ALL NATIONS UNIVERSITY COLLEGE

All Nations University Journal *of* Applied Thought (ANUJAT)
A Multidisciplinary Approach

Volume 6/Number 2 May 2019 Article 7

Effects of Cage Culture of Nile Tilapia (Oreochromis Niloticus) on Water Quality (Physiocochemical Parameters) in the Volta Lake at Ardec (Akosombo) and Fresh Volta Tilapia Farms (Akwamufie) in the Assuogyaman District of Ghana.

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Recommended Citation
Sossou, B. K., Boohene, M. & Sulemana, R. (2019) Effects of Cage Culture of Nile Tilapia (Oreochromis Niloticus) on Water Quality (Physiocochemical Parameters) in the Volta Lake at Ardec (Akosombo) and Fresh Volta Tilapia Farms (Akwamufie) in the Assuogyaman District of Ghana. *All Nations University Journal of Applied Thought*, 6(2):144-169.
Available at:
http://anujat.anuc.edu.gh/universityjournal/anujat/Vol6/No2/7.pdf

ABSTRACT

Three sampling points namely ARDEC, Volta Fresh Tilapia farm and a point where there is no farm (no cage) were selected for sampling. Sampling was carried out in cage and 50m and 10m both upstream and downstream away from the edge of the cage. In terms of depth, sampling was carried out at the surface and 5m below the surface of the cage. A total number of two hundred and fifty-two (252) water samples including forty-two (42) samples on monthly basis were collected for a period of six (6) months (March to August) and were analysed for temperature, total dissolved solids (TDS), total suspended solids (TSS), turbidity, conductivity, pH, dissolved oxygen (DO) and biological oxygen demand (BOD). Results revealed that at surface, both cultures recorded high temperatures as compared to control while control bottom recorded high temperature as compared to cage bottom for ARDEC and Fresh Volta Tilapia, Akwamufie. The control surface and control bottom had a considerably less or low suspended matter at both culture stations as compared to ARDEC and Akwamufie. There was variation in conductivity, turbidity and biological oxygen demand at cage side and control. The indicator variables for TDS appeared to be similar with the depth of the cage bottom being the highest among the culture stations. The minimum and maximum range of values of pH for both ARDEC and Akwamufie (SK2 and SK6) significantly fall within 6.41 – 6.85. ARDEC and Akwamufie in respect of pH has values of 6.88 and 6.85 respectively which was also significant in respect of the control stations pairing a pH value of 6.41($P < 0.005$) (SK7). Dissolved Oxygen increases along distances 10m and 50m upstream and downstream with respect to ARDEC at control side and rather decreases at cage side whilst Akwamufie decreases at control side and increases at cage side. The control surface and control bottom had a considerably less or low suspended matter at both culture stations as compared to ARDEC and Akwamufie. There was variation in conductivity, turbidity and BOD at cage side and control. The indicator variables for TDS appeared to be similar with the depth of the cage bottom being the highest among the culture stations.

Introduction

The culture of aquatic organisms being farmed in caged enclosures has been a venture of modern time in both developing and developed countries. According to Pillay and Kutty (2005), the origin of using cages to keep and transport fish for brief time period may be dated back to nearly two hundred years ago to the region of Asia. This originated even earlier as part of primitive practices of fisher folk who lived on boats on the Mekong (Phillips and De Silva, 2006). According to Delgado *et al*., (2003), there is anticipation that consumption of fish in developing countries will increase by 57 percent, from 62.7 million metric tons in 1997 to 98.6 million metric tons in 2020. The swift rise in the developing countries could be accounted to increasing affluence, fast population growth, and urbanization in these developing countries thus leading to major differences in demand and supply for animal protein, from both fish and livestock (Delgado *et al*., 2003).

Currently, depletion of water resources in Ghana and population increase has placed pressure on our water bodies and the Volta Lake is no exception. Aquaculture started with pond culture and pen culture. Unfortunately, these have not met the demands because of low stocking rate, low yield in harvest sometimes due to disease outbreak, water pollution, eutrophication and water unavailability during the dry season which do not permit farming throughout the year (Awity, 2005). As a result, attention has been moved to cage culture where cages have now been constructed on the Volta Lake for fish production. This is because it is believed that cage culture brings more yield due to its high stocking density, flowing nature and the nutrient load of the river. More cages are installed on daily basis leading to increased activities, more industries being drawn and increasing pollution (Awity, 2005).

Methodology

Sample and Sampling Technique

Two farms were selected for study using simple random sample. Sampling was conducted from cages at the Water Research Institute, Akosombo, Volta Fresh Tilapia Farm, Akwamufie and a neutral site (where there is no farm) which serves as control, all in the Assuogyaman District in the Eastern Region of Ghana. Sampling was conducted at five distances each from cages in the two farms at the study area. In each farm, sampling was carried out at 50m and 10m upstream away from the edge where cage is sited, 0m (from cages) and 10m and 50m downstream away from the edge of where the cage is sited. Sampling was also carried at two different depths, the bottom of the cage where the net of the cage suspends (that is at the depth of 5 m) and surface at each farm. The sample from cage at 0m was taken as the surface sample.

Sampling was also done at a site where there is no farming activity to serve as control. Samples were taken both at surface and at a depth of 5m below the surface of the water. This site was located at about 500m upstream of ARDEC farm. The following abbreviations were used; SK1 represents control surface whist SK2 is the control bottom. SK3 implies 50m upstream from the edge of the cage whiles SK4 is 10m upstream from the edge of the cage. SK5 represents the Surface water where the Cage was sited whereas SK6 represents Cage bottom. Lastly, SK7 and SK8 represent 10m downstream and 50m downstream respectively. The number of fishes reared per cage selected at Akwamufiewas80, 000 and that of ARDEC was 15,000. Sampling was carried out at the three sites monthly for 6 months (from March to August). The cages at ARDEC are rectangular while the ones at Akwamufie are circular in form.

Temperature and electrical conductivity were measured insitu using Senso Direct Con 200 meter. Water samples collected were kept in polythene bottles that were rinsed with portions of the Lake water after opening and lowered into river to fill until they got full up and were then closed. The samples were then stored in ice chest with ice blocks to prevent them from oxidation. The samples were sent to the chemistry laboratory of CSIR, Accra for analysis. Water samples were analyzed for Total Suspended Solids (TSS), Total Dissolved Solids (TDS) using the Gravimetric method, Turbidity using Nepholometric method. All water quality measurements and sample collection were made between 07:00 and 10:00 hours GMT and analyzed using standard methods (APHA/AWWA, 1998) as follows:

Data Analysis

Data analysis was conducted by using charts and ANOVA test of independence was used to compare among the stations. All analyses were performed using Statistic Packages for Social Sciences (SPSS) version 20, (2012). The analysis was based on graph of bar chart presenting the physical and chemical parameters. Further analysis was conducted using ANOVA test of independence to compare physical parameters with respect to the 0m-5m depth and distances 0m-50m distances from both downstream and upstream respectively. ANOVA test of independence was employed to compare all cage culture stations with the control station. Furthermore, correlation analyses were performed for the physical parameters. This was to help determine how related the physical parameters are correlated among themselves

Results and Discussion

Oreochromis niloticus on Physical Parameters of the Water from the Culture Site Temperature (Degree Celsius - °C)

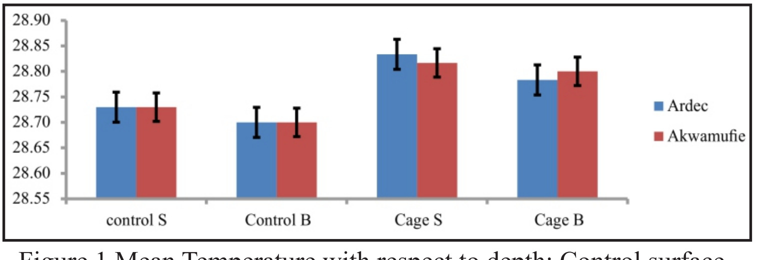

Figure 1 Mean Temperature with respect to depth: Control surface, Control bottom, Cage surface and Cage bottom

Figure 1 illustrates the temperature with respect to the depth of the culture stations. Water temperature at the control station (28.73) was significantly lower than the two culture sites (28.82 and 28.83 for Akwamufie and ARDEC respectively), (P = 0.000). Generally, temperature decreased with depth at both culture sites and control. Temperature was higher at ARDEC at cage surface as compared to Akwamufie but recorded lower values at cage bottom than Akwamufie.

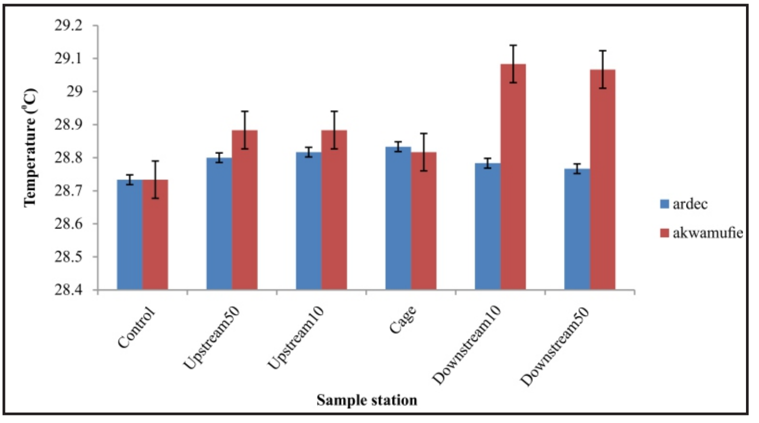

Figure 2 Mean temperature with respect to distance from cages: Control surface, 50m upstream, 10 m upstream, cage area - 0 m, 10m downstream and 50m downstream

Figure 2 shows the mean temperature with respect to distance from cages for both stations. It was observed that the mean temperatures ranged from 28.73 – 28.83°C and were in decreasing trend as culture distance from downstream to upstream at ARDEC whilst at Fresh Volta Tilapia, Akwamufie culture respectively the mean temperature of 28.78 – 29.08°C. It was realized that temperature at the control station was lower as compared to culture sites. ARDEC recorded higher value at cage site than Fresh Volta Tilapia, Akwamufie whereas at 10m and 50m downstream and upstream respectively, Fresh Volta Tilapia, Akwamufie recorded higher mean temperatures than ARDEC.

Turbidity (Nephelometric Turbidity Unit - NTU)

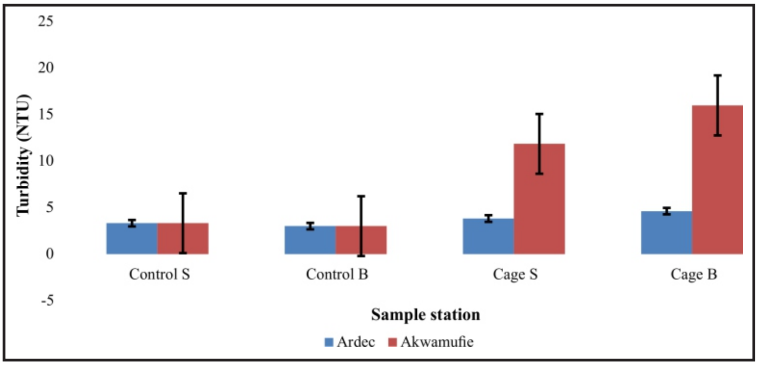

Figure 3 Mean turbidity with respect to depth:
Control surface, Control bottom, Cage surface and Cage bottom

Figure 3 represents the mean turbidity of the culture station with respect to the depth of water. The study revealed that at the control surface and bottom the mean of the Turbidity was almost the same for the culture stations with respect to the depth. There was however much variation comparing depth of Fresh Volta Tilapia, Akwamufie to ARDEC at the cage surface and bottom. Fresh Volta Tilapia, Akwamufie recorded 11.87 NTU and 15.99 NTU as against 3.83 NTU and 4.62 NTU at surface and bottom respectively thus values recorded at Akwamufie were more than three times higher than ARDEC.

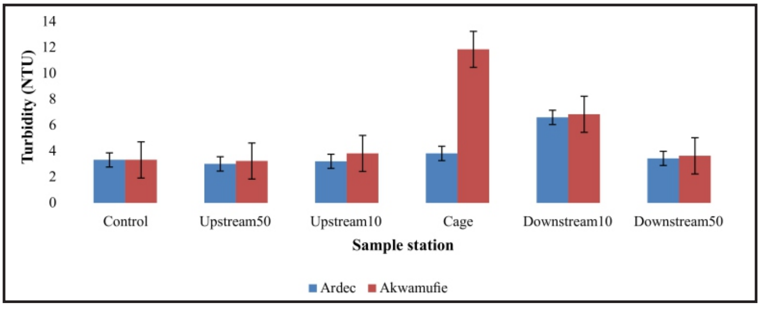

Figure 4: Mean turbidity with respect to distance at the surface:
Control surface, 50m upstream, 10 m upstream,
Cage area- 0 m, 10 m downstream and 50m downstream

Figure 4 represents the turbidity of the culture stations with respect to distance from cages. Mean turbidity values at control side, 10m upstream and 50m upstream at Fresh Volta Tilapia, Akwamufie were slightly higher than ARDEC. However, turbidity mean values at Fresh Volta Tilapia, Akwamufie were incomparably higher (11.83 NTU) than ARDEC (3.83 NTU) at cage side but were both significantly higher than control (3.33 NTU).

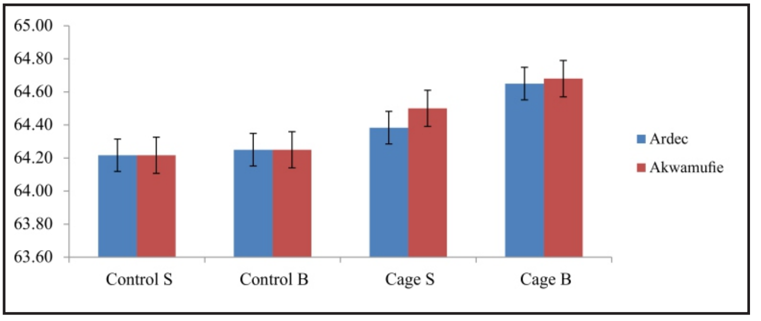

Figure 5: Mean conductivity with respect to depth:
Control surface, Control bottom, Cage surface and Cage bottom.

Figure 5 represents the mean values of conductivity with respect to the culture depth. Conductivity increased with depth at all points of sampling. Conductivity was significantly higher at cage side at ARDEC and Akwamufie than control indicating the presence of higher dissolved solids. However, conductivity was higher at Akwamufie at both surface and bottom compared to control.

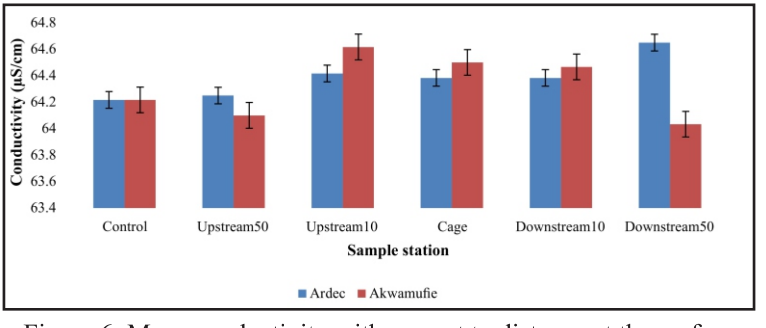

Figure 6: Mean conductivity with respect to distance at the surface:
Control surface, 50m upstream, 10m upstream,
Cage area - 0m, 10m downstream and 50m downstream.

Figure 6 illustrates the conductivity with respect to the distance. It was observed that values recorded at Akwamufie were higher than ARDEC with the exception of 50 m both upstream and downstream where both

ARDEC and control values were higher compared to Akwamufie. However values at cage side at both culture stations were significantly higher than control.

Total Suspended Solids (TSS) [milligram per litre – mg/L]

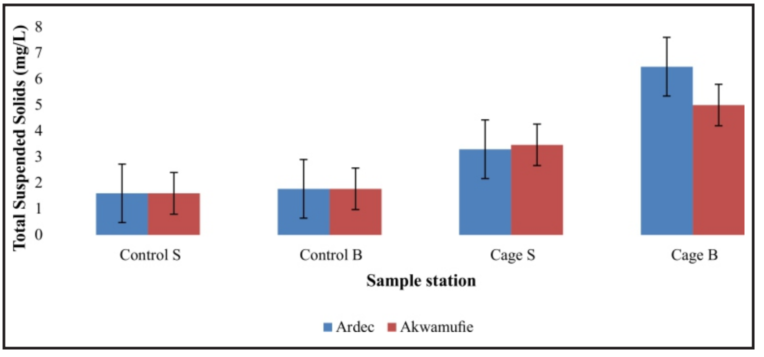

Figure 7: Mean total suspended solids (TSS) with respect to depth: Control surface, Control bottom, Cage surface and Cage bottom

Figure 7 represents the mean value of TSS with respect to the depth of the culture stations. It was observed that the mean TSS at the control surface and bottom were lower as compared to ARDEC and Akwamufie. At the cage surface, the mean TSS for Akwamufie was higher whiles at the cage bottom it was rather the mean TSS value for ARDEC.

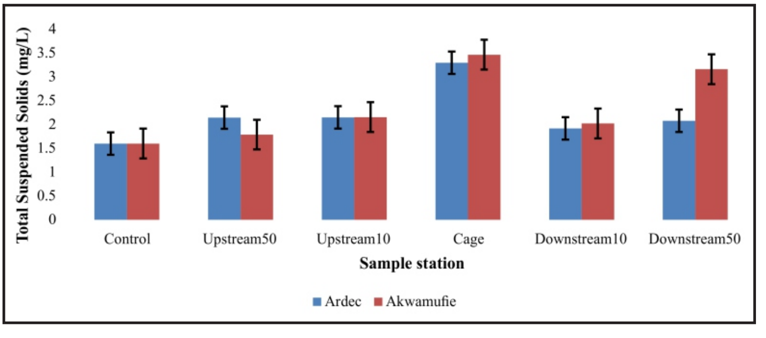

Figure 8: Mean total suspended solids (TSS) with respect to distance from cages: Control surface, 50m upstream, 10m upstream, Cage area- 0m, 10m downstream and 50m downstream.

Figure 8 illustrates the mean TSS with respect to the culture distances. The mean TSS for the control side and a 10m distance from upstream values for ARDEC and Akwamufie were almost the same. However, from the cage side, 10m downstream and 50m downstream the mean TSS for Akwamufie recorded higher values than that of ARDEC.

Total Dissolved Solids (milligram per litre – mg/L)

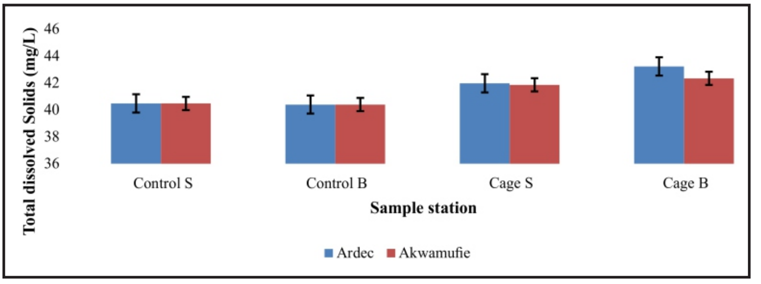

Figure 9 Mean total dissolved solids (TDS) with respect to depth: Control surface, Control bottom, Cage surface and Cage bottom.

Figure 9 illustrates the TDS with respect to the depth of the culture stations. The mean TDS from the control surface and bottom were the same for ARDEC and Akwamufie. There was variation between the cage surface and the bottom of the cage with respect to the depth of the culture while the rest of indicator variables appeared to be similar. However the depth of the cage bottom at ARDEC was the highest among the culture stations.

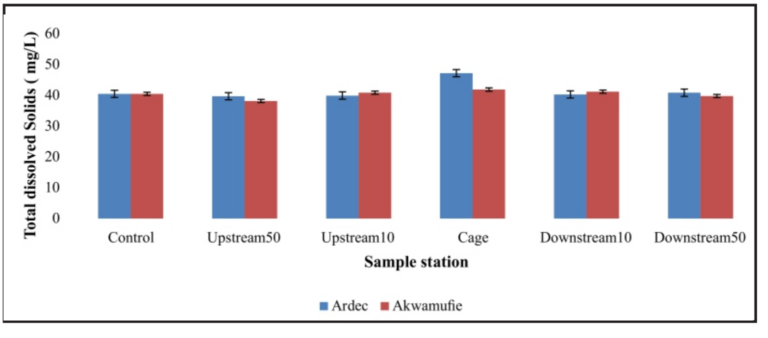

Figure 10: Mean total dissolved solids (TDS) with respect to distance at the surface: Control surface, 50 m upstream, 10 m upstream, Cage area- 0 m, 10 m downstream and 50m downstream.

Figure 10 illustrates the mean TDS with respect to the culture distance. The mean TDS at the control side was 40.48 each at ARDEC and Akwamufie. The mean TDS recorded with respect to the culture distance at the cage side was 47.2 for ARDEC and 41.9 for Akwamufie. The study found that at a distance of 10m downstream, the TDS was higher at both Akwamufie and ARDEC culture.

Oreochromis niloticus on Chemical Parameters of the Water from the Culture Site

pH (Hydrogen Ion Concentration- mole per litre)

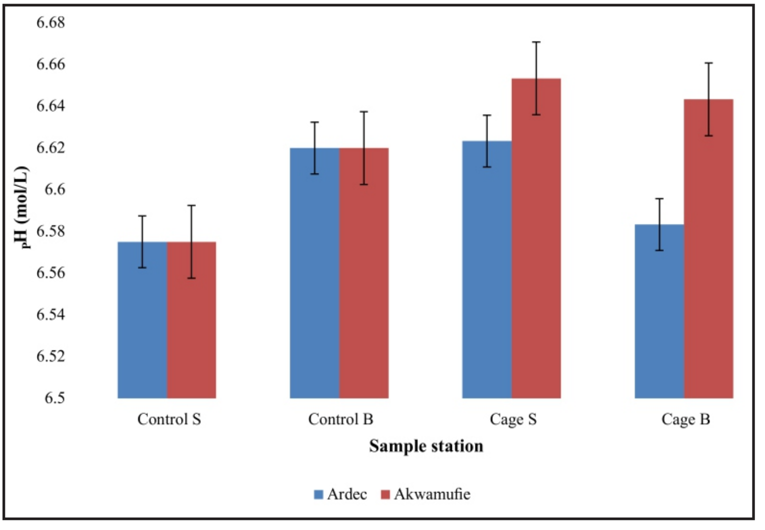

Figure 11: Mean pH (Hydrogen Ion Concentration) with respect to depth: SK1, SK2, SK5 and Sk6

Figure 11 illustrates the weighted mean of pH with respect to depth of the culture stations. It was observed that the control surface and bottom recorded the lowest pH level than the culture stations whereas the pH level at ARDEC were lower at the cage surface and bottom. The pH level for the month of May was the highest means at both ARDEC (6.86) and Fresh Volta Tilapia, Akwamufie (6.86) and the minimum values were recorded in July which amounted to 6.42 pH values at both culture stations.

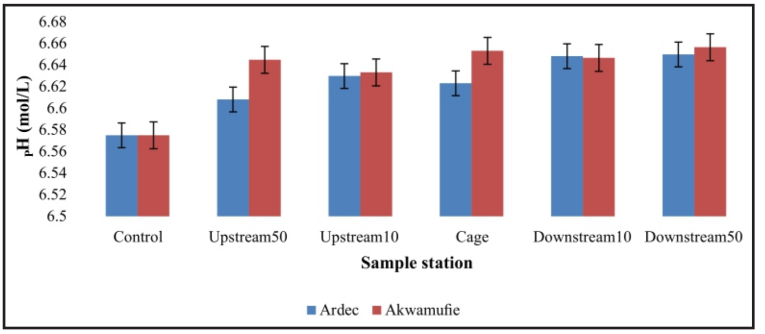

Figure 12: Mean pH (Hydrogen Ion Concentration) with respect to distance at the surface: SK1, SK3, SK4, SK5, SK7 and Sk8.

Figure 12 depicts the pH level of stations with respect to the distance. It was observed that at the control side pH level was lower than the cage side, although 10m and 50m respectively downstream and upstream ARDEC culture recorded lower values than that of Fresh Volta Tilapia, Akwamufie.

Dissolved Oxygen (DO) (milligram per litre – mg/L)

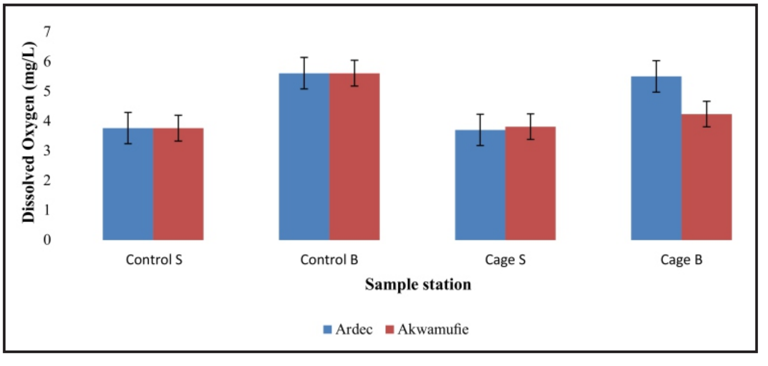

Figure 13: Mean DO (Dissolved Oxygen) with respect to depth: SK1, SK2, SK5 and SK6

Figure 13 stipulates the DO with respect to depth of the culture stations. It was realized that the mean of DO at the control surface and bottom were the same for both cultures but were lower than culture stations whereas the study found slight variation in the cage surface and bottom with respect to ARDEC and Akwamufie. It was realized that the depth from the control bottom and the cage bottom had more DO at both cultures; although ARDEC culture recorded higher DO than that of Akwamufie.

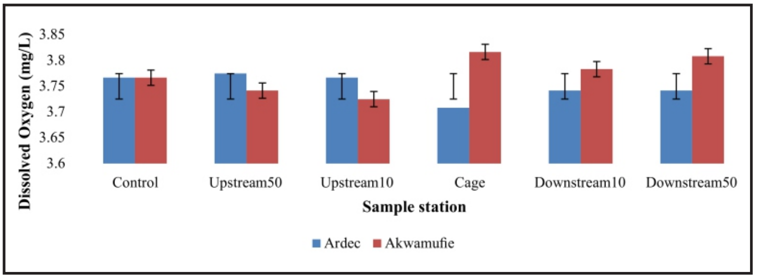

Figure 14: Mean DO (Dissolved Oxygen) with respect to distance at the surface: SK1, SK3, SK4, SK5, SK7 and Sk8.

Figure 14 shows the mean of DO with respect to culture distances. It was realized that the control station for both cultures recorded the same values whilst there was much variation between ARDEC and Fresh Volta Tilapia, Akwamufie at the cage side.

Biological Oxygen Demand (BOD) (milligram per litre – mg/L)

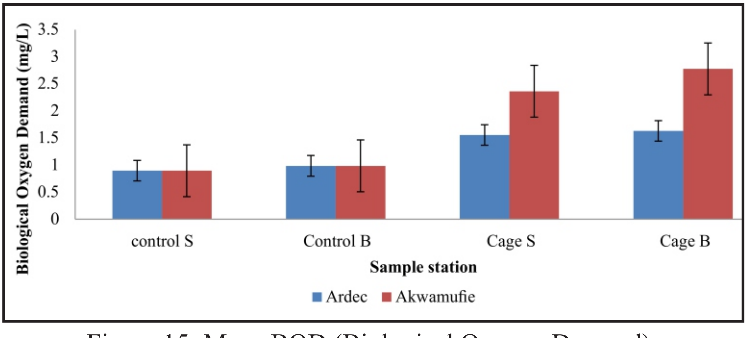

Figure 15: Mean BOD (Biological Oxygen Demand) with respect to depth: SK1, SK2, SK5 and Sk6

Figure 15 illustrates BOD level with respect to the culture depth. The study revealed that BOD at the control surface and bottom were the same whereas at the cage surface and bottom there is variation at ARDEC and Akwamufie. It was realized that the BOD at Akwamufie recorded higher mean BOD values that ARDEC. It was also realized that at ARDEC in the month of July BOD was higher for all factor variables whereas Akwamufie recorded the highest in June. It was established that BOD was higher at both culture stations for the cage surface and bottom.

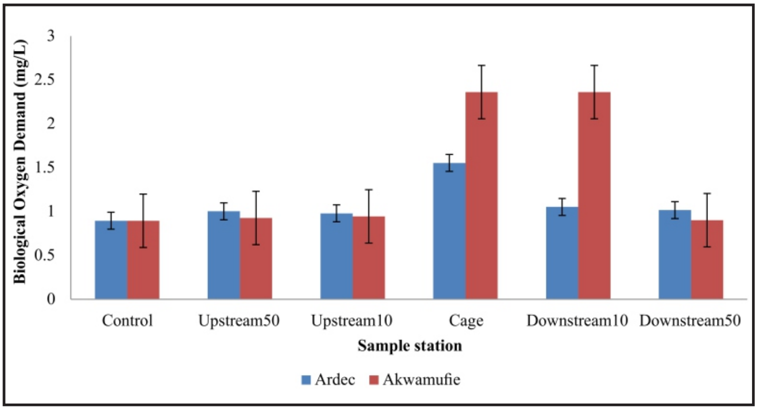

Figure 16: Mean BOD (Biological Oxygen Demand) with respect to distance at the surface: SK1, SK3, SK4, SK5, SK7 and Sk8.

Figure 16 shows BOD level with respect to the distance of the culture stations. It was found that the BOD at the cage area was higher than the control side. It was realized at the control station for 10m and 50m upstream, BOD was slightly higher at ARDEC than Akwamufie. It was observed that that apart from BOD at the cage surface which was highest at both culture stations, all the other factor variables were alternating with respect to the months. It was further realized that BOD at Akwamufie were more than that of ARDEC and BOD from 10m downstream.

Correlation of Physicochemical Parameters

Table 1 illustrates correlation of physico parameters considered for the study. Correlation of physic chemical parameters such as temperature, pH level, DO, TSS, TDS, conductivity and turbidity of the culture stations were observed to ascertain if one of the parameters has significant effect on one or more parameters.

Table 1. Correlations of Physicochemical Parameters

		Temperature	pH	DO	TSS	TDS	Conductivity	Turbidity
Temperature	Pearson Correlation	1	.044	.202	-.007	.245*	.201	-.051
	Sig. (2-tailed)		.717	.090	.952	.038	.091	.673
	N	72	72	71	72	72	72	72
Ph	Pearson Correlation	.044	1	-.281*	.453**	-.061	-.288*	.018
	Sig. (2-tailed)	.717		.018	.000	.614	.014	.880
	N	72	72	71	72	72	72	72
DO	Pearson Correlation	.202	-.281*	1	.100	.363**	.023	.139
	Sig. (2-tailed)	.090	.018		.406	.002	.849	.248
	N	71	71	71	71	71	71	71
TSS	Pearson Correlation	-.007	.453**	.100	1	.013	-.045	-.010
	Sig. (2-tailed)	.952	.000	.406		.911	.705	.935
	N	72	72	71	72	72	72	72
TDS	Pearson Correlation	.245*	-.061	.363**	.013	1	.011	.160
	Sig.(2- tailed)	.038	.614	.002	.911		.927	.179
	N	72	72	71	72	72	72	72
Conductivity	Pearson Correlation	.201	-.288*	.023	-.045	.011	1	-.129
	Sig. (2-tailed)	.091	.014	.849	.705	.927		.279
	N	72	72	71	72	72	72	72
Turbidity	Pearson Correlation	-.051	.018	.139	-.010	.160	-.129	1
	Sig. (2-tailed)	.673	.880	.248	.935	.179	.279	
	N	72	72	71	72	72	72	72

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Correlation of physical parameters such as temperature, pH level, DO, TSS, TDS, conductivity and turbidity of the culture stations were observed to determine whether one of the physicochemical parameters has significant effect on one or more parameters. It was observed that most of the physicochemical parameters do not correlate with each other with the exception of few parameters. The study revealed that temperature was correlated with DO at 0.038 significant levels. The pH level was found to have significant correlation with DO (0.018), TSS (0.000) and conductivity (0.014) parameters at the culture stations.

Dissolved Oxygen (DO) was significantly associated with pH level (0.018) and TDS (0.002). It was realized that TSS had significant relationship with pH of the culture stations. More so, TDS was found to be correlated with the temperature (0.038) of culture stations and DO (0.002) components. The study revealed that conductivity of the culture stations was found to be significantly related with (0.14) pH level at both stations whereas turbidity of the respective culture station had no significant effect on the other physical parameters.

Discussion

Physical Parameters

Temperature

In figure 1, it was realized that at the control and cage surface of the water, the temperature of Akwamufie culture was higher (29.08^{0}C) than ARDEC culture (28.83^{0}C) and the control station respectively although this reduces with respect to depth. Temperature range of 28-32^{0}C is proposed as good for tropical fish (Bhatnagar and Davi, 2004). This is in consonance with this research as the average range of temperature for the respective culture stations. In accordance with Figure 1, it was revealed that in as much as the depths of the cultures go deeper, it has a significant effect on the temperature and hence the temperature also decreases with respect to depth. This is similar to an emphasis in another study which presupposes a reduction in temperature of water when getting deeper to the base of a water body (Nyanti, *et al.,* 2012). The Analysis of Variance showed that the temperatures of the two culture stations differed significantly as deeper as the water gets. Figure 2 shows the mean temperature with respect to the culture depth at cage surface and bottom significantly higher than control.

The study established that the temperature for the two culture station differed significantly (0.000) as the depth of the culture stations increases.

From Figure 2, the temperature of the water varied across the two culture stations and the control station with a fluctuating trend from

10m and 50m distances downstream and upstream at the control and the cage side. Temperatures recorded from these distances were significantly unequal in respect of both culture stations but ARDEC recorded the lower temperature at the cage point as compared to Akwamufie but both higher than control. This is similar to a work done by Huang *et al.,* (1997) where water temperature at the control station (28.0 °C) was significantly lower than the three culture stations (28.44 – 29.25°C) ($P<0.0005$) with respect to both distance and depth.

Turbidity

From Figure 3, it was observed that the variations in factor variables of turbidity at Akwamufie are higher than ARDEC. This shows that suspended matter such as clay, silt, finely divided organic materials in organic matter, plankton and other microscopic organisms are higher or more at Akwamufie which is dense at cage bottom and surface throughout the data collection period. Hence the scattering of light being caused by the expression of the optical characteristics of a solution is revealed at Akwamufie than that of ARDEC as significantly higher as depth increases. It was realized that, there are significantly more suspended matter at cage surface and cage bottom for both ARDEC and Akwamufie. However, Akwamufie had significantly more suspended matter than ARDEC. On the other hand, the control surface and control bottom have a considerably less or low suspended matter at both culture stations and hence the variations in turbidity are invariant in respect of the controls for both stations. This finding is similar to a work done by Huang *et al.,* (2012) where turbidity increased with depth showing an increase in suspended solid concentration. This may likely be contributed by fish waste (feaces) as well as uneaten feed and their products of decomposition especially at the deeper part of the reservoir (Boyd, 2004.).

In accordance with Figure 4, the study revealed a slight variation in turbidity in respect to distance at ARDEC with the exception of a very significant variation at 10 m downstream which declares a considerably higher presence of suspended matter. On the other hand, Akwamufie rather recorded higher significant variations in turbidity at cage surface and 10 m downstream with respect to distance. It was then revealed that turbidity of the two systems of farming differs significantly in respect of distance of the culture stations as compared to control. This shows that, the presence of suspended matter for both ARDEC and Akwamufie varies insignificantly at control side as compared to the significant variations at cage side with Akwamufie contributing to the most variation at cage side with respect to distance portrayed by the difference between means of turbidity. This is similar to Nyianti *et al.,* (2012) work where higher levels of turbidity were recorded at cage side across varying distances as compared to control.

Conductivity

Figure 5 implies that averagely, the conductivity of Akwamufie is considerably higher than that of ARDEC but actually decreases in accordance with depth just as ARDEC decreases with depth. It was also revealed that the ionic strength in both culture stations is higher which facilitates increase in the conductivity of the culture stations with respect to depth. The study further showed that the concentration of electrolytes in Akwamufie is significantly higher than that of ARDEC. It was realized that the conductivity on the culture stations was positively skewed and hence it implies that there are significantly greater electrolytes and a greater ionic strength at the control bottoms, cage surfaces and cage bottoms at both culture stations but is significantly predominant at Akwamufie cage surface though control recorded lower values than culture sites. This finding is in consonant with Huang *et al.,* (2012) finding where electrical conductivity increased with depth showing an increase in dissolved solid concentration. This may likely be contributed by fish waste such as urine and feaces as well as uneaten feed and their products of decomposition especially at the deeper part of the reservoir (Boyd, 2004).

Figure 6 shows that the ionic strength that facilitates conductivity at Akwamufie farms is significantly different from ARDEC and hence statistically, the mean electrolytes at Akwamufie farms was significantly higher but reduces with trend in both culture stations with respect to distance. The conductivity at control side on both culture stations is significantly different as well as at the cage side for both upstream and downstream on both culture stations. Gassama *et al.,* (2012) reported an increase in conductivity values as depth increased in the Bicaz reservoir, Romania when there was no mixing in summer. This is different from our case due to the likelihood of moving water in the Volta River causing mixing. Electrical conductivity measured in this study were lower than the values (151 - 338 µS/cm) reported by Gassama *et al*., (2012) likely because of lower organic load at the various stations. The electrical conductivity values measured were lower than the standard of Interim National Water Quality Standard of Malaysia (INWQS) of 1000 µS/cm.

Total Suspended Solids

It was revealed from Figure 7 that, retained solids with respect to depth by month were statistically significant in May at both culture stations. Moreover, the TSS at akwamufie was statistically significant as compared to ARDEC and TSS at both culture stations decreases with depth. Hence, from Mitchell and Stapp (1992) filtration and flocculent can be employed to get rid of solids and decrease discoloration of aquaculture even as the mean TSS at both culture stations differed significantly ($P = 0.000$) as far as the two culture stations with respect to the depth of the culture stations are concerned. With respect to depth, the study revealed that at the control surface and bottom the TSS concentrations are insignificantly different at both culture stations but significantly different at cage surface which further acclaims that around 4.5mg/l the water quality criteria would be significantly suitable for species like salmonids (Aqua farmer, 2004) at both culture stations but more significant at Akwamufie even at cage bottom.

TSS with respect to distance from Figure 8 revealed that, the mean TSS for the two culture stations according to distance is statistically significant. It was further seen that the TSS with respect to distance were mostly concentrated for both ARDEC and Akwamufie but falls within the water quality criteria for aquaculture since the concentrations are respectively less than 80mg/l (Pillay and Kutty, 2005). Analytically, the variations in retained solids at both culture stations differs significantly at both cage side and control side hence filtration and flocculent proposed by (Mitchell and Stapp, 1992) can be employed to lower the concentration to suit the species of fish under consideration (Aqua farmer, 2004) at both upstream and downstream for the two culture stations for keeping the quantity on a secure side and fixed as a concentration limit. This study is similar to other findings where it is deduced that higher levels of TSS at cage site as compared to control is as a result of remains of feed that have not been eaten by fishes and faeces from their droppings being the main determinant of suspended solids in cage culture of Atlantic salmon and other finfish (EAO, 1996.Winsby *et al.,* 1996).

Total Dissolved Solids

Figure 9 showed that there exists a significant difference statistically in TDS on the two culture stations. The study further revealed that there was a slight significant difference in the proportion of solids that can pass through a 2 µm (or smaller) nominal pore size with respect to depth. With reference to TDS in accordance with depth, ARDEC at cage bottom has a greater proportion of solids that passes through a 2 µm (or smaller) nominal pore size as far as 43.23 as compared to Akwamufie's 42.35 and even at cage surface. It was further realized that TDS at ARDEC was significantly higher than Akwamufie but rather ties at the controls. This implies that the factors causing and facilitating the predominance of retained solids (TSS) at ARDEC are intense than that of Akwamufie.

Figure 10 shows that there is also a significant difference in the proportion of solids that passed through a 2 µm (or smaller) nominal pore size with respect to distance with the exception of cage surface for ARDEC and Akwamufie respectively which produced larger values and were very significantly different in both culture stations with distance. The graph revealed that, there is a significant difference between TDS means at both Control side and Cage side for ARDEC and Akwamufie farms. The culture stations had proven that the proportion of solids that passes through a 2 µm (or smaller) nominal pore size with respect to distance at both upstream and downstream differed significantly (0.000). Other studies show similar results where they concluded that nutrients which are soluble in feed and faeces (EAO, 1996; ASI, 1999; Chen *et* *al.,*1999; Pawar *et al.,*2002), fish breathing and metabolic wastes and nutrients from the sediment wastes that are re-introduced (EAO, 1996; ASI, 1999) are main determinants of dissolved nutrients from cage farming. Leftovers of chemicals used to maintain nets and other physical structures in the farms, destructive agents and preservatives in the feed might be considered as the second group of dissolved waste substances.

Chemical Parameters
pH

According to Figure 11, the minimum and maximum range of values of pH for both ARDEC and Akwamufie (control bottom and cage bottom) significantly fall within 6.41 – 6.85 and hence is certain that, the ground water at the respective culture stations are buffered by inorganic carbon equilibrium systems (Timmons *et al.,* 2002) which will have a significant effect on the fishes since fish growth is better and survival rate is high within the pH range of 6.0 - 9.0 whereas most surface waters (control surface and cage surface) also fall within the same pH range with respect to depth.

The result also revealed that a slightly more ARDEC fishes are likely to survive than Akwamufie in respect of pH values of 6.88 and 6.85 respectively which was also significant in respect of the control stations pairing a pH value of 6.41 at 10 m downstream.

The pH levels at Control Surface and Control Bottom as well as Cage surface and Cage bottom communicates that at both 0m and 5m respectively, the water turns acidic since pH is predominant though analysis of variance shows significant differences between cage area and control. This also reveals that the fish grow best in that region (Pillay, 1992). Other works also showed that there is an obvious decrease in pH as depth increase due to decaying organic matter especially from the vegetation which were not removed prior to impoundment and contribution from feed and waste from the cage culture (Huang *et al.,* 2011).

From Figure 12, the pH levels at both downstream and upstream will not reduce fish growth at Akwamufie even as it recorded the highest pH values as compared to ARDEC since its pH values are not outside the range of 6-9 (Timmons *et al.,* 2002). Analysis of variance shows significant differences between cage area and control.

Dissolved Oxygen

From Figure 13, the study revealed that DO fluctuate at both culture stations with respect to cage surface and cage bottom which could be postulated as being affected by the temperature at these areas due to the fact that temperature also has a direct effect on the amount of dissolved oxygen available to aquatic organisms (Barg, 1992).

From Figure 14, 50 m downstream at ARDEC recorded the lowest DO which was 2.85ppm < 3ppm which will not support warm or cold water fish in that region since aeration is needed by re-circulating systems to maintain DO at levels that are safe – from 3 parts per million to 5 parts per million as compared to the maximum ppm of ARDEC. The other points where water samples were taken (control surface, 10 m and 50 m both upstream and downstream and cage surface) at both ARDEC and Akwamufie are within the range 3ppm – 5ppm with respect to trend and hence will support re-circulating systems which oxygenation, maintain DO within this range (Moehl *et al*., 2006; Barg, 1992).

DO levels at cage bottom and control bottom have considerable high ppm and hence will facilitate fish growth at both culture stations (Barg, 1992). It was further revealed that as DO increases along distances 10m and 50m upstream and downstream with respect to ARDEC at control side and rather decreases at cage side whilst Akwamufie decreases at control side and increases at cage side. The study revealed and deduced that as the distance of the water changes DO component fluctuates, but a minimum DO concentration requirement of approximately 5.0 mg/l for warm water species to 7.0 mg/l for cold water fishes is needed for the optimal growth of fish according to Pillay and Kutty (2005). DO decrease with depth as there was little aeration asdepth increases. This may be due to oxygen being used up in the decomposition process as solid waste sink up.

Biological Oxygen Demand

From the study, it was realized that the demand for biological oxygen at Akwamufie was higher than ARDEC. Figure 15 shows that, there are significant variations in BOD with respect to depth at the cage surface and cage bottom as compared to control surface and control bottom for both ARDEC and Akwamufie. The variations in depth are significantly higher in Akwamufie than ARDEC and therefore the mean depth levels of BOD at the culture stations differ significantly between themselves.

With respect to Figure 16, at 50m upstream and downstream there exist slight variations in BOD unlike 10m upstream and downstream with respect to distance. It was further revealed that Akwamufie recorded the largest variations as compared to ARDEC and hence it could be established that there are significant variations in mean level of BOD with reverence to distance at the two culture stations.

In the process of decay of fish deed and waste, oxygen is consumed as indicated by higher BOD at all culture stations as compared with the control station. The movement of excess feed and waste downward also cause the BOD also to be not significantly higher as compared with the control station Nyanti, *et al.,* (2012).

Conclusion

The study found a significant difference in the mean values of the respective culture station with respect to distance and depth of the culture stations. Temperature of the culture stations was found to reduce as the depth of the water gets deep and distance get to upstream. Aquaculture has impacted the water quality as indicated by the lower pH, higher turbidity, conductivity, TSS, BOD. The impact of turbidity and conductivity were mostly at 10m depth downstream. However, the impact of TSS and BOD could be observed up to 10m from upstream of the culture stations.

When feed is deposited in a fish culture for a long time decomposition takes place and BOD are affected across depth and distances of culture stations and fishes may demand more oxygen to survive.

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