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Exponential Model of Surface Runoff Pollutant Dispersion in Lake Victoria, Gaba, Uganda

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Commonly used pollutant dispersion models in aquatic systems assume uniform mixing. This study aimed at one dimensional exponential modeling approach which does not involve assumptions of unmeasured parameters. Assessment of different land-use activities and quantification of pollutant loads and dispersion into the Lake was done. One-way ANOVA was used for testing difference in nutrients concentration at the sampling points and models were developed based on mathematical method of series and sequence. Land-use in Gaba area were built up areas (36.1%), wetlands (30.6%), Lake Victoria water (20.5%) and subsistence farmland (8.30%). Gaba fish landing site was identified as non point source (NPS) pollution hotspot and runoff from this site conveyed nutrients that contributed significantly to pollution of the Lake. Seasonal comparison of the Lake water revealed ammonia-N, nitrite-N and ortho-phosphate with higher concentration during the rainy season while nitrate-N exhibited higher concentration during dry season due to nitrification process. The respective distances traversed by nutrients were found to be 36 m for ammonia-N, 40 m for nitrite-N, 38 m for nitrate-N and 42 m for ortho-phosphate. The respective model concentrations of the pollutants compared well with measured concentration at the traversed distances even after rainfall events. However, results indicated effect of assumption of uniform mixing on nitrite and nitrate concentration. With elevated nutrients level, fish species would most likely become unavailable in near shore waters because they are unable to exploit the environment properly. The findings provides an alternative explanation to the ever dwindling fish stock within the lake and reduced fish catch by fishermen in Lake Victoria especially along shore settlement.

Keyword: Lake Victoria, exponential model, series method, land use, surface runoff, nutrients, residual function, non-point sources.

Introduction

Lake Victoria, a transboundary freshwater system between Kenya, Tanzania and Uganda is characterized by streams and rivers stretching as far as Burundi and Rwanda that feed into it (Rizzolio, 2000). It forms source of food, water, employment, transport, hydroelectric power, and recreation in the region. However, the Lake is the dumping ground for various types of wastes (Chege, 1995; Kyomuhendo, 2002; Matagi, 2002; MWLE, 2006). For example, pollution impact by municipal and industrial discharges is now visible in the shallow Winam Gulf in Kisumu (Kenya), near Mwanza (Tanzania) and Inner Murchison Bay (Kampala). The ecological health effect of Lake Victoria has been attributed to rapid increasing human population, clearance of natural vegetation along the shores for agricultural activities (Isabirye et al., 2001; Nkonya et al., 2002; MWLE, 2006), prolific growth and expansion of algae coverage (Kyomuhendo, 2002; Larsson, 2002), and discharge of untreated effluent from several industries in the catchment area (Matagi, 2002). As a result, there is increased treatment cost of potable water (Banadda et al., 2006) thereby affecting domestic supply.

United States Geological Survey (2008) reported that clearing of forest enhanced surface run-off loaded with nutrients into water bodies. Nyangababo (1987) demonstrated the presence of pollutants in streams feeding into Lake Victoria and concluded that their sources followed a pattern corresponding to Kampala City road networks. Pollutant types, quantity, mode of transportation, final deposition points, locations and sources are largely unknown for catchment areas of Lake Victoria. Moreover, there is no mechanism for assessing the impact of the resultant loads on the surface and subsurface of Lake Victoria water. Efforts to mitigate the impacts of this type of pollution by policy makers are limited due to financial constraints, land ownership issues, and non

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implementation of mitigation measures by local communities. Encroachment on wetlands further degraded the natural filtration of surface runoff. The green water in the Lake therefore bears links to contaminated water source and indiscriminate waste disposal within the catchment area. In Kampala, about 900 tones of solid wastes are generated daily, of which only about 40% is collected and disposed off by Kampala Capital City Authority (KCCA), while the rest is indiscriminately disposed off (Kulabako, 2004). The wastes end up into storm drainage systems during rainy season. Of the total effluent from industrial and domestic sources in the city, 10% is treated and the rest is discharged untreated (Kulabako, 2004). The informal peri-urban settlements located in valleys and wetlands with a high water table have a high population density of predominantly urban poor with inadequate basic services such as water supply and sanitation. With increased impervious surfaces in most areas, wastes find their way into streams, wetlands and lowland areas as runoff during rains. Inadequate planning or lack of it results into development in wetlands and steep slopes which has caused serious environmental problems such as water pollution and disease outbreaks (Mukwaya, 2004).

Land degradation in Uganda has attracted debates, concerns and received widespread public recognition resulting into the development of various policies, for example, the National Water Policy (1999), National Environment Management Act (1995), Water Action Plan (1993) as emanated from the Dublin and Rio de Janeiro United Nations Commission on Economics and Development (UNCED) process (1992) on fresh water resources. All these seek to address sustainable use of land and water resources. As land is changed from its original state to more intensive uses (Figure 1), water quality tends to deteriorate. Transition periods between different uses are especially critical and each progression towards more intensive land-use disrupts the natural processes which protect and preserve water quality. This can be monitored by assessing water quality along transects in the water body (Figure 1).

Figure 1. Transect (red line) in Lake Victoria and the surrounding of Gaba landing site.

While not all urban centers are predestined to poor water quality, as the intensity of land use increases, it becomes more important to manage water resources effectively. Currently, the capacity of the Kampala Capital City Authorities (KCCA) in the catchment area of Lake Victoria to provide basic services to meet the sanitary needs of the increasing population is limited as indicated by the uncollected heaps of garbage at some points. Therefore a cheaper approach in understanding the impact of catchment activities on Lake Victoria water quality is important.

A one dimensional mathematical model was developed by Banadda et al. (2011) to predict nutrient dispersion distance within Lake Victoria. The modeling approach used was based on the fundamental principle of conservation of mass for managing surface water quality (Biswas, 1976) that assumes uniform mixing of Lake water. This only occurs during June and July when established thermocline breaks down under the seasonal onset of the south-east trade winds and for a brief period at the end of July. During these times, the main water body becomes isothermal with respect to depth. The isothermal depth and stability of thermocline depends on the duration of the calm, warming period, and frequency and magnitude of mixing events. The surface water quality model requires net rate of addition or subtraction due to source and sinks to be known. Other parameters to be determined include; a constant area of flow and no concentration variation overtime. In addition, area of flow is assumed to remain relatively constant, no variation in concentration overtime, sample points are treated as a system where nutrients addition or subtraction (source and sink respectively) is constant, and model easily simplified to the general form as used by Banadda et al. (2011).

In this study, exponential modeling approach was found more appropriate to provide a more accurate approximation in nutrient dispersion. The method is applied widely in pollutant dispersion studies (Baran & Harmancioğlu, 1993; UNESCO, 2005; Eizel-Din et al., 2010). As a modeling approach, exponential model does not involve assumptions of unmeasured parameters which are part of other models (ecological model and estuary model). Therefore, identification and quantification of the non point source (NPS) and development of a tool for accurate prediction of pollutant dispersion extent enhances the understanding of pollution zone and contribute to controlling related impacts. The method is simple however, requires long period of data collection. This paper therefore, identified and characterized the land-use activities, quantified and assessed nutrients in surface runoff and dispersion in the Lake for one complete year, covering both wet and dry seasons. The research finding is thought to contribute towards strengthening of policies implementation on waste disposal and discharge that would minimize nutrient concentration in runoff thereby improving on Lake Victoria water quality.

Study area

The study was conducted at Gaba in Makindye Division, Kampala City (Figure 2). The relief of the area consists of undulating terrain both hills and valleys. The lands from hill-top to valleys are used for human settlements, yet the valleys are wetlands in most cases. Gaba is a landing site for fishing boats, and an abstraction point for domestic water supply for National Water and Sewerage Corporation (NWSC).

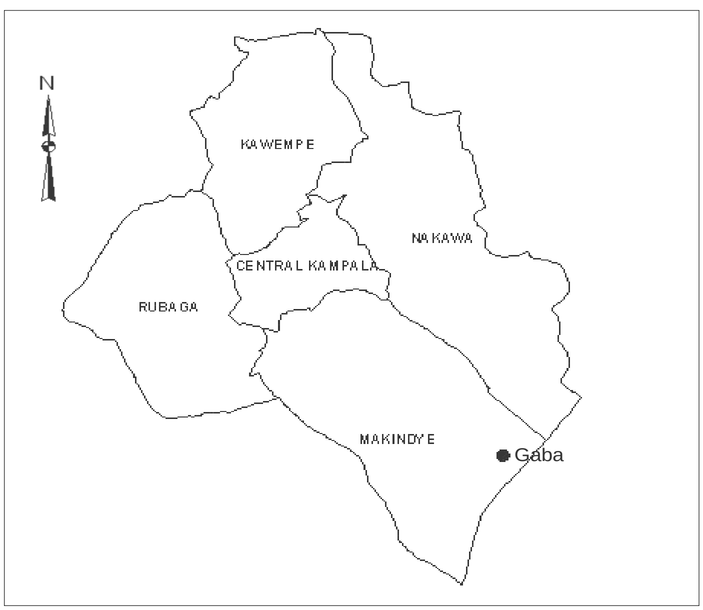

Figure 2. Map of Gaba in Makindye Division, Kampala-Uganda.

Being adjacent to Lake Victoria and characterized with high levels of activity, it is anticipated that big portion of surface runoff enter the lake without any form of treatment. Observation of shoreline also indicates changes of lake water to brownish colour when it rains and this colour returns to normal overtime. Runoff originating from far inland sources also converge close to this area, but because they pass through wetlands (a treatment facility), their pollutant concentrations were considered to be lower than that of the landing site. Thus the choice to carry out the study at Gaba. Furthermore, the site is a market place with bare soil surfaces, and high volume of generated solid wastes that are discharged into the lake.

The micro-catchment of Gaba experiences two rainy seasons per year with an annual average estimated to be over 1000 mm. The first rainy season stretches from mid February to end of May, and second rain season from mid August to end of December. Two dry spells from June to mid August and short spell between January and February separate the rainy seasons. Temperature range of the area is 15 - 30 ^{o}C most of the year.

Methodology

Land use activities and location of NPS hotspots

Google earth picture combined with Arc View GIS 3.3 were used to identify and characterize different land-use within the study area basing on observed variations in the picture, each with different potential for causing water pollution as non-point sources. The accuracy of identified land-use was improved using topographic sheets for the study area obtained from NARO-Kawanda. The classification system used was Biomass Uganda. This classification system is more suitable to Ugandan situation than other systems developed by FAO or USA which are different and more general from the current situation in the study area.

Data collection

Two rain seasons in the year 2008 were used for data collection and one dry season was used for the purposes of comparing the levels of lake pollution between dry and rain seasons. Runoff data used for model validation was collected separately during the second rain season. Data collection during first rain season started from mid August, 2008 to mid November, 2008. Second rain season data collection was in April, 2009. For dry season, data was collected from mid February, 2009 to late March, 2009. To ensure that samples were always taken from the same spot within the Lake, mapping of the sampling points were done using a hand held GPS and a boat. The sampling coordinates were stored in GPS and later traced during subsequent sampling. The mapping was done after rain events in order to locate storm water path in the lake / normal runoff areas within the Lake.

Sampling

Sampling was done during months when the lake was calm. Grab samples of runoff were taken just before they mix with the lake water. Samples in the lake were collected along a 50 m horizontal transect at interval of 10 m (Figure 1). The length of transect was determined from the point (shore line) where surface runoff entered the lake. GPS distance readings were supplemented using tape meter measurements on days when reception was poor. Samples were also drawn at vertical distances of 0.5, 1.0 and 1.5 m using a graduated hand pump connected to a delivery pipe. Vertical distances were measured from the water surface.

Sample bottles were rinsed thoroughly with the water to be collected before filing the bottles. Collected samples were stored in a cooler and transported to Wet laboratory, Makerere University, College of Agricultural and Environmental Sciences, Department of Environmental Management. Analysis of samples for nutrients (ammonia, nitrite, nitrate, and phosphate) was done within four (4) hours of sample collection using Wagtech Photometer 7100. Specific manual instructions for nutrients analysis were adhered to.

Statistical data analysis

Minitab software, Release 13 for windows was used for statistical analysis. One-way ANOVA was used for testing difference in nutrients concentration. All data were tested using Bartlett's and Levene's Tests, and Anderson Darling for equal variance and normality respectively. Significant level of the analysis was at values < 0.05. Symbols ≠ and = represent significant and non significant values respectively.

Modeling approach

The approach used exponential polynomial function to develop a mathematical model for generating pollutant (nutrients) dispersion trends when discharged into Lake Victoria (equation 1.0).

$$e^{x} = 1 + \frac{x}{1!} + \frac{x^{2}}{2!} + \frac{x^{3}}{3!} + ... -\infty < x < \infty \quad (1.0)$$

Models calibration

Model calibration was done only for horizontal distance. This was because of the missing data for the vertical distance. Modeled concentration and field measured values vere plotted on the same axis. Disperity at the point of discharge in the modeled and field measurements was corrected by multipying modeled concentration with a constant(s) (equation 1.1). The constant (s) used were determined through trial and error. This was done inorder to reduce high modeled concentration to field measured values.

$$Constant(K) \times Model = measured\,Concentraton \tag{1.1}$$

The magnitude of the constant was further altered to conform with the measured trend. Subsequent progress of distance into the lake under estimated the modeled concentration. Therefore, separate residual function was added at the point where deviation started in order for the models to conform to the measured trends. This was achieved through adding differences between adjusted models and measured concentrations. Subsequent correction of deviation resulted into equations of the plots that were residual function which caused models to conform to the field measurements.

Model Validation

Validation of model equations were performed using separate surface runoff data collected during second rain seasons. The correlation of model concentrations and lake concentration was obtained.

Results

Characterization of land-use activities

Gaba area borders Lake Victoria and consists of various land use types (Figure 3).

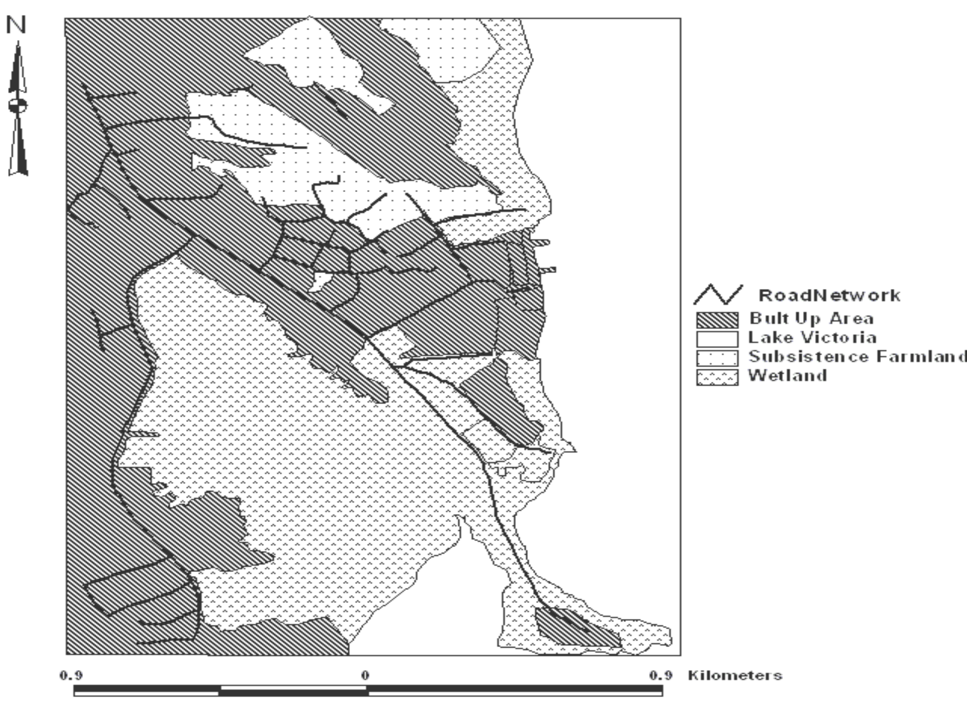

Figure 3. Land use activities in Gaba area.

Fish vending was the major activity at Gaba fish landing site. The area was dominated with residential and commercial blocks characteristic to peri-urban settlements. Assessment of nature of land-use on the shore settlement during preliminary study suggested pollution hotspots. Surface runoff was discharged directly into the lake forming a stream of brown storm water in the lake. This is attributed to the absence of surface water treatment facility. By virtue of proximity to the lake, pollutants originating from the fish landing site and possibly the neighboring areas directly enter the lake. NWSC abstraction station in the area reportedly experience increased water treatment cost due to increased pollution.

Siltation of inshore areas (< 0.5 m) was evident as indicated by water depth reduction. This affected vertical assessment.

Percentage coverage of land-use in Gaba area is represented in Table 1.

Table 1. Gaba land use types.

Land use types	Km^2	Coverage (%)
Bult up areas	0.13	36.1
Wetlands	0.11	30.6
Lake Victoria	0.09	25.0
Subsistence farmland	0.03	8.30

Altered land area (built up areas and subsistence farmland) contributed 44.4 % of the total area.

Wetlands

The percentage representation of wetland in the study area was 30.6%. The dominant wetlands vegetation included *Cyperus papyrus* and *Vossia cuspidata*. Encroachment due to subsistence farmland was observed to increase.

Built up areas

Built up areas constituted 36.1%. This was characterized by compacted soil, impervious slabs or concrete compounds and corrugated iron rooftops. The surrounding lacked enough facilities to collect domestic wastes. Solid wastes were dumped indiscriminately into the poorly maintained drainage channels and open grounds. As a result, there was poor sanitation in some parts of the area. In addition, poor drainage channels results into diffuse storm water paths to low land areas and degraded wetlands. The storm water ultimately ends up into Lake Victoria.

Subsistence farmland

Subsistence farmland constituted 8.3% of the total land-use. Food crops were commonly grown largely for households' consumption and some for sale. Farming was mainly practiced in lowland areas and wetlands edges.

Concentration of nutrients in surface runoff

Nutrients (ammonia-N, nitrite-N, nitrate-N and ortho-phosphate) concentrations in surface runoff before discharge into the lake are presented in Table 2.

Table 2. Mean ± standard error of nutrients concentration in runoff before discharged into Lake Victoria.

Concentration (mg/l)			
NH_3-N	NO_2-N	NO_3-N	PO_4-P
8.47±0.18 (8)	0.40±0.02 (8)	0.56±0.04 (8)	6.80±3.20 (8)

*Numbers in parenthesis are sample size.

Average nutrients concentration in the lake was highest for ammonia-N and lowest for nitrite-N. However, nutrient concentrations were not above the national bench mark (permissible level) for discharge into water bodies (NEMA, 1998). One - sample t – test / upper tailed test indicated none significant concentration of the nutrient when compared to the bench mark permissible concentration ($p > 0.05$). The variation of horizontal and vertical concentration of nutrients in the Lake for the rainy season is shown in Figure 4.

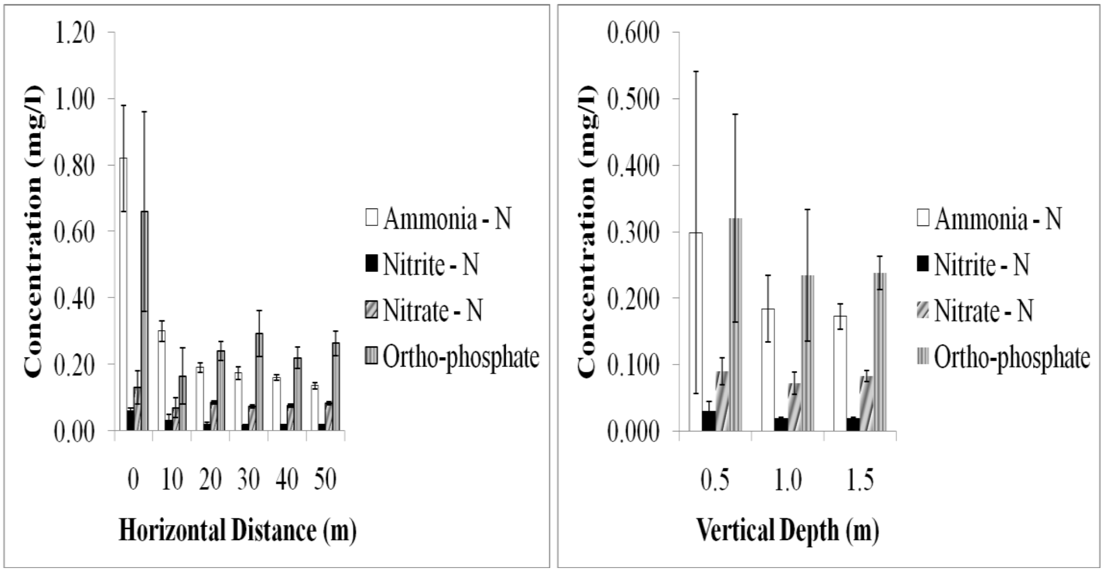

Figure 4. Mean nutrient concentration in the horizontal and vertical distance of the lake during rainy season. Zero (0) distance is the point of runoff discharge into the lake waters.

Ammonia-N exhibited highest concentration within 10 m from the discharge point and thereafter Ortho-phosphate had the highest concentration. Ortho-phosphate showed the highest concentration as compared to other nutrients throughout the measured vertical depth. Nutrients concentration for the dry season is represented in Figure 5.

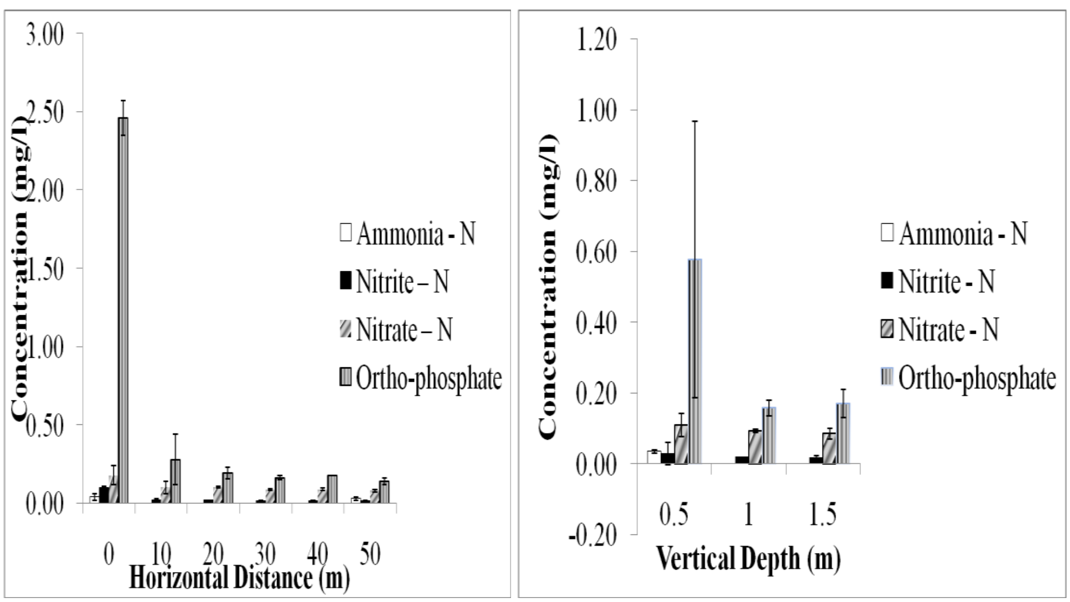

Figure 5. Mean nutrient concentration in the horizontal and vertical distance of the lake during dry season. Zero (0) distance is the point of runoff discharge into the lake waters.

Ortho-phosphate was highest followed by Nitrate-N in both horizontal and vertical distance during the dry season. Ammonia-N showed the least concentration in both cases. Generally, rainy season exhibited higher concentration than dry season.

Statistical analysis indicate nitrate-N concentration as significant in the vertical and horizontal direction ($p = 0.010$ respectively). The concentration trend for both directions was first rain season ≠ second rain season = dry season. There was no significant variation for the rest of the nutrients in horizontal and vertical directions ($p > 0.05$) except when compared to the runoff discharge point ($p < 0.05$).

Model generation process for nutrients dispersion coefficients

Prediction of dispersion distance traversed by nutrients carried in the surface runoff was performed by means of equation 1.0. The model equations were obtained when dispersion rates were plotted and their equations determined. The surface discharges into the lake were converted into its equivalents which obeys the dispersion rate within the lake. This is shown as exponential constants for the nutrients (Figure 6).

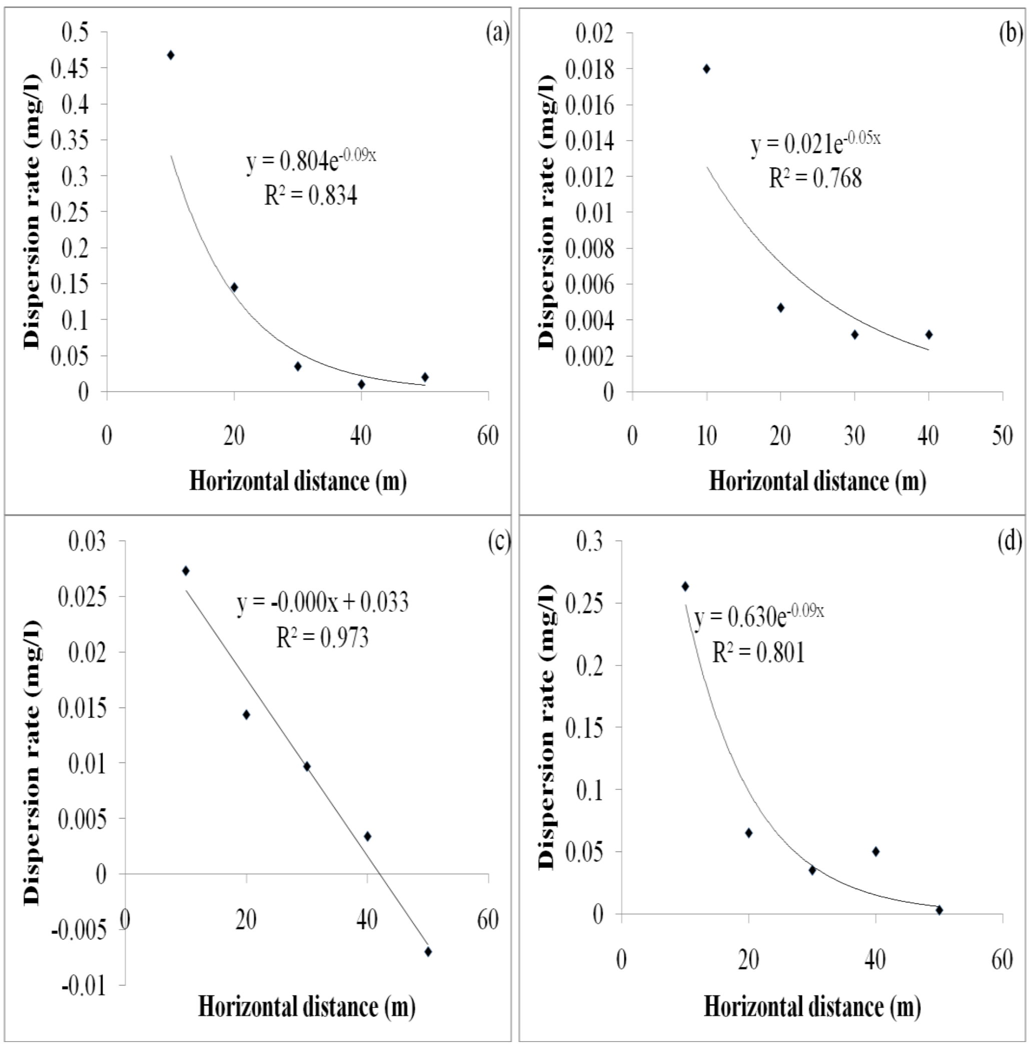

Figure 6. Graphs for the exponential constants for the concentration of nutrients of ammonia-N (a), nitrite-N (b), nitrate-N (c), and ortho-phosphate (d).

Nutrients dispersion rates could higly be explained by the horizontal distance from the lake inshore ($r^2 > 0.700$).

Verification of models output

Using exponential constants generated, modeled concentration for the nutrients were generated and plotted against the measured field concentration trend. This was done to determine whether the model prediction were in agreement with measured nutrients dispersion trends in the lake waters. The models over estimated nutrient concentrations for ammonia-N and nitrate-N but underestimated for nitrite-N and orthophosphate (Figure 7).

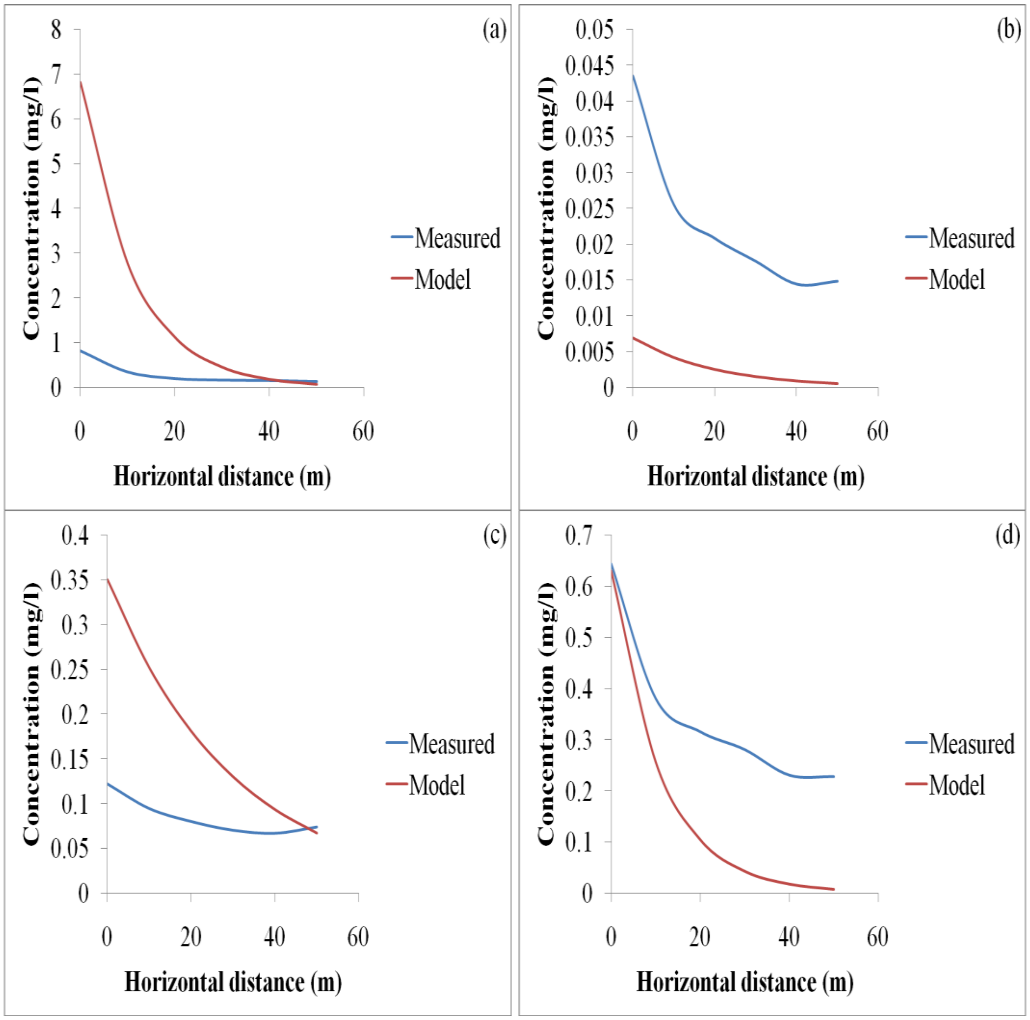

Figure 7. Comparison between model and measured nutrients concentration of Ammonia-N (a), Nitrite-N (b), Nitrate-N (c) and Orthophosphate (d)

Model calibration

Models calibration was done using equation 1.1. The constants enabled the modeled concentration at point of release to start at the same point as the measured concentration (Figure 8). The model and measured concentrations were in agreement for portion of the distances close to shore then deviated. Exponential constants for nitrite-N and nitrate-N were altered in order for the two curves to coincide (Figure 8: (b) and (c).

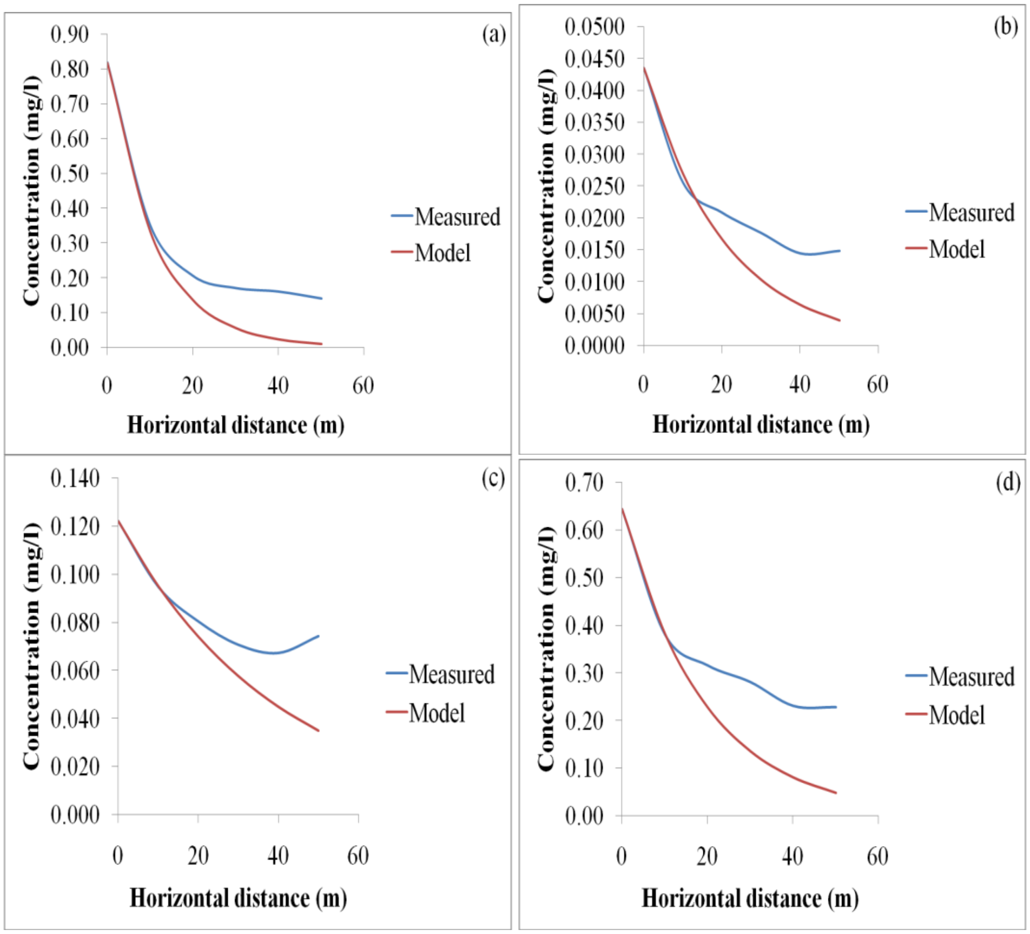

Figure 8. Modeled and measured concentration at zero distance (point of runoff discharge into the lake waters) of Ammonia-N (a), Nitrite-N (b), Nitrate-N (c) and Ortho-phosphate (d)

Equations 1.2 to 1.5 were therefore developed for part of the models which was in agreement with the measured trend. Where C_x and C_0 represents the concentration of nutrient at horizontal distances / sampling point x and initial discharge from upstream respectively.

Model equation for ammonia-N

$$C_x = 0.0965 C_0 e^{-0.09x} \tag{1.2}$$

Model equation for nitrite-N

$$C_x = 0.1318 C_0 e^{-0.048x} \tag{1.3}$$

Model equation for nitrate-N

$$C_x = 0.3486 C_0 e^{-0.025x} \tag{1.4}$$

Model equation for orthophosphate

$$C_x = 0.643 C_0 e^{-0.052x} \tag{1.5}$$

Estimation of residual functions

It was observed that the models underestimated the concentration of nutrients as it progressed into the lake from the shoreline. To correct this, residual functions were determined and added to the models from the points of departure. This was done by determining the difference between the models and the measured nutrient concentration (where the model began to underestimate nutrient concentration). The differences in concentration were then plotted against horizontal distance and the equation of the curves generated gave the residual functions that were then added to the models. This corrected part of the models which underestimated the measured nutrients concentration (Figure 9).

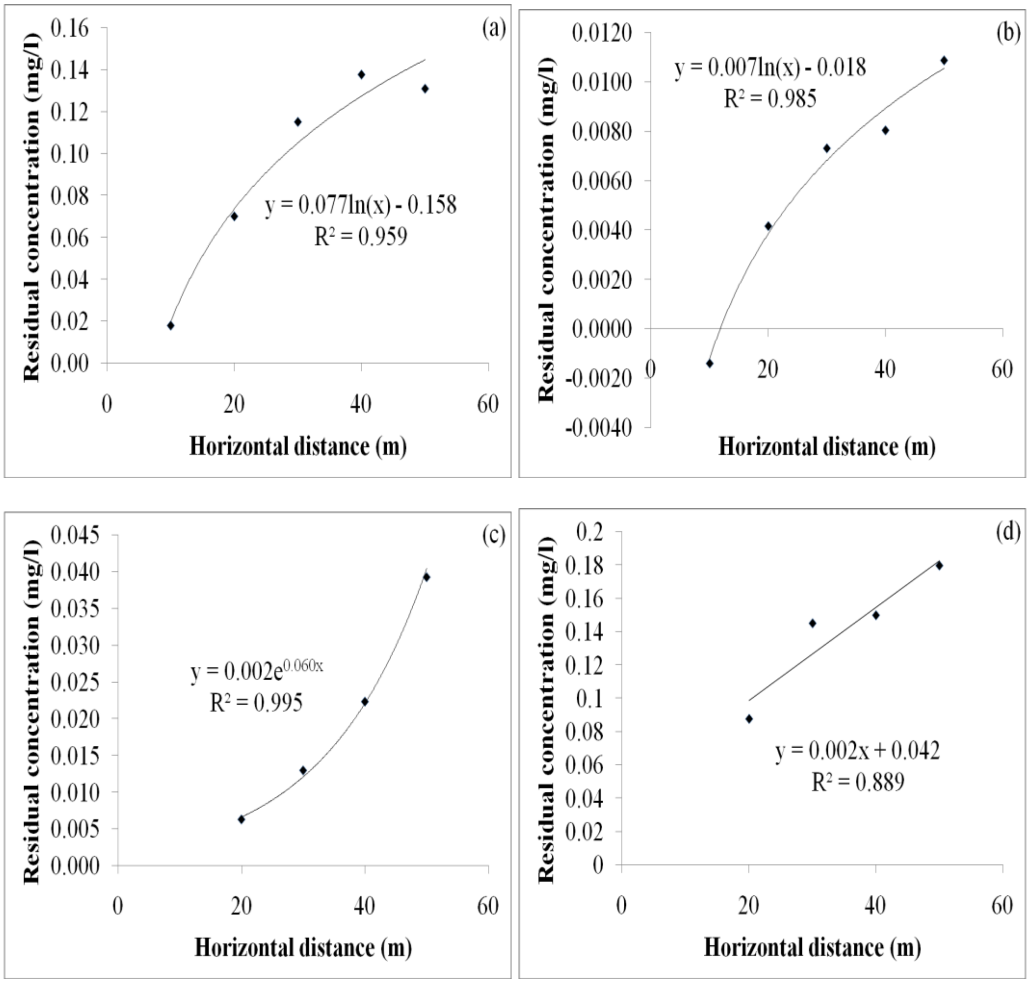

Figure 9. Residual function for Ammonia-N (a), Nitrite-N (b), Nitrate-N (c) and orthophosphate (d).

The residual equations that were developed for the different nutrients concentration are represented by *equations 1.6 – 1.9. Residual equation for ammonia-N*

$$[0.077Inx - 0.158]_{x>10m} \quad (1.6)$$

Residual equation for nitrite-N

$$[0.007Inx - 0.018]_{x>10m} \quad (1.7)$$

Residual equation for nitrate-N

$$[0.002e^{0.06x}]_{x>10m} \quad (1.8)$$

Residual equation for orthophosphate

$$[0.002x + 0.042]_{x>10m} \quad (1.9)$$

Calibrated models output for nutrients concentration in the Lake

The horizontal distance within the lake where model concentration equal to lake concentration is considered to be the distances to which nutrients dispersed into the lake (Figure 10)

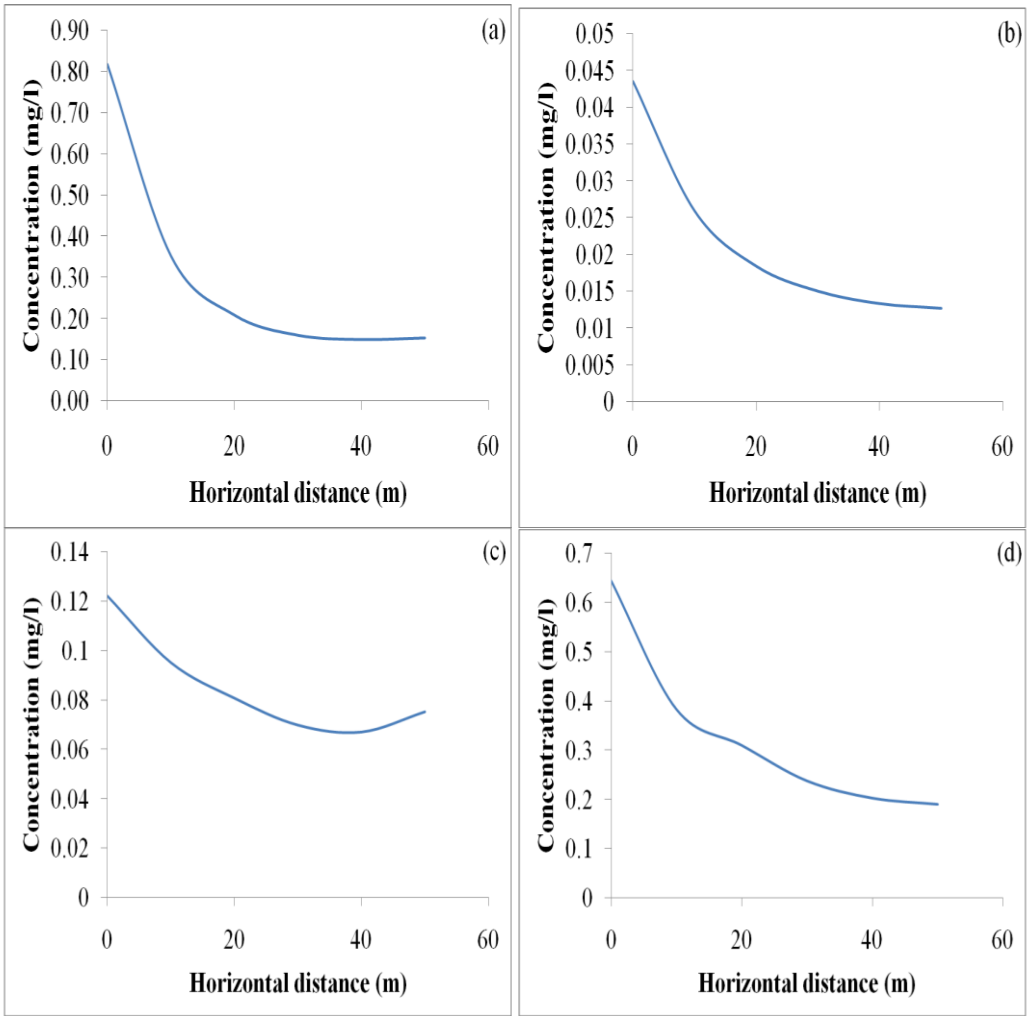

Figure 10. Calibrated model output: Ammonia-N (a), Nitrite-N (b), Nitrate-N (c) and Ortho-phosphate (d).

Model equations for nutrients concentration in the lake

The equations representing the models that can be used to predict dispersion distance for nutrients concentration within the Lake water system are presented in equations 1.10 - 1.13.

(a) Model equation for ammonia-N

$$0.0965C_0e^{-0.09x} + [0.077Inx - 0.158]_{x>10m} \quad (1.10)$$

(b) Model equation for nitrite-N

$$0.1318C_0e^{-0.048x} + [0.007Inx - 0.018]_{x>10m} \quad (1.11)$$

(c) Model equation for nitrate-N

$$0.3486C_0e^{-0.025x} + [0.002e^{0.06x}]_{x>10m} \quad (1.12)$$

(d) Model equation for ortho-phosphate

$$0.643C_0e^{-0.052x} + [0.002x + 0.042]_{x>10m} \quad (1.13)$$

Predicted horizontal distance of nutrients dispersion in the Lake using the models

Ammonia-N modeled in surface runoff into the lake dispersed to distance of 34 m. The modeled concentration at this distance was about 0.145 mg/l as compared with the measured concentration of 0.145 mg/l. Nitrite-N dispersed to 40 m with modeled concentration of about 0.016 mg/l as compared to measured concentration of 0.018 mg/l. Nitrate-N dispersed to 34 m with modeled concentration of 0.064 mg/l as compared with measured concentration of 0.064 mg/l. Ortho-phosphate reached horizontal distance of 42 m with modeled concentration of 0.20 mg/l as compared to measured concentration of 0.22 mg/l.

Model Validation

Ammonia-N, nitrite-N, nitrate-N and orthophosphate were validated using 9.0 mg/l, 0.4 mg/l, 0.56mg/l and 6.4mg/l respectively. R^2 values obtained from the validation process were; 0.998, 0.991, 0.909 and 0.963 for Ammonia – N, Nitrite – N, Nitrate – N and orthophosphate respectively (Figure 11).

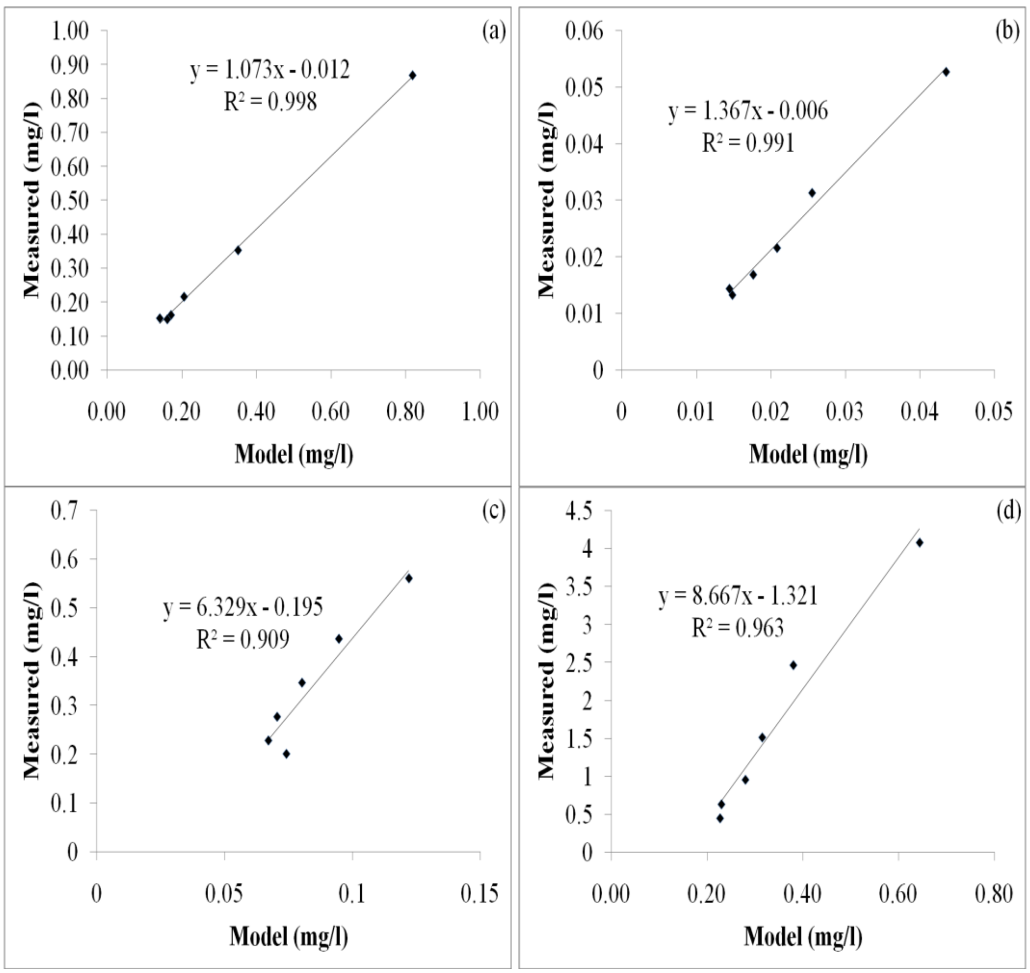

Figure 11. Validated nutrient models for Ammonia-N (a), Nitrite-N (b), Nitrate-N (c) and Ortho-phosphate (d).

Discussion

Gaba area consisted of wetlands (30.6%), subsistence farmland (8.3%), built up areas (36.1%) and Lake Victoria (25%). The wetlands are major pathway for surface runoff originating from far inland yet they are encroached upon. Land use changes have been reported in aquatic catchment in Tanzania overtime period from 1984 – 2001. Woodland and wetlands vegetation declined by 0.09% and 2.51% respectively

(Kashaigili & Majaliwa, 2010). The perceived principal drivers for the changes were found to be cultivation, overgrazing and population growth among others. Wetlands are known to facilitate natural treatment of waste water by nutrients uptake (Kansiime & Nalubega, 1999; Kanyiginya & Kansiime, 2010).

In general, nutrients transport into aquatic systems correlates with various indices of human activities in the catchment (Cole et al., 1993). FAO (1996) listed agriculture as a major cause of degradation of surface and groundwater resources through erosion, nutrient runoff and leaching. Zampella (2007) used Spearman's rank correlation for basin wide approach and distance weight, and revealed significant correlation between NOx-N and three land use categories. The ranks were urban land (0.71), upland agriculture (0.68) and altered land (0.76) compared to nitrogen (nitrite and nitrate). The strongest relationship was between nitrogen and total altered land, compared with urban land and upland agriculture. Basin wide approach had similar results as smaller sub classes of land use. The study demonstrated that water quality degradation is associated with upland land use which is generally good predictor of water-quality conditions. In this study, graphical analysis of physico-chemical parameters revealed increased nutrients concentration for rainy season. This is attributed to the discharge of nutrient in the runoff as compared to the background concentration of the lake during the dry season.

Waste water originating from Gaba fish landing site community was discharge untreated into lake Victoria as surface runoff. The average concentrations of the nutrients discharged were 8.47±0.18 mg/l for ammonia-N, 0.4±0.02 mg/l for nitrite-N, 0.56±0.04 mg/l for nitrate-N, and 6.8±3.20 mg/l for PO_4-P. Average nutrients concentration in the lake was highest for ammonia-N and lowest for nitrite-N. However, nutrient concentrations were not above the permissible level of discharge for ammonia-N (<7.5 mg/l), nitrite-N (0.1 mg/l), Nitrate-N (10 mg/l) and Phosphate (5.0 mg/l) (NEMA, 1998). One - sample t – test / upper tailed test indicated none significant concentration of the nutrient when compared to the bench mark permissible concentration ($p > 0.05$). Chapman (1999) reported that concentrations of nitrate-N in excess of 0.2 mg/l NO_3–N within lakes tends to simulates algal growth, an indication of possible eutrophic conditions. The concentration of nitrate released at the discharge point into the lake was greater than the concentration that stimulates eutrophication. However, because of dilution within the lake, the concentration drops below the maximum eutrophic limit.

Several biological assessment techniques have been used to quantify effects of human activities on biotic condition of aquatic ecosystems, these follows the idea that biological components respond to environmental degradation by modifying their functional and structural characteristics. Species abundance models provide a more detailed relationship between environmental conditions and fish assemblage structure, because abundance of species is a consequence of its ability to exploit the environment (Lima-Junior et al., 2006). The models represent distinct patterns of resource partitioning among species in the assemblage. With elevated nutrients level, fish species would most likely become unavailable in near shore waters because they are unable to exploit the environment properly. The findings could provide an alternative explanation to the ever dwindling fish stock within the lake and reduced fish catch by fishermen in Lake Victoria especially along shore settlement. However, the major causes of low fish catch was said to be over fishing within the Lake by fishermen who harvest even young fish.

Comparison between models and measured concentration of nutrients in the Lake

The modeled concentration for ammonia-N and nitrate-N compared well with measured concentration within the lake and the equations can be used to predict dispersion in the Lake. Nitrite-N and orthophosphate models showed slight difference from measured concentrations. Their models therefore requires longer period of data collection to improve on its accuracy. The distance the exponential models levels out represents the point nutrients are dispersed to after rainfall events thus represent zone of polluted lake water. Vertical depth measurements were not possible in the inshore (< 0.5 m) of the lake and this affected modeling of nutrients dispersion in the vertical direction. However, water depth provides a basis for uniform mixing (Herb et al., 2005).

Conclusion

Storm water directly discharged into Lake Victoria through runoff resulting into permissible nutrients concentration. Variation in nutrients dispersion was found to exist only in the longitudinal direction relative to the lake shore; pollutants concentration decreased exponentially in this direction until the concentrations level off, representing the distances traversed by each nutrient. Several biological assessment techniques based on assumptions are commonly used to quantify effects of human activities on biotic condition of aquatic ecosystems. This is because biological components respond to environmental degradation by modifying their functional and structural characteristics. In this study, results indicate effect of assumption of uniform mixing on nitrite and nitrate concentration. Therefore assumption may result into incomplete explanation of the functional and structural characteristics in the zones of aquatic systems.

Recommendations

There is need for devise management measures at Gaba fish landing site to control pollution of the lake. Urban planners need to incorporate storm water management systems into their development plans by incorporating water quality management strategies. Unfortunately, most of these measures require large spaces and where development has taken place the implementation becomes difficult.

Data collection should be extended beyond a year and used for the purpose of calibrating pollutants dispersion models to improve on the accuracy especially Nitrite-N, and orthophosphate model. However, emphasis should also be given to total concentration of nutrients for future research in order to arrive at the nutrient levels during rainfall events.

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