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Assessment of pond effluent effect on water quality of the Asuofia Stream, Ghana

Amankwaah, D.[1], Cobbina, S. J.[1*], Tiwaa, Y. A.[2], Bakobie, N.[1] and Millicent, E. A. B.[3]

[1]Department of Ecotourism and Environmental Management, Faculty of Renewable Natural Resources, University for Development Studies, Ghana.
[2]Ministry of Fisheries and Aquaculture Development, Fisheries Commission, Atwima Zone, Ghana.
[3]Environmental Biology and Health Division, CSIR Water Research Institute, Tamale, Ghana.

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The study was done to assess the effects of potential pond effluent on the physico-chemical parameters of the receiving streams. Forty two (42) samples were collected from five ponds, upstream and downstream stations of the receiving stream for a period of six months. *In situ* measurement was conducted for physical parameters using a portable multi-parameter water quality meter (HANNA, HI9828). Samples were collected and transported to the Water Research Institute laboratory, Tamale for the analysis. pH values recorded ranged between 7.6 and 7.9 pH-unit with a mean of 7.69±0.13 pH-unit for pond samples, 7.48 to 7.73 pH-unit with a mean of 7.59±0.1 pH-unit for downstream samples and 7.25 to 7.5 pH-unit with a mean of 7.36±0.11 pH-unit for upstream samples. The nitrate concentrations at the upstream stations (7.57±0.93 mg/l) was found to be higher than that of downstream (5.02±0.25 mg/l) and in ponds (5.0±0.25 mg/l). Comparatively, aquaculture ponds recorded physico-chemical parameters that are significantly higher than those recorded in stream locations. Nitrate and dissolve oxygen were significantly higher at the upstream than downstream and ponds. The study reveals that activities such as vegetables and cereal cultivation, livestock farming and refuse dumping within the watershed serves as source of pollution and nutrient enrichment in the receiving stream.

Key words: Nkawie, physico-chemical parameters, upstream, pond, effluent.

INTRODUCTION

The fisheries sector has played a vital role in the socio-economic development of Ghana since independence. The sector has the potential to contribute substantially to the national economy through employment, gross domestic product (GDP), foreign exchange earnings, food security and poverty reduction. Despite this great potential, the sector has over the past two decades registered a slow growth of 3% per annum, falling short of its expected potential. The sector accounts for 4.5% of the national GDP (DOF, 2009). Fish is the most important source of animal protein in Ghana. The country's total annual fish requirement has been estimated to be

*Corresponding author. E-mail: cobbinasamuel@yahoo.com or abalu096@gmail.com.

to be 880,000 tonnes while the nation's annual fish production average is 420,000 tonnes, leaving an annual deficit of 460,000 tonnes (DOF, 2009). This deficit is made up for, through fish imports which were estimated at 213,000 tonnes in the year 2007 and valued at US $262 million (DOF, 2007).

Aquaculture is an important economic activity in many countries and offers opportunities that contribute to poverty alleviation, employment, community development, reduction of exploitation of natural resources and food security in tropical and subtropical regions. Also, aquaculture can have direct negative impacts on wild populations of fish, birds and mammals such as seals and sea lions (Siyanbola and Adebayo, 2012). Aquaculture in Ghana is still in the developing stage even though it started about 50 years ago.

Ghana is endowed with good natural resources such as land and water (rivers, lakes and the sea) that can support aquaculture production (Cobbina, 2010). According to reports from the Directorate of Fisheries (2009) there are a number of constraints affecting the expansion of aquaculture in Ghana. These include lack of adequate supply of seed, lack of quality fish seed and suitable feeds. Low investment from the private sector is also listed as one of the major problems as well as lack of information concerning economic profitability of aquaculture. Aquaculture in Ghana is mostly done on a subsistence basis with very few commercial operators. According to Hiheglo (2008) most people in Ghana see aquaculture as a part-time, limited investment hobby due to the poor regard they have for aquaculture as an economic activity.

Water released from ponds that are partially or completely drained has greater concentrations of nutrients, organic matter and suspended solids than overflow from ponds following storms. The majority of food fish ponds are partially drained at 5 to 6-year intervals with complete draining after 15 to 20 years. However, some ponds are drained each year such as: most fry and fingerling ponds and food fish ponds that are not seinable. Concentrations of most water quality variables are highest in the final 20 to 25% of water released when ponds are completely drained. Thus, particular attention should be given to techniques for enhancing the quality of pond draining effluent and especially the final effluent from ponds (BMP, 2002). Pollution of water resources by fish farm effluents is probably the most common complaint, and this concern has attracted the greatest amount of official attention in most nations (Boyd, 2003). Four main components of aquaculture wastewater of interest include: nutrients (including nitrogen (N) and phosphorus (P)), biochemical oxygen demand (BOD), suspended solids, and pathogens (Cripps and Kelly, 1996). Up to 80% of feed ingested by fish is released to the pond environment as faecal solids and dissolved nutrients and organic matter, with just about 20% retained as fish biomass (Boyd and Tucker, 1998; Tucker and Hargreaves, 2003). Nitrogen and phosphorus are the key nutrients generated in aquaculture systems (Boyd and Massaut, 1999). Increase in concentration of organic matter, nutrients and suspended solids in culture ponds leads to an increase in oxygen demand, eutrophication and turbidity in receiving waters (Naylor et al., 2000).

With the current high rate of global population growth the reliance on farmed fish production as an important source of protein is likely to increase (FAO, 2007; Naylor et al., 2000). The rate of waste generation within the system also increases. The concentration of organic matter, nutrients and suspended solids in ponds increases, and this directly increases oxygen demand, eutrophication, and turbidity in receiving waters (Lin and Yi, 2003; Naylor et al., 2000). This is especially the case in developing countries where there is a high reliance on organic fertilizer and natural feeding in the mostly semi-intensive systems (Diana et al., 1997; Ofori, 2000). In Ghana, it is required that, all aquacultural projects and recreational fishing obtains a permit from the Fisheries Commission, which is accompanied by environmental impact assessment upon which a licensed is issued for any project to be commenced because aquaculture is a potential polluter of the environment (Fisheries Act, 2002). The Aquaculture Adaptive Trial Centre has been in operation since 1992 and there has not been any measure to control its effluents from getting into the receiving stream, Asuafia. These effluents can pose serious threat to environmental media such as water. The main objective of this study was to assess the potential effect of the effluents from the pond on the Asuofia stream.

MATERIALS AND METHODS

Study area

The study was carried out in Nkawie, the capital of the Atwima-Nwabiagya district in the Ashanti Region (Figure 1). The district lies within the latitudes 6°.40 N and 1°.49 W and longitude 6°.67 N 8°.17 W with an elevation of 317 ft (97m) above sea level. The district records an average annual rainfall of 1270 mm. It has two rainy seasons; the major rainy season starts in March, peaking in May, and the minor from July with a peak in August, tapering off in November. The period from December to February is dry, hot and dusty. The average daily temperature is approximately 27°C (ANDA, 2006).

Site description

The study was carried out in the Aquaculture Adaptive Trial Centre, Nkawie (Figure 2). The centre is a fish farm and a demonstration centre for the fisheries Commission of the Ministry of Food and Agriculture, established in the 1992 by the ministry. The main objective of its establishment is to conduct trials on fish species, fish feed and all agro chemicals used in the fish farm industry before they are recommended to farmers. The centre has four (4) production ponds having an average size of 2500 m^2 and five nursery

Figure 1. Map of Ghana with Atwima Nwabiagya District (Nkawie).

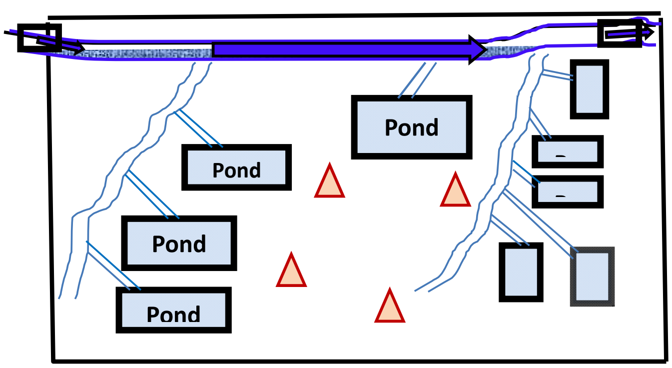

Figure 2. The Aquaculture Adaptive Trial Centre, Nkawie.

ponds with an average size of 200 m^2. The centre shares a southern boundary with the Asuofia stream and it is designed such that the pond effluent drain into the stream by gravity through constructed drainage pipes. The stream runs through Toase, Nkawie Panyin, where the centre is located, and to Anwona Krom where it joins the Kobiri River.

Water sampling and physico-chemical analysis

In situ measurements were conducted for physical parameters such as pH, temperature, total dissolved solids and electrical conductivity using a portable multi-parameter water quality meter (HANNA, HI9828). Samples collected were kept at 4°C in ice chest and transported to the CSIR-Water Research Institute, laboratory, Tamale, on the same day of collection for analysis of total phosphate, dissolved oxygen and nitrate. A total of 42 samples were collected from seven different locations thus, five (5) ponds, downstream station (150 m from the entry point of the effluent) and upstream station (100 m from the entry point of the effluent) of the receiving stream and were taken at two different points within each sampling unit between 8:00 am and 9:30 am for a period of six months (November 2012 to April 2013). For dissolved oxygen (DO) determinations, separate samples were collected into 300 ml plain glass bottles and the DO fixed using the azide modification of Winkler's method. Nutrients (nitrate-nitrogen and phosphate-phosphorous) were determined spectropho-tometrically. Dissolved oxygen, nitrate and phosphate analyses were in accordance with APHA et al. (1998) standard procedure.

Statistical analysis

Mean values of each parameter measured at all locations were compared and analyzed statistically, using one and two-sample t-tests, of Genstart Recovery, Edition 4 adjusted to 95% confidence limits.

RESULTS AND DISCUSSION

The pH values recorded ranged between 7.6 and 7.9 pH-unit for pond samples, 7.48 to 7.73 pH-unit for downstream samples and 7.25 to 7.5 pH-unit for upstream samples (Table 1). The pH values recorded were within the acceptable range (6.5-8.5) of WHO for natural waters. The present study observed pH values that indicate minimal productivity of water in the receiving pond hence pond effluent effect is minimal. However, pH of the ponds (7.69±0.13 pH-unit) were found to be higher than downstream (7.59±0.10 pH-unit) and upstream (7.36±0.11 pH-unit) (Table 1). The statistical analysis indicates that the effect of pond effluents on the pH at the downstream was not significantly different ($p = 0.20$). Pulatsu et al. (2004) also reported similar trend on the impact of trout farm on the receiving stream, Karasu, Turkey. The high pH levels in ponds can be attributed to over feeding, photosynthesis and respiration of algae as it can affect the natural acid-base balance of aquatic systems (WQA, 1996). Although, the ponds recorded higher pH than downstream and upstream, its contribution to downstream's pH is not significant ($p=0.2$) (Table 2). This suggests that there are other sources that contribute to the pH level of the stream.

The temperature values recorded ranged between 23.9 and 29.2°C for pond samples, 22.3 to 28.32°C for downstream samples and 22.1 to 27.38°C for upstream samples. The temperature of the ponds (27.1±2.26°C) were found to be higher than downstream (26.0±2.12°C) and upstream (25.16±2.10°C) (Table 1). Statistically, the study revealed that the pond's effluent have a significant impact on temperature of the stream, at the downstream station ($p = 0.001$) (Table 2). This can be attributed to the high exposure of standing ponds water to the sun. Similar trend was reported by Ansah (2010) who studied the impacts of pond effluents on receiving streams in Ashanti and Brong- Ahafo regions of Ghana. The high levels

Table 1. Results of physico-chemical parameters measured in ponds and stream samples.

Parameter	Pond		Downstream		Upstream		WHO STD
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	
pH	7.6-7.9	7.69±0.13	7.48-7.73	7.59±0.1	7.25-7.5	7.36±0.11	6.5-8.5
Temperature (°C)	23.9-29.2	27.1±2.26	22.3-28.32	26±2.12	22.1-27.38	25.16±2.1	-
EC (µS/cm)	0.16-0.19	0.17±0.01	0.26-0.34	0.3±0.03	0.15-0.18	0.16±0.01	0.1-10
DO (mg/l)	8.8-9.7	9.35±0.36	7.5-9.4	8.38±0.63	12.9-16.5	14.78±1.45	41866
TDS (mg/l)	100-120	105±7.64	210-250	227±14.91	100-110	102±3.73	1000
PO_4 (mg/l)	0.58-0.72	0.64±0.06	0.06-0.13	0.09±0.02	0.05-0.08	0.07±0.01	2.5
NO_3 (mg/l)	4.7-5.39	5±0.25	4.69-5.25	5.02±0.23	6.35-8.7	7.57±0.93	10

Table 2. One-sample t-test analysis summary.

Parameter	Sample	Size	Mean	Variance	Standard deviation	Standard error of mean	Probability (p)
pH	Pond-DS	6	0.13	0.18	0.39	0.17	0.2
Temp (ºC)	Pond-DS	6	-1.1	0.18	0.43	0.17	0.001
EC (µS/cm)	Pond-DS	6	0.13	0.002	0.05	0.02	0.001
DO (mg/l)	Pond-DS	6	-1	0.19	0.43	0.18	0.303
TDS (mg/l)	Pond-DS	6	121.7	216.7	14.72	6.01	<0.001
PO_4 (mg/l)	Pond-DS	6	-0.54	0.01	0.09	0.04	<0.001
NO_3 (mg/l)	Pond-DS	6	0.02	0.26	0.51	0.21	0.92

of temperature in ponds could also be attributed to sediments loads in ponds as it is reported by Poole and Berman (2000).

The electrical conductivity recorded ranged from 0.16 to 0.19 µS/cm for pond samples, 0.26 to 0.34 µS/cm for downstream samples and 0.15 to 0.18 µS/cm for upstream samples (Table 1). The electrical conductivity of downstream (0.30±0.03 µS/cm) was found to be higher than upstream (0.16±0.01 µS/cm) and ponds (0.17±0.01 µS/cm). Electrical conductivity (EC) is a measure of water capacity to convey electric current. It signifies the amount of total dissolved salts (Dahiya and Kaur, 1999).

The present study indicates that the impact of pond effluents on the down stream's electrical con-ductivity (EC) was highly significant ($p = 0.001$) (Table 2). Surface runoff from farming activities and refuse dumping sites close to the stream might have contributed to the high electrical conductivity levels in the stream. Earlier study by Adam and Keith (2012) reported that surface runoff, effluents, minerals and salts from urban runoff during heavy rainfall contribute to high levels of electrical conductivity in the receiving streams. The high electrical conductivity levels at the downstream station could also be attributed to the high levels of total dissolve solids because electrical conductivity is a function of total dissolved solids (TDS) (ions concentration) which determines the quality of water (Tariq et al., 2006).

The dissolved oxygen concentrations recorded ranged from 8.8 to 9.7 mg/l for pond samples, 7.5 to 9.4 mg/l for downstream samples and 12.9 to 16.5 mg/l for upstream samples. The dissolve oxygen (DO) at the upstream (14.78±1.45 mg/l) was found to be higher than down-stream (8.38±0.63 mg/l) and ponds (9.35±0.36 mg/l) (Table 1). Dissolved oxygen is important parameter in water quality assessment and reflects the physical and biological processes prevailing in the water. The DO values indicate the degree of pollution in water bodies. The values were higher in the months of November, December, March and April when rainfall was high than in January and February when rainfall was minimal at all locations. The DO values recorded in the downstream are lower when compare with ponds and upstream indicating oxygen consumption is taking place. The demand for oxygen does not occur directly where the effluent or runoff water is discharged but instead somewhere downstream where decomposition finally occurs (Adam and Keith, 2012). Hamblin and Gale (2002) also added 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 downstream. This explains why downstream recorded the least dissolve oxygen level. The pond effluents contributions to the downstream's dissolve oxygen was found to be significant ($p= 0.003$) (Table 2). This findings conforms to that of Pulatsu et al. (2004) who reported significant dissolved oxygen levels as a result of the impact of trout farm on the receiving stream, Karasu.

The total dissolved solids concentrations recorded ranged from 100 to 120 mg/l for pond samples, 210 to 250 mg/l for downstream samples and 100 to 110 mg/l for upstream sample. The total dissolve solids (TDS) of the downstream (230±0.02 mg/l) were found to be higher than upstream (100±0.004 mg/l) and ponds (110±0.004 mg/l) (Table 1). The level of TDS of the stream is within the acceptable standards (<1000 mg/l) and is considered to have an excellent taste (< 300 mg/l) (WHO, 1996). Total dissolved solids indicate the salinity behaviour of groundwater. Water containing more than 500 mg/l of TDS is not considered desirable for drinking, but in unavoidable cases 1500 mg/l is also allowed (Shrinivasa and Venkateswaralu, 2000). Statistical analysis indicates that the effect of pond effluent on the downstream TDS was highly significant ($p < 0.001$) (Table 2). Similar trend was reported by Ansah (2010) who study the impacts of pond effluents on receiving streams in Ashanti and Brong- Ahafo regions of Ghana. The high levels of TDS concentrations at downstream station could be attributed to the pond's effluent. However, surface runoff from farming activities and refuse dumping site closed to the stream might have also accounted for the high levels of TDS concentrations in the downstream.

The phosphate concentrations recorded ranged from 0.58 to 0.72 mg/l for pond samples, 0.06 to 0.13 mg/l for downstream samples and 0.05 to 0.08 mg/l for upstream sample. The phosphate concentration of the pond (0.64±0.06 mg/l) was found to be higher than downstream (0.09±0.02 mg/l) and upstream (0.07±0.01 mg/l) (Table 1). The phosphate concentrations were within WHO standard of 2.5 mg/l.

Phosphate may occur in surface water as a result of domestic sewage, detergents and agricultural effluents with fertilizers. The values were lower in ponds during the months of November, December, March and April, when rainfall was higher than in January and February when rainfall was minimal. Statistical analysis indicates that the impact of pond effluents on the downstream phosphate concentration was highly significant ($p < 0.001$) (Table 2). This collaborates with Ansah (2010) and Pulatsu et al. (2004) findings, that study the impacts of pond effluents on receiving streams in Ashanti and Brong- Ahafo regions of Ghana and the impact of trout farm on the receiving stream, Karasu, respectively. The high phosphate concentrations in ponds could probably be attributed to an agro-chemical, vitazyme, which was used to boost phytoplankton growth in the ponds as they contain high concentration of phosphate (Meertens et al., 1995). The accumulation of decomposited solid waste releases labile phosphorous to the water column (Kelly, 1992, 1993). This could have contributed to the high levels in receiving streams during rainfall periods (Rao, 2011). The fish feed and faeces might have contributed to high phosphate concentrations. Bureau and Cho (1999) reported that, dissolved carbon, nitrogen and phosphorus are released into the water column by solubilization from feed and faeces and through the gill and urinary excretions of fish. According to Perry et al. (2007), it is not possible to find a high phosphate concentrations if the algae are already blooming, as the phosphates are already in the algae but not in water. This explains the low levels of phosphorus observed at the upstream because algae were observed at some sections of the upstream.

The nitrate concentrations recorded ranged from 4.7 to 5.39 mg/l for pond samples, 4.69 to 5.25 mg/l for downstream samples and 6.35 to 8.7 mg/l for upstream samples. The nitrate concentrations at the upstream stations (7.57±0.93 mg/l) was found to be higher than downstream (5.02±0.25 mg/l) and in ponds (5.0±0.25 mg/l) (Table 1). The mean concentrations were higher in the months of November, December, March and April when rainfall was higher at the upstream and downstream stations than in January and February when rainfall was minimal. However, the mean values reduced in ponds when rainfall was higher and increased with minimal rainfall. Surface water contains nitrate due to leaching of nitrate with the percolating water. Surface water can also be contaminated by sewage and other wastes rich in nitrates. Statistically, the effect of pond effluents on the downstream nitrate concentration was not significant ($p = 0.07$) as compared to the upstream ($p < 0.001$) (Table 2). This contradicts Ansah (2010) and Pulatsu et al. (2004) findings, that reported high levels in ponds than receiving streams. Runoff from refuse dumping sites and farming activities affect nitrate concentrations greatly in receiving waters as fertilizers used on farms, through leaching and surface runoff into the stream during heavy rainfall could have contributed to the high levels in receiving streams (Rao, 2011). This further explains why nitrate concentrations were higher at upstream and downstream stations during rainfall periods. However, the nitrate concentrations observed did not exceed the Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 10 mg/l for drinking water (Self and Waskom, 2008).

Conclusion

The study revealed that ponds effluents have no significant effect on the receiving stream based on all physico-chemical parameters considered. The physico-chemical values recorded from ponds and the stream were within WHO stipulated limits. However, the study revealed that activities such as vegetables and cereal cultivation, livestock farming and refuse dumping within the watershed serves as source of pollution and nutrient enrichment in the receiving stream. The high concentration of nitrate at the upstream and high levels of total dissolve solids and electrical conductivity at the downstream station could have resulted from farming activities and a refuse disposal close to the stream. The study recorded concentrations of parameters at downstream sites that were close to that of fish ponds values. Which implies that, fish farms actually contributes to the concentrations of the parameters considered in the stream, and any potential effects in the future will depend on how effluents are managed, including effluent treatment, drainage design, frequency and volume of waste released.

In conclusion, the ponds effluent has a significant effect on almost all the parameters assessed in the stream with the exception of pH and nitrate. However, the effect of the pond effluents on the stream is currently not severe as all the parameters assessed were within the acceptable approved standards.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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