Assessment of the Impact of Solid Waste Disposal on the Portability of Surface Water and Groundwater Using Water Quality Index (WQI) in Kpassa, Nkwanta North District of Ghana

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Abstract
The emergence of the Water Quality Index (WQI) has helped to convey vital water quality information to stakeholders and the general public at certain locations and times based on water quality parameters. The present study was carried out to assess how improper solid waste disposal impacts on the potability of surface and ground water at Kpassa in the Nkwanta North District of the Volta Region in Ghana. Water samples were collected at different locations on the River Kpassa and from boreholes within Kpassa in the Nkwanta North District of Ghana. The quality of the water was assessed by testing various physicochemical parameters such as pH, EC, Total Dissolved Solid (TDS), Total Hardness (TH), Calcium, Magnesium, Nitrate, Sulphate, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD). Apart from turbidity that was observed to be high in the samples during the period of study (indicating the presence of organic matter pollution, domestic effluents and runoffs from agricultural fields), all the other water quality parameters in both surface and groundwater were lower compared to WHO/ICMR/BIS standards. The WQI for the surface water and the borehole water were 56.50 and 94.82 respectively. The study shows that the samples within the study area had poor water quality and therefore unsuitable for drinking and for domestic use. Regular water monitoring should be carried out especially with reference to the microbial analysis to give a better view of the water quality at Kpassa.
Keywords: Kpassa, Index, pollution, agriculture fields, Leachate

1. Background of the study

Water is considered an essential resource that helps to preserve life. About 70% of the surface area of the earth is occupied by water. One major source of water to rivers, streams, lakes, lagoons and even wetlands that helps to support human and aquatic organisms, is rainfall. These days, as a result of technological advancement, groundwater is obtained through mechanized boreholes, pipes and wells.

The importance of water cannot be overemphasized. Water is used for cooking, washing, drinking and for growing crops in irrigation fields. It is estimated that an average adult (53-63kg body weight) requires about 3 litres of water daily to maintain good health (Onweluzo and Akuagbazie, 2010). However, the fast growing population, urbanization, agricultural practices, industrialization, poor sanitation services, unexpected solid waste management, technological development and inappropriate water utilization practices has affected water quality and quantity worldwide (Singh and Kamal, 2014; Murtaza *et al.,* 2017). It is even assumed that clean water supply and sanitation related issues will continue to be core in many parts of the world with one-fifth of the global population lacking access to potable water (UNEP, 2008). In Africa alone, it is estimated that about 25 countries are likely to experience water stress (below 1,700m^3 per capita per year) by 2025 (Oni & Fasakin, 2016). The most vulnerable to this problem are mostly women and children. It is estimated that about 4,000 people die per day and 45,000 children under five years die yearly from diarrhea as a result of poor sanitation and bad drinking water quality (Bartram *et al.,* 2005; Water Aid, 2016). This number is quite phenomenal especially considering the population growth globally. Etim *et al.* (2013) posits that maintaining good water quality may help eradicate water-borne diseases and sanitation related problems

Water contamination occurs in two ways: natural and anthropogenic ways (Barakat *et al*., 2016). Water quality of recent is influenced by a number of factors. These include: mining activities, industrial effluents, sewage and domestic waste discharge, tourism, siltation, dumping of solid waste, encroachment and agricultural fields drainage into surface water bodies during run offs. The solid waste mixes with the liquid which results in the formation of leachate. At a point in time, the leachate diffuses into the soil and alters the physicochemical characteristics of both the surface water and groundwater. In a 2008 study, Vasanthi *et al.* observed that the leachate may contain some heavy metals, trace metals, ammonia and some organic compounds. The disposed solid waste and leachate do not only affect surface water but percolates and contaminates groundwater (Chavan *et al.,* 2014). Abdul-Razak *et al.* (2009) opined that water pollution is localized at the river banks owing to the indiscriminate disposal of untreated faecal matter and garbage, because of lack of adequate sanitary and waste disposal facilities. However, further studies have shown that water contamination leads to poor drinking water quality, loss of water supply, high cleanup cost, high cost of alternative water supply and health related problems (Harshan *et al.,* 2016).

In the present study, Kpassa and its surrounding communities rely on the Kpassa River and few sited boreholes for their water needs. Improper disposal of waste in the township and around the sources of water is one of the major health risk factors identified in the area. Even though there is a waste company responsible for managing the waste generated in the District, there is still low patronage of their services by the townsfolk. Rather, there is improper management of their solid waste, no approved dumping sites, with some individuals still engaging in open defecation. These waste and faecal matter are carried into the river during run offs. This affects and promotes a wide range of bacteria growth and may even negatively impact receiving water bodies and the health of the aquatic ecosystem. Several publications abound in the literature on the occurrences of waste in the water environment (Haseena *et al.,* 2017; Naidoo & Olaniran, 2013; Koopaei & Abdollahi, 2017). Apparently there is paucity of information in Ghana regarding solid waste impact on water quality especially within the eastern corridors of Ghana. Therefore, it is very imperative to examine solid waste impact on water quality at River Kpassa using an appropriate water quality index model.

Many water quality indices such as the Weight Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI) have been proposed and used by several national and international organizations (Tyagi *et al.,* 2013). But the problem is that, many of the indices proposed have many variations and limitations based on number of water quality variables used and are mostly not accepted worldwide (Bordalo *et al.,* 2001). It is therefore advisable to use WQI that is generally accepted worldwide with varying water quality parameters (Tyagi *et al.,* 2013). The emergence of the Water Quality Index (WQI) has helped to convey vital water quality information to the stakeholders and the general public (Harshan *et al.* 2016). The WQI also provides a single number that expresses the overall water quality at certain locations and time based on several water quality parameters (Etim *et al.,* 2013). One other major advantage of WQI is that, it incorporates data from multiple water quality parameters into a mathematical equation that rates the health of water quality with numbers (Singh & Kamal, 2014).

The current study seeks to:

a) Analyse some selected water quality parameters such as PH, Electrical Conductivity, Turbidity, Total Dissolved Solid, Total Hardness, Dissolved Oxygen, Biological Oxygen Demand, sulphate, nitrate, Calcium, magnesium and compare them with other standards.
b) Employ WQI model to assess the water quality of the surface water and groundwater in Kpassa in the Nkwanta North District of Ghana

2. Materials and methods

2.1 Study area

The Nkwanta North District whose District capital is Kpassa is located between latitude 7° 30′W and 8° 45′N and longitude 0° 10′W and 045′E. It has a population of about 64,553 and a surface area of about 1,098.9km^2 (GSS, 2012). The District is part of the tropical climatic zone characterized by a double maxima rainfall. The mean annual rainfall ranges from $922mm$ to $1{,}8700"4mm.$ The District has a number of rivers and streams but the major ones are the Oti River and the Kpassa River. The rivers and their tributaries are characterized by heavy agricultural activities. The widely used method of solid waste disposal is by public dump in the open space and for liquid waste disposal, the waste is thrown into the compound and on the streets. These untreated sewage and solid waste end up in the rivers and their tributaries via run offs.

2.2 Sample collection

Borehole water and river water samples from different locations in Kpassa town were collected. Water samples from the river were taken about 1m below at different locations with a pre-cleaned glass bottle using a hydro-bios sampler (Tongo *et al.* 2017). The glass was treated with dilute HCl and rinsed with distilled water to prevent microbial activities. Before taking the samples at every point, the glass bottles were rinsed with the sample and then filled with the samples. Borehole water samples were also collected at different locations of the town. All the water samples were kept at 4 ºC in ice chest and transported to the Ecological Laboratory (ECOLAB) at the University of Ghana, for analysis. Sampling bottles had appropriate labels on them, and record was made of each bottle.

2.3 Physico-chemical analysis

All the water quality analyses were based on standard methods as prescribed in the APHA *et al.* (1998). The PH uses a PH meter and turbidity with a Nephelometric HACH 2100 P Turbidimeter. Conductivity was measured with Cybersan 510 conductivity meter. Sulphate was obtained by the turbidimetric method and nitrate determined by hydrazine reduction methods. Calcium and magnesium were analyzed using the standard procedure prescribed by APHA (1998). DO and BOD concentrations were obtained using an oximeter and BOD meter respectively.

2.4 Water Quality Index (WQI) model

In this study, twelve (11) water quality parameters were determined from the Kpassa River and the groundwater. But 10 were used for the computation of the Water Quality Index. WQI was computed using the standards of drinking water quality proposed by WHO, Bureau of Indian Standards (BIS) and the Indian Council for Medical Research (ICMR) (Yogendra & Puttaiah, 2008). The weighted method was used in the calculation of the WQI since it determines the effect of solid waste dumping on the immediate ground and surface water bodies based on the prevailing conditions (Oni & Fasakin, 2016). The quality rating index (q_n) was obtained using the model equation: $\mathbf{q_n = 100[Vn - Vio] / [Sn - Vio]}$

(Let there be n water quality parameters and quality rating (qn) corresponding to n^{th} parameter is a number reflecting relative value of this parameter in the polluted water with respect to its standard permissible value) qn = Quality rating for the n^{th} Water quality parameter Vn = Estimated value of the n^{th} parameter at a given water sampling station Sn = Standard permissible value of the n^{th} parameter Vio = Ideal value of nth parameter in pure water *(i.e., 0 for all other parameters except the parameters pH and Dissolve oxygen[7.0 and 14.6 mg/l respectively])*

The unit weight is inversely proportional to the recommended standard value Sn. That is $Wn \propto \frac{1}{Sn}$. Therefore, **Wn = k/Sn** Where Wn= unit weight for n^{th} parameter Sn= standard permissible value for n^{th} parameter and k = proportionality constant. The overall WQI was calculated by the model equation. $\mathbf{WQI = \sum q_n Wn / \sum Wn}$

Table 1: Water Quality Index and water quality status

Water Quality Index level	Water quality status
0 - 25	Excellent water quality
26 - 50	Good water quality
51 - 75	Poor water quality
76 - 100	Very poor water quality
>100	Unsuitable for drinking

Source: (Yogendra & Puttaiah, 2008)

Table 2: Drinking water standards, recommending Agencies and unit weights (All values except PH and electrical conductivity are in mg/l)

Parameters	Standards	Recommended agency	Unit weight
PH	6.5-8.5	ICMR/BIS	0.2190
Elect. conductivity	300	ICMR	0.3710
Total Dissolved Solids	500	ICMR/WHO	0.0055
Total Hardness	300	ICMR/BIS	0.0062
Dissolved Oxygen	5	ICMR/BIS	0.3732
BOD	5	ICMR	0.3732
Nitrate	45	ICMR/BIS	0.0412
Sulphate	150	ICMR/BIS	0.01236
Calcium	75	WHO/ICMR	0.0221
Magnesium	30	BIS/ICMR	0.0332

Source: Yogendra &Puttaiah, 2008; Etim *et al.*, 2013

3. Result and discussion

3.1 Physico-chemicals

Eleven physico-chemical parameters were used for the characterization of the Kpassa surface river and boreholes that are sources of drinking water in the study area. Table 3 and 4 are the descriptive statistics of water quality parameters considered under this study.

Table 3: Descriptive statistics of water quality parameters of River Kpassa

Parameters	Minimum	Maximum	Mean ± SD
PH	**6.46**	**6.59**	**6.54 ± 0.06**
EC (µS/cm)	**23**	**62**	**38.29 ± 12.83**
TDS (mg/l)	**15**	**40**	**25 ± 8.08**
Turbidity (NTU)	**66.5**	**105**	**86.06 ± 14.32**
DO (mg/l)	**5.42**	**9.42**	**7.42 ± 1.53**
BOD (mg/l)	**2.25**	**6.25**	**4.18 ± 1.56**
NO_3-N (mg/l)	**0.1**	**1.2**	**0.40 ± 0.51**
SO_4 (mg/l)	**3**	**6**	**1.2 ± 2.36**
Ca (mg/l)	**0.001**	**26.87**	**14.09 ± 8.42**
Mg (mg/l)	**42.41**	**63.87**	**42.81 ± 20.32**
TH (mg/l)	**0.0041**	**269.97**	**164.90 ± 82.67**

Table 4: Descriptive statistics of water quality parameters of Boreholes in Kpassa

Parameters	Minimum	Maximum	Mean ± SD
PH	**6.14**	**7.13**	**6.70 ± 0.32**
EC (µS/cm)	**22**	**788**	**503 ± 247.45**
TDS (mg/l)	**14**	**504**	**323 ± 157.94**
Turbidity (NTU)	**0.5**	**35.4**	**7.5 ± 13.18**
DO (mg/l)	**4.11**	**8.64**	**7.4 ± 1.59**
BOD (mg/l)	**2.53**	**12.40**	**4.9 ± 3.39**
NO_3-N (mg/l)	**0.2**	**2.3**	**0.79 ± 0.74**
SO_4 (mg/l)	**1.0**	**12**	**4.43 ± 4.43**
Ca (mg/l)	**0.001**	**0.76**	**0.17 ± 0.28**
Mg (mg/l)	**0.001**	**1.14**	**0.16 ± 0.43**
TH (mg/l)	**0.0082**	**5.97**	**1.13 ± 2.19**

The PH for the surface water samples and the ground water samples in the Kpassa at the period of study ranged from 6.46-6.59 and 6.14-7.13 respectively. The PH values were slightly acidic thus indicating corrosiveness in the water. High PH levels in water decreases the effectiveness of disinfection agent such as chlorine (Etim *et al.,* 2013; UNICEF, 2008). The average values of the pH in both waters were within the recommended range 6.0 – 9.0 of Ghanaian standard for drinking water use (WRC, 2003).

Electrical conductivity is directly related to the concentration of dissolved salts, inorganic materials, and carbonated compounds in water. The more the ions that are present in water, the higher the electrical conductivity. The presence of the ions in the water depends largely on the temperature, concentration and the types of ions present (Salifu *et al.,* 2017). The EC values for the borehole samples were above the recommended standards of ICMR of 300µS/cm as shown on table 4. This could be attributed to inorganic substances such as metallic, bicarbonate and chloride ions which were introduced naturally or through domestic effluents and runoff from agricultural fields into the groundwater.

Turbidity in water is caused by the growth of phytoplankton and human induced activities such as construction, mining, agricultural activities, storm water runoff, pollution from dusty roads and industries. Normally in water bodies such as lakes, rivers and reservoirs, high turbidity reduces the attenuation of light thus interfering the growth and photosynthetic activities of aquatic plants. The obscuring of the light may even affect some water species that uses light for their movement. The turbidity values of the samples were above the permissible limits of the Indian Council for Medical Research (ICMR) obtained by Sharma & Chhipa, 2016. This result indicates the presence of organic matter pollution, domestic effluents and runoffs with high suspended materials in the water sources (Yisa and Jimoh, 2010). It is therefore possible that the water may have associated risk of bacterial and viral disease due to the transmission of disease causing agents and other particulate matter (Abdul-Razak *et al.,* 2009).

The major natural sources of hardness in water include dissolved polyvalent metallic ions from sedimentary rocks, seepage and runoff from the soil (Cutruvo, 2011). The rocks mostly contain calcium and magnesium present in hard water. According to Sengupta (2013), hard water provides a supplementary contribution to Calcium and Magnesium intake in human beings and so persistent intake of water containing magnesium salts and sulphate may result in diarrhea and laxative related problems. Urinary concretions, stomach disorder and diseases of kidney or bladder are produced by hardness without any conclusive proof (Saleem *et al.,* 2016). Findings from the research during the period of assessment were virtually below the proposed levels of ICMR/BIS of 300mg/l.

DO is the most important indicator of the health of a water body and its capacity to support a balanced aquatic ecosystem of plants and animals. Wastewater containing organic pollutants and the decomposition of materials in the water, may lead to the depletion of oxygen in the water. Generally, a higher dissolved oxygen level indicates better water quality. When dissolved oxygen levels are too low, some fish and other organisms may not be able to survive. The DO ranged 5.42-9.42mg/l for the Kpassa River was above the optimum level of 5.00mg/l proposed by ICMR. However, the average DO for the Kpassa river water samples of 7.42 ± 1.53mg/l was within the proposed Ghana Raw Water Criteria and Guide- lines for aquaculture use (5.0 - 8.0 mg/l) (Darko *et al.* 2013)

Biochemical Oxygen Demand helps to assess the level of pollution of surface water and the ground water (Etim *et al.,* 2008). BOD is therefore directly influenced by the decomposition of organic materials, nitrogen oxidation and aeration of aquatic plants during photosynthesis (Attua *et al.,* 2014). The BOD level in the ground water and the surface river water at the time of study ranged 2.53-12.40mg/l and 2.25-6.25mg/l respectively. This may probably be due to discharge of organic wastes (refuse, human and animal excreta, soap) into the water, resulting in the uptake of oxygen in the oxidative breakdown of these wastes (Abdul-Razak *et al.,* 2009). BOD level in the surface water indicates that the river is becoming eutrophic. When BOD level is high, it decreases the DO level because bacterial decomposition in the water environment, uses oxygen in the water thus reducing its level.

When nitrogen fertilizers are used to enrich soils, nitrates may be carried by rain, irrigation and other surface waters through the soil into ground water. Nitrate-N concentration depends on the activity of nitrifying bacteria which in turn get influenced by presence of dissolved oxygen (Etim *et al.,* 2008). High nitrate levels in water indicate the possible presence of other contaminants such as disease-causing organisms, pesticides, or other inorganic and organic compounds that causes health problems (Akpor & Muchie, 2011). High intake of nitrate elevated levels in water affects cardiovascular system, nervous system and also produces gastric cancer (Saleem *et al*., 2016). The average concentration of NO_3^- in the borehole water samples (0.79 ± 0.74mg/l) was higher than that of the surface water of 0.40 ± 0.51mg/l in this study. This indicates that nitrate concentration were due to the leaching from agricultural land. All of the nitrates results from the samples were well below the level of 45 mg/l, qualifying the water quality as good. The sulphate values at all locations were found to be below the allowable limits being prescribed in (WHO, 2012) for drinking water and ICMR as shown on table 2.

Calcium is naturally present in water. It may dissolve from rocks such as limestone, marble, and calcite. Calcium is a dietary requirement for all organisms apart from some insects and bacteria. Calcium phosphate is required for bone structure and teeth structure of terrestrial organisms. Less intake of calcium is associated increased risk of nephrolithiasis, osteoporosis, hypertension, colorectal cancer and coronary artery diseases obesity and insulin resistance (Saleem *et al.,* 2016). However, the calcium values at all locations were found to be below the permissible limits being prescribed by WHO as indicated on table 2.

3.2 Water quality index analysis (WQI)

Table 5: Water Quality Index for groundwater (Boreholes) samples from Kpassa

Parameters	Observed values	Standard values (Sn)	Unit weight (Wn)	Quality rating q_n	Wnq_n
pH	6.7	6.5 – 8.5	0.2190	60.00	13.140
EC	503	300	0.371	167.67	62.206
TDS	323	500	0.0055	64.60	0.355
DO	7.3	5.00	0.3732	76.04	28.378
BOD	4.9	5.00	0.3732	98.00	36.574
NO_3-N	0.7	45	0.0412	1.56	0.064
SO_4	4.4	150	0.01236	2.93	0.036
Ca	0.175	75	0.0221	0.23	0.005
Mg	0.164	30	0.0610	0.55	0.034
TH	1.129	300	0.0062	0.38	0.002
TOTAL			$\Sigma Wn = 1.4848$	ΣWnq_n=**140.794**	

Water Quality Index (WQI) for the borehole water samples $= \Sigma Wnq_n / \Sigma Wn = 140.794 / 1.4848$

Water Quality Index (WQI) for the borehole water samples = **94.82**

Table 6: Water Quality Index for surface water (River) samples from Kpassa

Parameters	Observed values	Standard values (Sn)	Unit weight (Wn)	Quality rating q_n	Wnq_n
pH	6.5	6.5- 8.5	0.2190	33.33	7.299
EC	38	300	0.3710	12.67	4.701
TDS	25	500	0.0055	5.00	0.028
DO	7.00	5.0	0.3732	79.17	29.546
BOD	4.18	5.0	0.3732	83.60	31.200
NO_3-N	0.4	45	0.0412	0.89	0.037
SO_4	1.3	150	0.01236	0.87	0.011
Ca	14	75	0.0221	18.67	0.412
Mg	50	30	0.0610	166.67	10.320
TH	165	300	0.0062	55.00	0.341
TOTAL			$\Sigma Wn = 1.4848$	ΣWnq_n=83.889	

Water Quality Index (WQI) for the river water samples = $\Sigma Wnqn / \Sigma Wn = 83.889/1.4848$
Water Quality Index (WQI) for the river water samples = **56.50**

The Water Quality Index for both the surface water and the ground water in the study area were computed and the result is shown on tables 5 and 6. Water quality index (WQI) was used to assess water quality relative to the standard for domestic use and to provide insight into the degree to which water quality is affected by human activity (Abdul-Razak *et al.,* 2009). From the application of the Water Quality Index for the determination of the portability of the surface and groundwater in the Kpassa, Nkwanta North District of Ghana, the water quality indices for the river water and the borehole samples were 56.50 and 94.82 respectively. The findings therefore indicate that the surface and groundwater have a poor water quality and therefore unsuitable for drinking and domestic purposes.

4. Conclusion and recommendation

The results suggest that the concentrations of the total dissolved solids, total hardness, nitrate-nitrogen, dissolved oxygen, biological oxygen demand, sulphate, calcium and manganese were lower in both the surface and groundwater compared to the WHO/ICMR/BIS standards. Turbidity was observed to be high in the samples during the period of study. This may be an indication that the river and the borehole water samples had poor quality during the period of study and therefore may be unsuitable for drinking and domestic use.
Regular water monitoring should be carried out especially with reference to the microbial analysis to give a better view of the water quality in Kpassa

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