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Application of water quality index method in water quality assessment

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ABSTRACT

The water quality index (WQI) method rather than the conventional water quality standard approach was applied in evaluating the surface water quality of the Jakara basin, Kano, Northern Nigeria. The objective of this study is to provide water quality index reference values and pattern for targeted environment. Thirty surface water samples were collected: twenty three samples along River Getsi and seven surface water samples along the main channel River Jakara. Twenty three quality parameters namely: pH, temperature, turbidity, electrical conductivity, dissolve oxygen, biochemical oxygen demand, Fecal Coli form, total solids, nitrates, phosphates, cobalt, iron, nickel, manganese ,copper, sodium, potassium, mercury, chromium, cadmium, lead ,magnesium, and calcium were analyzed. The study used nine physicochemical and bacteriological parameters converge into single value as suggested by National Science Foundation-Water Quality Index (NSF-WQI). The result reveled that S2,S3,S4,S5,S12,S15,S17 of the River Getsi fall under very bad water quality while other sampling points within the same stream shows Bad water quality. On the other hand out of the seven sampling points within River Jakara, only S25 shows Very bad, others fall within Bad water quality. In general water in the Jakara basin fall under very bad category and pose a danger in any form of water consumption. The water quality index scheme performed better in water quality pollution trend analysis due to its sensitivity to changes in water quality at different point in time.

Introduction

River Jakara flows in North east direction almost across Kano metropolitan. Jakara stream being together with its tributaries, main water source of this region with more than 5 million inhabitants (Olofin et al., 2008). As consequences of such a high population, the river receives many inputs from both natural and anthropogenic origin that may cause deterioration of water quality.

Surface water quality has been a subject of study in many parts of the world. The quality of the surface water depends upon the major and minor elements constituents, which also depends on the quality of the sources of water and distributions (Oteze, 1990). Rivers are important resources for human civilizations as they meet water demand for various uses apart from supporting flora and fauna, improving aesthetic and landscape quality, moderating climate and providing resources for hydro-power (Sharma, 2008).The overriding interest in water has been both its quality and quantity. Water quality is it is fitness for the intended used based on meeting the minimum criteria of the physico-chemical and microbiological properties compared with water quality guidelines given by environmental agencies.

Water quality index (WQI) expresses the list of constituents and their concentrations in a water sample into a single value. A water quality index was developed in order to integrate the composite influence of various physical, chemical and biological parameters measured (Mozafar, 1990), this enables comparison of different samples for quality on the basis of the index value for each sample. Water quality index was first introduced in 1848 about 162 years ago in Germany where the present or absence of certain organism in water was used as fitness indicator of a water source. The use of numerical scale to represent gradation in water quality levels is a recent phenomenon, beginning with Horton index.

The mathematical expression generally known as Water Quality Index (WQI) was developed at the National Sanitation Foundation (NSF) during 1970's.It seems that the NSF's appears to be the most comprehensive that has been carried out to date and has been discussed in various papers (Oteze, 1990).

With the advent of WQI, it serves as a convenient tool to examine trends, highlight specific environmental conditions and help decision makers in evaluating the effectiveness of their respective regulatory programmes (Onyebanjo et al 2010).Kano state is drained by essentially two drainage systems, both were supposed to be part of the inland drainage system of the Hadejia-Jama'are-Komadugu-Yobe Basin (H-JKYB). However, while the drainage of River Kano-Challawa drains essentially northeast ward to the Lake-Chad, first over the Basement complex and later over the Sedimentary formation in the North – eastern part, the Jakara channel having been dammed disappeared after the Dam at wase and hence does not contribute to the H-JKYB system any longer. This leaves Kano and Challawa as the only important headstreams of the system, even when both of them are dammed at Tiga and Challawa Gorge respectively. Essentially, the two systems dominate and control both surface and ground water drainage in Kano state. While Kano system drains the southern part at the confluence near Tamburawa (Tanko A.I, 2008).

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It is relevant to point out that the water provision in Kano metropolis and all other settlements around rely on the system, indeed the land use pattern in Kano city is such that the three major industrial estate, and with the heaviest densities of wet industries rely on the systems for their water needs and contribute effluent significantly to the system. That forms the most significant sources of pollution in Kano state (Tanko,A.I 2008).From the above we can summarize that pollution in the Jakara system result due to industrial activities in the Bompai industrial estate form where effluent is discharged through the Getsi stream into Jakara. In addition to this, domestic waste is also added to the channel without any form of treatment (Tanko, A.I 2008).

The present study aims at the assessment of the water quality index WQI of River Jakara with respect to portability in comparison with other recommended water quality standard and provides WQI references values and the trend for the environment.

Materials and Method

Kano city is one of the largest cities in Nigeria and second to the largest traditional city in the West African sub-region. Kano city is located on latitude 12^o25^1N to 12^040^1N and longitude 8^035^1E to 8^045^1E. The geology of the study area is Basement complex rocks; the topography is relatively flat looking terrain, resulting from wind drift materials overlaying the parent rock, the dominant slope is between 0^0-2^0 making the area a gently sloping pediplain. The hydrology is predominantly surface water consisting of ponds and streams (Olofin, 2008).

The climate is the tropical wet and dry type coded as Aw by Koppen's classification of climate. Rainfall is very critical element in the area because of its deficiency during the dry season. The wet season last for 4-5 months (May to September),with a mean annual rainfall of about 800mm.Temprature ranges from 21^0C in the coolest months (December and January) to 35^0C in the hottest months (April and May).Four distinct seasons are experienced, which are dry and cool, dry and hot, wet and warm and dry and warm seasons (Olofin,2008)

Thirty surface water samples were collected(Fig.1)Twenty three samples were collected along River Getsi at approximately 400 meters interval due to various land use around the area. Seven surface water samples were collected along the main channel River Jakara at approximately 1km interval. The samples were carried out during the dry season when there were no natural flows in most of the rivers. Two surface samples (S1 and S2) were collected near one of the Bompai tannery industry along the River Getsi. Six surface water samples (S3, S4, S5, S6,S7,S8) were collected in the heavily residential areas of Zangon-Dakata, Tudun-Murtala along River Getsi. The other remaining sampling sites (S9-S23) is agriculturally dominated sites while samples collected (S24-S30) is mainly samples collected along River Jakara.

Figure 1 Map of Nigeria showing Kano State and Sampling Stations

Prior to the sampling, the sampling plastic bag and the DO/BOD glass container were thoroughly washed and rinsed twice with the sample itself to prevent contamination.

The physicochemical parameters used to assess the quality of the water include pH, temperature, conductivity, Total solids, Dissolved oxygen, $BOD_{5,}$ Copper (Cu),Iron (Fe), Nickel (Ni), Manganese (Mn), Copper (cu),Sodium (Na),Potassium (K),Chromium (Cr),cadmium(Cd),Lead (Pb),Magnesium (Mg),Calcium (Ca).

The temperature of the water samples were measured at the site of collection using THL-360-050W Gallenkamp Griffin, Mercury-in-Glass thermometer. The pH and conductivity values were obtained using Jenway 6405, while ammonia nitrate, iron, nickel, manganese, sodium, potassium, magnesium, total solids,DO,BOD_5 were determined as outlined by HACH, chromium, cadmium, lead and copper were analyzed using Atomic Absorption Spectrometer (AAS) ALPHA 4 Model.

Water Quality Index (Wqi) Method

The overall quality of the water was estimated using National Sanitation Foundation Water Quality Index, NSF-WQI, commonly used in USA. This mathematical assessment provides an easily visualizable unitless single value for comparison of the quality status of the river with similar body of water internationally.

The basic procedures associated with the development of the Water Quality Index include parameter selection, transformation of the parameters of different units into a common scale, assignment of weightings and aggregation of sub-indices to produce a final index score.

Water Quality Index is a 100 point scale ranging from 0 (worst) to 100 (best) that summarizes result from a total of nine different measurement when complete (Jonnalagadda et. al (1990).Since a typical water sample may have hundreds of constituent parameters including elements, organics and in-organics WQI would become unwidely if each and every possible constituents is included in the index.

Nine parameters are combined into one numerical indicator of water quality (Otto,1978). The nine physic-chemical commonly used are DO, BOD_5, NO_3^-, P-PO_3^-, temperature, turbidity and total solids.

Different water quality parameters are expressed in different units. Otto (1978) developed rating graphs for the conversion of the parameters into unit less sub-index single value ranging from 0 to 100.

The graph used to estimates the various rating sub-indices (qi) for the various parameters are based on the curve of Otto (1978).

It is required to further assign weightings to each parameter with some to be of greater importance than others, the sum of the importance weight is 1.00.

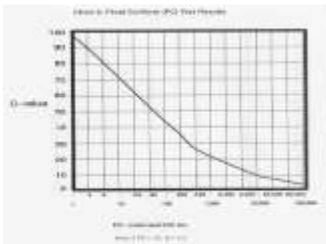

Fig 2 Rating Curve for Fecal coliform

In the final step, the sub-indices are aggregated to obtain the final score using the equation below:

$$WQI=\sum_{i=1}^{n} Wi - qi$$

Where qi is the quality of the ith parameter (a number between 0 and 100 read from the appropriate sub index graph) and Wi is the weight of the ith parameter.

NSF WQI is an excellent management and general administration tool in communicating water quality information. This index have been widely field tested and applied to data from a number of geographical areas all over the world in order to calculate Water Quality Index (WQI) of various water bodies critical pollution parameters were considered (pradyusa,2009).

Table 2. Shows an example of the procedures of calculating WQI for sample 30.The result of physico-chemical parameters are presented in table 2.

Result

Most of the parameters fall within bad and very bad WQI interpretation (Tab 3).WQI values for jakara basin vary from 16.45 to 400.45. Sampling site S2, S3, S4, and S5 revealed very bad water quality (Tab 3) this can be connected to high industrial and domestic wastewater dumped into the Getsi stream. The WQI trends for the two main stream of Jakara basin shows bad water quality from the up streams down to the downstream for both R.Getsi and R.Jakara and this will be linked to increase risk of infectious diseases transmission (Kistemann et al 2003).

Though, with the WQI classification none of the water quality falls within Excellent, Good or medium WQI interpretation, R. Getsi is more polluted than R. Jakara.

Table 4 present Descriptive statistics of the River Jakara and R.Getsi, From the above table P value is greater than 0.05(95%),($p>0.05$).This shows that there is no significance differences between quality of water in R.Getsi and that of R.Jakara, meaning they all fall under bad water(ott, 78).Similar reports were made by maconachie, R et al (2003)that River Jakara is Highly polluted by indusrial and residential waste dumping into the river through point and non-point sources.

Conclusion:

In conclusion, compared to standards the surface water studied could be regarded as physically, chemically and biologically unaccepted and unsafe for use as raw water for drinking, animal herding, recreational activities and the irrigation of food crops to be consumed raw.

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Table 1 Assigned Importance Weight for parameters NSF-WQI (Ott, 1978)

Parameters	Unit	Importance Weight
DO	% sat	0.17
Fecal Coli form	100ml	0.16
pH	Standard Unit	0.11
BOD_5	mg/l	0.11
Nitrates	mg/l $N0_3$	0.10
Phosphates	Mg/l po_4-p	0.10
Temprature	^0C	0.10
Turbidity	NTU	0.08
Total Solids	Mg/l	0.07
		1.00

Table 2 Calculation of the WQI for S30

	Result	Unit	Q-Value(Wi)	Weight value(qi)	wiqi(sub-total)
pH	7.2	Stand.Unit	92	0.11	10.12
Fecal Coliform	75	100ml	47	0.16	7.52
DO	7.9	%sat	6	0.17	1.02
BOD_5	1.9	mg/l	82	0.11	9.02
Temprature	31	^{0}C	10	0.10	1.00
Total Phosphate	4.2	mg/l po_4-p	16	0.10	1.60
Nitrates	85	mg/l $N0_3$	4	0.1	0.40
Turbidity	21.55	NTU	60	0.08	4.80
Total Solids	215	mg/l	71	0.07	4.97
WQI VALUE	40.45				

Table 3 WQI for Jakara basin

Sampling Code	River	Latitude	Longitude	Elevation (ft)	WQI Value	WQI interpretation
S1	Getsi	$12^{0}02^{I}50.82^{II}N$	$8^{0}33^{I}20.74^{II}E$	1474	28.53	Bad
S2	Getsi	$12^{0}02^{I}52.46^{II}N$	$8^{0}33^{I}21.41^{II}E$	1461	23.60	Very Bad
S3	Getsi	$12^{0}02^{I}54.22^{II}N$	$8^{0}33^{I}22.09^{II}E$	1471	16.45	Very Bad
S4	Getsi	$12^{0}02^{I}56.72^{II}N$	$8^{0}33^{I}21.75^{II}E$	1479	19.17	Very Bad
S5	Getsi	$12^{0}02^{I}57.90^{II}N$	$8^{0}33^{I}21.32^{II}E$	1480	17.10	Very Bad
S6	Getsi	$12^{0}02^{I}58.09^{II}N$	$8^{0}33^{I}19.73^{II}E$	1475	28.03	Bad
S7	Getsi	$12^{0}02^{I}59.17^{II}N$	$8^{0}33^{I}19.25^{II}E$	1479	31.34	Bad
S8	Getsi	$12^{0}02^{I}59.67^{II}N$	$8^{0}33^{I}18.17^{II}E$	1475	27..34	Bad
S9	Getsi	$12^{0}02^{I}59.47^{II}N$	$8^{0}33^{I}17.30^{II}E$	1472	34.54	Bad
S10	Getsi	$12^{0}02^{I}59.92^{II}N$	$8^{0}33^{I}16.32^{II}E$	1468	37.04	Bad
S11	Getsi	$12^{0}02^{I}59.74^{II}N$	$8^{0}33^{I}14.66^{I}E$	1465	25.81	Bad
S12	Getsi	$12^{0}02^{I}59.58^{II}N$	$8^{0}33^{I}14.45^{II}E$	1464	20.15	Very Bad
S13	Getsi	$12^{0}03^{I}00.45^{II}N$	$8^{0}33^{I}14.00^{II}E$	1463	28.25	Bad
S14	Getsi	$12^{0}03^{I}02.13^{II}N$	$8^{0}33^{I}13.29^{II}E$	1463	27.27	Bad
S15	Getsi	$12^{0}03^{I}03.21^{II}N$	$8^{0}33^{I}12.56^{II}E$	1465	22.52	Very Bad
S16	Getsi	$12^{0}03^{I}03.43^{II}N$	$8^{0}33^{I}11.46^{II}E$	1463	21.80	Very Bad
S17	Getsi	$12^{0}03^{I}06.08^{II}N$	$8^{0}33^{I}11.85^{II}E$	1460	30.94	Bad
S18	Getsi	$12^{0}03^{I}05.59^{II}N$	$8^{0}33^{I}14.34^{II}E$	1454	31.78	Bad
S19	Getsi	$12^{0}03^{I}08.03^{II}N$	$8^{0}33^{I}14.95^{II}E$	1454	26.00	Bad
S20	Getsi	$12^{0}03^{I}10.20^{II}N$	$8^{0}33^{I}13.73^{II}E$	1464	27.46	Bad
S21	Getsi	$12^{0}03^{I}09.56^{II}N$	$8^{0}33^{I}08.97^{II}E$	1457	29.28	Bad
S22	Getsi	$12^{0}03^{I}10.21^{II}N$	$8^{0}33^{I}06.75^{II}E$	1457	34.86	Bad
S23	Getsi	$12^{0}03^{I}10.82^{II}N$	$8^{0}33^{I}04.58^{II}E$	1458	31.89	Bad
S24	Jakara	$12^{0}03^{I}09.48^{II}N$	$8^{0}33^{I}02.67^{II}E$	1460	35.33	Bad
S25	Jakara	$12^{0}03^{I}12.55^{II}N$	$8^{0}32^{I}56.53^{II}E$	1463	24.88	Very Bad
S26	Jakara	$12^{0}03^{I}09.38^{II}N$	$8^{0}32^{I}55.08^{II}E$	146	33.67	Bad
S27	Jakara	$12^{0}03^{I}04.75^{II}N$	$8^{0}32^{I}52.52^{II}E$	1461	34.56	Bad
S28	Jakara	$12^{0}03^{I}00.12^{II}N$	$8^{0}32^{I}48.85^{II}E$	1463	33.03	Bad
S29	Jakara	$12^{0}02^{I}56.48^{II}N$	$8^{0}32^{I}48.12^{II}E$	1462	36.69	Bad
S30	Jakara	$12^{0}02^{I}51.82^{II}N$	$8^{0}32^{I}45.53^{II}E$	1466	40.45	Bad

Table 4. Descriptive statistical

z-Test: Two Sample for Means		
	River Getsi	*River Jakara*
Mean	113.7173913	34.08857143
Known Variance	171810.1976	22.51951429
Observations	23	7
Hypothesized Mean Difference	0	
z	0.92112004	
P(Z<=z) one-tail	0.178493879	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.356987758	
z Critical two-tail	1.95	

Table 5. Interpretation of WQI (After Ott,1978)

WQI	Interpretation
0 - 25	Very Bad
26 - 50	Bad
51 - 70	Medium
71 - 90	Good
91 - 100	Exellent