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Determination of Water Quality Index for Groundwater in Yaba and Ibafon Areas of Lagos, Nigeria

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Abstract: *The Water Quality Index (WQI) in Yaba and Ibafon areas of Lagos State was calculated in order to ascertain the quality of water for public consumption. WQI indicates water quality in terms of index numbers and offers a useful representation of overall quality of water. In this study, WQI was determined on the basis of various physico-chemical parameters like pH, electrical conductivity, total dissolved solids, total alkalinity, total hardness, total suspended solids, calcium, magnesium, chloride, nitrate, sulphate, dissolved oxygen and biological oxygen demand. The weighted arithmetic index method has been used for the calculation of water quality index of the waterbody. The WQI of the Control Water was 38.62, while the water from Yaba groundwater, Ibafon community borehole and the Ibafon community well gave 112.7, 370.9 and 186.6 respectively. The results indicate that the quality of water in the study areas is poor as suspected and this can be attributed to the highly dense population as well as heavy commercial activities in the areas.*

Keywords: *Groundwater, Physicochemical parameters and Water quality.*

I. Introduction

Water is unarguably the most essential and precious natural resource. Several organisms, such as anaerobes can survive without oxygen, but no living organism can survive without water. 97% percent of the world's water is found in oceans icecaps/glaciers makes 2% while fresh groundwater makes up about 0.6 percent. A huge volume of fresh water is in water bearing geological formation (Horne, 1992).

Groundwater occurs beneath the water table in geologic forms and they account for about 95% of freshwater for domestic use. It exists as water fills the pores of sedimentary rocks and also exists in cracks and fractures in crystalline rocks such as granite or limestone (Hartman et al., 2005). The permeability of the aquifer is determined by the extent of interpenetration and sizes of the pore Such aquifers release water to wells by draining the pores and fractures of the partially saturated sediments or rocks that surround the well. Groundwater is generally stored in aqueducts, underground layers of porous rocks that are saturated with water. These aqueducts receive water as soil becomes saturated with precipitation or through stream and river runoff. As the aqueducts exceed their capacity for water storage, they will bleed water back into streams or rivers. The aqueducts maintain a natural balance of water, alternatively receiving or giving water as their saturation levels oscillate. Throughout this process, water constantly moves between surface and groundwater sources, sharing contaminants. Langelier Saturation Index was used to calculate the corrosion index. Corrosion refers to the degradation of a metal by electrochemical or chemical reaction with its environment or by physical wearing away.WQI is single number quality rating for ground and surface water at a certain geographical location and time based on reliable water quality parameters. The significance of WQI is that it turns complex water quality information into a form that is understandable and usable by the general public.

Study Area

Yaba is a suburb of Lagos, Nigeria with latitude 6.5097ᴼN and longitude 3.3863ᴼE and Ibafon Community is situated in Ajeromi-Ifelodun local government second- order administrative division and is located in Lagos, Nigeria. The estimate terrain elevation above Sea level is 6 meters.Latitude 6ᴼ28'1.42'' longitude 3ᴼ19'29.75". Nigeria is located approximately between latitude 4ᴼ and 14ᴼ North of the equator, and between longitude 2ᴼ2' and 15ᴼ east of the Greenwich meridian.

II. Materials And Methods

The water samples from the water body were collected from three locations with plastic containers previously washed with detergents and HNO_3 acid and later rinsed with sampled water several times. 2M HNO_3 was added to samples for metallic ions determination, this is to maintain the stability of the oxidation state of the various elements in solution and prevent precipitation, and analysed for up to 13 physicochemical parameters in accordance with established literature procedures. Parameters like dissolved oxygen, electrical conductivity and pHwere monitored on- site while parameters like hardness, total suspended solid, total alkalinity, calcium,

chloride, chloride, magnesium, sulphate, biological oxygen demand and nitrate were analysed in the laboratory in accordance to the standard procedures of APHA (1995).
The WQI was calculated in accordance with the recommendation by the World Health Organisation (WHO), and Standard Organisation of Nigeria (SON). The weighted arithmetic index method (Brown et. al.,) was used for the calculation of WQI of the waterbody. The following expression can be used to calculate the Quality rating or sub index (q_n)

$q_n = 100[V_n-V_{io}]/[S_n-V_{io}]$

(Let there be n water quality parameters and quality rating or subindex (q_n) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value.)

q_n = Quality rating for the n^{th} water quality parameter
V_n = Estimated value of the n^{th} parameter at a given sampling station.
S_n = Standard permissible value of the n^{th} parameter.
V_{io} = Ideal value of n^{th} parameter in pure water. (i.e., 0 for all other parameters except the parameter pH = 7.0)
Unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter.

$W_n = K/S_n$

W_n = Unit weight for the n^{th} parameters.
S_n = Standard value for n^{th} parameters.
K = Constant for proportionality.
The overall Water Quality Index was calculated by aggregating the rating with the unit weight linearly.

$WQI = \sum WnQn / \sum Wn$

Table 1. Water Quality Index (WQI) and status of water quality (Ramakrishniah, Sadashivaiah and Ranganna 2009)

Water Quality Index Level	Water Quality Status
<50	Excellent water quality
50-100	Good water quality
100-200	Poor water quality
200-300	Very Poor water quality
>300	Unsuitable for drinking

Table 2. Drinking Water standards recommending Agencies and unit weights. (All values except pH and Electrical Conductivity are in mg/L)

S/No.	Parameters	Standards	Recommended Agency	Unit Weight
1	pH	6.5-8.5	WHO/SON	0.2190
2	Electrical Conductivity	300	WHO/SON	0.371
3	Total Dissolved Solids	500	WHO/SON	0.0037
4	Total Alkalinity	120	WHO/SON	0.0155
5	Total Hardness	300	WHO/SON	0.0062
6	Total Suspended Solids	500	WHO	0.0037
7	Calcium	75	WHO	0.025
8	Magnesium	30	WHO	0.061
9	Chlorides	250	WHO/SON	0.0074
10	Nitrate	45	WHO/SON	0.0412
11	Sulphate	150	WHO/SON	0.01236
12	Dissolved Oxygen	5.00	WHO/SON	0.3723
13	Biological Oxygen Demand	5.00	WHO/SON	0.3723

III. Results And Discussion

Table 3. Variations of the physicochemical parameters of the waterbody:

S/No.	Parameters	Yaba Water	Ibafon Borehole	Ibafon Well
1	pH	6.5	6.9	6.9
2	Electrical Conductivity	1051	4118	1943
3	Total Dissolved Solids	615	2057	1035
4	Total Alkalinity	50	300	305
5	Total Hardness	16.03	72.14	46.09
6	Total Suspended Solids	3	9	18
7	Calcium	3.2	16.03	10.02
8	Magnesium	1.91	7.63	5.01
9	Chlorides	45	600	95
10	Nitrate	0.04	0.03	0.05

11	Sulphate	21	22	59
12	Dissolved Oxygen	4.02	4.64	3.92
13	Biological Oxygen Demand	0.62	2.89	2.18

Table 4. Calculation of Water Quality index of Control Water

S/No.	Parameters	Observed Values	Standard Values (S_n)	Unit Weight (W_n)	Quality rating (q_n)	W_nq_n
1	pH	6.9	6.5-8.5	0.2190	6.67	1.46
2	Electrical Conductivity	268	300	0.371	89.33	33.14
3	Total Dissolved Solids	136	500	0.0037	27.2	0.10
4	Total Alkalinity	<0.001	120	0.0155	0.0008	0.0000124
5	Total Hardness	5.2	300	0.0062	1.73	0.01
6	Total Suspended Solids	1	500	0.0037	0.2	0.0074
7	Calcium	2.51	75	0.025	3.35	0.08
8	Magnesium	1.6	30	0.061	5.33	0.33
9	Chlorides	35	250	0.0074	14	0.10
10	Nitrate	0.02	45	0.0412	0.04	0.001648
11	Sulphate	45.78	150	0.01236	30.52	0.38
12	Dissolved Oxygen	3.02	5.00	0.3723	60.4	22.49
13	Biological Oxygen Demand	0.12	5.00	0.3723	0.57	0.21
				$\sum Wn = 1.51$	$\sum Qn = 239.34$	$\sum WnQn = 58.31$

Water Quality Index of Control Water $=\frac{\sum WnQn}{\sum Wn}$=58.31/1.51=38.62

Table 5. Calculation of Water Quality index in Yaba

S/No.	Parameters	Observed Values	Standard Values (S_n)	Unit Weight (W_n)	Quality rating (q_n)	W_nq_n
1	pH	6.5	6.5-8.5	0.2190	33.33	7.30
2	Electrical Conductivity	1051	300	0.371	350.33	129.97
3	Total Dissolved Solids	615	500	0.0037	123.00	0.46
4	Total Alkalinity	50	120	0.0155	41.67	0.65
5	Total Hardness	16.03	300	0.0062	5.34	0.03
6	Total Suspended Solids	3	500	0.0037	0.60	0.00
7	Calcium	3.2	75	0.025	4.27	0.11
8	Magnesium	1.91	30	0.061	6.37	0.39
9	Chlorides	45	250	0.0074	18.00	0.13
10	Nitrate	0.04	45	0.0412	0.09	0.00
11	Sulphate	21	150	0.01236	14.00	0.17
12	Dissolved Oxygen	4.02	5.00	0.3723	80.40	29.93
13	Biological Oxygen Demand	0.62	5.00	0.3723	2.95	1.10
				$\sum Wn = 1.51$	$\sum Qn = 680.35$	$\sum WnQn = 170.24$

Water Quality Index $=\frac{\sum WnQn}{\sum Wn} = \frac{170.24}{1.51} = 112.7$

Table 6. Calculation of Water Quality index in Ibafon Borehole.

S/No.	Parameters	Observed Values	Standard Values (S_n)	Unit Weight (W_n)	Quality rating (q_n)	W_nq_n
1	pH	6.9	6.5-8.5	0.2190	6.67	1.46
2	Electrical Conductivity	4118	300	0.371	1372.67	509.26
3	Total Dissolved Solids	2057	500	0.0037	411.40	1.52
4	Total Alkalinity	300	120	0.0155	250.00	3.88
5	Total Hardness	72.14	300	0.0062	24.05	0.15
6	Total Suspended Solids	9	500	0.0037	1.80	0.01
7	Calcium	16.03	75	0.025	21.37	0.53
8	Magnesium	7.63	30	0.061	25.43	1.55
9	Chlorides	600	250	0.0074	240.00	1.78
10	Nitrate	0.03	45	0.0412	0.07	0.00
11	Sulphate	22	150	0.01236	14.67	0.18
12	Dissolved Oxygen	4.64	5.00	0.3723	92.80	34.55
13	Biological Oxygen Demand	2.89	5.00	0.3723	13.76	5.12
				$\sum Wn = 1.51$	$\sum Qn = 2474.69$	$\sum WnQn = 559.99$

Water Quality Index $= \frac{\sum WnQn}{\sum Wn} = \frac{559.99}{1.51} = 370.9$

Table 7. Calculation of Water Quality index in Ibafon Community Well.

S/No.	Parameters	Observed Values	Standard Values (S_n)	Unit Weight (W_n)	Quality rating (q_n)	W_nq_n
1	pH	6.9	6.5-8.5	0.2190	6.67	1.46
2	Electrical Conductivity	1943	300	0.371	647.67	240.29
3	Total Dissolved Solids	1035	500	0.0037	207.00	0.77
4	Total Alkalinity	305	120	0.0155	254.17	3.94
5	Total Hardness	46.09	300	0.0062	15.36	0.10
6	Total Suspended Solids	18	500	0.0037	3.60	0.01
7	Calcium	10.02	75	0.025	13.36	0.33
8	Magnesium	5.01	30	0.061	16.70	1.02
9	Chlorides	95	250	0.0074	38.00	0.28
10	Nitrate	0.05	45	0.0412	0.11	0.00
11	Sulphate	59	150	0.01236	39.33	0.49
12	Dissolved Oxygen	3.92	5.00	0.3723	78.40	29.19
13	Biological Oxygen Demand	2.18	5.00	0.3723	10.38	3.86
				$\sum Wn = 1.51$	$\sum Qn = 1330.75$	$\sum WnQn = 281.74$

Water Quality Index $= \frac{\sum WnQn}{\sum Wn} = \frac{281.74}{1.51} = 186.6$

Langelier Saturation Index

The Langelier Saturation Index (LSI) is an equilibrium model derived from the theoretical concept of saturation and provides an indicator of the degree of saturation of water with respect to calcium carbonate. It can be shown that the langelier saturation index (LSI) approximates the base 10 logarithm of the calcite saturation level. The langelier saturation level approaches the concept of saturation using pH as a main variable.

If LSI is negative-No potential to scale, the water will dissolve $CaCO_3$.

If LSI is positive- Scale can form and $CaCO_3$ precipitation may occur.

If LSI is close to zero- Borderline scale potential.

Water quality or changes in temperature, or evaporation could change the index.

LS I= pH- pH_s

pH_s is the pH at saturation in calcite

$pH_s = (9.3+ A + B) – (C + D)$

Where A = (Log_{10} (TDS) – 1/ 10 B= -13.12 x Log_{10} (°C + 273) +34.55

C = Log_{10}(Ca^{2+} as $CaCO_3$) – 0.4 D = Log_{10} (Alkalinity as $CaCO_3$)

Langelier Saturation Index (LSI)	Yaba	Ibafon Borehole	Ibafon Well	Description
Negative	-2.6	-0.7	-0.9	No Tendency to scale

The values of various physicochemical parameters for the calculation of water quality index are presented in Table 3. Water Quality index calculation for the areas were shown in the table 4, 5, 6, and 7. Table 4 calculations indicate the excellent quality water for the control and poor quality water for Yaba and Ibafon well, while Ibafon borehole is unsuitable water quality for domestic use by calculation (Ramakrishniah, 2009).

The value of temperature for Yaba, Ibafon borehole and Ibafon wells are 29.5, 29.2 and 29°C respectively. It was noted that high water temperature enhances the growth of micro organism and may increase taste, odour, colour and corrosion problems. In presents study pH ranged between 6.5-6.9 which conform to WHO and SON standard for drinking water. Although pH usually has no direct impact on consumers, it is one the most important operational water quality parameters (Sinha, 1995). Electrical Conductivity and total dissolved solids were also found to be very high compared to WHO and SON standard for drinking water.

The alkalinity of water may be caused by dissolved strong bases such as sodium or potassium hydroxide (and other hydroxides containing compounds), hydroxide ions are always present in water, even if the concentration is extremely small. The alkalinity of Yaba water conform to the SON standard while Ibafon borehole and Ibafon well has a value above the SON standard. This could be harmful to the domestic use (Brian O. 2007). Chloride is one of the most important parameter in assessing the water quality. Munawar (1970) is of the opinion that higher concentration of chlorides indicates higher degree of organic pollution. In the present study the concentration of chloride for Yaba and Ibafon well conform to WHO/NIS standard while Ibafon borehole has higher concentration of chlorides.

The range of hardness analyzed fell below WHO/SON standard for drinking water. Hardness caused by calcium and magnesium usually results in excessive soap consumption and subsequent scum formation. The corrosion index employed is langelier saturation index which shows that LSI for all the water analysed shows negative which indicate that the water is undersaturated with respect to calcium carbonate. Undersaturated water has a tendency to remove existing calcium carbonate protective coatings in pipelines and equipment. The concentration of dissolved oxygen regulates the distribution of flora and fauna. The present study indicates that the results were below the WHO/SON standard for the drinking water. Biological oxygen demand is a parameter to assess the organic load in a waterbody.The biological parameters were not detected except total heterotrophic bacteria which are non-colifom species of bacteria that use an organic substance for their development. The presence of THB in drinking water is not an indication that the water presents a health risk; rather, no specific significant or health standards are associated with these non-pathogenic, non-coliform bacteria.

From the foregoing observations of the physicochemical parameters, it can be concluded that the waterbody shows with a relatively higher concentration of chlorides, electrical conductivity and total dissolved solids indicate the poor water quality and unsuitability of water for domestic use.

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