# Impact of effluent discharge from a medium-scale fish farm on the water quality of Odo-Owa stream near Ijebu-Ode, Ogun State, Southwest Nigeria

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## Abstract

This study aimed to assess the impact of effluent discharge from a medium-scale aquaculture fish farm on the water quality of a nearby receiving stream, Odo-Owa stream, near Ijebu-Ode (06° 49′ N, 003° 56′ E) in Ogun State, Southwest Nigeria. Some physicochemical water quality parameters of the effluent receiving stream were determined at seven selected sites, above and below the effluent discharge point into the stream to assess the effluent impact on the water body. The seven sampling stations comprised three stations (A–C) located upstream of the effluent discharge point (Station D), two stations (E and F) located downstream of Station D, while the seventh station (Station G) was a close-by reference groundwater source. The water quality parameters investigated include five physical parameters (water temperature, apparent color, true color, turbidity and transparency), seven general chemical parameters (pH, conductivity, TDS, total alkalinity, total hardness, ammonia and DO), seven major ions ($Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, $Cl^-$, $SO_4^{2-}$ and $HCO_3^-$), three nutrient compounds ($PO_4^{3-}$, $NO_3^-$ and $NO_2^-$) and five heavy metals ($Hg^{2+}$, $Mn^{2+}$, $Fe^{2+}$, $Cu^{2+}$ and $Zn^{2+}$). Water samples were collected from each sampling station twice per season: dry season (December 2013 and February 2014) and rainy season (April and July 2014), and analyzed in the laboratory using standard analytical methods. The result showed a significant difference ($P < 0.05$) in most of the investigated parameters between the impacted (Stations A–C) and unimpacted sections (Stations E and F) of the effluent receiving stream. Ammonia was about nine times higher; true color was more than five times higher; apparent color, depth, alkalinity, $HCO_3^-$ and $SO_4^{2-}$ were each more than two times higher, while pH, $Ca^{2+}$, $Na^+$, $K^+$, $Cl^-$ and $PO_4^{3-}$ were generally higher along the impacted section than the unimpacted section of the receiving stream. Except for $Hg^{2+}$, the mean concentrations of all the heavy metals analyzed ($Fe^{2+}$, $Mn^{2+}$, $Zn^{2+}$ and $Cu^{2+}$) were also higher in the impacted portion than in the unimpacted portion. Seasonal variations across the water stretch showed that the mean ($\pm$ SE) concentrations of TDS, turbidity, $PO_4^{3-}$, $Mn^{2+}$, $Fe^{2+}$ and $Hg^{2+}$ were significantly higher ($P \leq 0.05$) in the rainy season than in the dry season. The WQI was more fair (26–50) at the unimpacted (48.42) section of the water stretch as well as in the rainy (48.36) than it was in the impacted section (47.62) as well as during the dry season (45.36). The effluent discharge point, D (40.50), recorded the least WQI. This study showed that effluent discharge from the investigated medium-scale fish farm had a significant negative impact on the water quality of the receiving Odo-Owa stream and the indicator parameters comprised of ammonia, color and alkalinity.

**Keywords** Effluent · Fish farm · Receiving stream · Physicochemical parameters · Water quality index

## Introduction

Aquaculture plays an important role in the development of many national economies and a key role in the socio-economic resilience of rural areas, potentially offering valuable and skill-based employment opportunities and, in some cases, stabilizing the economic base of otherwise fragile communities (Edwards 1999; Muir 1999; Haylor and Bland 2001). Fish production is very important for many reasons. Fish is one of the most staple food items for man

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as it provides a rich source of essential protein for human consumption. The flesh of fish is also readily digestible and immediately utilized by the human body, which makes it sustainable for regions of the world with a high carbohydrate diet, like Africa (FAO 2005). Ayoola and Abotti (2010) have reported increasing patronage of fish products as an alternative source of cheap, high-quality animal protein as opposed to beef and other animal products, due to its health and nutritional reasons.

In Nigeria, fish supply is from four major sources, namely artisanal fisheries, industrial trawlers, aquaculture and imported frozen fish (FDF 2007). Fish production from aquaculture has maintained a higher increasing rate when compared to artisanal sources; it supplied between 5 and 22% of total domestic fish production over the period of 2000–2007 (FDF 2007). As yet, this increasing production is not able to meet the increasing rate of consumption because of the wide gap between fish demand and supply (FDF 2008), which is on the rise as a result of population explosion in the country in recent years (Falaye and Jenyo-Oni 2009). The long-term solution to the domestic fish supply gap still lies in boosting domestic production through sustainable aquaculture practices (Aihonsu 2001). Akinrotimi et al. (2007) reported that there is evidence that a substantial part of fish production from homestead farms, rural aquaculture and small-scale fish farms scattered all over the country are not documented.

Fish farming is characterized by extensive use and management of inputs like feed, lime and fertilizer, with a potential for the spread of pathogens. There is also a high rate of generation of waste materials, which include organic matter, nutrients and suspended solids in ponds, and these directly impact on the quality of receiving streams through oxygen depletion, eutrophication and turbidity (Beasley and Allen 1974; Shireman and Cichra 1994; Naylor et al. 2000; Lin and Yi 2003; Tucker and Hargreaves 2003). The negative environmental impact of aquaculture is demonstrated in many ways including user conflicts, change of ecosystems, water pollution, etc. Of these possible negative impacts, pollution of water resources is the most common complaint and the one that has attracted the greatest attention through the nations (Tookwinas 1996; Boyd and Tucker 2000; Cripps and Bergheim 2000). This situation is applicable to Odo-Owa effluent receiving stream in Idomila, Ijebu-Ode, Southwest Nigeria, where the present study was carried out. According to USAID (2010), Ogun State is the fifth highest fish producer in Nigeria and Ijebu-Ode area is one of the major contributors to this success recorded by the state.

It is believed that data obtained on the physicochemical water quality of Odo-Owa effluent receiving stream can be useful for its management and pollution monitoring, particularly for its aquaculture, domestic, irrigation and pollution control purposes. Also, the data could be used as a baseline and/or reference in assessing future likely changes that could result from various anthropogenic activities which include fish farming, agricultural practices, lumbering exercise and natural occurrences. The results obtained can be used to formulate appropriate pollution monitoring, management and control relating to aquaculture practice.

## Materials and methods

### The study area

The investigated water body is Owa Stream (Odo-Owa) near Ijebu-Ode, Ogun State in Southwest Nigeria. The stream rises locally in Eruwon, from two close-by first-order stream sources which later joined together downstream also in Eruwon (Ijebu-North East Local Government Area of Ogun State). These two first-order streams are "Yeye" rising from approximately 06° 83.032′ N, 003° 95.924′ E and "Sesemogun" from approximately 06° 82.971′ N, 003′ 96.032′ E (Table 1). The stream flows southerly, passes close to Ijebu-Ode (Ijebu-Ode Local Government Area) and Imoru (Odogbolu Local Government Area) and empties into the Atlantic Ocean via Iwopin lagoon in Ogun Waterside of Ogun State. The climate of the area is characterized by two distinct seasons: rainy season (March–October) and dry season (November–February), and it is warm throughout the year with average monthly temperature in the range of 28 °C and 35 °C, while the relative humidity is in the range of 85 and 95%.

Odo-Owa stream serves as a major natural water source upon which members of the riparian communities depend on fish farming, domestic water supply and some socioeconomic activities. The stream is one of the many headstreams that constitute the Ogun River drainage system. It receives virtually all the aquacultural wastes from the fish farm under investigation. The investigated fish farm practices an extensive system of aquaculture production and has been in operation for over a decade. The farm has more than one hundred and fifty earthen ponds and four concrete ponds owned by different individual fish farmers. The number of ponds to a farmer, level of operation and returns on capital are determined by the farmer's financial capability and/or his/her managerial potential. The ponds which are used to culture mainly catfish, *Chrysichthys nigrodigitatus* (locally known as "Eja aaro" or "Obokun"), ranged in dimension from $0.5 \times 0.5 \times 05$ m$^3$ to $1.5 \times 2.0 \times 1.5$ m$^3$ and are managed by artisans, mainly male folks within the 16–55 years age bracket. Formulated fish feeds are used mainly by most farmers to raise fish from fingerlings to market size, as imported feeds are too expensive for the farmers to afford. Few farmers use imported feeds to raise their fish from fingerlings to table size before they are transferred to the earthen ponds.

**Table 1**  Grid coordinates and site description of investigated sampling stations

| Sampling station | Site grid coordinates | | Mean stream depth (cm) | Distance from station D (km) | Site description |
|---|---|---|---|---|---|
| | Latitude (N) | Longitude (E) | | | |
| A | 06° 49′ 49″ | 003° 57′ 33″ | 9.5 ± 0.2 | 1.217 | Water source A ("Yeye" stream) |
| B | 06° 49′ 46″ | 003° 57′ 37″ | 6.1 ± 0.0 | 1.264 | Water source B ("Sesemogun" stream) |
| C | 06° 49′ 45″ | 003° 57′ 33″ | 19.8 ± 1.2 | 1.140 | Confluent point of streams A and B |
| D | 06° 49′ 22″ | 003° 57′ 4″ | 33.9 ± 2.9 | 0.0 | Effluent discharge point into the receiving stream |
| E | 06° 49′ 12″ | 003° 56′ 57″ | 32.2 ± 3.4 | 0.363 | A point on the river close to integrated farm |
| F | 06° 48′ 33″ | 003° 56′ 11″ | 19.1 ± 2.3 | 2.209 | At Oke-Owa, a point on Odo-Owa river where socioeconomic activities like car wash takes place |
| G | 06° 48′ 12″ | 003° 55′ 46″ | NA | 3.223 | Reference groundwater body |

$D$ = The point of effluent discharge into Odo-Owa stream was chosen as a reference point

*NA* not applicable

Locally formulated feeds tend to pollute pond water more than the imported feeds, subsequently polluting the receiving water bodies. This is because the locally produced feeds are heavier than the imported ones and thus sink to pond bottom quicker and pollute the pond systems through the process of organic decomposition which utilizes and depletes the pond dissolved oxygen. The production cycle is usually between 4 and 6 months, depending on the level of expertise. That is, fish are cropped/harvested after spending up to 4 or 5 months in the earthen pond. Usually, water is totally egressed from the ponds in order to ensure total cropping; this in turn contributes to the turbidity concentration in the receiving stream. Ponds are later left for about 2 to 4 weeks in preparation for the following production season. Effluent discharge from the farm under consideration into the receiving stream is a point source mode of pollution.

Other significant activities going on in the study area include agricultural practices, notably the cultivation of rice, maize, sugarcane and cassava as well as lumbering. Some of these farming activities, at different stages of production, require the use of various agrochemicals which ultimately find their ways into the stream water. Also, ritual and religious activities which involve the killing and sprinkling of animals' blood and bathing and washing which involve the use of soaps and detergents are carried out along the receiving stream.

### Selection and description of sampling stations

A total of seven sampling stations (designated Stations A–G) were established for this study. Stations A to C represented the unimpacted section of the receiving Odo-Owa stream; Station D was located at the effluent discharge point. Stations E and F were downstream of Station D and represented the impacted section of the receiving stream, while Station G served as a reference water body. Station G is a groundwater source used by the riparian communities for domestic purposes. These sampling stations (Table 1) were georeferenced with a handheld global positioning system (GPS) set, and the locations were marked (using buoys) for subsequent recognition.

### Sampling program

Water samples for analysis were collected four times from each sampling station comprising two times in the dry season (December and February 2013) and two times in the rainy season (April and July 2014). Sampling at each station was carried out at a fixed time of the day from about 08:00 to 18:00 h of each sampling date. At each sampling station, water samples were taken just below the water surface using uncontaminated 2.5-L plastic bottles.

### Laboratory analyses

Tables 2 and 3 present highlights of the various analytical methods used for the analyses and/or determination of the samples for the selected water quality parameters. The analysis was carried out within the holding time of each parameter, according to applicable standard methods (APHA 1995, 1998; Golterman et al. 1978; Willis and Savory 1995). The impact was determined by comparing the water quality of the unimpacted stations (A–C) with that of the impacted stations (E&F) as well as by comparing the latter stations with reference water (Stations G) and the Nigerian Standard for Drinking Water Quality (NSDWQ). Adequate quality control and quality assurance (QC/QA) measures were taken for all the determinations.

**Table 2**  Highlights of analytical methods used for water quality determinations

| Parameter | Method | Procedure/equipment | Unit | References |
|---|---|---|---|---|
| *Physical* | | | | |
| Color | Spectrophotometer | Colorimeter (Whatman filter paper, 110 mm) $\lambda = 430$ nm | Pt.Co. | APHA (1995) |
| Turbidity | Nephelometric | Colorimeter $\lambda = 540$ nm | NTU | APHA (1995) |
| Total dissolved solids (TDS) | Electrolytic | Conductivity/TDS meter | mg/L | APHA (1995) |
| Conductivity | Electrolytic | Conductivity/TDS meter | µS/cm | APHA (1995) |
| *Chemical* | | | | |
| Chloride ($Cl^-$) | Mohr titration | (0.01 M) Mercuric nitrate ($Hg(NO_3)_2$) and diphenylcarba-zone-bromophenol blue (mixed indicator) | mg/L | Golterman et al. (1978) |
| Calcium ($Ca^{2+}$) | Complexometric titration | (0.01 M) $Na_2EDTA$ and calcon indicator | mg/L | Golterman et al. (1978) |
| Magnesium, ($Mg^{2+}$) | Complexometric titration | (0.01 M) $Na_2EDTA$ and Eri-ochrome Black T indicator | mg/L | Golterman et al. (1978) |
| Ammonia ($NH_3$) | Titrimetric | Titration/PONDLAB 200 (NT Laboratories Ltd., Kent, UK) multi-test and Tetra water test kits | mg/L | APHA (1998): method 2120, "color by visual comparison" |
| Bicarbonate ($HCO_3^-$) | Titrimetric | Titration/PONDLAB 200 (NT Laboratories Ltd., Kent, UK) multi-test and Tetra water test kits | mg/L | APHA (1998): method 2120, "color by visual comparison" |
| Nitrate ($NO_3^-$) | Titrimetric | Titration/PONDLAB 200 (NT Laboratories Ltd., Kent, UK) multi-test and Tetra water test kits | mg/L | APHA (1998): method 2120, "color by visual comparison" |
| Nitrite ($NO_2^-$) | Titrimetric | Titration/PONDLAB 200 (NT Laboratories Ltd., Kent, UK) multi-test and Tetra water test kits | mg/L | APHA (1998): method 2120, "color by visual comparison" |
| Dissolved oxygen (DO) | Titrimetric | Titration/PONDLAB 200 (NT Laboratories Ltd., Kent, UK) multi-test and Tetra water test kits | mg/L | APHA (1998): method 2120, "color by visual comparison" |
| Total hardness ($CaCO_3$) | Titrimetric | Titration/PONDLAB 200 (NT Laboratories Ltd., Kent, UK) multi-test and Tetra water test kits | mg/L ($CaCO_3$) | APHA (1998): method 2120, "color by visual comparison" |

$\lambda$ = wavelength, nm = nanometer ($10^{-9}$) cm

*NA* not applicable

## Water quality index, WQI

The water quality index, WQI, was calculated from the point of view of the suitability of surface and/or groundwater for human consumption. In calculating WQI in the present study, five parameters, namely pH, nitrate, dissolved oxygen, turbidity and phosphate, were used and the calculation was based on an online Water Quality Index Software (WQI Project 2017).

## Results and discussion

The results of the investigated physicochemical parameters in the sampling stations are presented in Tables 4, 5, 6, 7, 8, 9 and 10. Generally, most of the investigated parameters (24 of them) were of higher concentrations in the impacted section than in the unimpacted section, while the other parameters were higher in the unimpacted section than in the impacted section of the effluent receiving stream. Also,

**Table 3** Highlights of analytical methods used for water quality determinations

| Parameter | Instrument used | Wavelength, $\lambda$ (nm) | Unit | References |
|---|---|---|---|---|
| *Instrumentation* | | | | |
| Phosphate ($PO_4^{3-}$) | JENWAY 6405 UV/Vis spectrophotometer | 470.0 | mg/L | Golterman et al. (1978) |
| Sulfate ($SO_4^{2-}$) | JENWAY 6405 UV/Vis spectrophotometer | 425.0 | mg/L | Golterman et al. (1978) |
| Sodium ($Na^+$) | Flame emission spectrophotometer (FES) | 589 | mg/L | Golterman et al. (1978) |
| Potassium ($K^+$) | Flame emission spectrophotometer (FES) | 769 | mg/L | Golterman et al. (1978) |
| Copper ($Cu^{2+}$) | Atomic absorption spectrophotometer (AAS) | 324.7 | mg/L | Willis and Savory (1995) |
| Manganese ($Mn^{2+}$) | Atomic absorption spectrophotometer (AAS) | 279.5 | mg/L | Willis and Saviry (1995) |
| Mercury (Hg) | Atomic absorption spectrophotometer (AAS) | 253.7 | mg/L | Willis and Savory (1995) |
| Iron ($Fe^{2+}$) | Atomic absorption spectrophotometer (AAS) | 248.3 | mg/L | Willis and Savory (1995) |
| Zinc ($Zn^{2+}$) | Atomic absorption spectrophotometer (AAS) | 213.9 | mg/L | Willis and Savory (1995) |

a general pattern of progressive decrease in concentrations of investigated parameters (except DO, $Cu^{2+}$, $Fe^{2+}$ and $Mg^{2+}$) was observed from the point of effluent discharge (Station D) into the stream to the last impacted sampling station F. According to Chapman (1992), effluent discharge would be deemed to impact a stream if the concentration of a given physicochemical variable is higher in the effluent or just below its point of discharge and decreases significantly with increasing distance downstream. This submission agrees with the pattern of spatial reduction in effluent concentrations, downstream, as recorded in this study. Ojo and Adeniyi (2012) observed a similar pattern in a study on the impacts of hospital effluent discharges on the physicochemical water quality of a receiving stream at Ile-Ife, Southwest Nigeria.

The overall average value of water turbidity in the unimpacted stretch of the investigated stream was $18.89 \pm 2.80$ NTU as opposed to $33.05 \pm 3.5$ NTU in the impacted portion of the water stretch, while the overall average value recorded at the effluent discharge point was $38.75 \pm 8.9$ NTU as shown in Table 4. Silapajarn and Boyd (2005) observed that streams into which effluents flowed directly from catfish ponds had higher concentrations of suspended solids, turbidity, nutrients and biochemical oxygen demand, compared to reference streams in the same Alabama (USA) watershed. This result is lower than 91.1 NTU reported by Muhibbu-din (2011) in a study on the physicochemical parameters of the effluent-impacted stream at Obafemi Awolowo University, Ile-Ife, Nigeria. Water turbidity in the present study was significantly ($P < 0.05$) higher in the rainy season ($29.09 \pm 3.72$ NTU) than it was in the dry season ($18.34 \pm 2.90$ NTU). This might be attributed to heavy rainfall leading to an increase in surface runoff and erosion carrying soil/silt and partially dissolved or un-dissolved organic matters (Morokov 1987) as well as fish cropping and pond preparations in the rainy season for the new production cycle. Olalekan et al. (2012) reported a similar trend in a

work on Ogun River. All the values recorded in this study are higher than the Nigerian Federal Environmental Protection Agency (FEPA 1991) stipulated value of $< 1$ NTU for discharge into the surface water freshwaters and 5 NTU (WHO 2004 and NSDWQ 2007) for drinking. The elevated turbidity levels at the effluent discharge point as well as in the impacted portion of the stream could be attributed to the effluents from the fish rearing systems, particularly during cleaning/preparations, for new production season (Hinshaw and Fornshell 2002; Kendra 1991) and water runoff or excess phytoplankton growth (USEPA 1997). Turbidity causes aesthetic degradation of the receiving stream and other effects such as the reduction in the light penetration through the water body and its attendant effect on the photosynthetic rates of algae and submerged macrophytes and clogging of respiratory surfaces of gills of fish or nets of filter-feeding invertebrates (Hellawell 1986).

The pH values recorded for both the stream and effluent discharged point ranged between 6.4 and 7.2 pH units, that is, from moderately acidic through neutral to moderately alkaline, as shown in Table 4. The mean pH values recorded in all the sampling stations except at Station B (5.6) fell within the stipulated Nigerian FEPA pH tolerance limit (6.0–9.0) for effluents to be discharged into surface waters and the EU pH protection limits of 6.0–9.0 for fisheries and aquatic life (Chapman 1996). The value obtained at Station B is therefore capable of causing serious harm to the aquatic life downstream; it also makes it dangerous for direct consumption considering the 6.50–8.50 recommended by the Nigerian Standard for Drinking Water Quality (NSDWQ). In the work of Chinedu et al. (2011) on the assessment of water quality in Canaanland, Ota, Southwest Nigeria, they reported that all the water samples except the bottled/sachet Hebron water and Iju River water were acidic (5.96–6.54).

Dissolved oxygen is an important factor used for water quality assessment. The effect of waste discharge on a surface water source is largely determined by the oxygen

**Table 4** Mean values of water quality parameters of the investigated stream

| Parameter | USS | EDP | ISS | RWB | ANOVA | |
|---|---|---|---|---|---|---|
| | (A–C) | (D) | (E&F) | (G) | F | P |
| *Channel characteristics* | | | | | | |
| River channel depth (cm) | 11.78 ($\pm$1.92) | 33.93 ($\pm$2.66) | 28.4 ($\pm$2.29) | NA | 30.91 | 1.37E−05*** |
| River channel width (cm) | 66.2 ($\pm$27.16) | 411.0 ($\pm$22.06) | 298.68 ($\pm$25.73) | NA | 38.62 | 2.96E−06*** |
| *Hydro-physical* | | | | | | |
| Air temp. (°C) | 27.42 ($\pm$0.38) | 29.50 ($\pm$1.04) | 29.0 ($\pm$0.47) | 29.1 ($\pm$1.1) | 8.86 | 1.23E−03*** |
| Water temp. (°C) | 26.46 ($\pm$0.32) | 28.0 ($\pm$0.82) | 28.04 ($\pm$0.35) | 30.0 ($\pm$2.7) | 8.088 | 1.95E−03*** |
| App. color (Pt.Co.mg/L) | 185.15 ($\pm$13.93) | 475.80 ($\pm$84.12) | 390.5 ($\pm$37.52) | 123.9 ($\pm$47.98) | 18.04 | 1.41E−05*** |
| True color (Pt.Co.mg/L) | 9.99 ($\pm$7.02) | 59.96 ($\pm$9.23) | 53.64 ($\pm$13.0) | 0.0 ($\pm$0.0) | 8.73 | 7.33E−03*** |
| Turbidity (NTU) | 18.89 ($\pm$2.80) | 38.75 ($\pm$8.9) | 33.05 ($\pm$3.5) | 10.2 ($\pm$3.5) | 9.18 | 1.02E−03*** |
| *General chemical* | | | | | | |
| pH | 6.58 ($\pm$0.22) | 7.10 ($\pm$0.2) | 7.20 ($\pm$0.09) | 6.40 ($\pm$0.1) | 4.66 | 1.90E−02** |
| Conductivity ($\mu$S/cm) | 76.11 ($\pm$9.36) | 84.85 ($\pm$3.88) | 87.41 ($\pm$3.13) | 19.80 ($\pm$1.99) | 13.49 | 1.07E−04*** |
| TDS (mg/L) | 45.48 ($\pm$5.68) | 50.32 ($\pm$1.91) | 51.79 ($\pm$2.03) | 11.66 ($\pm$1.3) | 12.78 | 1.5E−04*** |
| Alkalinity (mg/L $CaCO_3$) | 24.85 ($\pm$2.72) | 62.1 ($\pm$17.22) | 58.43 ($\pm$6.8) | 31.1 ($\pm$4.4) | 12.19 | 2.01E−04*** |
| Total hardness (mg/L$CaCO_3$) | 48.95 ($\pm$5.14) | 44.5 ($\pm$4.07) | 45.98 ($\pm$4.4) | 40.0 | 0.26 | 0.769 |
| Ammonia, $NH_3$ (mg/L) | 0.17 ($\pm$0.05) | 1.625 ($\pm$0.375) | 1.53 ($\pm$0.40) | 0.0 ($\pm$0.0) | 1.22 | 2.90E−03*** |
| DO (mg/L) | 5.43 ($\pm$0.55) | 3.375 ($\pm$0.55) | 4.1 ($\pm$0.55) | 5.5 ($\pm$1.24) | 1.60 | 0.22 |
| *Major ions* | | | | | | |
| $Ca^{2+}$ (mg/L) | 7.67 ($\pm$0.81) | 6.38 ($\pm$1.0) | 8.50 ($\pm$1.28) | 2.8 ($\pm$1.2) | 3.903 | 3.34E−02** |
| $Mg^{2+}$ (mg/L) | 2.44 ($\pm$0.33) | 1.48 ($\pm$0.40) | 2.29 ($\pm$0.56) | 1.24 ($\pm$0.2) | 1.007 | 0.380 |
| $Na^+$ (mg/L) | 5.25 ($\pm$0.26) | 6.61 ($\pm$0.25) | 6.50 ($\pm$0.2) | 3.10 ($\pm$0.2) | 33.74 | 7.92E−08*** |
| $K^+$ (mg/L) | 2.74 ($\pm$0.26) | 5.10 ($\pm$0.22) | 5.31 ($\pm$0.21) | 0.85 ($\pm$0.06) | 63.7 | 1.49E−10*** |
| $Cl^-$ (mg/L) | 5.54 ($\pm$0.55) | 7.03 ($\pm$0.39) | 6.88 ($\pm$0.48) | 1.7 ($\pm$0.3) | 14.07 | 8.06E−05*** |
| $SO_4^{2-}$ (mg/L) | 2.26 ($\pm$0.38) | 7.43 ($\pm$1.53) | 6.50 ($\pm$1.03) | 0.49 ($\pm$0.32) | 12.63 | 1.61E−04*** |
| $HCO_3^-$ (mg/L) | 29.9 ($\pm$3.3) | 74.52 ($\pm$20.66) | 70.1 ($\pm$8.2) | 37.38 ($\pm$5.34) | 12.14 | 2.07E−04*** |
| *Nutrient compounds* | | | | | | |
| $NO_3^-$ (mg/L) | 1.57 ($\pm$0.89) | 3.5 ($\pm$0.89) | 1.63 ($\pm$0.54) | 0.0 ($\pm$0.0) | 0.023 | 0.952 |
| $NO_2^-$ (mg/L) | 0.09 ($\pm$0.05) | 0.26 ($\pm$0.80) | 0.13 ($\pm$0.4) | 0.0 ($\pm$0.0) | 0.309 | 0.584 |
| $PO_4^{3-}$ (mg/L) | 0.34 ($\pm$0.14) | 0.51 ($\pm$0.29) | 0.495 ($\pm$0.14) | 0.31 ($\pm$0.26) | 0.383 | 0.685 |
| *Heavy metals* | | | | | | |
| $Hg^{2+}$ (mg/L) | 0.03 ($\pm$0.006) | 0.03 ($\pm$0.006) | 0.026 ($\pm$0.002) | 0.005 (0.005) | 3.349 | 0.051 |
| $Mn^{2+}$ (mg/L) | 1.39 ($\pm$0.15) | 1.55 ($\pm$0.19) | 1.59 ($\pm$0.09) | 1.63 ($\pm$0.19) | 0.830 | 0.448 |
| $Fe^{2+}$ (mg/L) | 1.87 ($\pm$0.13) | 2.12 ($\pm$0.49) | 2.45 ($\pm$0.26) | 2.39 ($\pm$0.30) | 2.257 | 0.125 |
| $Cu^{2+}$ (mg/L) | 0.054 ($\pm$0.02) | 0.054 ($\pm$0.03) | 0.067 ($\pm$0.02) | 0.134 ($\pm$0.08) | 1.384 | 0.269 |
| $Zn^{2+}$ (mg/L) | 0.147 ($\pm$0.09) | 0.292 ($\pm$0.21) | 0.182 ($\pm$0.09) | 0.178 ($\pm$0.084) | 0.004 | 0.956 |

*USS* unimpacted sampling station; *EDP* effluent discharge point; *ISS* impacted sampling station; *RWB* reference water body; *NA* not applicable

* Significant; $p < 0.05$

** Highly significant; $p < 0.01$

*** Very highly significant; $p < 0.001$

balance of the system, and its presence is essential in maintaining biological life within a system (DFID 1999).

The mean concentration of dissolved oxygen (DO) in the unimpacted water stretch ($5.43 \pm 0.55$ mg/L) was slightly higher than in the impacted stretch ($4.1 \pm 0.55$ mg/L), indicating that more oxygen consumption took place downstream, and this could be for the oxidation of waste discharge

from Idomila fish farm into the stream (Table 4). This situation is similar to what Amankwaah et al. (2014) reported in water quality assessment of Asuofia stream, Ghana. Hamblin and Gale (2002) reported that the biological and chemical oxygen demand of wastes discharged from land-based aquaculture facilities can reduce dissolved oxygen concentrations in lotic waters for short distances. Ruiz-Zarzuela

**Table 5** ANOVA statistics of seasonal variations in the water quality parameters of Owa Stream, Ogun State, Nigeria

| Parameter | Dry season samples Mean ± SE | Rainy season samples Mean ± SE | ANOVA statistics | |
|---|---|---|---|---|
| | | | F | P |
| TDS (mg/L) | 36.15(±3.86) | 50.56(±5.54) | 4.55 | 0.043* |
| Turbidity (NTU) | 18.34(±2.90) | 29.09(±3.72) | 5.188 | 0.031* |
| Phosphate, $PO_4^{3-}$ (mg/L) | 0.72(±0.13) | 0.08(±0.03) | 22.79 | 6.1E−05*** |
| Manganese, $Mn^{2+}$ (mg/L) | 1.20(±0.09) | 1.82(±0.06) | 32.34 | 5.5E−06*** |
| Iron, $Fe^{2+}$ (mg/L) | 1.91(±0.18) | 2.48(±0.18) | 4.79 | 0.0379* |
| Mercury, $Hg^{2+}$ (mg/L) | 0.55(±0.17) | 0.02(±0.003) | 9.98 | 0.004** |

* Significant; $P < 0.05$

** Highly significant; $P < 0.01$

*** Very highly significant; $P < 0.001$

**Table 6** ANOVA statistics of seasonal variations among impacted and unimpacted sampling stations in the water quality parameters of Owa Stream, Ogun State, Nigeria

| Parameter | Dry season | | ANOVA statistics | | Rainy season | | ANOVA statistics | |
|---|---|---|---|---|---|---|---|---|
| | Unimpacted | Impacted | F | P | Unimpacted | Impacted | F | P |
| TDS (mg/L) | 34.97(±4.62) | 46.22(±1.10) | 5.611 | 0.039* | 56(±8.73) | 57.37(±2.14) | 0.023 | 0.882 |
| Turbidity (NTU) | 10.71(±1.56) | 29.23(±2.59) | 37.55 | 0.000*** | 27.06(±2.30) | 36.88(±6.44) | 2.059 | 0.182 |
| Phosphate, $PO_4^{3-}$ (mg/L) | 0.65(±0.21) | 0.83(±0.21) | 0.368 | 0.557 | 0.02(0.01) | 0.16(±0.05) | 5.929 | 0.035* |
| Manganese, $Mn^{2+}$ (mg/L) | 1.07(±0.20) | 1.30(±0.04) | 1.316 | 0.278 | 1.72(±0.99) | 1.87(±0.08) | 1.551 | 0.241 |
| Iron, $Fe^{2+}$ (mg/L) | 1.75(±0.18) | 1.94(±0.37) | 0.219 | 0.650 | 1.99(±0.19) | 2.96(±0.22) | 10.51 | 0.009** |
| Mercury, $Hg^{2+}$ (mg/L) | 0.021(±0.00) | 0.024(±0.00) | 0.44 | 0.521 | 0.024(±0.00) | 0.028(±0.00) | 0.719 | 0.416 |

* Significant; $P < 0.05$

** Highly significant; $P < 0.01$

*** Very highly significant; $P < 0.001$

**Table 7** Variations in water quality index of Owa Stream, among different sampling stations among reference water body, Ogun State, Nigeria

| USS | EDP | ISS | RWB | ANOVA | |
|---|---|---|---|---|---|
| (A–C) | (D) | (E&F) | (G) | F | P |
| 48.42 (±3.41)% | 40.5 (±3.52)% | 47.62 (±2.35)% | 47.0 (±2.74)% | 0.75 | 0.53 |

*USS* unimpacted sampling station; *EDP* effluent discharge point; *ISS* impacted sampling station; *RWB* reference water body

**Table 8** Variations in water quality index of Owa Stream, in dry and rainy seasons, Ogun State, Nigeria

| DS | RS | ANOVA | |
|---|---|---|---|
| | | F | P |
| 45.36 (±2.31)% | 48.36(±2.62)% | 0.73 | 0.39 |

*DS* dry season; *RS* rainy season

et al. (2009) reported that uneaten excess feed breakdown results in the production of algal bloom; the algal blooms die and settle to the bottom of the effluent receiving water body where their decomposition depletes the oxygen. Algal toxins can also bio-accumulate and biomagnify through the food chains and food webs and reach toxic levels in some organisms meant for human consumption (Camargo and Alonso 2006). It was discovered that the DO concentration recovered significantly with increasing distance downstream. DO standard for drinking purposes is 6 mg/L (WHO 2004), whereas that for sustaining fish and aquatic life is 4–5 mg/L (Rao 2005). The DO values recorded in this study fell slightly above the value of ≥ 4 mg/L set by the Nigerian Federal Ministry of Environment as the permissible level for surface water quality for public supplies.

Nitrate is the most oxidized form of nitrogen compounds, and it is commonly present in surface and groundwaters, because it is the by-product of the aerobic decomposition of organic nitrogenous matter. The nitrate profile, as presented in Table 4, showed lower mean concentrations in the unimpacted stretch (1.57 ± 0.89 mg/L) of Owa stream than in the impacted stretch (1.63 ± 0.54 mg/L). Surface water sources can also be contaminated with nitrate by sewage and

**Table 9** Relationship between the water quality parameters of unimpacted and impacted stretches of the effluent receiving stream

| Parameter | Unimpacted sampling stations (USS) ($n=12$) | Impacted sampling stations (ISS) ($n=12$) | $F$ | $P$ value |
|---|---|---|---|---|
| *Channel* | | | | |
| Depth (cm) | 11.78($\pm$1.92) | 28.40($\pm$2.29) | 30.91 | 1.37E−05*** |
| River channel width (cm) | 66.2($\pm$27.15) | 298.68($\pm$25.73) | 38.62 | 2.96E−06*** |
| *Hydro-physical* | | | | |
| Water temp. (°C) | 26.46 ($\pm$0.32) | 28.04($\pm$0.35) | 11.05 | 0.003** |
| App. color (Pt.Co.mg/L) | 185.15($\pm$13.93) | 390.5($\pm$37.52) | 26.32 | 3.84E−05*** |
| True color (Pt.Co.mg/L) | 9.99($\pm$7.02) | 53.64($\pm$13.0) | 8.72 | 0.007** |
| Turbidity (NTU) | 18.89($\pm$2.80) | 33.05($\pm$3.5) | 9.98 | 0.004** |
| *General chemical* | | | | |
| pH | 6.58($\pm$0.22) | 6.97($\pm$0.12) | 5.92 | 0.023* |
| Conductivity ($\mu$S/cm) | 76.11($\pm$9.36) | 87.41($\pm$3.13) | 1.31 | 0.264 |
| TDS (mg/L) | 45.48($\pm$5.68) | 51.79($\pm$2.03) | 1.09 | 0.307 |
| Alkalinity (mg/L$CaCO_3$) | 24.85($\pm$2.72) | 58.43($\pm$6.8) | 21.01 | 0.0001*** |
| Total hardness (mg/L$CaCO_3$) | 48.95($\pm$8.2) | 45.98($\pm$4.07) | 0.10 | 0.750 |
| Ammonia, $NH_3$ (mg/L) | 0.17($\pm$0.0) | 1.53($\pm$0.3) | 11.22 | 0.002** |
| Dissolved oxygen, DO (mg/L) | 5.43($\pm$0.55) | 4.1($\pm$0.55) | 2.96 | 0.099 |
| *Major ions (mg/L)* | | | | |
| $Ca^{2+}$ | 7.67($\pm$0.81) | 8.50($\pm$1.28) | 0.29 | 0.592 |
| $Mg^{2+}$ | 2.44($\pm$0.33) | 2.29($\pm$0.56) | 0.05 | 0.825 |
| $Na^+$ | 5.25($\pm$0.26) | 6.51($\pm$0.17) | 16.48 | 0.000*** |
| $K^+$ | 2.74($\pm$0.26) | 5.31($\pm$0.21) | 60.17 | 9.82E−08*** |
| $Cl^-$ | 5.54($\pm$0.55) | 6.88($\pm$0.48) | 3.36 | 0.080 |
| $SO_4^{2-}$ | 2.26($\pm$0.38) | 6.52($\pm$1.03) | 15.17 | 0.000*** |
| $HCO_3^-$ | 29.9($\pm$3.3) | 70.13($\pm$8.16) | 20.91 | 0.000*** |
| *Nutrient compounds (mg/L)* | | | | |
| $NO_3^-$ | 1.57($\pm$0.89) | 1.63($\pm$0.54) | 0.00 | 0.952 |
| $NO_2^-$ | 0.09($\pm$0.05) | 0.13($\pm$0.04) | 0.31 | 0.584 |
| $PO_4^{3-}$ | 0.338($\pm$0.14) | 0.495($\pm$0.14) | 0.62 | 0.438 |
| *Heavy metals (mg/L)* | | | | |
| $Hg^{2+}$ | 0.03($\pm$0.007) | 0.026($\pm$0.002) | 0.26 | 0.614 |
| $Mn^{2+}$ | 1.39($\pm$0.15) | 1.59($\pm$0.09) | 1.27 | 0.271 |
| $Fe^{2+}$ | 1.874($\pm$0.13) | 2.45($\pm$0.26) | 3.99 | 0.058 |
| $Cu^{2+}$ | 0.054($\pm$0.02) | 0.067($\pm$0.02) | 0.18 | 0.674 |
| $Zn^{2+}$ | 0.147($\pm$0.093) | 0.182($\pm$0.086) | 0.08 | 0.784 |

\* Significant; $P<0.05$

\*\* Highly significant; $P<0.01$

\*\*\* Very highly significant; $P<0.001$

other wastes rich in nitrates. Statistically, there was no significant spatial difference ($P>0.05$) between the impacted and unimpacted portions of the stream, and this agrees with the result of Amankwaah et al. (2014). The mean nitrate values obtained for both the upstream ($1.57\pm0.89$ mg/L) and downstream ($1.63\pm0.54$ mg/L) in this study were far lower than the values of 5.2–8.6 mg/L and 16.4–22.4 mg/L reported by Mustapha and Omotosho (2005) in their work on the physicochemical properties of Moro Lake, Kwara State, Nigeria. As shown in Table 4, the mean nitrate value

at the effluent discharge point (D) ($3.5\pm0.89$ mg/L) was about fifty-four times higher than the value recorded at the last sampling Station (F) ($0.065\pm0.03$ mg/L) and confirms the huge nitrate loading from the fish farm into the Owa stream. It also shows a significant decrease in concentrations with increasing distance downstream which is similar to the trend recorded by Ojo and Adeniyi (2012). The $0\pm0$ mg/L recorded at the reference water body (Station G) again confirms that there was little or no impact of aquaculture practice on the groundwater source in the area. On

**Table 10** Effluent discharge impact on water quality parameters of the receiving stream and recovery

| Parameter | %Impact at station E | %Impact at station F | %Recovery at station F |
|---|---|---|---|
| *Hydro-physical* | | | |
| Water temp. (°C) | 6.83 | 4.8 | 2.3 |
| App. color (Pt.Co.mg/L) | 54.1 | 36.6 | 60.4 |
| True color (Pt.Co.mg/L) | 85.3 | 69.7 | 350.2 |
| Turbidity (NTU) | 41.3 | 33.0 | 21.2 |
| *General chemical* | | | |
| pH | 4.9 | 7.3 | 1.5 |
| Conductivity (μS/cm) | 17.9 | 10 | 10.6 |
| TDS (mg/L) | 18.5 | 7.6 | 14.5 |
| Alkalinity (mg/LCaCO$_3$) | 57.0 | 55.1 | 10.1 |
| Total hardness (mg/LCaCO$_3$) | 0.10 | 10 | 9.0 |
| Ammonia, NH$_3$ (mg/L) | 90.8 | 83 | 529.4 |
| Dissolved oxygen, DO (mg/L) | 55.1 | 0.6 | − 35.0 |
| *Major ions (mg/L)* | | | |
| Ca$^{2+}$ | 22.5 | 16.6 | 9.1 |
| Mg$^{2+}$ | 10.9 | 21.3 | 36.9 |
| Na$^+$ | 21.6 | 15.3 | 9.5 |
| K$^+$ | 49.2 | 49.2 | 0 |
| Cl$^-$ | 25.1 | 9.2 | 23.5 |
| SO$_4^{2-}$ | 74.9 | 24.7 | 265.5 |
| HCO$_3^-$ | 56.9 | 54.9 | 10.0 |
| *Heavy metals (mg/L)* | | | |
| Hg$^{2+}$ | 20 | 3.4 | − 13.3 |
| Mn$^{2+}$ | 15.6 | 11.3 | 5.7 |
| Fe$^{2+}$ | 8.8 | 41.2 | − 60.4 |
| Cu$^{2+}$ | 21.7 | 28.9 | − 12.9 |
| Zn$^{2+}$ | 5.7 | 2.0 | 105.4 |
| *Nutrient compounds (mg/L)* | | | |
| NO$_3^-$ | 18.9 | 95.9 | 79.9 |
| NO$_2^-$ | 10 | 72.2 | 83.3 |
| PO$_4^{3-}$ | 42.3 | 12.8 | 58.8 |

the whole, the values recorded in this study were all within the 20 mg/L recommended limit by FEPA (1991) effluent limitation standards and 50 mg/L maximum permitted limit for drinking (NSDWQ 2007; WHO 2004).

Ammonia is a dissolved gas present naturally in surface and wastewaters and in some well waters. It is the major nitrogenous waste product of fish and also results from the decomposition of organic matter. It is quite soluble in water, especially at low pH, and ordinarily it is removed by plants or bacteria (as a nutrient or energy source). Ammonia in water is present in two forms—unionized ammonia (NH$_3$) and the ionized form (NH$_4^+$)—and the relative proportion of each type depends on pH and temperature. At a high pH, a smaller amount of total ammonia nitrogen causes toxic effects (Boyd 1990). The ammonia profile in this study showed it was nine times higher in the impacted ($1.53 \pm 0.3$ mg/L) portion of the water stretch than in the unimpacted ($0.17 \pm 0.0$ mg/L) portion, indicating huge ammonia contributions from the fish farm and its deleterious impact on the water quality of Odo-Owa stream. Statistically, there was a significant difference ($P < 0.05$) between the two stretches of the water body relative to the discharge point. Apart from its high direct toxic effect on aquatic animals (Green et al. 2001; Brinker 2009; Akinrotimi et al. 2011), the contributions of ammonia to the reduction in the aesthetic value of the environment, with putrefying odor emanating from these areas, have also been reported (Akinrotimi et al. 2011). The effluent discharge point (D) recorded the highest ammonia mean ± concentration, while no ammonia was detected in the reference water body (G). The release of this gas and other wastes on a continual basis can lead to the build-up of some pathogenic organisms which can result in the outbreak of epidemic diseases. The range of ammonia concentration recorded in this study (0.1–1.625 mg/L) is far higher than the WHO (2008)-permitted drinking water standard value (< 0.2 mg/L or up to 0.3 mg/L in anaerobic waters) and 0.2–0.5 mg/L set by Warrier–Hansen (1982) for fish farm effluent and the recommended level of 0.11–05 mg/L for river water.

Total alkalinity gives an indication of the good quality of water and its capacity to effectively regulate the pH and buffer capacity of the stream water (Meade 1989). It is a reflection of the stream's carbonates and bicarbonate profiles (Wetzel 2001) with the likelihood of silicates and phosphates contributing to it (Moshood 2008). The present study indicates the impact of effluents on the downstream's total alkalinity. Sugunan (1995) reported that total alkalinity above 40 mg/L CaCO$_3$ is indicative of high biological productivity. As indicated in Table 4, all the total alkalinity values obtained in this study fell within the WHO (2002) specifications (120 mg/L) allowed for domestic and recreational applications of water.

Phosphate may occur in surface water as a result of detergents, agricultural effluents with fertilizers and domestic sewage. The mean concentrations of phosphate recorded in the impacted portion (0.495 mg/L) of the water stretch were higher than the unimpacted portion (0.34 mg/L) (Table 4) and were nine times higher ($P < 0.001$) in the dry season ($0.72 \pm 0.13$ mg/L) than in the rainy season ($0.08 \pm 0.03$ mg/L) for this study (Table 5). The trend is similar to the report of Olalekan et al. (2012) in their study on Ogun River, Southwest Nigeria. Also, it agrees with the findings of Amankwaah et al. (2014), Ansah (2010) and Pulatsu et al. (2004) on the assessment of pond effluent effect on water quality of the Asuofia stream, Ghana. The results obtained in the present study are above the Nigerian Federal Ministry of Environment maximum permissible value of 0.05 mg/L. The high phosphate values obtained in the

investigation could be attributed to the phosphorus in run-off from domestic, municipal and agricultural wastes (non-point source) flowing into the river as well as washing along the riverside with detergent (Correl 1998). According to Kelly (1992, 1993), accumulation of the decomposed solid waste releases labile phosphorous to the water columns. This could have contributed to the high levels in receiving streams during rainfall (Rao 2011). The uneaten fish feed, feces and other forms of excretion could have contributed to the elevated phosphate in the impacted portion of the effluent receiving stream. Bureau and Cho (1999) reported in their work that dissolved carbon, nitrogen and phosphorus are released into the water column by solubilization from feed and feces and through the gill and urinary excretions of fish. According to Perry et al. (2007), it is not possible to find high phosphate concentrations if the algae are already blooming, as the phosphates are already in the algae but not in water. This may explain the situation observed at some sections of the water upstream, where algal growth was observed. The upstream section of Odo-Owa stream, except at the confluence point (Point C), consists of smaller river channel width (Table 4) and low water velocity. The mean value of phosphate recorded in this study (1.37 mg/L) is within the WHO acceptable standard (2.5 mg/L) for open waters but much higher than that of the Nigerian Ministry of Environment maximum permissible level of 0.05 mg/L. Stone and Thomforde (2010) gave the range of phosphate for typical surface water as 0.005 to 0.5 mg/L. The overall mean concentrations of the investigated metals of Owa Stream and the reference water body are presented in Table 4.

Table 9 shows the comparison of the overall mean concentrations of all the investigated physicochemical parameters in both unimpacted and impacted sampling stations of the receiving stream. The comparison shows the water quality of unimpacted and impacted stretches of the receiving stream to be significantly ($P < 0.05$) different for water temperature, turbidity, pH, $Na^+$ and $K^+$. The table shows that the mean $\pm$ concentration of ammonia was nine times higher; true color was about six times higher; river channel width was about five times higher; apparent color, water depth, alkalinity, $HCO_3^-$ and $SO_4^{2-}$ were more than two times greater in the impacted than in the unimpacted stretch.

## The relationships among the investigated sampling stations

The relationship among the investigated sampling stations (based on water quality physicochemical parameters) was
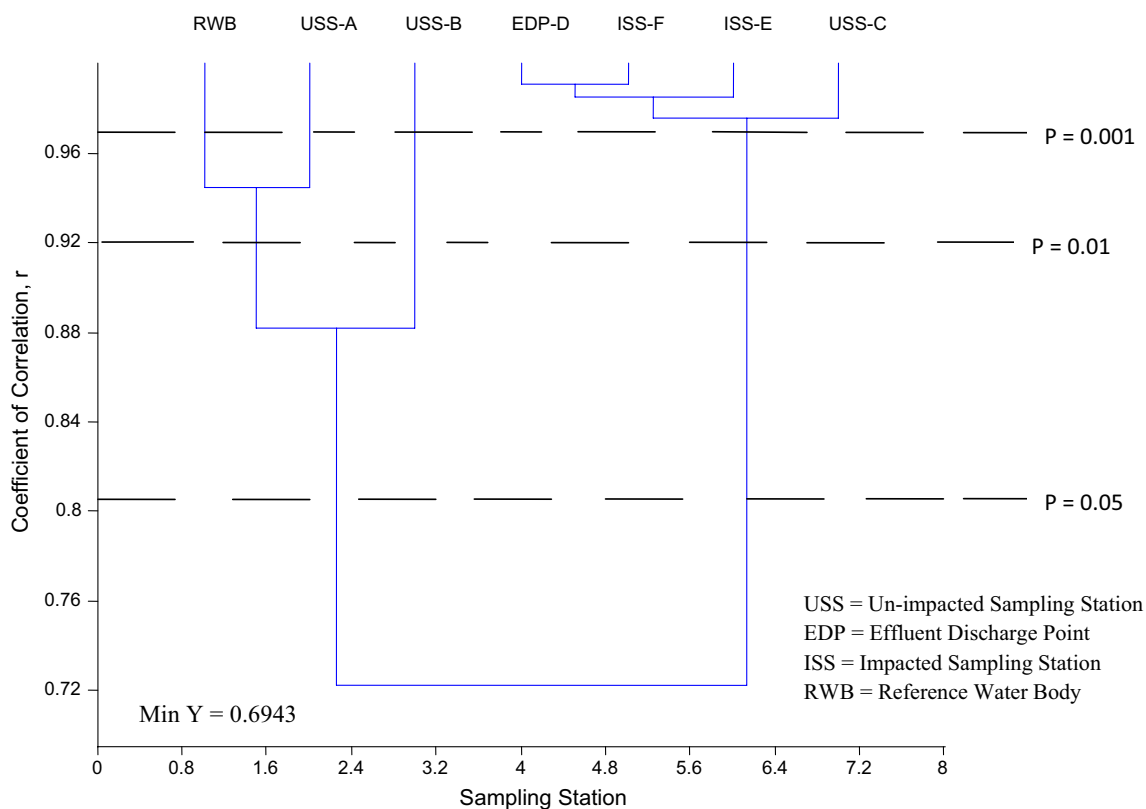


**Fig. 1** Cluster diagram showing the relationships among the investigated sampling stations based on their physicochemical water quality parameters. $n = 29$; $r = 0.361$, $P < 0.05$; $r = 0.463$, $P < 0.01$; $r = 0.588$, $P < 0.001$

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established using cluster analysis, and the result is shown in Fig. 1. All the investigated sampling stations could be broadly grouped into two clusters comprising sampling stations A, B and G as one cluster group and the other stations as the second cluster ($P > 0.05$). The first cluster comprised the unimpacted and the reference station, while the second cluster comprised Stations C–F (effluent discharge and the impacted stations). This is an indication that the grouping was with regard to the effluent impact on the investigated physicochemical parameters of the receiving stream.

## Water quality index (WQI) assessment of the stream

The parameters used to determine the WQI of Odo-Owa stream were dissolved oxygen, turbidity, pH, nitrate and phosphate, respectively. The WQI was generally fair (26–50%). It was the highest at the unimpacted (48.42) stations and lowest at the effluent discharge point (40.5) (Table 7). The WQI was also fair throughout the annual cycle, but slightly higher in the rainy season (48.36) than in the dry season (45.36) (Table 8).

## Effluent pollution impact on receiving stream

Table 9 shows the percentage impact of the aquaculture effluent discharged at the Station D into Odo-Owa stream as assessed downstream at Stations E and F and the extent to which the stream recovered at Station F. The observed trend of the stream recovery from aquaculture effluent impact in this study shows a general progressive increase from Station E to the last sampling Station F. This trend follows the stream recovery pattern described by Peirce et al. (1990), Nathanson (2000) and Ojo and Adeniyi (2012).

## Conclusion

This study characterized the physicochemical quality of the upstream section (Stations A, B and C) effluent discharge point (Station D), downstream section (Stations E and F) of aquaculture effluent-receiving Odo-Owa stream and reference water body (G). The water qualities revealed that the mean concentrations of turbidity, apparent color, true color, $NH_3$, $PO_4^{3-}$, $Fe^{2+}$, $Mn^{2+}$ and $Hg^{2+}$ were above the FEPA (1991) effluent limitation standards. The difference between the water qualities of impacted and unimpacted stretches of the effluent receiving stream was significant ($P < 0.05$) for more than half of the parameters. All the investigated parameters (except total hardness, DO and $Hg^{2+}$) were higher in the impacted section than in the unimpacted section, thus indicating the negative impact on the receiving stream. The effluent qualities varied among the investigated parameters and decreased (except DO, $Fe^{2+}$, $Mn^{2+}$ and $Hg^{2+}$) gradually

from the outpour downstream. The pronounced increase in ammonia, major ions and nutrient compounds indicated that the discharge from the medium-scale fish farm is both inorganic and organic. Water quality index determination showed that Odo-Owa stream is very bad, both in the dry (26.88) and in the rainy (32.42) seasons. There is a desirable need to analyze the sediment compositions of Odo-Owa stream and some samples of fish being raised in this farm settlement for in-depth knowledge on the impact of the aquacultural practice on the receiving stream.

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