E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2019; 7(4): 01-06

www.fisheriesjournal.com
Received: 01-05-2019
Accepted: 03-06-2019

Theuri Olive Wairimu
Department of Environmental Sciences, Kenyatta University, P.O. Box, Nairobi, Kenya

Kitur Esther
Department of Environmental Sciences, Kenyatta University, P.O. Box, Nairobi, Kenya

Ngugi CC
Department of Natural Resources, Karatina University, P.O. Box 1957, Karatina, Kenya

Mwangi BM
Department of Biological Sciences, Murang'a University of Technology, P.O. Box 75, Murang'a, Kenya

Nzeve JK
Department of Environmental Sciences, Machakos University, P.O. Box 136, Machakos, Kenya

Correspondence
Theuri Olive Wairimu
Department of Environmental Sciences, Kenyatta University, P.O. Box, Nairobi, Kenya

Impact of aquaculture development on water quality of fish ponds in gatundu North and south sub-counties, Kenya

Theuri Olive Wairimu, Kitur Esther, Ngugi CC, Mwangi BM and Nzeve JK

Abstract
Aquaculture development in Kenya has increased in the recent past due to Government support, however, information on its influence on water quality is scanty. This study looked at the influence of fish culture on water quality in fish ponds. Water samples were collected from pond inlets and fish ponds and physico-chemical parameters analyzed. Means of measured parameters at the pond inlets were; Temp(21.27±3.31 °C), DO(4.45±0.73mg/l), EC(27.38±17.21µS/cm), TDS(368.61±135.21mg/l), pH(7.31±0.45), N-NO_3(2.06±2.38mg/l) and PO_4-P(0.29±0.41mg/l) while mean values inside the ponds were; Temp (23.58±3.85 °C), DO(4.89±1.09mg/L), EC(34.63±19.50µScm^{-1}) TDS(493.13±136.67mg/l), pH(7.68±0.50), NO_3(2.76±2.35mg/L) and PO_4-P (1.71±1.50mg/L). Values of measured parameters were within acceptable limits for aquaculture as per WHO standards. All parameters significantly increased in pond water as compared to inlet water showing that aquaculture was contributing to deterioration of the water quality in fishponds. This calls for effluent treatment, regular monitoring and sensitization of farmers on good aquaculture practices.

Keywords: Aquaculture development, fish culture, water quality, physico-chemical parameters

1. Introduction

Aquaculture in the world has been practiced in many countries and is the only sustainable solution to the declining natural fish stocks as a source of food [1]. On the global scene, aquaculture has seen a rapid growth in the recent past [2] and is projected to contribute over 50% of the total fisheries production by 2020 [3]. Kenya's natural fish stocks from lakes and rivers, contribute about 90% of the national fish production statistics, there's however a declining production trend since the wild stocks have reached maximum sustainable yield [4, 5]. The Economic Stimulus Programme (ESP) implemented by the Kenya Government from 2009 to 2012 increased production from aquaculture from a mere 4000 MT to slightly over 20,000MT in 2013[6, 7]. Before ESP, aquaculture in the country was practiced mainly in semi-intensive systems, where ponds were fertilized and feeds used as supplements to increase fish yields [8]. However, during ESP farmers embraced more intensive systems towards increasing pond productivity [7]. Pond fertilization generates high nutrient levels that lead to increase in natural pond productivity [9]. Remains of fish feeds that are not consumed by fish accumulate in the pond water and may deteriorate fish pond water quality [10, 11]. Aquaculture development is therefore faced with a challenge of increasing productivity whereas ensuring minimal impact on the environment [12].

Pollutants of Fish pond water include; residual food, faecal matter, pathogenic bacteria, viruses and parasites, suspended solids, drugs and disinfectants [13]. Pond waste water if disposed untreated can therefore alter water quality in the receiving waters [14]. A global concern over the impact of aquaculture on the environment has led to promotion of good aquaculture practices that are environment-friendly [15]. Although aquaculture continues to expand, information on the impact of aquaculture on the environmental is minimal [11]. This research therefore, sought to address the impact of aquaculture growth on the fish pond water quality in Gatundu, Kenya.

2. Materials and Methods

2.1 Study Location

This study was carried out in Gatundu North and Gatundu South Sub Counties of Kiambu County, Kenya (Figure 1). The study area lies between latitude (1°1′0″ S) and longitude (36°56′0″ E) and between altitude 1520 m and 2280 m above sea level [16]. It is 50 Km North West of the Kenyan capital city Nairobi and covers an area of 481.1 Km².

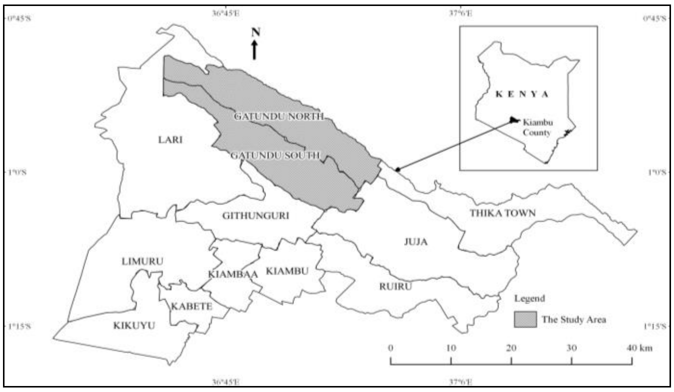

Fig 1: Map of Kiambu County Showing the Location of Gatundu the study area. (***Source***: Kiambu County Government, 2013)

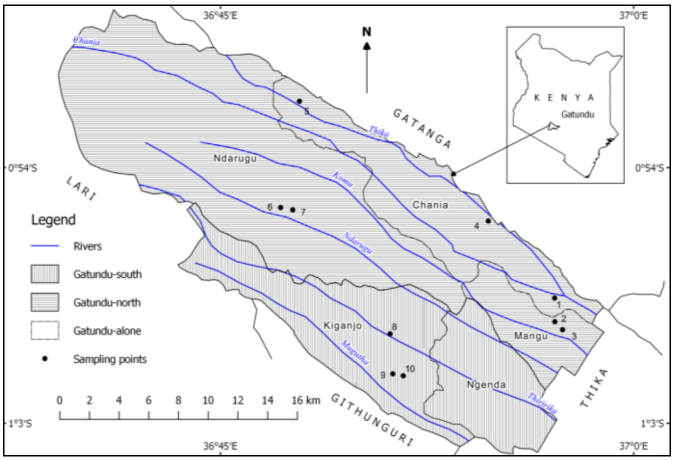

Fig 2: Map showing location of Gatundu the study area and the sampling sites (**Source:** Modified: Kiambu County Government, 2013).

2.2 Data Collection

Water samples were collected from 10 fish ponds purposively selected. The ponds had a minimum maturity of sixth months from stocking. An agreement was made with the farmers not to do a complete harvest or dispose the pond waste water during the study period. Selected physical parameters were measured on site. A multi-electrode water testing probe (Model: DO 5510 MRC) was used to determine the water temperature and Dissolved Oxygen (DO), while pH was measured using pH meter (Model: HI 98107 HANNAH). Total Dissolved Solids (TDS) was determined using TDS meter (Model: 4076 Jenway) while Electrical Conductivity meter (Model: 4010 Jenway) was used to measure EC. Sampling plastic bottles of 250 ml were cleaned using 10% nitric acid and rinsed in distilled water. Prior to sample collection the bottles were rinsed three times with sample water. Sampling was then done at two points; at the inlet of the pond just before the water got into the fish pond and at the farthest point of the pond from the inlet, a meter away from the pond dyke to ensure no influence by the inflow and human or animal activity. Scooping of the sample was done at a depth of 0.3m below water surface. Water samples were collected every 2 months for a period of 11 months starting May 2015 to March 2016. Samples for the analysis of Nitrates and phosphates were taken through standard laboratory procedures [17]. UV-Visible spectrophotometric method was used to determine nitrate concentrations while Molybdenum blue method was used to determine Phosphate concentrations.

2.3 Data Analysis

Statistical Program for Social Sciences (SPSS) was used for data analysis. One-way Analysis of Variance (ANOVA) was used to determine significant difference ($p \leq 0.05$) within pond samples and within inlet water samples. Independent t-test was used in the comparison of means between inlet and pond water, while Student Newman Keuls (SNK) test was used to separate the means where there was a significant difference.

3. Results and Discussions

3.1 Temperature

Water temperature among ponds and among inlet water did not differ significantly ($p = 0.836$) and ($p = 0.819$) respectively. There was however a significant difference between inlet and pond water ($p = 0.001$) as shown in Table1. Mean temperature in inlet water was (21.27 ±3.31 ºC) and (23.58±3.85 ºC) in pond water. The values were well within permissible limit for aquaculture, which is 15-35 ºC but slightly below optimal levels for tilapia and catfish 25-32 ºC [18] and WHO limit (25 ºC). Inlet and pond water temperature differed significantly since the pond water was static and shallow. This results in warmer ambient temperatures due to long hours of exposure to the sun’s rays. Aquaculture activities also increase suspended particles in water which absorb heat from sunlight more efficiently thus warming up pond water faster than the clearer inlet water. Temperature range observed in the study (17.5-32 °C) was within range of 18-32 °C of Bangladesh fish ponds [19], 20.9-33.8 °C reported in India [20], 23.2-32.7 °C in South East Brazil [21] and 21-28 °C in Ghana ponds [22]. Temperature recorded in Inlet water (17-29 °C) was within range of studies in tropical river ecosystems, rivers of Gatundu South recorded 19.55-23.05 ºC [23], River Narmada in India (22.4-29 ºC) [24] while 26.8-33.7 ºC was reported in River Asu of Nigeria [25].

3.2 Dissolved Oxygen (DO)

DO did not differ significantly among ponds ($p = 1.142$) and among inlets ($p = 0.903$). Pond water had significantly higher levels of DO than inlet water ($p = 0.011$). Mean DO in pond water and inlet water was 4.89±1.09mg/L and 4.45±073 mg/L respectively (Table 1). The DO levels in pond water is presented in Table 2 while Table 3 shows the range for the inlet water. The DO levels were within WHO requirements of 4-6 mg/L but slightly below the optimum for aquaculture [18].

Fertilization of pond water by farmers in a bid to increase productivity caused algal growth and consequently increased DO significantly in the pond water as compared to the inlet water. The DO in pond water (4.72-5.02 mg/L) was within range of similar studies done in Bangladesh ponds 1.1-6.9mg/L [26], Bayelsa ponds in Nigeria 2.8-5.1mg/L [27] and 2.0-8.6mg/L in Karnataka India [28]. DO levels in inlet water (2.98-6.94mg/L) were within the same range with those reported in river Kibisu 2.26-8.94mg/L [29], Asu river of Nigeria 3.0-8.7mg/L[25] and 4.16-8.8 mg/L in India [24], but lower than 6.37-7.76mg/L reported in Gatundu south rivers [23].

Table 1: Physico-chemical parameters in pond and inlet water

Parameter		Mean±SD	Min -Max	P - Value
Temperature (^{0}C)	Pond	23.58±3.85	17.5-32	$P = 0.001$
	Inlet	21.27±3.31	17-29	
pH	Pond	7.68±0.50	6.8-9	$P < 0.001$
	Inlet	7.31±0.45	6.4-8.7	
Dissolved Oxygen (mg/L)	Pond	4.89±1.09	3.77-7.42	$P = 0.011$
	Inlet	4.45±0.73	2.98-6.94	
TDS (mg/L)	Pond	493.13±136.67	230-820	$P < 0.001$
	Inlet	368.61±135.21	198-736	
Conductivity (µs/cm)	Pond	34.63±19.50	9-83	$P = 0.037$
	Inlet	27.38±17.21	9-78	
Nitrates (mg/L)	Pond	2.76±2.35	0.16-9.81	$P = 0.105$
	Inlet	2.06±2.38	0.03-8.38	
Phosphates (mg/L)	Pond	1.71±1.50	0.01-4.76	$P < 0.001$
	Inlet	0.29±0.41	0.01-1.86	

Table 2: Means ± SD values of Physico-chemical parameters in fish pond water. (Means within the same column with similar superscripts do not differ significantly from one another).

Site	Temp. °C	DO (mgL^{-1})	pH	TDS (mgL^{-1})	EC (µScm^{-1})	Nitrates (mgL^{-1})	Phosphates (mgL^{-1})
P1	23.58±3.72	4.81±1.15	7.95±0.55	484.83±107.92	35.60±13.79^b	1.47±1.70	1.28±0.94
P2	25.67±6.47	4.87±1.18	7.77±0.29	540.50±97.18	33.17±18.76^b	3.22±2.42	2.26±1.83
P3	24.33±4.18	4.97±1.33	7.97±0.56	497.33±134.38	27.00±15.19^a	2.55±3.60	1.20±1.02
P4	22.00±4.38	4.72±1.07	7.77±0.73	373.67±52.21	26.20±14.69^a	2.98±1.26	2.28±1.54
P5	24.83±3.37	4.77±1.08	7.67±0.54	591.60±181.26	18.40±4.51^a	3.28±3.07	2.41±1.93
P6	22.25±3.52	5.02±1.33	7.53±0.35	436.17±90.27	37.33±20.53^b	1.89±1.82	1.20±1.45
P7	22.33±4.03	4.77±1.10	7.32±0.41	579.00±182.62	33.33±20.18^b	3.12±3.09	2.32±1.16
P8	23.00±2.10	5.01±1.12	7.52±0.52	469.17±111.16	33.17±17.84^b	2.90±1.86	0.69±0.68
P9	23.67±3.44	4.94±1.14	7.70±0.60	488.83±171.73	34.50±20.23^b	2.44±1.97	1.51±1.75
P10	24.17±3.31	5.00±1.29	7.58±0.21	480.00±164.23	63.67±18.57^c	3.79±2.65	1.69±2.01

3.3 pH

There was significant difference in pH between pond water and inlet water ($p<0.001$). However, there were no significant difference in pH recorded among the ponds sampled and among the inlet water samples ($p>0.05$). The significant difference noted could be as result of algae productivity since farmers fertilized pond water to increase fish production. Mean pond water pH for pond and inlet water is presented in Table 1 while the pH range of pond water and in inlet water are presented in Table 2 and Table 3 respectively. PH range in ponds (6.8-9) was within WHO limit for aquaculture which is (6.5-8.5). The levels were also optimal for fish growth (6.7-9.5) [30]. Results of this study (7.32-7.96) were similar to related studies in Bangladesh ponds (pH 7.0-8.8) [31] and pH 6.7-7.4 in Ogun state, Nigeria [32]. PH range in the inlet water was similar to studies done in Gatundu South rivers [23] where pH range of 6.68 -7.63 was recorded.

Table 3: Means ± SD values of Physico-chemical parameters at the inlet. (Means within the same column with similar superscripts do not differ significantly from one another).

Site	Temp. (^{0}C)	DO (mgL^{-1})	pH	TDS (mgL^{-1})	EC (µScm^{-1})	Nitrates (mgL^{-1})	Phosphates (mgL^{-1})
S1	19.83±3.54	4.62±0.39	7.43±0.21	311.33±98.45	21.83±4.02^a	0.48±0.32	0.07±0.03
S2	23.17±5.71	4.55±0.59	7.25±0.29	364.67±146.55	28.50±12.91^a	1.50±2.93	0.29±0.47
S3	21.83±4.26	4.46±0.52	7.47±0.47	457.17±214.31	19.00±6.42^a	0.61±0.44	0.58±0.84
S4	20.67±3.93	4.49±0.83	7.53±0.24	387.00±141.75	23.00±12.31^a	1.95±3.16	0.35±0.27
S5	22.33±2.94	4.32±0.75	7.38±0.35	409.80±53.42	20.00±6.00^a	4.28±2.78	0.19±0.16
S6	20.67±2.66	4.44±0.70	7.05±0.59	398.17±91.31	29.33±20.29^a	1.38±1.53	0.16±0.16
S7	21.67±3.27	4.01±0.28	7.18±0.37	417.83±102.19	27.00±8.10^a	1.62±1.65	0.21±0.24
S8	20.83±2.14	4.65±1.16	7.27±0.62	268.00±101.24	24.00±15.07^a	2.79±2.81	0.13±0.14
S9	21.67±1.75	4.68±0.93	7.33±0.72	327.33±184.19	22.00±14.64^a	2.32±2.51	0.07±0.05
S10	20.00±2.19	4.23±0.99	7.23±0.49	343.25±116.80	56.67±28.07^b	3.40±2.14	0.66±0.46

3.4 Total dissolved Solids (TDS)

TDS levels between pond and inlet water varied significantly ($p<0.001$), concentrations among ponds and among inlets were however not significantly different (p=0.234) and (p=0.420) respectively. Mean TDS in pond water was 493.13±136.67mg/L, while mean TDS in inlet water was 368.61±135.21mg/L (Table 1). TDS values for pond water and inlet water are presented in Table 2 and Table 3 respectively. Recorded TDS levels in both pond and inlet water were within WHO (1000mg/L) requirements for aquaculture. TDS in pond water was significantly higher than at the inlets due to use of feeds, fertilizers and manure in aquaculture which increases dissolved ions and consequently TDS levels. The TDS levels in this study (373-591mg/L) were higher but within range of other studies, Nigeria ponds reported wider ranges of 22-906 mg/L [33] and 40-620mg/L [34], while ponds in Bangladesh had much lower TDS levels of 87.6 to 220mg/L [19]. TDS levels in inlet water (268-457mg/L) were within range of 257-348mg/L recorded in River Kibisu [29], but higher than River Narmada which recorded a range of

146-274mg/L [24].

3.5 Electrical Conductivity

Electrical Conductivity (EC) levels in pond and inlet water was significantly different (p=0.037). Concentrations among ponds and among inlets were also significantly different (p=0.014) and (p=0.004) respectively. Mean EC levels in pond water (34.63±19.50µS/cm) and inlet water (27.38±17.21µS/cm) were within WHO limit for aquaculture (1000µS/cm), but below the optimal requirement (100-2000µS/cm) [30]. Use of manure for pond fertilization and fish feeds in ponds increased TDS, ionic concentration and hence EC in fish ponds causing significant difference in EC between inlet and pond water. EC in aquatic systems is influenced greatly by the bedrock on which rivers flow [36]. The geological characteristics of the surroundings [35] influenced EC levels which were significantly different among ponds and among inlets. Weather patterns during the study period also caused fluctuating water levels influencing water temperature, TDS and consequently EC [37]. Student Newman Keuls (SNK) test revealed high EC in Pond 10 both at the inlet and pond water. The pond which was situated near a tea plantation could have been influenced by leaching of agricultural inputs into inlet water and then into pond water.

A Similar study in Busia County recorded EC levels of 34.67-86.67µS/cm [36], which were within range of this study (18.40-63.67 µS/cm). South East Brazil ponds had a wider range of 24µS/cm to 610 µS/cm [21] while Ghana and India ponds recorded higher EC levels of 102.2-132.30 µS/cm [22] and 118.7-206.6 µS/cm [20] respectively. EC levels at the inlets in this study (19.00-56.67µS/cm) were within similar range as Gatundu south rivers (25.20-134.40 µS/cm) [23] but lower than River Benue of Nigeria that reported 64.70-139.60 µS/cm, [38] and 134.9-166 µS/cm in River Kibisu[29].

3.6 Nitrate-Nitrogen (NO_3-N)

Levels of Nitrate-Nitrogen were not significantly different between pond and inlet water (p=0.105) as shown in Table 1. Concentrations within ponds and within inlet water were also not significantly different (p=0.882 and p=0.133 respectively). Means of Nitrate-Nitrogen concentrations were 2.76±2.35 in pond water and 2.06±2.38 in inlet water (Table 1). Levels in pond and inlet water were within WHO limit (50mg/L) and within optimal range for aquaculture 0.1 to 4.5mg/l [39]. It was expected that nitrate levels in pond and inlet water would be significantly different due to fish culture impact on pond water, [40] However, this study showed no significant impact of fish culture on nitrates. This could be due to oxidization of Nitrates to nitrites and ammonia by aerobic bacteria in the nitrogen cycle [41].

Similar studies found insignificant impact of fish culture activities on Nitrate-Nitrogen levels in fish pond effluent [42,43], However studies on Nigeria ponds recorded nitrate levels of 2.21-4.91mg/L and 1.21- 9.24mg/L [33, 44] which were higher than this study (1.47-3.79mg/L). Nitrate-Nitrogen levels in inlet water (0.48-4.28mg/L) were higher than 0.05-4.4 mg/L recorded in Ethiopia [45], 0.01-0.05mg/L in River Asu [25] and 0.66 to 0.70mg/L in Gatundu south rivers [23].

3.7 Ortho-Phosphates (PO_4-P)

Levels of orthophosphate concentration in pond water and inlet water were significantly different *p*<0.001 (Table 1). There was however no significant difference within sampled pond water (p= 0.543) and within inlet water samples (p=0.366). Orthophosphate levels in this study were within WHO limits for aquaculture (0.03-3mg/L). Use of fertilizers and phosphorous-rich fish feeds impact phosphate concentrations in fish ponds significantly [46]. More mature ponds have higher levels of phosphates [47]. Orthophosphate levels in pond water in this study (0.69-2.41mg/L) were within range of 0.51-1.28mg/L reported in India [28]. Nigeria ponds however had higher and wider ranges of 1.40-4.51mg/l and 0.01- 0.90mg/L [33, 44]. Orthophosphate levels in inlet water (0.07-0.66 mg/L) were within range of 0.02-0.16mg/L in Nigeria [25], 0.35-0.6mg/L in Gatundu south [23], and 0.112-0.546mg/L in River Narmada [24].

4. Conclusion

This study concluded that fishpond waste water quality is within the allowable limits thus not an immediate threat to the aquatic systems. However, aquaculture activities are significantly impacting on the quality of pond water. There was a significant increase in concentration of physico-chemical parameters in fish ponds as compared to the inlets except for nitrate-nitrogen. These results imply substantial influence of fish culture activities on water quality and show potential for pollution of recipient waters by untreated pond waste water. However, the study noted an increase in Dissolved Oxygen (DO) and pH levels in ponds as compared to the inlets this implies that Good Aquaculture Practices could actually improve pond water quality. The study therefore recommended that fish pond waste water be treated before release to open water bodies to avoid eutrophication of receiving waters. Other safe disposal methods like irrigation of appropriate plants and aquaculture recirculation systems be considered. Regular monitoring of fish pond water quality will be critical for sustainable aquaculture development. Training of fish farmers on Good Aquaculture Practices such as optimal fertilization and efficient feeding is important in maintaining and even improving pond water quality.

5. Acknowledgement

The study was partially funded by Aqua fish Collaborative Research Support Programme.

6. References

1. Bene C, Arthur R, Norbury H, Allison EH, Beveridge M, Bush S *et al.* Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. World Development. 2016; 79:177-196
2. Brugere C. Ridler NB. Global aquaculture outlook in the next decades: An analysis of national aquaculture production forecasts to 2030. Food and Agriculture Organization of the United Nations, 2014, 1001.
3. FAO. Food and Agriculture Organization. The state of world fisheries and aquaculture (SOFIA) In: F.F. j7FAO, Rome, Italy, 2014.
4. Kaliba AR, Ngugi CC, Mackambo JM, Osewe KO, Senkondo E, Mnembuka B *et al.*, Potential effect of aquaculture promotion on poverty reduction in Sub-Saharan Africa. Aquaculture International. 2007; 15:445-459.
5. Munguti JM, Kim JD. Ogello EO. An overview of Kenyan Aquaculture: Current status, challenges, and opportunities for future development. Fisheries and Aquatic Sciences. 2014; 17:1-11.
6. MOFD: Ministry of Fisheries Development. Fisheries Annual Statistical Bulletin, 2012, 32-34

7. Musa SA, Aura CM, Owiti GE, Nyonje BE, Orina PA, Charo-Karisa HA *et al.* Fish farming enterprise productivity program (FFEPP) as an impetus to *Oreochromis niloticus* (L.) farming in Western Kenya: Lessons to learn. African Journal of Agricultural Research. 2012; 26:1324-30.
8. Charo-Karisa H. Gichuri M. Overview of the Fish Farming Enterprise Productivity Program. End of Year Report Fish Farming Enterprise Productivity Program Phase I, Aquaculture Development Working Group Ministry of Fisheries Development, Kenya, 2010.
9. Omondi JG, Gichuri WM, Veverica KA partial economic analysis for Nile tilapia and sharp toothed catfish polyculture in central Kenya. Aquaculture Research. 2001; 32:693-700.
10. Ogello EO, Munguti JM. Aquaculture: a promising solution for food insecurity, poverty and malnutrition in Kenya. African Journal of Food, Agriculture, Nutrition and Development. 2016; 16:11331-11350.
11. Kiithia SM, Khroda GO. Sediments yields and transport within the Nairobi river basin, Kenya: in river, coastal and estuarine morpho dynamics River Coastal Estuarine Morpho dynamics (RCEM) Tsinghua University press, Beijing, 2011.
12. Navarrete MF, Sanz LS. Martin A. Does bivalve molluscs' polyculture reduce marine finfish farming environment impact. Aquaculture Research. 2010; 306:101-107.
13. Gravningen K. Driving forces in aquaculture: different scenarios towards. In: Arthur R, Nierentz J. (Eds.), Global Trade Conference on Aquaculture. United Nations, Rome, 2007, 19-26.
14. Dempster T, Uglem I, Sanchez-Jerez P, Fernandez-Jover D, Bayle-Sempere J, Nilsen RA *et al* Coastal salmon farms attract large and persistent aggregations of wild fish: an ecosystem effect. Marine Ecology Progress Series. 2009; 385:1-14
15. CIFA/OP24. Africa regional aquaculture review, FAO Regional Office for Africa, Accra, Ghana 2000, 50 pp.29 November - 05 December 1972, Rome, 1973, 34.
16. DDP: District Development Plan, Gatundu District. Ministry of Planning, 2012.
17. APHA: American Public health association. Standard methods for the examination of water and waste water (20th ed.), Washington, DC, USA, 1998.
18. Boy CE. Water quality in ponds for aquaculture. Research and Development Series. Number 43. International Centre for Aquaculture and Aquatic Environments, Alabama Agricultural Experimental Station, Auburn University, Alabama, 1998, 402.
19. Gupta T, Mithra D. Hydro Biological characteristics of some semi-intensive fish culture ponds of Lumding town of Nagaon district, Assam. Current World Environment. 2013; 8(1):101-115. http://dx.doi.org/10.12944/CWE.8.1.15
20. Dixit R, Wasiullah Deepti M, Kuppusamy P, Udai B, Asha S *et al.* Bioremediation of heavy metals from soil and aquatic environment: An overview of principles and criteria of fundamental processes. Sustainability Sustainable Use of the Environment and Resources, doi: 10.3390/su7022189. 2015; 7(2): 2189-2212.
21. Simone MC, Eleonona A, Carla FM, Vera LM. Low water quality in tropical fish ponds in S.E Brazil. Annals of the Brazilian Academy of Sciences, http://dx.doi.org/10.1590/0001-3765201420130092, 2013.
22. Ansa YB, Frimpong EA, Amisah S. Characterization of potential aquaculture pond effluents and physico-chemical and microbial assessment of effluent receiving waters in Central Ghana. African Journal of Aquatic Science. http://dx.doi.org/10.2989/16085914.2013.767182, 2013.
23. Minoo MC. Impacts of aquaculture on water quality and economic benefits in Central Kenya: A case study of Gatundu south Constituency. MSc. Thesis. University of Nairobi, 2015.
24. Singh PK Shrivastava P. Analysis of water quality of River Namada, International Journal of Current Research, 2018, 10(06).
25. Nwinyimagu AJ, Nwonumara GN, Ani C, Ukaje IO. Evaluation and Management of the physicochemical variables of Asu River, South East Nigeria. Journal of Sustainable Development http://dx.doi.org/10.5539/jsd.v9n2p54, 2016, 9(2).
26. Munni MA, Fardus Z, Mia MY, Afrin R. Assessment of pond water quality for fish culture: A Case study of Santosh region in Tangail, Bangladesh. Journal of Environmental Science and Natural Resources. 2013; 6(2):157-162
27. Keremah RI, Davies OA, Abezi ID. Physico-chemical analysis of fish pond water is freshwater areas of Bayalsa state Nigeria. Green Journal of Biological Science. 2014; 4(2):033-038.
28. Kiran BR. Physico-chemical characteristics of fish ponds of Bhadra project at Karnataka. Rasayar Journal. 2010; 3(4):671-676.
29. Sindani BW. Assessment of water quality status of River Kibisi, Kenya using the ephemeroptera, plecopteran and trichoptera (EPT) index. M.Sc. Thesis, Kenyatta University, Kenya, 2013.
30. Bhatnagar A. Pooja D. Water quality guidelines for the management of pond fish culture. International Journal of Environmental Sciences, 2013, 3(6).
31. Sharmeen R, Jewel AS. Cyanobacterial blooms and water quality in two urban fish ponds. University Journal Rayshahi University. 2008; 27:79-84
32. Olaniyi O. Assessment of water quality characteristics for aquaculture uses in Abeokuta Nigeria. Lakes, Reservoirs and Ponds. 2013; 7(1):9-19
33. Ehiagbonare JE, Ogunride YO. Physico-chemical analysis of fish pond water in Okada and its environs, Nigeria. Africa Journal of Biotechnology. 2010; 9(36):5922-5928
34. Ipeaiyeda AR. Obaje GM. Impact of cement effluent on water quality of rivers: A case study of Onyi River at Obajana, Nigeria. Congent Environmental Sciencehttp://doi.org/10.1080/23311843.2017.1319102. 2017; 3(13):19-102.
35. Ekubo AA, Abowei JFN. Review of some water quality management principles in culture fisheries. Research Journal of Applied Sciences, Engineering and Technology. 2011; 3:1342-1357.
36. Makori AJ, Abuom PO, Kapiyo R, Anyona DN Dida GO. Effects of water physico-chemical parameters on tilapia (*Oreochromis niloticus*) growth in Teso North sub County, Busia County, 2017.
37. DilipJ, Rehi DC, Shailza V. Physico-chemical assessment of water quality of River Namada in Jabalpur city area of

Madhya Pradesh. International Journal for Research in Applied Science and Engineering Technology (IJRASET), 2017, 5.
38. Akaahan TJA, Olabanji FM, Azua ET. Studies on regression analysis between Electrical Conductivity and Total Dissolved Solids as environmental variables in lower river Benue, Makurdi, Nigeria. African Journal of Water Conservation and Sustainability. 2017; 5(5):221-229
39. ANZECC. The Australian and New Zealand guidelines for fresh and marine water quality guidelines http://www.agriculture.gov.ai/site____________collection documents/water/ nwqms-guidelines. 2000; 4(4):11.
40. Hlavac D, Adamek Z, Hartman P. Effects of supplementary feeding in carp ponds on discharge water quality: A review article. Aquaculture International. 2014; 22:299-312.
41. Ajibare. Assessment of physical chemical parameters of water in Illaje local Government area of Ondo state, Nigeria. International Journal of Fisheries and Aquatic Studies. 2014; 1(5):8492
42. Bowley DG Allan GL. Nutrients in pond-based aquaculture discharge water used for irrigation. NSW Department of primary industries, Port Stephen fisheries Institute. https://www.dpi.nsw.gov.au...Bowley-and-Allan, 2011.
43. Amirkolaie AK. Environmental impact of nutrient discharged by aquaculture waste water on Horez River. Journal of Fisheries and Aquatic Science. 2008; 3:275-279.
44. Ayanwale AV, Minnin MA, Olayemi KI. Physico-chemical properties of selected fish ponds in Nigeria: Implication of artificial fish culture. Webmed Central Biology 2012; WM C003751 doi: 10.9754/journal. Wmc. 2012; 3(10):003751
45. Niels DT, Seid TM, Peter LM, Pieter B. Water quality assessment of streams and wetlands in South West Ethiopia. Water, MDPI, 2016.
46. Suqiura SH, Dong FM, hardy RL. A new approach to estimating the minimum dietary requirement of phosphorous for large rainbow trout based on non-faecal excretions of phosphorous and nitrogen. Journal of nutrition. 2000; 130(4):865-72.
47. Yeo SE, Binkowski FP, Morris JE. Aquaculture effluents and waste by products characteristics, potential recovery and beneficial reuse. North Central Regional Aquaculture Centre (NCRAC) technical bulletin, 2004.