area. The soil type is humic nitosol (alfisol) derived from quartz trachyte. The soil is deep and well drained (Muthoni & Kabira, 2010) [10].




***Source*:** (google maps, 2015).Website: ww.googlemaps.com

**Fig 1:** Map of Kiambu showing Tigoni the study area

8 ponds were selected, stratified random sampling design was employed to select 8 ponds from which water samples were collected from. Pond A was located S1$^0$ 1261, E36.6697’, Pond B S1$^0$ 1855 E36 7027’, Pond C S1$^0$ 1522 E36 7145’, Pond D S1$^0$ 1395 E36 6773’, Pond E S1$^0$ 1679 E36 7005’, Pond F S1$^0$ 1207 E36 6569’, Pond G S1$^0$ 1532 E36 7314’ and Pond H S1$^0$ 1518 E36.6940’. Pond A, C, D and E were liner ponds while Pond B, F, G and H were earthen ponds

### Sampling procedure

Sampling points were identified in all the sample ponds away from inlet and outlets. Each field measurement was done at depth of 30cm from the water surface to avoid sampling the micro-layer. 500 ml of water was collected from each sampling pond at a depth of 30 cm. Field measurements and sampling was done twice a month for four months at the same point one samples was collected from each of the sample pond in two weeks intervals between July and November 2015. Altogether, sixty four (64) samples were collected and used for analysis. Sampling was done according to standard sampling principles and guidelines outlined in American Public Health Association (APHA, 1998) [11].

### Field Measurement

### Physical parameters

The temperature was measured using a thermometer, pH was measured using a pH meter, with a temperature compensation to 25 $^o$C, Conductivity was measured using a conductivity meter, dissolved oxygen was measured using Oxygen meter and Secchi depth was measured using a Secchi disc, with a diameter of 20cm with a black and white pattern on the upper surface.

### Chemical parameters

Sampling points were identified in all the sample ponds away from inlet and outlets water samples were collected at a depth 30cm from the water surface. Sampling was done according to standard sampling principles and guidelines outlined in American Public Health Association (APHA, 1998) [11]. Biochemical Oxygen Demand (BOD) was determined using the dilution method while for phosphates and nitrates were determined using UV-VIS Spectrophotometer method.

### Data analysis and presentation

Data analysis was done using Statistical Package for Social Sciences (SPSS) Version 20. One way ANOVA was used to determine differences in water characteristics in aquaculture ponds, t-test to determine significant difference in water characteristics for aquaculture in Tigoni. Results were presented using graphs, tables and charts.

## Results and Discussion

Physical parameters of temperatures, pH, conductivity, transparency and dissolved oxygen were analysed using one way ANOVA to determine the difference between mean in pond, t-test to determine difference from the desired mean and the following water characteristics found.

**Table 1:** Mean ± Standard Error Value of the Physical Parameters measured during the study period (July to November, 2015)

| Pond | Temperature (Mean±SE) $^0$C | pH (Mean±SE) | Conductivity (Mean±SE)µS/cm | Secchi depth (Mean±SE)cm | DO mg/l (Mean±SE) |
|---|---|---|---|---|---|
| Desired range | 20-28 | 6.5-9.0 | 15-30 | 150-500 | 3mg/l (minimum) |
| A | 21.15±1.08$^{ab}$ | 9.09±0.76$^{b}$ | 190.25±127.86$^{a}$ | 20.06±6.03 $^{abc}$ | 4.72±1.26$^{ab}$ |
| B | 21.20±1.92$^{ab}$ | 8.63±0.25$^{ab}$ | 356.63±68.49 $^{ab}$ | 17.00±3.70$^{abc}$ | 4.41±1.28$^{ab}$ |
| C | 20.31±1.86$^{ab}$ | 8.52±0.23$^{ab}$ | 416.50±168.93$^{b}$ | 20.66±6.03$^{abc}$ | 4.03±1.39$^{a}$ |
| D | 19.98±1.54$^{a}$ | 9.01±1.02$^{b}$ | 239.13±194.14$^{ab}$ | 14.13±3.36$^{a}$ | 5.24±1.61$^{ab}$ |
| E | 21.38±1.66$^{ab}$ | 8.12±0.76$^{ab}$ | 234.85±143.83$^{ab}$ | 24.10±8.25$^{bc}$ | 5.73±2.32$^{ab}$ |
| F | 22.54±1.62$^{b}$ | 7.66±0.83$^{a}$ | 243.63±154.6$^{ab}$ | 24.25±7.19$^{bc}$ | 4.60±1.17$^{ab}$ |
| G | 21.26±1.32$^{ab}$ | 7.57±0.52$^{a}$ | 203.94±98.22$^{a}$ | 28.38±7.13$^{c}$ | 6.63±1.37$^{b}$ |
| H | 19.69±1.38$^{a}$ | 8.65±1.03$^{ab}$ | 330.06±76.13$^{ab}$ | 24.67±7.21$^{bc}$ | 4.26±1.09$^{ab}$ |
| p-value | | <0.001 | 0.013 | 0.001 | 0.016 |

(*) Mean values followed by the same small letter(s) within the same column do not differ significantly. ±SE means standard error.

## Temperature

The mean temperatures measured during the study period showed variations, the temperature ranged from 19.69±1.380$^0$C to 22.54±1.62$^0$C (Figure 2). According to one way ANOVA temperature in pond D and H differ significantly from pond F (p=0.002, df=7) and (p=0.001, df=7) respectively (Table 1) the other ponds did not have a significant difference from each other.

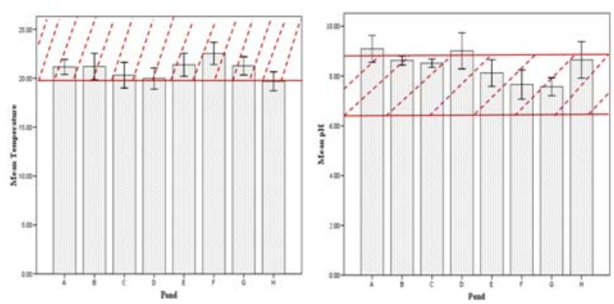



**Fig 2:** Mean temperature and pH values in the ponds studied with vertical bars indicating ±SE

In general the water temperatures were low due to the geographical zone of the study area which is highly influenced by the Aberdare Forest Ecosystem as it is located on the eastern side of the southern edge of Aberdare Escarpment. Pond H recorded lowest temperatures due to water flowing in and out which lowered the water temperature in the ponds also the vegetation cover near the pond provided a cooler environment for the pond lowering the temperatures. In pond F, which was an earthen pond higher temperatures were recorded because the inlets were controlled which allowed water to stand for long allowing progressive increased of temperatures also the pond was shallow allowing heating up of the water. Pond D which also had low temperatures that differed significantly from pond F had diversion of stream directly to the pond which contributed to the lowering of the pond water temperatures.

According to (Zweig, Morton, & Stewart, 1999) [12], the acceptable ranges for optimal growth for warm water fish is 20-28 $^0$C, the water temperature recorded in all ponds during the study period were within the range except pond D and H (Figure 2). Generally, the mean temperature recorded in all the ponds were close to studies done by (Musyoki, 2015) [13], on aquaculture water quality in Gatundu, central Kenya who got a mean range of 19°C to 23.4 °C. The results were also comparable to studies by (Laibu, 2010) [14], who recorded a mean range of 18 to 29 $^0$C in a study done on fish pond water in Abothuguchi Central, Meru County.

## pH

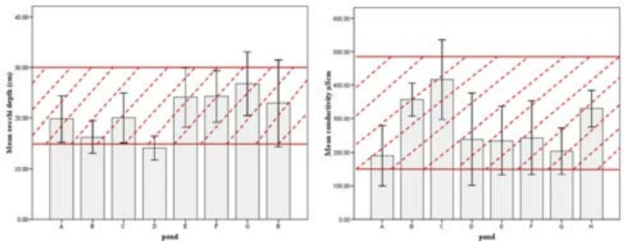
The mean values of pH recorded in the eight ponds varied as shown in (Figure 2). The mean pH ranged from 9.09±0.76 to 7.57±0.52. The lowest was 7.57±0.52 in pond G and the highest was 9.09±0.76 in pond A (Table 1). One way ANOVA indicated pond A was significantly different from F and G (p=0.000, df=7), and (p=0.000, df=7) respectively also pond D had a significant difference from F and G and (p=0.001, df=7), (p=0.000, df=7) respectively but all the other pond didn't differ significantly (table 1).

In pond A the high pH may be as a result of high pH in water pumped into the pond that could have been influenced by the soils in the water source causing a rise in pH in water. It could also be attributed to high amount of nutrients which was evidence with low secchi depth and which was also the case in pond. The inflow in earthen ponds can carry acid from the soils in the area causing a drop in pH in flow in flow out pond system practiced in pond H. In pond F and G the mean was good for fish culture since it was neither acidic nor alkaline, this was probably because of the water exchanged practiced in the aquaculture ponds. The significant difference in pond F and G from A and D could be due to the nature of the pond as pond F and G were earthen while D and A were liner ponds these is because in earthen pond the soil influences the soil pH.

According to (Zweig, Morton, & Stewart, 1999) [12] the desired range for fish production is 6.5-9.0, the recorded means pH values in all the sample ponds were within acceptable range except pond A and D (Figure 2). The mean pH recorded in all the ponds were in the range of between 5.9 and 9.4 recorded in fish ponds in Kiambu and Machakos (Ngwili, 2014) [15]. The mean recorded in earthen pond F and G was close to the mean value of 7.0 recorded in earthen ponds in studies done by (Mwachiro, Makilla, Bett, & Ndeje, 2012) [16]. On a comparative study of cage and earthen pond culture of oreochromis Jipe, in Lake Jipe, Taita/Taveta District the results were also in the range studies done by (Musyoki, 2015) [13], on aquaculture on water quality in Gatundu, central Kenya.

## Secchi depth

The study showed secchi depth recorded during the study showed modest variations (figure 3). The mean secchi depth ranged from 14.13±3.36 in the pond D to 28.38±7.3 in pond G (table 1). One Way ANOVA analysis showed there was a significant difference between pond D and G (p=0.002 df=7) (table 1).



*The area highlighted in red indicates desired range

**Fig 3:** Mean secchi depth and conductivity values in the ponds studied with vertical bars indicating ±SE

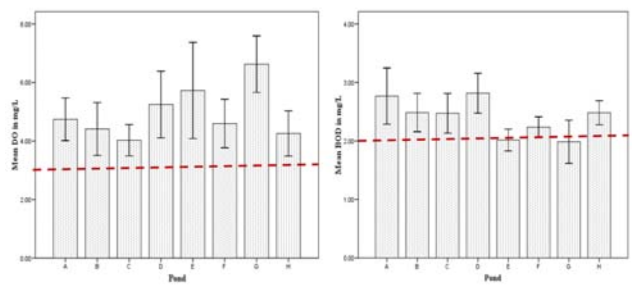
The higher Secchi depth in pond G is because the pond was fed was fed with water coming from a nearby spring that was low in nutrients also lack of plants and suspended particles allowed light to penetrate to a higher depth while. Pond D, the low secchi depth was as a result of accumulation of nutrients from left-over food material in the liner pond and also due to the shallow depths of the aquaculture ponds as slight breeze is enough to stir up the bottom sediments leading to an increased suspension. The use of manure in the fish ponds to stimulate algal growth to serve as primary producers and subsequently increase fish yield could have increased nutrients load (Nweze, Mahmoud, & Aisha, 2015) [17] and this could have lowered the secchi depth readings. The pond was stocked with cat fish which are bottom dwellers, which extensively stir the benthic Sediments while searching for benthic invertebrates, which is their key food item (Koekemoer & Steyn, 2005) [18].
During the study periods all the ponds except pond D were in the desired range (Figure 3). According to (Ngugi, Bowman, & Omolo, 2007) [19], aquaculture ponds should a secchi depth of 15-30cm, all the study ponds were in the desired range. The results were lower than studies done by (Munni, Fardus, Mia, & Afrin, 2013) [20], who recorded a mean range of 32.5-57.5 cm in fish ponds in Tangail, Angladesh was recorded. The results were also lower than 32.5-57.5 cm recorded by (Munni, Fardus, Mia, & Afrin, 2013) [20] in fish ponds in Tangail, Bangladesh.

**Conductivity**

The mean values of conductivity recorded varied in the eight ponds. The highest mean was recorded in pond C with a mean of 416.5±68.93, while the lowest was recorded in pond A with a mean of 190.25±127.86 (Table 1). According to one way ANOVA pond C showed a significant difference from pond A and G. (p=0.002, df=7) and (p=0.003, df=7) respectively (table 1).
In general, Pond C had the highest conductivity with a mean of 416.50 and pond A had the lowest mean of 190.25 while G had 203.94±98.22. In pond A, the wide range of conductivity may be as a result of variation in dissolved particles in the liner pond due to accumulation over time. Pond G the conductivity values variations in earthen pond could have been influenced by the low amount of total dissolved solids in inflow water and water residence time in the pond. The total dissolved solids load is determined by the type of soils at the area which may have affected the in Pond, the low conductivity in the earthen can be related with low nutrient load which is evidence with high mean secchi depth of 28.38±7.13 recorded.
The World Health Organization (WHO) limit for conductivity is 150-700 µS cm-1 (WHO, 2003) [21] for drinking and potable water, based on the limit conductivity in all the ponds was in the limit (Figure 3). In general, the results were in the range of studies by (Lazzari & Baldisserotto, 2008) [22] who recorded a higher mean range of 190-416 on studies done on fish farming waste in Sau Paula and studies done by (Keremah, Davies, & Abezi, 2014) [23] Bayelsa State, Nigeria where a range of 117.3+91.01 to 378.4+130.20 µSiemens/cm were recorded. However, the results showed a wider range than studies on pond water quality in Santosh Tangait by (Munni, Fardus, Mia, & Afrin, 2013) [20], who got a mean range of 138-274µsiemens/cm.

**Dissolved Oxygen**

The values of dissolved oxygen recorded varied in the eight ponds, the highest mean was recorded in pond G with a mean of 6.63±1.37, while the lowest was recorded in pond C with a mean of 4.03±1.39 (Table 1). According to t-test only in pond G, there were significant difference from the recommended annual mean dissolved oxygen (t=7.500, df=7, P=0.000). One Way ANOVA showed pond C differed significantly from pond G (p=0.002, df=7) (table 1).



*The area highlighted in red indicates desired range

**Fig 4:** Mean DO and BOD values in the ponds studied between July and November 2015 bars indicate ±SE

All the ponds did not have significant difference from recommended mean except pond G which had a significant difference, the difference was due to high amount of dissolved oxygen present in water flowing into the pond. In addition, in pond G the high levels of DO can be related to the flow in and flow out system in the pond which allow for continuous supply of dissolved oxygen and aeration of water in the ponds. In Pond C, the accumulation of nutrients that could be as a result of feed left over in the pond may have used up DO during decomposition affecting the dissolved oxygen negatively. The reduction in DO could be as result of increased uptake of DO by microorganisms during breakdown of accumulated organic matter in the pond.
According to (Zweig, Morton, & Stewart, 1999) [12] aquaculture ponds should have a minimum of 3mg/l. Generally, the results were comparable to the study done by (Kiran, 2010) [24], who recorded DO ranged between 2.0 mg/L and 8.6 mg/L in study done in fish ponds of Bhadra Karnataka. The dissolved oxygen recorded during this study is also comparable with observations by (Musyoki, 2015) [13], done in aquaculture ponds in Gatundu, Central Kenya and 3.2-10.0mg/l was recorded and (Keremah, Davies, & Abezi, 2014) [23] recorded mean range of 2.8+0.20- 6.6+0.18mg/l.

**BOD**

The values of BOD recorded varied in the eight ponds as shown in figure 4 Pond D had the highest mean of 2.82±0.48 while pond G had the lowest mean of 1.99±0.52 (table 2). The lowest BOD was 1.4 mg/l recorded in Pond G, while the highest was in pond A which recorded 3.81 mg/l.

**Table 2:** Chemical parameters

| Ponds | BOD (Mean±SE)mg/l | $PO_4^-$ (Mean±SE)mg/l | Nitrates (Mean±SE)mg/l |
|---|---|---|---|
| Desired range | 2mg/l(minimum) | 0.01-3mg/l | 0.01-4.5mg/l |
| A | 2.76±0.68$^{b}$ | 4.82±21.60$^{ab}$ | 0.38±0.10$^{a}$ |
| B | 2.52±0.53$^{ab}$ | 1.69±3.31$^{ab}$ | 0.92±0.47$^{a}$ |
| C | 2.48±0.48$^{ab}$ | 0.57±0.93$^{a}$ | 1.81±0.61$^{a}$ |
| D | 2.82±0.48$^{b}$ | 3.28±9.74$^{ab}$ | 1.48±0.17$^{a}$ |
| E | 2.01±0.26$^{a}$ | 1.36±2.63$^{a}$ | 2.12±0.45$^{a}$ |
| F | 2.23±0.25$^{ab}$ | 0.51±1.05$^{a}$ | 2.65±0.34$^{a}$ |
| G | 1.99±0.52$^{a}$ | 0.82±1.31$^{a}$ | 4.95±1.46$^{b}$ |
| H | 2.48±0.29$^{ab}$ | 5.76±1.59$^{b}$ | 8.86±1.20$^{c}$ |
| P-value | 0.001 | 0.001 | <0.001 |

(*)Mean values followed by the same small letter(s) within the same column do not differ significantly.

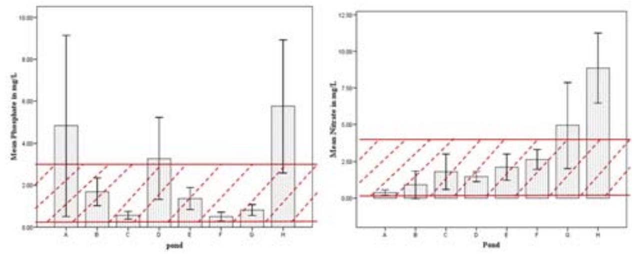
According to t-test all the pond did not show significant difference from the recommended mean. According to one way ANOVA pond A differed significantly from pond E and G, (p=0.002, df=7), (p<0.001, df=7) and also pond D differed significantly from E and G (p= 0.001, df=7), (p=0.001, df=7) respectively as shown in table 2.

In pond A and B waste feed accumulation in aquaculture ponds may increase the BOD levels. In pond C, the BOD may be related to low nutrients evident with high secchi depth. In pond D, nutrients accumulation in aquaculture ponds may have increased the BOD levels and this is an evident due to the low secchi depth of 14.13±3.36cm. In pond E, the low BOD concentration may have been as a result of the low turbidly obvious with high secchi depth of 24.10±8.25cm which indicated low nutrients that increase BOD. In pond F, waste feeds accumulation in aquaculture ponds may have contributed to the BOD levels. In pond G, the flow in flow out system in the pond may have contributed to the low BOD as decomposition of organic matter in such ponds is low.

According to (Bhatnagar & Devi, 2014) [25], aquaculture ponds are should have a mean of 2mg/l, all the ponds were within the desired range. The results in all the ponds compared studies done by (Deka, 2015) [26], where a comparative study of the seasonal trend in two fresh water aquaculture ponds of Assam was done and a mean range of 1.34 to 3.02 mg/l was recorded. The mean of pond D which had the highest mean was close to studies by (Keremah, Davies, & Abezi, 2014) [23] Bayelsa State, Nigeria where a mean of 2.9+0.60mg/l was recorded in fish ponds. However, a wider range was recorded by (Kiran, 2010) [24] on a study on fish ponds of Bhadra Project at Karnataka who recorded a mean range of 0.8mg/l to 6.6mg/l and a study by (Olopade, 2013) [27], on assessment of water quality characteristics for aquaculture uses in Abeokuta North local government area, Ogun state, Nigeria who recorded mean range of 2.50 to 6.70mg/l

### Phosphate

The values of phosphate recorded varied in the eight ponds. Pond H recorded the highest mean of 5.76±1.59mg/L while, pond F recorded the lowest mean of 5.06±1.05mg/L (figure 5). According to one way ANOVA pond H differ significantly from pond C, E, F and G (p=0.001, df=7),( p=0.004, df=7), (p=0.001, df=7) and (p=0.001, df=7) respectively (table 2).



*The area highlighted in red indicates desired range

**Fig 5:** Mean phosphate and nitrates concentration in the ponds studied between July and November 2015 bars indicate ±SE

In pond F, the low phosphate may have resulted from ponds being supplied with water from source low in phosphates and the flow in flow out system which could have controlled accumulation of phosphates in the pond. In pond H, the high levels of phosphates in the aquaculture pond could be due to water from a source being loaded with fertilizers as a result of inflow of runoff high in inorganic fertilizers from surface runoffs from surrounding farms that are washed into standing water bodies from farms that surround them (Jafari & Gunnale, 2006) [28]; (Fikrat, Hassan, Saleh, & Jasi, 2010) [29] which was also the case in the pond as soil run-off that have high phosphate concentrations coming from tea farms that are dominant in the area. The low level of pond management and the fact that the pond was earthen pond could have increased phosphate levels in the water.

According to (Bhatnagar & Devi, 2014) [25] aquaculture ponds are required to have a range of 0.01-3mg/l, all the ponds recorded a concentration in the desirable range (figure 5). The mean was in the range of 1.40 - 4.51 mg/l recorded by (Ehiagbonare & Ogunrinde, 2010) [30] in their study of fish pond water in Okada and its environs, Nigeria but the mean of pond H was slightly high. However the pond 3 ponds had a wider than the mean range recorded by (Kiran, 2010) [24] in fish ponds of Bhadra Project at Karnataka where a phosphate mean level varied from 0.51 to 1.28 mg/l. The mean in pond F that recorded the lowest mean was similar to studies by (Laibu, 2010) [14], in fish pond water in Central Meru County where a mean ranging from 0 – 2.81 mg/l as recorded.

### Nitrates

The values of nitrates recorded varied in the eight ponds as shown in figure 5. Pond H recorded the highest mean of 8.86±1.20 while pond A recorded the lowest mean of 0.38±0.10 (figure 5). According to one way ANOVA, pond G and H showed significant difference from the other ponds. Pond G differed from A and B (p=0.000, df=7), C (p=0.005, df=7), D(p=0.002, df=7), E(p=0.010, df=7) F(p=0.035, df=7) and H(p=0.001 df=7), while pond H had significant difference from pond A,B,C,D,E,F(p=0.000, df=7) and G (p=0.001, df=7) (table 2).

In pond A, low nitrates may be as results of low levels of nitrates concentration in water being pumped into the pond and water exchanged done in liner ponds may have contributed to low nitrates in the ponds. In pond H, ponds use of inputs containing nitrogen (inorganic fertilizers that have higher levels of nitrate), and where pond being fed from water source containing run off from tea farms which is with high

inorganic fertilizer containing nitrates. Nitrates concentration differences in the dam reservoir can be due to the inflow of inorganic fertilizers from surface runoffs from neighbouring farms into the dam reservoir. According to (Ndiwa, 2011) [31] nitrate levels are significantly higher in reservoir which have been fertilized using farm manure which was also done in the ponds. In the study a wider range than 3.17 – 4.50 mg/L that of a study done by (Dinesh, Karthik, & Rajakumar, 2017) [32] on pond water in Tamil Nadu, India.
According to (Bhatnagar & Devi, 2014) [25], aquaculture ponds require to have a range of 0.01-4.5 mg/l, all the study ponds were within the desired range. Pond A which recorded the lowest mean was in the range of 0.01– 3.8mg/l which was recorded by (Shafei, 2016) [33], on a study in fish pond culture in Lake Manzala, Egypt and the range of 0.4 to 1.1 mg/l recorded by (Musyoki, 2015) [13], in Gatundu, Kenya. The mean concentration in pond H which recorded the highest mean was in the range of studies by (Kiran, 2010) [24] who recorded 4.5 mg/L to 8.0 mg/L in fish ponds of Bhadra project at Karnataka.

## Conclusions
Water characteristics in some study ponds showed a significant difference. Mean temperature were in the lower range, conductivity in all ponds were within desired range, BOD there was no significant difference in all ponds from the desired mean, nitrates all ponds were within desired range except pond G and H which were above range, and for phosphates Pond A,D and H were above range.

## Recommendations
There is need for sustainable aquaculture system which will increase water temperature such as greenhouses fish farming and RAS to treat and conserve water.
Further research is necessary to determine variation in water characteristics aquaculture ponds in different seasons of the year. Due to the high amount of phosphates in the aquaculture, there is need for research on the agriculture activities and the influence on water quality in the area.
Fish farming in Kenya is limited to few fish species in the region hence; more research is required on other species that may adopt better to the temperature range in the area, since the temperature was in the range they affected the production in terms of time taken to achieve the market size which affect the income generation.

## Acknowledgement
I am sincerely grateful to all those that made this research work a success. I wish to express my sincere gratitude to my supervisors, Dr. James Koske and Dr. Esther Kitur Esther, Kenyatta University.

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