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Application of Water Quality Index (WQI) to Assess Suitability of Water from Different Sources for Human Consumption in Hong Local Government Area, Adamawa State, Nigeria

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Abstract

This study evaluates the quality of water from various sources—stream, borehole, and well—in the Hong metropolitan area of Hong Local Government, Adamawa State, using the Water Quality Index (WQI) technique. The objective is to determine the suitability of these water sources for human consumption and domestic use by computing WQI values based on key physico-chemical parameters. Water samples were collected from multiple locations and analyzed for pH, total alkalinity, total hardness, calcium, magnesium, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total dissolved solids, and total suspended solids. The WQI values varied across sampling sites, reflecting spatial differences in water quality. Findings indicate that borehole water samples consistently fall within acceptable WQI ranges, confirming their suitability for drinking and domestic purposes. In contrast, stream water samples exhibited poor WQI ratings, rendering them unsafe for human consumption. The study concludes that while borehole water presents a reliable source of potable water in the region, stream water requires treatment before use. These results underscore the importance of regular water quality monitoring to inform safe water resource management in rural and peri-urban areas.

Keywords: Water Quality Index; Physico-Chemical Parameters; Borehole Water; Stream Water; Hong Metropolitan

INTRODUCTION

Water of good drinking quality is of basic importance to human physiology and man's continued existence depends very much on its availability. An average man (of 53 kg – 63 kg body weight), requires about 3 litres of water in liquid and food daily to keep healthy (Onweluzo&Akuagbazie,2010). Unsafe water is a global public health threat, placing persons at risk for a host of diarrheal and other diseases as well as chemical intoxication (Hughes &Koplan, 2005). Most of the fresh water bodies all over the world are getting polluted, thus decreasing the portability of water (Chandra, Sofingh&Tomar, 2012).

The WQI should be calculated by using standards of drinking water quality recommended by the World Health Organization and Indian Council for Medical Research (ICMR). (Brown, et al,1972).

Water quality index (WQI) provides a single number that expresses the overall water quality at a certain location and time based on several water quality parameters. The objective of WQI is to turn complex water quality data into information that is understandable and usable by the public. A number of indices have been developed to summarize water quality data in an easily expressible and easily understood format.

The WQI which was first developed by Horton in the early 1970s is basically a mathematical means of calculating a single value from multiple test results (Miller, et al, 1986).

Assembling different parameters into one single number leads an easy interpretation of index, thus providing an important tool for management purposes. An index is a useful tool for "communicating water quality information to the public and to legislative decision makers;" it is not "a complex predictive model for technical and scientific application". From the application of water quality index for the determination of the quality of water from different sources in the Niger Delta region of Nigeria, it is concluded that all the pipe borne water and bore hole water samples analysed in this study are fit and suitable for drinking and for other domestic applications while the stream water samples are found unfit and unsuitable for human consumption based on the water quality index standard applied in this study. The source of pollution of these streams as observed at the site includes human activities as defecation and dumping of untreated waste. The streams could be free or level of pollution reduced if proper measures are put in place to discourage the users from polluting the water in order to bring about improved health (Etim, et al, 2013).

Water of good drinking quality is of basic importance to human physiology and man's continued existence depends very much on its availability. An average man (of 53 kg – 63 kg body weight), requires about 3 litres of water in liquid and food daily to keep healthy (Onweluzo, & Akuagbazie, 2010). This fact apparently accounts for why water is regarded as one of the most indispensable substances in life and like air it is most abundant (Okonko, et al, 2008). Increase in human population has exerted an enormous pressure on the provision of safe drinking water especially in developing countries (Umeh, et al, 2005). Unsafe water is a global public health threat, placing persons at risk for a host of diarrheal and other diseases as well as chemical intoxication (Hughes & Koplan, 2005). Most of the fresh water bodies all over the world are getting polluted, thus decreasing the portability of water (Chandra, Singh & Tomar, 2012).

The importance of water to man cannot be over emphasized. He can survive longer without food than without water. He requires it for his cooking, washing, sanitation, drinking and for growing his crops and running his factories. Therefore modern man like his primitive ancestors is heavily dependent on water for his sustenance. But because water is freely available through rainfall, until recently man has tended to take this resource for granted. Apart from its industrial use water is a necessary social amenity. The provision of good quality water can help in eradicating water-borne diseases and in improving the general sanitation of Nigeria's towns and villages (Ayoade, 1975).

MATERIALS AND METHODS

The Study Area

Hong is a town and a Local Government Area in Adamawa State, Nigeria. Hong is the capital city of the Kilba. It is on coordinates $10^0$13`54`N $12^0$55`49`E. It has an area of

2,588km^{2}and a population of 260,900. The wet season is oppressive and overcast, the dry season is partly cloudy and hot year round. Over the course of the year, the temperature typically varies from 59^{0}F to101^{0}F and is rarely below 54^{0}F or above.

Research Design

The research adopted for this study is the pure experimental design.According to Awotunde and Ugodulunwa (2004) described pure experimental design as a research design where the researcher manipulates one or more independent variables to observe the effect on a dependent variable, while controlling for potential confounding variables. This design is most suitable for this study because the variable in the study are controllable.

Sample Collection

Borehole water, well water and stream water was sampled from different parts of the town as; Thabu (T), Kukurpu (K) and Dulbuni (D) areas, three (3) times with interval of two (2) weeks. All plastics and glasses utilized were pre-treated by washing with dilute HCl (0.05m) and later rinsed with distilled water, and air-dried in a dust free environment. At the collection point, containers were rinsed with relevant samples twice and filled with samples and then corked tightly. Some parameters were analyzed and recorded at the side of collection such temperature, pH and Electrical Conductivity (EC).

Physico-Chemical Analysis

The analysis of various physico-chemical parameters analyzed namely pH, temperature, Turbidity, Total Hardness, calcium, magnesium, electrical conductivity, dissolved oxygen, biochemical oxygen demand and Total Dissolved Solids, were carried out in Adamawa State University, Mubi. Department of Fisheries Studies as per methods described in (American Public Health Association (APHA), 1992 and WHO., 1992).

Calculation of Water Quality Index

In this study, application of water quality index to assess the suitability of water for human domestic use and consumption, ten important parameters were chosen. The WQI should be calculated by using standards of drinking water quality recommended by the World Health Organization and Indian Council for Medical Research (ICMR) as in table 1 and 2.

Table: 1 Drinking water standards, recommending Agencies and unit weights. (All values except P^H and electrical conductivity are in mg/l)

S/N	Parameters	Standards	Recommended Agency	Unit Weight (Wn)
1	P^H	6.5-8.5	WHO/ICMR	0.1951
2	Total dissolved solids	500	WHO/ICMR	0.0033
3	Total hardness	300	ICMR	0.0055
4	Calcium	75	WHO/ICMR	0.0221
5	Magnesium	50	WHO/ICMR	0.0332
6	Dissolved oxygen	5	WHO/ICMR	0.3317
7	Biochemical oxygen demand	5	WHO/ICMR	0.3317
8	Sulphate	150	ICMR	0.0111
9	Nitrate	45	ICMR	0.0369
10	Chlorides	250	ICMR	0.0066
11	Total suspended solids	500	WHO	0.0033
12	Electrical conductivity	300	ICMR	0.0055
13	Total alkalinity	120	ICMR	0.0138

ND= Not detected

Table 2: water quality index and quality of water

Water quality index level	Water quality status
0-25	Excellent water quality
25-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

RESULTS AND DISCUSSION

The results of the physico-chemical parameters of the different samples of bore hole water , well water and stream water analysed are as shown in Tables 3, 4 and 5 respectively. From the results, it can be seen that the concentrations of the respective parameters are below the WHO/ICMR standards as shown in Table 2. Water quality index indicates the quality of water in terms of index number which represents overall quality of water for any intended use (Etim, et al, 2013). In this study, the WQI is established from important physico-chemical parameters such as pH, total alkalinity, chlorides, sulphate, nitrate, total hardness, calcium, magnesium, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total dissolved solids and total suspended solids.

The results indicate that the different water samples analysed from borehole water are safe for human consumption and for other domestic purposes as from table 3 where about

60% of the parameters were within the range of the standard water quality index while the samples analysed from well and stream waters are not safe for human consumption (Asuquo& Etim, 2012a), where 40% and 30% were with the range of standard water quality.

The above water quaalkalinitylity index is supported by the following physico-chemical parameters, namely pH, total , chlorides, sulphate, nitrate, total hardness, calcium, magnesium, electrical conductivity, dissolved oxygen, biochemical oxygen demand, total dissolved solids and total suspended solids. Among all the physico-chemical parameters selected for the WQI calculations, pH is an important parameter which determines the suitability of water for various purposes (Chandaluri, et al, 2010). In the present study, pH ranges from 6.8 to 8.9, 6.8 to 8.20 and 7.0 to 8.9 for the entire, borehole water, well water and stream water samples analyzed respectively. This shows that the pH range obtained for all water samples were with the recommended range of 6.50 to 8.50 (WHO, Geneva, 2000 and ICMR, 1975). High pH levels are undesirable since they may impart a bitter taste to the water. Furthermore, the high degree of mineralization associated with alkaline water will result in the encrustation of water pipes and water-using appliances and nearness of the source of water to the hills from where more mineralization are deposits in water as observed TBs, TWs and TSs on tables 3, 4 and 5. The combination of high alkalinity and calcium with low pH levels may be less corrosive than water with a combination of high pH, low alkalinity and calcium content. High pH levels also depress the effectiveness of disinfection by chlorination, thereby requiring the use of additional chlorine or longer contact times (Chandra, Singh, & Tomar, 2012). The pH of most natural water bodies range from 6.5 to 8.5 while the deviation from neutral pH is as a result of free carbon dioxide or bicarbonate in the water body (Edet, Etim, &Titus, 2012).

In natural water, dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron and manganese (Chandra, Singh, & Tomar, 2012). They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. Total dissolved solids (TDS) in borehole water samples analysed were within the recommended standards for drinking water. TDS in drinking water has also been associated with natural source, sewage, industrial wastewater, urban run-off and chemical used in water treatment process (Asuquo& Etim, 2012b). Hardness is a measure of the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. The principal hardness causing ions are Calcium, Magnesium Bicarbonate, Carbonate, Chloride and Sulphate (Asuquo &Etim, 2012a). The total hardness values of the present study were found to be 88.3%, 94.5% and 87.3% for the entire bore hole water, well water and stream water samples analysed respectively, that showed that they are poor water quality or having high hardness which can be as result of nearness to hill.

Magnesium is often associated with calcium in all kinds of water. Magnesium is essential for chlorophyll growth and acts as a limiting factor for the growth of phytoplankton. Therefore, depletion of magnesium reduces the number of phytoplankton's population (Chandra, Singh & Tomar, 2012). The quantities of Calcium in natural water depend upon the type of rocks. Small concentration of calcium is beneficial in reducing the corrosion in water pipes. Magnesium hardness particularly associated with sulphate ion has laxative effect on persons unaccustomed to it. In the present study, Calcium and Magnesium contents are with within the recommended standards. Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Dissolved Oxygen (DO) is an important parameter which is essential to the metabolism of all aquatic organisms that posses aerobic respiration (Wetzel, 2001). Presence of DO in water may be due to direct diffusion from air and photosynthetic activity of autotrophs (Shanthi, Ramasamy, &Lashmanperumalsamy, 2002). Oxygen can be rapidly removed from the waters by discharge of oxygen demanding wastes (Chandaluri, et al, 2010). The values of DO obtained in this study are within the recommended standards except for some samples of stream water analysed.

The biochemical oxygen demand, abbreviated as BOD, is a test for measuring the amount of biodegradable organic material present in a sample of water. The results are expressed in term of mg/L of BOD which microorganisms, principally bacteria will consume while degrading these materials. Biochemical oxygen demand (BOD) is the parameter used to assess the pollution of surface water and ground water (Asuquo, &Etim, 2012b). The values obtained for BOD in this study are within the recommended standards for bore hole water and well water while stream water its BOD is not recommended. Electrical conductivity (EC) is the measure of the ability of an aqueous solution to convey an electric current. This ability depends upon the presence of ions, their total concentration, mobility, valence and temperature. The EC values recorded in this study for bore hole water and stream water were within not the recommended standards, while water from well was within the recommended standard

Sulphate cannot readily be removed from drinking water, except by expensive process such as distillation, reverse osmosis or electrodialysis. The concentrations of sulphate in all the samples analysed in this study ranged from 0.01 to 17.00 mg/L. Diarrhea can be induced at sulphate levels greater than 500 mg/L but typically near 750 mg/L. While sulphate imparts a slightly milder taste to drinking water than chloride, no significant taste effects are detected below 300 mg/L (Etim, et al, 2013). Nitrate concentration depends on the activity of nitrifying bacteria which in turn get influenced by presence of dissolved oxygen. In the present study the values of nitrate obtained were within the recommended standards for the entire water samples analysed. Nitrate is the most important nutrients in an ecosystem (Chandaluri, et al, 2010). Generally water bodies polluted by organic matter exhibit higher values of nitrate.

Excess of chloride in inland water is usually taken as index of pollution. The salts of sodium, potassium and calcium contribute chlorides in water. Large contents of chloride in freshwater is an indicator of pollution (Chandra, Singh & Tomar, 2012). The sewage water and industrial effluent are rich in high chloride and hence the discharge of these wastes result in high chloride level in fresh water. SMCL (Secondary Maximum Contaminant Limit.) of 250 mg/L for chloride is the level above which the taste of the water may become objectionable to the consumer. In addition to the adverse taste effects, high chloride concentration levels in the water contribute to the deterioration of domestic plumbing, water heaters and municipal water works equipment. High chloride concentrations in the water may also be associated with the presence of sodium in drinking water. In the present study, the values of chloride obtained were within the recommended standards for the entire water samples analysed.

Table 3: Water Quality Index for Borehole Water Samples in Hong Metropolitan, Adamawa State

S/N	Parameters	DB1	DB2	DB3	TB1	TB2	TB3	KB1	KB2	KB3	Standard	WQS %
1	PH	7.0	7.6	7.5	7.2	8.9	8.1	6.8	7.6	7.4	6.5 – 8.5	8
2	$D.O_{mg/L}$	8.0	55	6.2	8.0	5.8	7.2	7.5	6.4	5.3	5	34
3	$E.C_{ppm}$	70	70	60	90	70	70	50	50	70	30	123

S/N	Parameters	DB1	DB 2	DB 3	TB1	TB 2	TB 3	KB1	KB 2	KB 3	Standard	WQS %
4	TDS$_{ppm}$	80.9	74.5	30.2	29.5	98.3	29.1	168	90.1	29.9	500	26
5	TEMP^{0}C	30.0	30.7	88	29.5	28.6	66	25.8	29.7	86		24
6	Total Hardness$_{ppm}$	88	86	48	68	64	38	88	86	48	500	88.3
7	Calcium$_{ppm}$	50	46	40	28	60	28	68	56	38	75	38.7
8	Magnesium$_{ppm}$	38	40	0.50	40	4	0.39	20	30	3.98	50	74.8
9	Turbidity$_{NTU}$	-0.65	0.34	3.3	-1.17	0.56	3.4	-0.65	0.84	1.4		
10	BOD$_{mg/L}$	1.5	2.0	3.3	1.7	3.2	3.4	1.5	1.8	1.4	5	46

KEY: DB= Dulbuni borehole, TB= Thabu borehole, WQS= water quality status,

Table 4: Water Quality Index for Well Water Samples in Hong Metropolitan, Adamawa State

S/N	Parameters	DW 1	DW 2	DW 3	TW 1	TW 2	TW 3	KW 1	KW 2	KW 3	Standard	WQS %
1	PH	6.8	7.0	7.5	7.5	8.2	7.9	7.5	8.0	7.7	6.5 – 8.5	9
2	D.O$_{mg/L}$	8.0	7.3	5.8	5.1	5.1	5.3	7.5	7.6	5.2	5	26
3	E.C$_{ppm}$	40	30	20	45	80	50	33	35	90	30	56.7
4	TDS$_{ppm}$	66.2	32.0	27.3	52.0	50.0	28.3	33.1	36	27.9	500	92.2
5	TEMP^{0}C	29.2	27.9	0.00	26.2	28.2	66	25.2	26.5	8		7.3
6	Total Hardness$_{ppm}$	0.00	0.00	0.00	62	60	42	8	0.00	-	500	94.6
7	Calcium$_{ppm}$	0.00	0.00	0.00	220	40	24	8	0.00	-	75	46.1
8	Magnesium$_{ppm}$	-	0.00	19	-	20	0.51	-	0.00	1.29	50	77.2
9	Turbidity$_{NTU}$	10.63	14.2	1.2	-0.45	0.46	4.7	-0.72	0.38	1.7		
10	BOD$_{mg/L}$	2.0	2.8		4.2	1.9		3	1.9		5	64

KEY: DB= dulbuni well, TB= thabu well, WQS= water quality status,

Table 5: Water Quality Index for Stream Water Samples in Hong Metropolitan, Adamawa State

Parameters	DS1	DS2	DS3	TS1	TS2	TS3	KS1	KS2	KS3	Standard	WQS %
PH	7.1	8.9	8.5	7.7	8.5	7.0	7.3	8.9	8.2	6.5 – 8.5	6.7
D.O$_{mg/L}$	7.6	7.8	5.0	8.4	4.4	10.4	7.6	5.3	9.1	5	26
E.C$_{ppm}$	30	20	10	70	60	50	90	100	80	30	89
TDS$_{ppm}$	33.6	20.9	25.9	70.9	69.3	27.7	98.7	107	24.6	500	89.4
TEMP^{0}C	33.0	26.7	80	27.9	30	80	31.1	25.6	80	-	24.3
Total Hardness$_{ppm}$	80	60	50	80	29	63	80	48	80	500	87.3
Calcium$_{ppm}$	53	38	30	80	1.9	25	80	40	-	75	54
Magnesium$_{ppm}$	27	32	21.5	-	10	54.0	-	8	1.27	50	78.2
Turbidity$_{NTU}$	25.3	7.3	1.4	1.37	0.91	7.1	1.67	1.36	5.4	-	
BOD$_{mg/L}$	1.7	2.9		1.2	1.8		1.6	1.4		5	76

KEY: DB= Dulbuni Stream, TB= Thabu Stream, WQS= Water Quality Status,

Sulphate cannot readily be removed from drinking water, except by expensive process such as distillation, reverse osmosis or electrodialysis. The concentrations of sulphate in all the samples analysed in this study ranged from 0.01 to 17.00 mg/L. Diarrhea can be induced at sulphate levels greater than 500 mg/L but typically near 750 mg/L. While sulphate imparts a slightly milder taste to drinking water than chloride, no significant taste effects are detected below 300 mg/L (Etim, et al, 2013). Nitrate concentration depends on the activity of nitrifying bacteria which in turn get influenced by presence of dissolved oxygen. In the present study the values of nitrate obtained were within the recommended standards for the entire water samples analysed. Nitrate is the most important nutrients in an ecosystem (Chandaluri, et al, 2010). Generally water bodies polluted by organic matter exhibit higher values of nitrate.

Excess of chloride in inland water is usually taken as index of pollution. The salts of sodium, potassium and calcium contribute chlorides in water. Large contents of chloride in freshwater is an indicator of pollution (Chandra, Singh & Tomar, 2012). The sewage water and industrial effluent are rich in high chloride and hence the discharge of these wastes result in high chloride level in fresh water. SMCL (Secondary Maximum Contaminant Limit.) of 250 mg/L for chloride is the level above which the taste of the water may become objectionable to the consumer. In addition to the adverse taste effects, high chloride concentration levels in the water contribute to the deterioration of domestic plumbing, water heaters and municipal water works equipment. High chloride concentrations in the water may also be associated with the presence of sodium in drinking water. In the present study, the values of chloride obtained were within the recommended standards for the entire water samples analysed.

CONCLUSION

Assembling different parameters into one single number leads an easy interpretation of index, thus providing an important tool for management purposes. An index is a useful tool for "communicating water quality information to the public and to legislative decision makers;" it is not "a complex predictive model for technical and scientific application". From the application of water quality index for the determination of the quality of water from different sources in Hong metropolitan, Adamawa state of Nigeria, it is concluded that all the bore hole water and well water samples analysed in this study are fit and suitable for drinking and for other domestic applications, except some few parameters that were not fit while the stream water samples are found unfit and unsuitable for human consumption based on the water quality index standard applied in this study. The source of pollution of these streams as observed at the site includes human activities as defecation, dumping of untreated waste and nearness to hill where some ions deposit and animal feces from the hill. The streams could be free or level of pollution reduced if proper measures are put in place to discourage the users from polluting the water in order to bring about improved health.

Recommendations

In mitigating some of the problems associated the various sources of water in Hong town the following recommendations were proffered in order to make water from the various sources suitable for domestic use:

1. Even though borehole water is considered safe for human consumption and domestic purposes; it is pertinent to ensure that regular water quality tests are conducted after every six months to ensure that water remains safe for use.
2. Community enlightenment should be conducted on the need for proper water handling and storage practices.
3. Since well and stream water are not safe human consumption, it is recommended that such water should be purified by filtration or disinfecting to remove contaminants and pathogens.
4. The community should be enlightened on the risks linked to the consumption of untreated well and stream water.
5. Going by the P^H ranges for borehole water and stream water which fall within the recommended range of 6.50 to 8.50, it is therefore, recommend to be monitored to ensure overall water safety. Other water quality parameters should also be monitored to ensure overall water safety.
6. Since dissolved solids in the water originate from weathering of rocks and soil, it is therefore important that regular water testing for the various dissolved solids are conducted time to time to ensure the water remains safe for consumption.
7. Due to the high total hardness levels of water samples collected in the study area, it is recommended that water softening measures be conducted to reduce the hardness levels. Also regular inspection and maintenance should be conducted.

If the above recommendations are implemented, it will help in mitigating the problems associated with poor water quality in Hong town and its environs.

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