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SOLUTE LOADS IN A WASTE-PRONE STREAM AND THEIR ENVIRONMENTAL IMPLICATIONS

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Abstract

Water is an important component of human life, and a major focus in the Sustainable Development Goals. Dissolved solids and conductivity, otherwise known as solute loads, are key and complementary parameters of water quality. Their presence in water at a particular magnitude portend ecological and health implications to the environment. The present study examined the spatial and temporal variations in dissolved solids and conductivity values in a waste-prone stream within a university campus in Nigeria. The main objective of the study was to determine the concentrations of dissolved and conductivity and their relationship in the stream. Values of conductivity, and total dissolved solids (TDS) were obtained at seven locations along the stream, at a weekly interval, using a calibrated handheld TDS /conductivity meter. Results showed that the conductivity and TDS exceeded recommended limits for domestic water use, and that fetching the stream water for domestic use may foretell health challenges if untreated. The study concluded that people who drink untreated stream water are vulnerable to dangers of water contamination in many areas in the region.

Keywords: Dissolved solids, water chemistry, conductivity, stream systems

INTRODUCTION

Water is a major component of the Sustainable Development Goals (SDG). Therefore, the demand for quality water is governed by both physical and behavioural justifications. Physical justification explains the availability of water, including the location and chemical composition (physio-chemical and biological). Behavioural justifications, however, include the demand, use and choice for quality that are often determined by economic and health considerations. In many rural areas in sub-Saharan Africa, where sources of water are limited to supplies by government/non-governmental organisations, many rural dwellers tend to consume water from streams, which many consider pristine. In southwestern Nigeria, the self-purification capacity of streams is taken as a concept to suggest that 'dirty water does not kill' (*egbin omi kii paa'yan*).

It has been argued that water quality deterioration in streams usually comes from excessive nutrient input, acidification, eutrophication, heavy metals contamination, organic pollution, agricultural runoff and obnoxious land use practices. These imports often determine the concentration of dissolved solids and conductivity of the stream, causing decline in the water socio-economic function, structural biodiversity change in the stream catchment. Electrical conductivity and total dissolved solids have proved to be necessary tools for determining water quality. One important tool for evaluating water quality and character in a catchment is a detailed knowledge of the electrical conductivity and the dissolved solid. Electrical conductivity (or conductivity) is the ability of a substance to conduct an electric current or allow electricity to pass through its body. In water system, it is dependent on the concentration of dissociated salts and dissolved gases, but also on colloidal suspension (Hussein, Sen, Koyun, & Demirkiran, 2019). Consequently, conductivity is affected by temperature, pressure and rate of flow. Electrical conductivity is widely applied as a basic tool to assess water quality. Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. Dissolved solids comprise inorganic salts (including calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and some quantities of organic matters that are dissolved in water. Dissolved solids in stream water originate from natural sources such as sewage, urban runoff, industrial wastewater, carbonate deposits, salt deposits, storm water, and agricultural runoff, and point and non-point wastewater discharges. According to Boyd (2020) dissolved solids can be referred to as filterable residue or a concentration of dissolved substances in water, mineral and organic matter.

The measurement of specific conductivity and dissolved solids in streams is an integral part of water monitoring programmes, often because its measurement, unlike many other analytical techniques, is simple to carry out on the field (Manning, 2016, Kumar, Raina & Sharma, 2019). The values of specific conductivity may also be readily related to the total dissolved solids (TDS) which has been regarded as a better indicator of water quality than its discharge (Daniels, Zipper, Orndorff, Skousen, Barton, McDonald, & Beck, 2016, Butler & Ford, 2018). The relationship between the dissolved solids and electrical conductivity is often described by a parameter that varies according to chemical composition.

In general, the total dissolved solids concentration is the sum of cations (positively charged) and anions (negatively charged) ions in the water. It is an indicator of general quality of the water. Since the electrical conductivity and TDS are used in assessment of water quality, this study seeks to establish a relationship between the two, the relationship established could then be helpful in predicting dissolved solids from future conductivity measurements and vice versa. Water from streams is essential for irrigation and other uses. Water with a high composition of total dissolved solid for instance, can also affect the quality lives, both fauna and flora (Jayawardana, Gunawardana, Udayakumara, & Westbrooke, 2017). To prevent the danger to health of plants and animals alike, it is essential to determine the quality of a water source before the water is drawn for any form of consumption.

The relationship between conductivity and dissolved solids of water has been expressed to vary with location, climate and water chemistry. According to Rusydi (2018), the relationship between electrical conductivity and dissolved solids is complex, depending on the chemical composition and the ionic strength. However, there are many instances where the relative composition of water is reasonably constant in a given region or study site and hence the dissolved solids – conductivity relation can be established in the laboratory with a reasonable accuracy over a wide concentration range. In many cases, electrical conductivity measurement has been used to estimate dissolved solids in stream water, because the conduction of current in an electrolyte solution is primarily dependent on the concentration of the ionic species (Rice, Baird & Eaton, 2017, Mishra, & Nagda, 2020). Both tools have, however, proved to be essential water monitoring and assessment tools. The relationship to be established between the two is to determine a conversion factor. The dissolved solid, displayed by the conductivity/TDS metre is calculated from the conductivity of water (equation 1; Sharma, Rishi, & Keesari, 2017).

$$TDS = k_C \times conductivity \quad (1)$$

TDS = summation of dissolved solids at various sampling points, expressed in mgl^{-1}
Conductivity is expressed in μScm^{-1} *at* $25^{o}C$;
kc= the correlation factor which usually varies between 0.55 and 0.8

Conductivity has been used, either generally or specifically to estimate dissolved solids in natural waters since the 1970s (Clark, Greer, Zipper, & Hester, 2016; Daniels et al., 2016). Studies hypothesized a conversion factors of 0.54-0.96 in natural water, and an empirical relationship exists between dissolved solids and electrical conductivity; which due to iron pairing in solutions of high ionic strength, the relationship may not be applicable in saline waters (Al Dahaan, Al-Ansari, & Knutsson, 2016; Ingale, Bobdey & Gorghate, 2018; Olson & Cormier, 2019; Jemily, Sa'ad, Amin, Othman, & Yusoff, 2019). Consequently, studies have explored the relationship of TDS and conductivity to determine water quality (e.g. Zhang, Zhang, Huang & Gao 2017; Taylor, Elliott, & Navitsky, 2018). Many of these studies have assumed that the relationship can be summed up to an equation and that the relationship may differ with underlain geological composition and structure and landuse or land cover (e.g. Al Dahaan, Al-Ansari & Knutsson, 2016; Jakhrani, Soni & Shar, 2019).

The present study area, Asunle stream receives wastes from an open dumpsite near an incinerator, at the Obafemi Awolowo University, campus. Leachates from dumpsites are sources of salts into the stream. The aim of this study is to examine the relationship between electrical conductivity and dissolved solid in Asunle stream, Obafemi Awolowo University, Ile-Ife, such that the relationship established could then be used to predict dissolved solids from future conductivity measurements. The specific objectives are to determine the concentration of dissolved Solids and corresponding values of conductivity in Asunle stream, Obafemi Awolowo University, Ile-Ife; and examine the relationship between the conductivity and dissolved solids in the study area.

METHOD

Study Area

Ile-Ife, the location of the study area is a town in the South Western region of Nigeria, between Latitude 7^{o}28'and 7^{o}31'N and Longitude 4^{o}30'and 4^{o}31'East. The Asunle stream is a perennial stream whose source is located about 0.25 km uphill from the Obafemi Awolowo University Ile-Ife refuse incinerating site (Figure 1). The stream serves as the water source for several farmlands of the study area and runs a stretch of more than 10 km, cutting across human communities such as Abagbooro, Agbogbo and Amuta (Ogunfowokan, Obisanya & Ogunkoya, 2013). Dwellers living along this stream rely on the water from the stream for household purposes, irrigation and agricultural applications, palm oil processing, and mixing and dilution of pesticides used for spraying cocoa and other crops.

The climate of the area has a contrast between well-defined dry and wet seasons. The wet season occurs from April to October with an annual rainfall of about 2500 mm at the coast and about 1220 mm at the northern limit of the forest belt. The monthly mean minimum temperature is about 22.48°C while the monthly mean maximum temperature is about 31.24°C with an average yearly temperature of about 26.6°C. Furthermore, the average yearly relative humidity is about 76.05% (Eludoyin, 2014).

Image of the burning at dumpsite near the stream channel at the time of the study

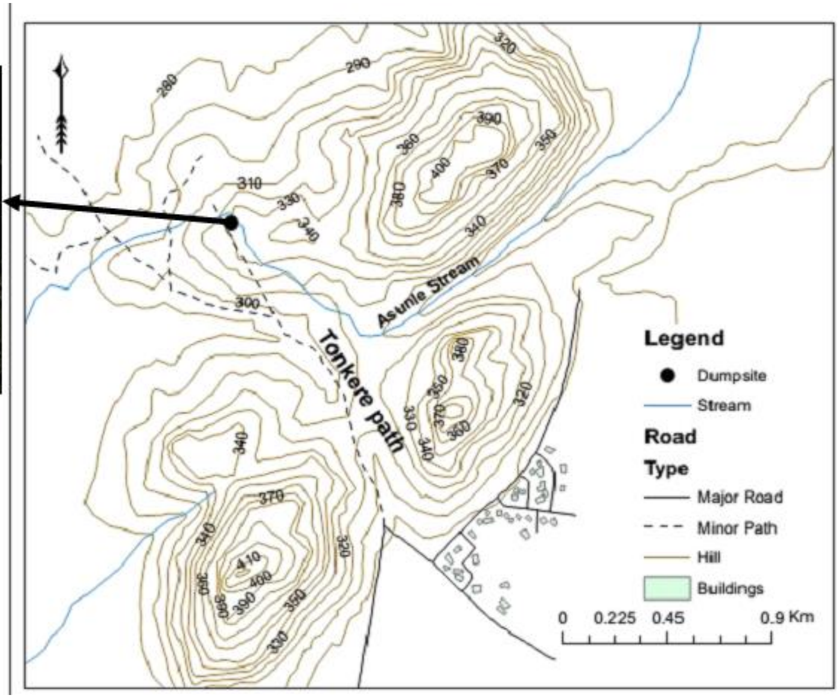

Figure 1. The study area in Obafemi Awolowo University, Ile-Ife Campus, Nigeria

In terms of relief and drainage, the Southwestern part of Nigeria in which the study area is located is dominated by relief which rises gently from the coast northwards to the area of crystalline rocks where inselbergs rise abruptly above the surrounding plains (Adebekun, 1978). The geology of the study area exhibits that of any Southwestern Nigerian region, which overlies metamorphic rocks of the basement complex, the great majority of which are ancient being of pre-Cambrian age. These rocks show great variation in grain size and in mineral composition, ranging from very coarse grain pegmatite to fine-grained schist and from acid quartzite to basic rocks consisting largely of amphibolites; mainly Iwo, Ondo and Egbeda Associations (Smith & Montgometry, 1962; Lal, 2019). They are sub-divided into sedentary, hill-creep and hill-wash soils each. The Iwo Association soils are derived from coarse-grained granitic rocks and coarse gneisses; the Ondo Association from medium-grained granitic rocks and medium-grained gneisses; and the Egbeda Association from fine-grained biotite gneisses and schist. There are five key land cover types in Ile-Ife; they include built-up area, vegetation bare soil, water body and wetland. There are also three key land use types, which include residential, commercial and institutional land use areas. The estimated total area of the study area is approximately 275.5 km^2 with43.4% of the land use covered by vegetation (mostly secondary vegetation), when about 79.4km^2 (28.82 %) is occupied by built-up settlements.

Data

Data used for this study were obtained from primary and secondary sources. The primary data included records of dissolved solids, conductivity and temperature. These were obtained *in-situ* (on the field) at the upstream midstream and downstream of the Asunle stream channel. The conductivity and dissolved solids were determined using handheld TDS/conductivity metre. Secondary data included imagery and topographical map of the study area, and these were obtained from the website of Google Earth and the archive of the Department of Soil Science, Obafemi Awolowo University, Ile-Ife, respectively. The measurement of dissolved solid and conductivity were determined *in-situ* from three sampling points i.e. the upstream, midstream and the downstream of the stream channel. The measurements were taken before and after the events of rainfall, between the months of February and March, 2017. Measurements for the two variables were taken twice in the month of February (before rainfall) and twice in the Month of March (after rainfall) at an interval of two weeks.

Data Analysis

Data were analysed using descriptive and inferential statistics. The relationship between conductivity and dissolved solids was evaluated using regression analysis. Analysis was achieved using the Statistical Package for Social Scientist (SPSS, IBM version 20). Whereas the statistical values for distribution and regression were computed in SPSS, Paleontological Statistics (Past 3) was used in assessing the spatial variations in conductivity and dissolved solids concentration through gridding. Gridding is the interpolation of scattered 2.5D (coordinates; X, Y and concentrations of dissolved solids and conductivity) data points into a regular grid, using the coordinates and the corresponding data values. The Inverse Distance Weighting (IDW) approach of interpolation was used for mapping. The IDW is a deterministic, nonlinear interpolation technique that uses a weighted average of the attribute (phenomenon) values from nearby sample points to estimate the magnitude of that attribute at non-sampled locations.

RESULTS

General characteristics of selected parameters

Table 1 shows the results of the descriptive characteristics (the mean, standard deviation and the coefficient of variation) of the variables researched on along the Asunle stream. The mean conductivity concentration of various sampling points from the source towards the downstream points ranged between 393.3 and 565.5µScm^{-1}. Highest mean conductivity (565.5µScm^{-1}) was observed at the mid-stream. In addition, coefficient variation of the distribution of conductivity indicates that it varied more (17.8%) at the upstream than the other parts of the stream. The variations tend to fluctuate after the upstream; it first reduced to point C in the midstream, subsequently increased and later decreased towards the downstream. The mean Dissolved solid along the streams was between 199.8ppm and 282.8ppm. For both Dissolved solid and conductivity, the highest concentration was observed at the midstream, with the concentration slightly reducing downstream. In terms of TDS, its concentrations reduced from the upstream towards the midstream, and later rose at the downstream. Highest value of coefficient of variations of the TDS occurred at the upstream (17.8%). In general, both conductivity and TDS varied similarly, in terms of their coefficient values, with highest values of coefficient of variations at 17.7 and 17.8%.

Table 1: Mean and coefficient of variation (%, in parenthesis) of selected conductivity and dissolved solids along Asunle Stream

Stream course	Sampling point	Coordinates		Variables	
		Eastings (x)	Northings (y)	Conductivity (uScm^{-1}) (n=4)	TDS(ppm) (n=4)
Upstream	A	0668277	0833019	466.3 (17.8)	233.3 (17.7)
	B	0668277	0833020	565.3 (6.7)	282.5 (6.7)
Mid-stream	C	0668274	0833023	565.5 (5.0)	282.8 (4.9)
	D	0668223	0833113	507.5 (10.6)	266.3 (3.6)
	E	0668258	0833051	489.5 (2.8)	244.5 (2.8)
Downstream	F	0668266	0833054	463.5 (4.6)	231.8 (4.6)
	G	0668243	0833096	399.3 (7.9)	199.8 (8.0)
		Overall mean		**493.8 (13.8)**	**248.7 (13.5)**

Spatio-temporal variations in conductivity and dissolved solids

The results of the spatial analysis of the selected variables are presented in Figure 2. The mean conductivity peaked at the upstream (280 μScm^{-1}) and decreased downstream in similar pattern with the TDS distribution downstream. This pattern suggests dilution of the stream, and exhaustion of sediments and solute concentration downstream. In addition, the results of the analysis of variance between the upstream, downstream and midstream indicate significant difference in the concentration of both conductivity and TDS between the upstream and downstream ($\rho \leq 0.05$) in the one hand, and between midstream and downstream concentrations on the other hand (Table 2). The result of the ANOVA however, does not indicate significant difference in the concentrations of the two variables (Conductivity and TDS) between the upstream and downstream.

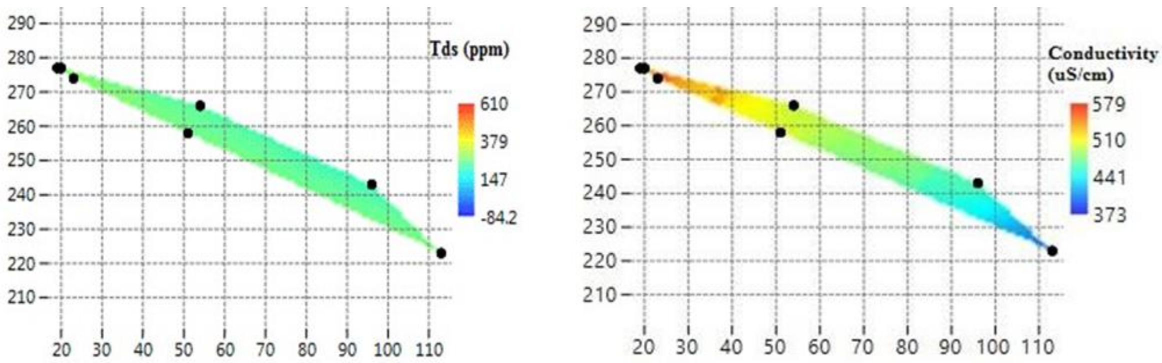

Figure 2: Spatial distribution of dissolved solids and conductivity in the stream channel

Table 2: Analysis of variance between the upstream, midstream and downstream

Parameter	Overall ANOVA		Multiple comparison		
	F-value	F-probability	Midstream	Upstream Downstream	Midstream Downstream
Conductivity	6.716	0.005	0.981	0.024	0.008
TDS	8.503	0.002	0.866		

Relationship between conductivity and dissolved solids in the stream

Figure 3 shows the graphical relationship between conductivity and total dissolved solid in the study area. The relationship is essentially linear ($R^2 = 0.924$) and direct (positive). The regression equation is as given in equation 2.

$$y = 14.5 + 0.47x + 9.5 \quad (2)$$

Where: y= total dissolved solids in mgl^{-1},x = conductivity (μScm^{-1})

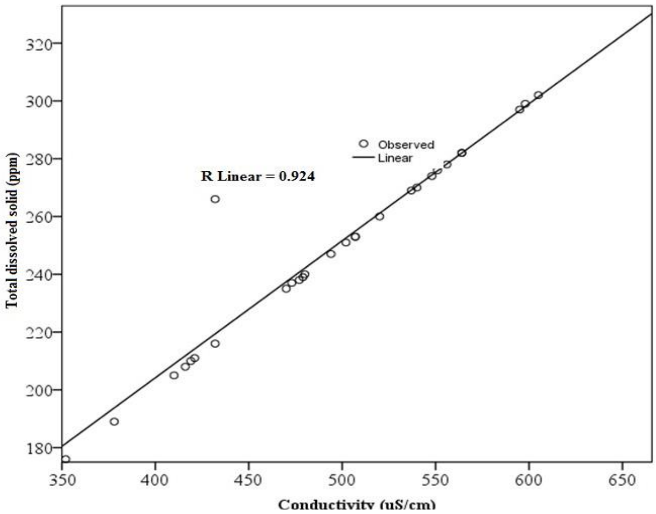

Figure 3: Relationship between conductivity and dissolved solid

Ecological and health implication

The stream is a typical source of water for both domestic and recreational uses in many areas in sub-Saharan Africa. The present stream receives leachate from the waste dumpsites and incinerating facilities near it. Consequently, both conductivity and dissolved solids were high at upstream. Ash and other products of burns when washed to a water source can significantly increase the concentration of dissolved solids and conductivity. Both conductivity and dissolved oxygen obtained in this study are greater than the recommended limits for domestic, recreational and agriculturalpurposes (World Health Organisation, 2017). The high values of conductivity indicate high chemical concentrations in the water systems, and this, therefore, suggests the need for an extensive monitoring of the river that the studied stream drains into. This is important since the neighboring settlements of the study area are rural areas whose large population may depend on stream water for domestic uses.

DISCUSSION AND CONCLUSION

Streams are generally known as an important water source for agricultural, commercial and potable uses, especially among rural populations in many developing countries in the tropics. Streams are also considered to be open sewers whose physical and bio-chemical compositions reflect the impact of the immediate and distant environments (Eludoyin, Ofoezie & Ogunkoya, 2004; Coetser, Heath & Ndombe, 2007). Furthermore, streams are important composite of different sources of water, including precipitation, soil water and ground water systems. Stream water and runoffs are media for pollutant transfer, in both dissolved and solid form, and this makes downstream settlements that are far from a point of pollution to become potentially vulnerable to the effects of land use activities at a distant upstream (Bracken, Wainwright, Ali, Tetzlaff, Smith, Reaney & Roy, 2013). Consequently, understanding of water quality is important to human health and livelihoods. The present study was focused on one of the few urban land use activities around a stream, which is being by farmers for washing and bathing after farming activities. Whereas the possibility of swallowing part of the water is high during bathing, there was no evidence that the water is consumed within 10m distance away from the waste dumpsite and incinerating site.

This study investigated temporal changes in dissolved solids and conductivity concentration, as well as their relationship between the two water quality parameters. Determination of the two water parameters was achieved *in-situ* by the use of a handheld TDS/conductivity meter, a relatively low-cost approach to water quality determination. The TDS and conductivity, as well as pH are composite parameters, and their values are capable of providing insights into the state of the water quality. Generally, the stream is prone to waste due to the dumpsite that was situated just a few metres away from its point source. The study showed that the dissolved solids and conductivity concentration in the stream were high; expectedly because, of the proximity to dumpsite. Both TDS and conductivity deduced downstream, expectedly own to dilution. High dissolved solids and conductivity are known to express contamination of the water source. In terms of the relationship between TDS and conductivity, the study revealed no significant difference when compared with what is documented for other streams in similar environment (e.g. Eludoyin et al., 2004). Nonetheless, this postulation will still require further investigation, especially with varying temperature to confirm, since previous studies (such as Sharma et al., 2017; Boyd, 2020) have indicated the importance of temperature in chemical reactions in water. In all, the study concluded that conductivity and TDS in the stream exceeded recommended limits for domestic water use, and that fetching the stream water for domestic use may foretell health challenges if untreated. The study recommends awareness that people who drink untreated stream water are vulnerable to dangers of water contamination, and consequently advocates improved rural water scheme at the Ile-Ife and other regions with similar experience.

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