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Geographical Information System (GIS) Mapping of Spatio-Temporal Pollution Status of Rivers in Ibadan, Nigeria

Olanike K. Adeyemo and Olutayo O. Babalobi
Department of Veterinary Public Health and Preventive Medicine,
University of Ibadan, Ibadan, Nigeria

Abstract: More accurate spatio-temporal predictions of urban environment are needed as a basis for assessing exposures as a part of environmental studies and to inform urban protection policy and management. In this study, an information system was developed to manage the physico-chemical pollution information of Ibadan river system, Oyo State, Southwest Nigeria. The study took into account the seasonal influences of point and non-point discharges on the levels of physico-chemical parameters. The overall sensitivity of the watershed to physicochemical environmental pollution revealed that during dry season, of the 22 (100%) sample points, only 3 (13.6%) were unpolluted; 6 (27.3%) were slightly polluted; 10 (45.4%) were moderately polluted; 2 (9.1%) were seriously polluted and 1 (4.5%) was exceptionally polluted. During rainy season, 3 (13.6%) were unpolluted; 7 (31.8%) were slightly polluted; 9 (40.9%) were moderately polluted; 2 (9.1%) were seriously polluted and 1 (4.5%) was exceptionally polluted. There is a considerable environmental risk associated with the present level of pollution of the Ibadan river water body on fish health and biodiversity. This research provides a basis for aquatic management and assist in policy making at national and international levels. Appropriate strategies for the control of point and non-point pollution sources, amendments and enforcement of legislation should be developed.

Key words: GIS, physico-chemical parameters, water quality, watercourse contamination, Nigeria

INTRODUCTION

Assessing the environmental impact of Non-Point Source (NPS) pollutants at a global, regional and localized scale is a key component to achieving sustainability of agriculture, as well as preserving the environment. Assessment involves the determination of change of some constituent over time. In recent years concern has shifted more to pollutants that are low in concentration, but ubiquitous in nature and referred to as NPS pollutants. The NPS pollutants are contaminants of surface and subsurface soil and water resources (e.g., sediment, fertilizers, pesticides, salts and trace elements) that are diffuse in nature and cannot be traced to a point location. Often times, NPS pollutants are naturally occurring such as salts and trace elements in soils or are the consequence of direct application by humans (e.g., pesticides and fertilizers), but regardless of their source they are generally the direct consequence of human activities (e.g., agriculture, urban runoff, hydro-modification and resource extraction).

The threat of NPS pollutants varies throughout the world. Yet, NPS pollutants are a problem of global importance (Kleinschmidt *et al.*, 2000; Noreña-Barroso *et al.*, 2007). The reason is because NPS pollution problems do not recognize the boundaries between nations, nor are they necessarily isolated by the physical barriers between continents. In most developing countries, discharges from point sources have increased significantly as a result of industrialization and high living standards-despite environmental regulations. Additionally, excessive nutrient loading to rivers in these countries has been accompanied by untreated wastewater discharges (Soto-Jiménez *et al.*, 2003; Ajibade, 2004). The Global Environmental Monitoring System (GEMS) of the United Nation Environmental Program (UNEP) reported heavy pollution in several rivers around the World. Little emphasis, however, has been placed on reducing pollutant loads from diffuse sources which are becoming increasingly important. Burrough (1986) identified three components or aspects to GIS-based environmental modeling: data, GIS and model.

Environmental protection of urban areas includes a wide variety of techniques in order to determine individual factors of pollution and stress of the urban environment. Within these fields, monitoring and environmental

Corresponding Author: Olanike K. Adeyemo, Department of Veterinary Public Health and Preventive Medicine, University of Ibadan, Ibadan, Nigeria Tel: +234-805-545-45440

modeling have been created with a few aims: to estimate short term and long term changes, to develop models that can simulate a real environmental situation and to aid the decision making process. Due to the increasingly more powerful desktop computing systems with constantly improving graphic capabilities and modest financial cost to individuals and agencies, the collected data are processed and analyze in the frame of computer information systems. Considering to the nature of collected measurements, the research requires spatio-temporal data management. The increase in computing power and graphics is facilitating the advance of geographic information systems-GIS, which can effectively satisfy these tasks. Geographic Information System (GIS) technology can be used to automate and improve the computation of spatio-temporal data. Capabilities of the GIS include mainly management of spatial data in the form of map layers, which can visualize real objects by vector and raster data formats together with graphs and multimedia presentations. Data analysis and modelling in the frame of the GIS represent one of the next steps.

MATERIALS AND METHODS

Study area: Ibadan (Oyo state, Nigeria) is the largest city in West Africa and the second largest in Africa, with land size covering an area of 240 km^2. The city is located on geographic grid reference longitude 3°5E, latitude 7°20N (Filani, 1994).

Types of data: All data were previously collected from a study conducted on upstream and downstream samples of rivers in each of the eleven local government areas in Ibadan metropolis between October 2003 and March, 2004 during the dry season. This was repeated between August and September, 2004 during the rainy season. This paper synthesizes the data generated in a form lending itself to GIS presentation and appreciation. The data used are those of hydrographic features and physico-chemical water parameters.

Water quality data

Selecting Indicators: Dunnette (1979), based on perceived requirements of freshwater, recommended that variables of concern to water quality should be selected from five commonly recognized impairment categories including: (1) oxygen status, (2) eutrophication, (3) health aspects, (4) physical characteristics and (5) dissolved substances. Each assessed stream segment was therefore considered either impaired or non-impaired for a given type of pollution when their value of the parameter is compared to the WHO standards. It is important to note that the six water quality indicators were selected based on their amenability to field testing, their generally accepted importance to freshwater quality and their relevance as a measure of average water quality. The parameters assessed are: Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), pH and nutrients (Nitrate, phosphate and chloride. Previously determined water quality data (Adeyemo, 2005) was used for the relative ranking/index for each impact parameter across the study area and the cumulative ranking/index was then inferred for each river/stream assessed. The sensitivity of each river assessed, based on the value of the water quality parameter assessed was classified thus:

BOD	**Sensitivity**
≤30	Nil
31-16	Low
61-90	Medium
91-120	High
121-150	High +
151-180	High ++
>180	High +++
DO	**Sensitivity**
>11	Nil
9.1-10	Low+
8.1-9	Low
7.1-8	Medium
6.1-7	High
5.1-6	High+
≤5	High++
Nitrate	**Sensitivity**
0-1	Nil
1.1-2	Low+
2.1-3	Low
>3	High
Phosphate	**Sensitivity**
0-0.1	Nil
0.11-0.5	Low
0.51-1.0	Medium
1.1-1.5	High
1.51-2.0	High+
pH	**Sensitivity**
6.5-9.5	Nil
<6.5	High
>9.5	High
Chloride	**Sensitivity**
≤250	Nil
251-500	Medium
501-750	High
751-1000	High+
1001-1250	High++
≥1250	High+++

Indicator transformation: Water quality indicators are generally expressed in many different units (for example: parts per million, counts per volume, percent of saturation, etc.). This makes simple aggregation impossible. As a consequence, another important step in developing an index involves the transformation of all indicators to an equal, dimensionless scale. This is generally accomplished through the use of rating curves, where indicator concentration is mapped against a dimensionless measure such as relative water quality value (Farabi, 2005; Takken *et al*., 2005). Using the data generated from the six parameters assessed. The resultant overall physicochemical assessment of each river was computed thus:

Overall assessment

- Nil sensitivity is regarded as zero (0)
- Other sensitivity grading was allotted with one (1)

Score	Overall sensitivity	Water quality
1 in 6	Low+	Unpolluted
2 in 6	Low	Slightly polluted
3 in 6	Medium	Moderately polluted
4 in 6	High	Seriously polluted
5 in 6	High+	Exceptionally polluted
6 in 6	High++	Ominously polluted

Manipulation of data: Using the map of the sample locations as the base map, the data generated from the hydrographic feature data and physicochemical parameters was used to generate maps of the pollution status of the study area using a GIS software; Arc View 3.2.

RESULTS AND DISCUSSION

With increase in urbanization and socio-economic activities in Ibadan and other cities in Nigeria, most of the freshwater ecosystem in the country is subject to various pressures from human activity. There is therefore a need for increased understanding of inputs, distribution and fate of contaminants. Results of the physicochemical assessment during dry and rainy seasons are presented as Table 1 and 2, respectively. The map of African and Nigeria showing Ibadan and the study sites is Fig. 1 while GIS mapping of the overall assessment of the pollution status of the study area based on the different physicochemical parameters during the two seasons are presented as Fig. 2 and 3 for dry and rainy seasons, respectively.

In assessing the physicochemical parameters, the BOD showed that during the dry and rainy season, 6 (27.3%) and 7 (31.8%) of the sample points were

Table 1: Physico-chemical determination of water quality of rivers in Ibadan during the dry season

LGA	Sample point	BOD	DO	pH	Nitrate	Phosphate	Chloride	Overall assessment
Akiuyele L.G.A Downstream	Ajibode	Low	Medium	Nil	Nil	Nil	High	High
Akiuyele L.G.A upstream	IITA	Low	High	Nil	Nil	Nil	High	Medium
Ibadan North L.G.A Downstream	Orogun express	Nil	Nil	Nil	Nil	High +	High	Low +
Ibadan North L.G.A Upstream	Orogun bridge	Nil	High	Nil	Nil	High +	Nil	Medium
Iddo L.G.A Downstream	Eleyele bridge	Low	Nil	Nil	Nil	High +	Nil	Low
Iddo L.G.A Upstream	Apete bridge	Low	Nil	Nil	Nil	High +	Nil	Low
Ibadan North-West L.G.A Downstream	ISAAC oil	Low	Medium	High +	Nil	High +	Medium	High +
Ibadan North-West L.G.A Upstream	FAN Milk valley	Medium	Nil	Nil	Nil	High +	Medium	Medium
Ibadan South-West L.G.A Downstream	Oluyole estate	Low	Nil	Nil	Nil	High +	High +	Medium
Ibadan South-West L.G.A Upstream	IAR and T Bridge	Low	Nil	High +	Nil	High +	High +	High
Ona Ara L.G.A Downstream	Abonde village	Low	Nil	Nil	Nil	High +	High	Medium
Ona Ara L.G.A Upstream	Ogbere TI-O-YA	Low	Nil	Nil	Nil	High +	Nil	Low
Egbeda L.G.A Downstream	Onideure Efun Old Ife RD	Low	Nil	High	Nil	High +	Nil	Medium
Egbeda L.G.A Upstream	New gbagi market	Medium	Nil	High	Nil	High +	Nil	Medium
Ibadan North-East L.G.A Downstream	CAC Oremeji express	Medium	Nil	Nil	Nil	High +	High	Medium
Ibadan North-East L.G.A Upstream	Ogbere at IFE RD	Medium	Nil	Nil	Nil	High +	High	Medium
Ibadan South-East L.G.A Downstream	Ogunpa at Lagos-Ibadan express RD	Low	Nil	Nil	Nil	High +	High	Medium
Ibadan South-East L.G.A Upstream	Ogunpa at Ibadan grammar SCH. Molete	low	Nil	Nil	Nil	High +	Nil	Low
Lagelu L.G.A Downstream	Akobo estate	Nil	Nil	Nil	Nil	High +	High	Low
Lagelu L.G.A Upstream	Akobo	Nil	Nil	Nil	Nil	High +	Nil	Low +
Oluyole L.G.A Downstream	Odo ona elewe	Nil	Nil	Nil	Nil	High +	High	Low
Oluyole L.G.A Upstream	New Garage barrack orita challenge	Nil	Nil	Nil	Nil	High +	Nil	Low +

Table 2: Physico-chemical determination of water quality of rivers in Ibadan during the rainy season

LGA	Sample point	BOD	DO	pH	Nitrate	Phosphate	Chloride	Overall assessment
Akinyele L.G.A Downstream	Ajibode	Nil	Nil	Nil	Nil	High +	High	Low
Akinyele L.G.A Upstream	Iita	Low	Nil	Nil	Nil	High +	Nil	Low
Ibadan North L.G.A Downstream	Orogun express	Nil	Nil	Nil	Nil	High +	High	Low +
Ibadan North L.G.A Upstream	Orogun bridge	Nil	High	Nil	Nil	High +	Nil	Medium
Iddo L.G.A Downstream	Eleyele bridge	Low	Nil	Nil	Nil	High +	Nil	Low
IDDO L.G.A UPSTREAM	Apete bridge	Low	Nil	Nil	Nil	High +	Nil	Low
Ibadan North-West L.G.A Downstream	ISAAC oil	Low	Medium	High +	Nil	High +	Medium	High +
Ibadan North-West L.G.A Upstream	FAN milk valley	Medium	Nil	Nil	Nil	High +	Medium	Medium
Ibadan South-West L.G.A Downstream	Oluyole estate	Low	Nil	Nil	Nil	High +	High +	Medium
Ibadan South-West L.G.A Upstream	IAR and T bridge	Low	Nil	High +	Nil	High +	High +	High
Ona Ara L.G.A Downstream	Abonde village	Low	Low +	Nil	Nil	High +	Nil	Medium
Ona Ara L.G.A Upstream	Ogbere Ti-O-Ya	Low	Medium	High	Nil	High +	Nil	High
Egbeda L.G.A Downstream	Onideure Efun old IFE RD	Low	Nil	High	Nil	High +	Nil	Medium
Egbeda L.G.A Upstream	New GBAGI Market	Medium	Nil	High	Nil	High +	Nil	Medium
Ibadan North-East L.G.A Downstream	CAC Oremeji express	Medium	Nil	Nil	Nil	High +	High	Medium
Ibadan North-East L.G.A Upstream	OGBERE AT IFE RD	Medium	Nil	Nil	Nil	High +	High	Medium
Ibadan South-East L.G.A Downstream	Ogunpa at Lagos-Ibadan express RD	Low	Nil	Nil	Nil	High +	High	Medium
Ibadan South-East L.G.A Upstream	Ogunpa at Ibadan Grammar Sch. Molete	Low	Nil	Nil	Nil	High +	Nil	Low
Lagelu L.G.A Downstream	Akobo Estate	Nil	Nil	Nil	Nil	High +	High	Low
Lagelu L.G.A Upstream	Akobo	Nil	Nil	Nil	Nil	High +	Nil	Low +
Oluyole L.G.A Downstream	Odo Ona Elewe	Nil	Nil	Nil	Nil	High +	High	Low
Oluyole L.G.A Upstream	New Garage Barrack Onta challenge	Nil	Nil	Nil	Nil	High +	Nil	Low +

Score	Overall sensitivity	Water quality
1 in 6	Low+	unpolluted
2 in 6	Low	Slightly polluted
3 in 6	Medium	Moderately polluted
4 in 6	High	Seriously polluted
5 in 6	High+	Exceptionally polluted
6 in 6	High++	Ominously polluted

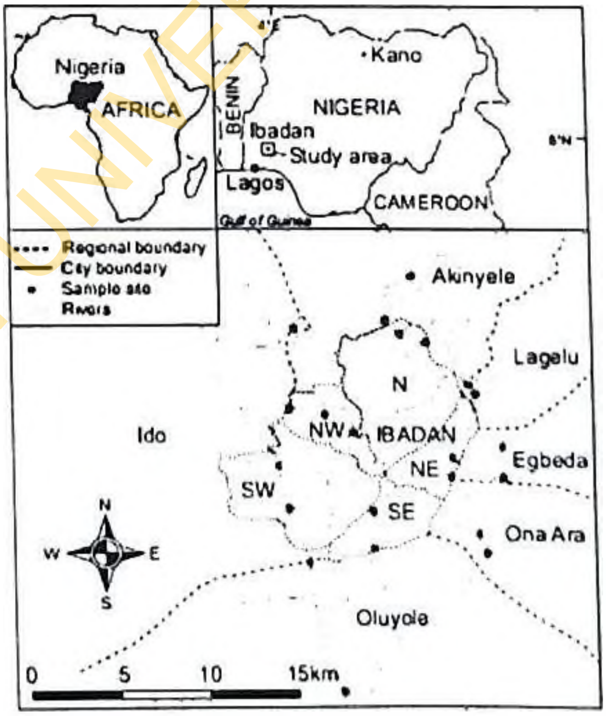

Fig. 1: A map of Nigeria showing Ibadan and the study area

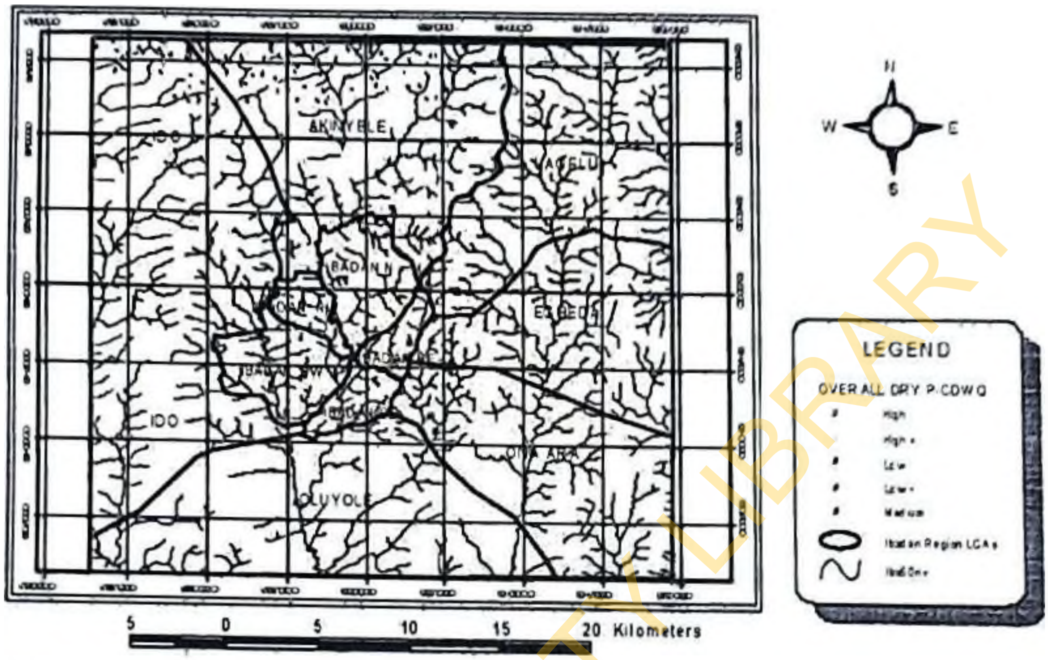

Fig. 2: Overall quality using physico-chemical parameters during dry season

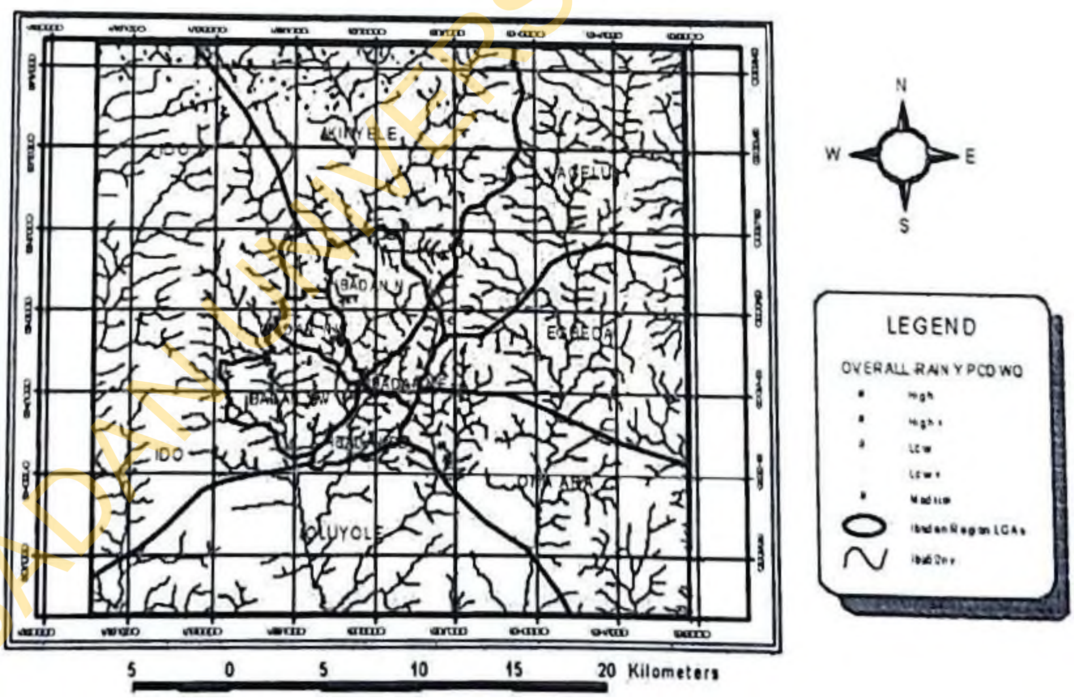

Fig. 3: Overall quality using physico-chemical parameters during rainy season

unpolluted, 12 (54.5%) were slightly polluted and 4 (9.9%) were moderately polluted respectively. For the DO; 18 (81.8%) and 19 (86.4%) were unpolluted during the dry and rainy season, respectively; 2 (9.1%) were moderately polluted and 1 (4.54%) was seriously polluted for both seasons. pH assessment showed that 18 (81.8%) and 17 (77.3%) were unpolluted; 2 and 3 (13.6%) were seriously polluted for dry and rainy season, respectively while 2 (9.1%) were exceptionally polluted for both seasons. Nitrate levels were low during the two seasons. Phosphate assessment revealed that only 2 (9.1%) sample points were unpolluted during the dry season while 20 (90.9%) and 22 (100%) were seriously polluted during the dry and rainy season respectively. Raw sewage is the source of nitrates and phosphates in rivers (Aggarwal *et al.*, 2000; Adeyemo, 2003).

Excessive nutrient loading from animal wastes and fertilizers has an effect on water quality in agro-ecosystem. If urban and agricultural development continues at the current rate, further degradation of the aquatic ecosystem and increasing risk to human and animal health should be expected if drinking water supplies are not protected. Chloride assessment results revealed that 9 (40.9%) and 11 (50%) were unpolluted; 9 (40.9%) and 7 (31.8%) were seriously polluted during the dry and rainy season, respectively; 2 (9.1%) were moderately polluted and 2 (9.1%) also exceptionally polluted during both seasons.

The overall sensitivity of the watershed to physicochemical environmental pollution revealed that during dry season, of the 22 (100%) sample points, only 3 (13.6%) were unpolluted; 6 (27.3%) were slightly polluted; 10 (45.4%) were moderately polluted; 2 (9.1%) were seriously polluted and 1 (4.5%) was exceptionally polluted. During rainy season, 3 (13.6%) were unpolluted; 7 (31.8%) were slightly polluted; 9 (40.9%) were moderately polluted; 2 (9.1%) were seriously polluted and 1 (4.5%) was exceptionally polluted. The results have shown that there are no significant differences in the sensitivities of the rivers sampled to pollution based on physicochemical parameters during the dry and rainy seasons.

The results of this study also clearly illustrate the utility of the water quality assessment indices for succinctly identifying the relative health of Ibadan freshwater with respect to their suitability for fish culture. Liu *et al.* (2003) demonstrated that recovery of polluted rivers in developing countries depended in part on the enforcement of necessary legislation and the development of suitable institutional capabilities. Such institutional and technical systems include both the disposal of domestic sewage and the treatment and disposal of industrial wastewaters in order to adopt an integrated management of river systems. This study indicates sub-standard water quality in most part of Ibadan River system. We therefore conclude that inland river quality in Nigeria should be monitored frequently to develop highly significant empirical models; in order to improve visualization of health risks, supporting environmental and infrastructure planning and public health care measures.

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