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Assessment of rainfall intensity on temporal water quality of Awba Dam, Nigeria

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Abstract
Runoff from rainfall can significantly contribute to variation in the quality of surface waters. The effects of rainfall intensity on surface water quality is increasingly becoming a cause for concern because of its indirect impact on the cost of water treatment, and consequently on the quantity of water available for public water supply. Recent hydrological reports in Nigeria indicate significant increase in the average annual rainfall. Hence, this paper investigates the sensitivity of some water quality indicator parameters of Awba dam in South Western Nigeria to temporal variation in rainfall intensity. Representative water samples were collected for a period of five years (2008 – 2012), and analyzed using standard analytical methods. The results showed that Awba dam has a low level of alkalinity. True Colour Units, turbidity and chloride concentrations were initially high, but decreases with increasing rainfall intensity. The pH and iron concentration have minima response to fluctuations in rainfall values. The water quality indicator parameters showed consistent and significantly high correlation with the temporal rainfall intensity during comparatively low rainfall periods and this suggests occurrence of significant influence of the varying rainfall amount on the water quality of Awba dam, though the relationship becomes complex with increasing amount of rainfall.
Keywords: Rainfall runoff, Water quality, Awba dam, Sensitivity, Indicator parameters

1 Introduction

Runoff from rainfall can significantly contribute to variation in the quality of surface water depending on the local and regional land use pattern, ground surface slope, soil type, amount of impervious surfaces, as well as duration and intensity of the rainfall event (Martin and Hollabaugh, 2002). The water quality variation is often reflected as changes in the water quality indicator parameters, in addition to bacteriological load which is frequently interpreted as an indication of microbial contamination. Kistemann *et al.,* (2002) investigated three tributaries of different drinking water reservoirs and showed significant presence of total microbial loads in the watercourses, resulted from rainfall and extreme runoff events. Also, Van Vliet and Zwolsman (2008) compared water qualities during different seasons and established varying deteriorating trend in the water quality with varying rainfall intensity.

Also, several authors have worked on precipitation occurrence, distribution and intensity. Hanson *et. al.,* (1989) simulated daily precipitation for mountainous areas using hydrological model while Hanson and Woolhiser (1990) worked on the effects of annual and regional precipitation on model parameters in the simulation of daily rainfall. Also, Potter *et al.,* (2005) determined the effects of rainfall seasonality and soil moisture capacity on mean annual water balance within the Australian catchments while Ologunorisa and Tersoo (2006) in their studies concluded that extreme rainfall variation is a major global cause of flooding. The qualitative and quantitative impact of climate change on water resources have also been studied widely with a clear focus on water quantity (Pfister *et al.,* 2004; Middelkoop *et al.,* 2001; and Murdoch *et al.,* 2000).

Surface water is a major source of raw water in Nigeria, and contributes significantly to the nation's water supply system. Most of the rivers and streams in Nigeria are largely replenished through runoff from rainfall. The Nigerian Meteorological Agency review bulletin reported that rainfall intensity in 2010 over the country was approximately 200 – 300 percent higher than the average normal rainfall (NIMET, 2010). The effects of rainfall intensity on surface water quality is increasingly becoming a cause for concern because of its indirect impact on the cost of water treatment, and consequently on the quantity of water available for public water supply. Awba reservoir is an earth dam originally constructed in 1964 in Ibadan, Nigeria to enhance water supply to Ibadan University community, as well as for fish production and research purposes. The current capacity of the reservoir is 227 million liters of water (Figure 1) hence its relevance to the host community cannot be over-emphasized. Therefore, the aim of this paper is to assess the sensitivity of water quality indicator parameters of Awba dam in South Western Nigeria, to varying rainfall intensity.

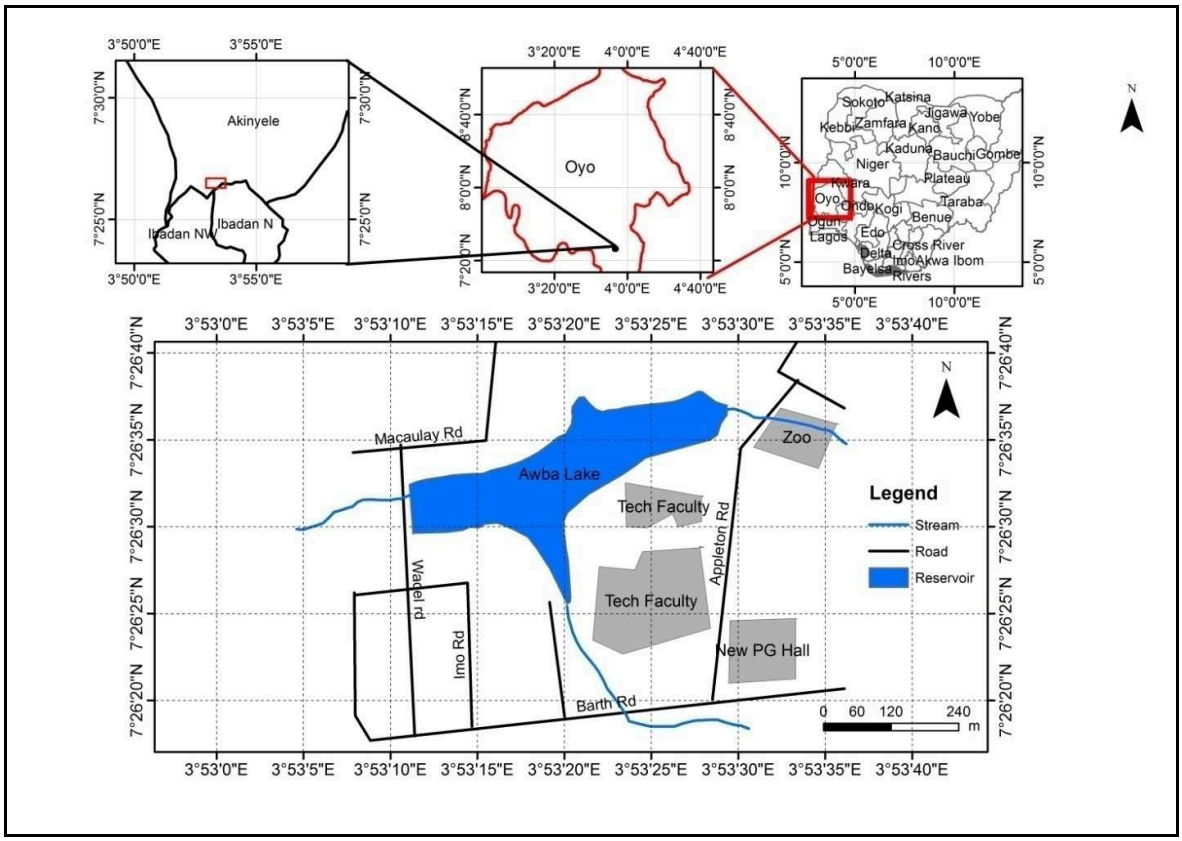

Figure 1: Location of Awba Dam

2 Methodology

Weekly representative water samples were collected from locations within the Awba dam watershed for a period of five years (2008 – 2012), using thoroughly rinsed 500 ml sampling bottle. The bottle was filled by lowering it upside down at arm's length under the water and capped when no more bubbles was observed. The water sample was stored in a cooler for delivery to the laboratory, and subsequently analyzed for the following water indicator parameters: colour, turbidity, pH, total alkalinity, total hardness, total dissolved solids (TDS), iron and chloride.

The true color was determined by removing all suspended substances through filtration and the colour of the water sample was measured by visual comparison with a series of specific color scale using spectrophotometer. The TDS and the turbidity were measured using Hanna Portable TDS meter and Nephelometer, respectively. The pH and total alkalinity (as CaCO3 in mg/L) were also determined using Hanna portable pH meter and H_2SO_4 standard titration method. The total hardness (mg/L as $CaCO_3$) was determined using EDTA titrant and standard laboratory titrimetric equipment. The chloride concentration was also measured using silver nitrate solution titration method, while total iron concentration was determined using spectrophotometer. The corresponding five year rainfall data for the study area were acquired from the Department of Geography, University of Ibadan, Nigeria. The measure of the level of sensitivity of the water quality indicator parameters to varying rainfall intensity was established using statistical algorithm and graphical software package.

3 Results and Discussion

The average monthly and total annual rainfall intensities for the study area are presented in Figure 2. The monthly rainfall data reflects seasonal variation while the total annual rainfall showed a progressive increase in intensity. The temporal variation of the water quality indicator parameters and the rainfall intensity are presented in Figures 3 - 5. The correlation coefficients (r) and the associated level of significance (p) between the rainfall intensity and the water quality indicator parameters are presented in Figures 6 and 7, respectively.

The range of values obtained for the TDS was 220 – 462.5 mg/l (Figure 3). The TDS concentration was lowest for the corresponding lowest rainfall intensity obtained in 2008. The range of computed correlation coefficient values with the rainfall intensity was 28 – 66 %. The highest value was obtained in 2008 ($r = 66$, $p = 0.02$), and

progressively decreases with increasing rainfall amount, and this suggests occurrence of influence of other environmental factors affecting the degree of correlation for the concentration of TDS obtained with increasing rainfall. Also, the chloride concentration obtained over the period of this assessment was 99 – 398 mg/l (Figure 3). Similar to the trends obtained for the TDS, there was significant association between the rainfall intensity and the chloride concentration ($r = 43 – 65$; $p << 0.01 – 0.04$), for 2008 – 2010, when the rainfall intensity is comparatively low. The values of correlation coefficient obtained for 2011 and 2012 are comparatively lower, with no indication of any significant relationship.

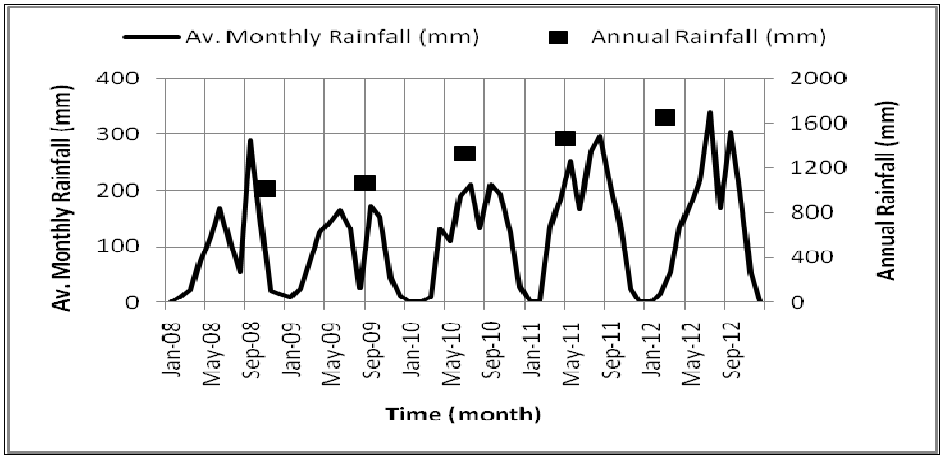

Figure 2: Annual and average monthly rainfall data

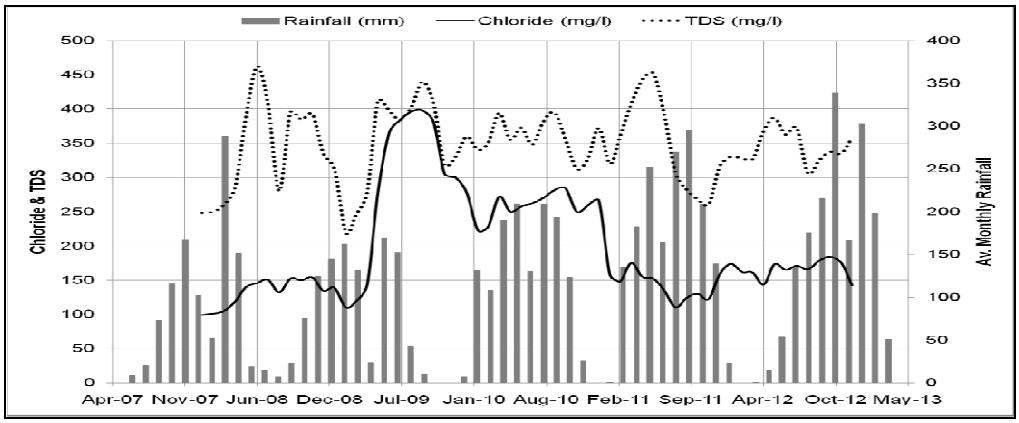

Figure 3: Chloride and TDS variations with rainfall

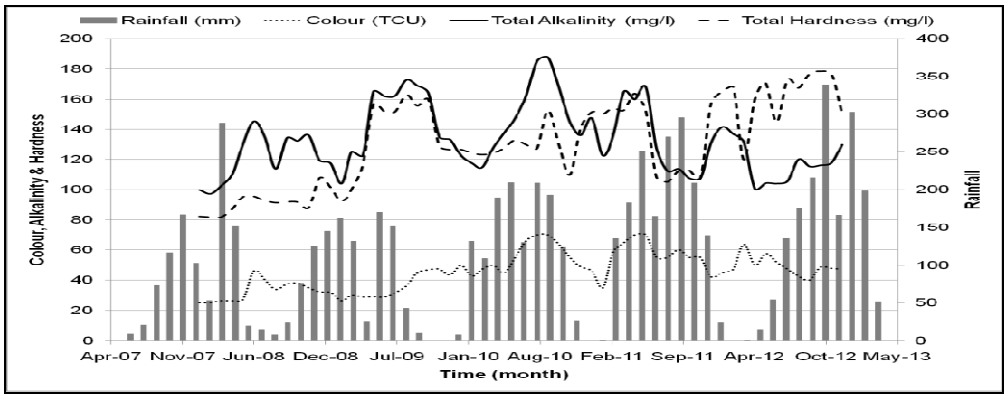

Figure 4: Colour, Alkalinity, and Hardness variations with rainfall

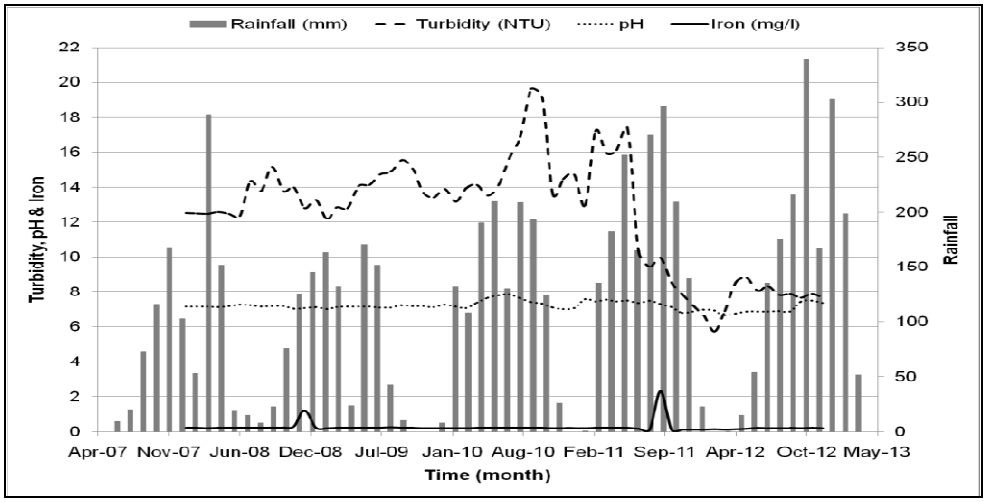

Figure 5: P^H, Total Iron and Turbidity variations with rainfall

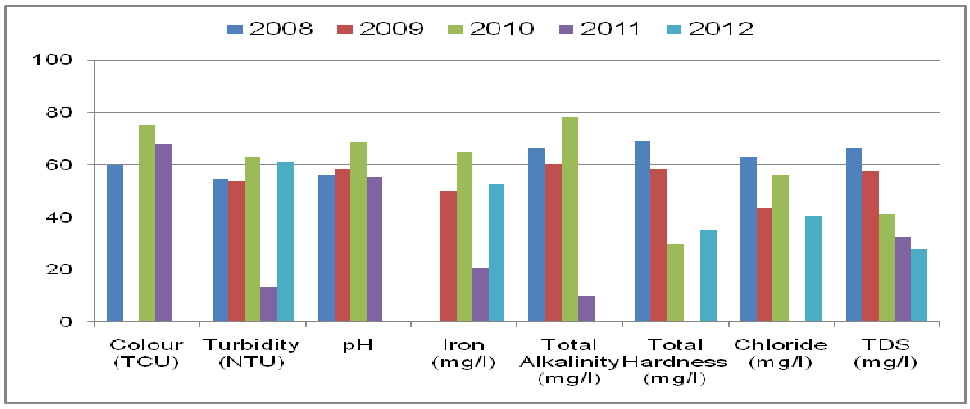

Figure 6: Correlation coefficient of rainfall intensity and water quality parameters

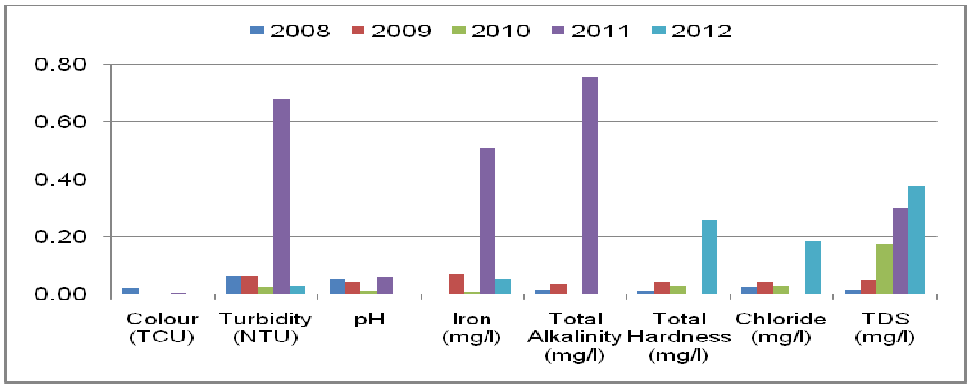

Figure 7: Level of significance (p) of the calculated Correlation coefficient

The range of values obtained for the colour indicator for the period of study (2008 and 2012) is 25 – 70 TCU (Figure 4). The range of correlation coefficient values (r) obtained for the same period is 60 – 75 %. The corresponding measure of significant level (p) is less than 0.05 in all the cases, which in turn suggest that high colour unit value is significantly associated with high rainfall intensity. That is, the colour became denser during the peak of the raining season, perhaps due to high concentration of humus soil fraction indicative of

contamination. Further to this, the range of values obtained for the total alkalinity was 98 – 185 mg/l (Figure 4). This total alkalinity concentration is relative low compared to the desirable concentration limit of 200 mg/l for drinking water (WHO, 2011), and therefore Awba dam is considered to possess limited mitigating capability in the event of occurrence of acid related pollution incidence. The correlation coefficient (r) values obtained for the total alkalinity and rainfall intensity for 2008 and 2010 ranges between 60 and 78 %, with significant probability values ($p < 0.05$). These period (2008 – 2010) have relatively lower rainfall intensity compared to the 2011 and 2012. The trend of values obtained for the total alkalinity is similar to that obtained for TDS. In addition, the pattern in the range of values obtained for the total hardness (Figure 4) is consistent with that previously reported for TDS, total alkalinity and chloride. Relatively high correlation coefficient values ($r = 30 – 70$; $p << 0.01 – 0.04$) were also observed for the total hardness. The correlation coefficient values for subsequent years (2011 and 2012) were lower and no level of significant relationship was established between the rainfall intensity and total hardness indicator.

The ranges of values obtained for the pH, total iron and turbidity are presented in Figure 5. There was consistency in the trend of data obtained for these three indicator parameters compared with those previously reported. The total iron concentration and pH values show minima variation in their values in response to varying rainfall intensity. Conversely, the turbidity values appear to be relatively high with significant variation in response to temporal rainfall intensity, suggesting a high influential role played by the latter.

4 Conclusion

The sensitivity of some water quality indicator to temporal variation of rainfall intensity was investigated. A gradual but steady increase was observed in the rainfall intensity during the period of study. The pH and iron concentration have minima response to fluctuation of the rainfall. The water quality indicator parameters show consistent and significant correlation with the temporal rainfall intensity between the 2008 and 2010, where total annual rainfall value is comparatively low. Unpredictable trend in the relationship exists during the 2011 and 2012, and this corresponds to the period where the rainfall intensity values were relatively high. In conclusion, the established significant correlated trend between rainfall intensity and water quality indicator parameters during 2008 and 2010 suggest that the water quality of Awba dam was significantly influenced by the varying rainfall intensity, and the complexity of this relationship increases with increasing amount of rainfall The observed complexity and unpredictability in the trend of the relationship is assumed to be attributed to occurrence of other environmental factors induced by high rainfall intensity.

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