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Full Length Research Paper

Microbiological quality of water collected from boreholes sited near refuse dumpsites in Port Harcourt, Nigeria

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This study assessed and compared the water quality of six selected bore holes used around dumpsite and non-dumpsite areas in Obio-Akpor and Ikwerre Local Government Areas, Port Harcourt. Water quality monitoring and analyses of the bio-physico-chemical variables (pH, total suspended solids (TSS), total dissolved solids (TDS), colour, total coliform, faecal coliforms and some water borne pathogens) were carried out on the water samples collected from the six boreholes. Results showed a total heterotrophic bacterial count ranging from 3.7 x 10^5 to 6.6 x 10^5 cfu/ml and 3.1 x 10^5 to 4.4 x 10^5 cfu/ml for near dumpsite and non-dumpsite borehole water samples, respectively, while the total coliform count ranged from 47 to 1,100 most probable number (MPN)/100 ml and 43 to 210 MPN/100 ml for near dumpsite and non-dumpsite samples, respectively. The borehole water samples from both study areas had high counts of faecal coliforms (*Escherichia coli*), and pathogens (*Salmonella, Shigella* and *Vibrio* spp.) were detected in high numbers in the water samples near dumpsite. Colour, pH, TDS and TSS concentrations in the near dumpsite samples were significantly different when compared to non-dumpsite water samples. Continuous water quality monitoring is encouraged to effectively analyze the impact of dumpsites on the environment and human health.

Key words: Dumpsites, non-dumpsites, heterotrophic bacteria, coliform pollution, boreholes.

INTRODUCTION

Waste generation by man started since the beginning of civilization as a consequence of human activities, involving the production of goods and services and the consumption of natural sources. Dumpsite is a piece of land where waste materials are dumped. Waste materials could be garbage dump, rubbish dump, waste yard, toxic waste and domestic refuse (United Nations, 1992).

Port Harcourt city has many industries working at various industrial estates. These industries generate large quantities of municipal solid wastes per day but unfortunately, there is no treatment and disposal facility for the management of the wastes from these areas. These wastes are disposed in a disorganized manner, at several dumpsites within the streets. The major danger associated with drinking water sources is the possibility of its recent contamination by sewage or human and animal excreta (Pipes, 1981). Another problem is sitting of drinking water system (wells and boreholes) near a refuse dumpsite or landfill. Water is essential to sustain life and a satisfactory supply of drinking water must be made available to all consumers (WHO, 2006). Recently, epidemics of cholera have been reported from different parts of India, Nigeria and Zimbabwe. The outbreak was caused by *Vibrio cholera* 01 isolated from municipal taps and wells (Sur et al., 2006). Outbreaks of typhoid fevers and dysentery were linked to unsanitary mixing of some water supplies and sewage. It has been reported by WHO (2003) that 80% of sicknesses and deaths among children in the world are caused by unsafe drinking water. On the average, every 8 s in the world, a child dies of

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contaminated water. The use of normal intestinal organisms as indicators of fecal pollution is universally accepted for monitoring and assessing the microbiological safety of water supplies (Dissanayake et al., 2004).

Coliform bacteria are a group of intestinal bacteria used as indicators to determine if treated water is acceptable for human consumption. Coliforms will not likely cause illnesses. However, the presence of coliforms in drinking indicates the presence of disease-causing organisms (Nwachukwu and Otokunefor, 2006).

Groundwater has been naturally very clean because of its filtering effect; however it can become polluted with nutrients and toxic chemicals when surface water carrying these substances drains into the groundwater environment (USEPA, 2001). A ground water aquifer may be as little as 30 m from the surface or as much as 300 m. Although, it costs more to pump water from deeper aquifer, the water quality in deeper ones are better than the shallow ones since contaminants which the water may be carrying are removed as the water moves through the rock (USEPA, 2001). It is essential that water be examined regularly and frequently as contamination may be intermittent and may not be detected by simple tests. This study work was therefore designed to assess and compare the biological variables (total coliforms, faecal coliforms, *Vibrio, Salmonella* and *Shigella* spp.) and physico-chemical variables (total dissolved solids (TDS), total suspended solids (TSS), colour and pH) in water samples from bore holes located at varying distances from a dumpsite and those from non-dumpsite areas in Obio-Akpor and Ikwerre Local Government Areas, Port Harcourt.

MATERIALS AND METHODS

Study areas and sampling procedures

Water samples were collected from six private boreholes. Three samples (A, B and C) were from boreholes located near dumpsites, and the other three samples (D, E and F) were from boreholes located in non-dumpsite areas in Obio-Akpor and Ikwerre Local Government Areas, Port Harcourt. The near dumpsite boreholes are located along East-west road in Obio-Akpor LGA, while the non-dumpsites boreholes are located along Ikwerre road in Ikwerre LGA. Bore hole A was sited 20 m from the dumpsite, borehole B was 25 m from the dumpsites, while borehole C was 10 m from the dumpsites. The depth of boreholes near dumpsite was 50 m from the surface, while depth of boreholes from non-dumpsite areas was 75 m from the surface.

To obtain the water samples, the nozzle of each of the boreholes was sterilized with cotton wool soaked in acetone-alcohol. The tap was turned on and allowed to run for two minutes after which, sterilized containers were carefullyuncapped and held under the running tap. The samples were immediately taken to the laboratory for analysis. This study was carried out between the month of April and August, 2008 at the Department of Microbiology major laboratory, University of Port Harcourt. A total of 12 water samples were collected during the study period.

Isolation of total culturable heterotrophic bacteria

The spread plate method was used. Ten-fold serial dilution of each water sample was prepared aseptically in sterile physiological saline up to 10^{-3} and 0.1 ml aliquot of each dilution was plated on dried nutrient agar plates in triplicate. All incubations were conducted at 35°C for 24 h under aerobic conditions and plates containing 30 to 300 colonies were selected and counted. The number of colony-forming units per ml (cfu/ml) was calculated by multiplying the number of colonies by the dilution factor.

Enumeration of total coliforms/faecal coliforms

The multiple tube fermentation method also known as the most probable number (MPN) was used to obtain the total coliforms and test was performed using three test tube sets to enumerate faecal coliform. All positive tubes from the MPN procedures were subcultured on Levine's EMB agar plates in triplicate and incubated at 35°C for 24 ± 2 h.

Isolation of *Salmonella/Shigella* species

The *Salmonella*/*Shigella* agar (SSA) was prepared according to the manufacturer's direction and 0.1 ml aliquot of each water sample was transferred onto the surface of the dried sterilized SSA plates. The plates were inoculated in triplicate and incubated at 37°C for 24 to 48 h. Thereafter, pure cultures were obtained by sub-culturing onto freshly prepared SSA plates and pure colonies were identified using biochemical reactions.

Isolation of *Vibrio* species

The thiosulphate citrate bile salt (TCBS) agar was prepared and poured into sterilized Petri dishes. It was allowed to solidify, after which, 0.1 ml of each water sample was transferred onto the dried agar plates in triplicate using a 1 ml pipette and spread evenly with a sterile hockey stick. It was incubated at 35°C for 24 to 48 h. After incubation, yellow colonies were counted and thereafter identified using biochemical reactions.

Identification of isolates

The cultural, morphological and biochemical characteristics of the respective isolates were compared with the criteria in Bergey's manual of Determinative Bacteriology (1994). The biochemical tests used in the identification and characterization of the isolates include: gram staining, motility, indole production, methyl red-voges Proskauer, citrate utilization, oxidase, catalase, coagulase and sugar fermentation tests.

Physico-chemical analyses

The water samples from each borehole near dumpsite and non-dumpsite areas were examined in terms of physical and chemical contents using the standard procedures of the American Public Health Association, (APHA), American Water Works Association (AWWA) and Water Environmental Foundation (WEF). The variables examined included pH using Model 27mk Pye unicam,

Table 1. Genera of microorganisms isolated from the borehole water samples (A to F) near dumpsite and non-dumpsite.

Isolate	Occurrence (n = 21)	Frequency of occurrence (%)
Shigella	5	23. 81
Escherichia	3	14. 29
Salmonella	3	14. 29
Enterobacter	2	9.52
Vibrio	2	9.52
Pseudomonas	2	9.52
Proteus	2	9.52
Staphylococcus	1	4.76
Bacillus	1	4.76

total suspended solids (TSS) using gravimetric determination, colour determination using HACH spectrophotometer (HACH company, Loveland colorando, USA) and total dissolved solids (TDS) using TDS-meter (HACH Company).

Statistical analysis

Analysis of variance (ANOVA) and Tukey's multiple comparison tests were used to compare the values of The heterotrophic bacterial (THB), total coliform and faecal coliform count between borehole water samples from near dumpsite and non-dumpsite areas. The result of the physicochemical analysis of the borehole water samples were compared using the same method. In this statistical analysis, if the p value is <0.05, the test is not significant but if p value is >0.05, then there is a significant different between the variables compared.

RESULTS

Nine genera of microorganisms (or bacteria) were identified (Table 1) from a total of 21 isolates. These genera include: *Shigella, Esherichia, Salmonella, Vibrio, Enterobacter, Pseudomonas, Proteus, Staphylococus* and *Bacillus*. Out of the nine genera, *Shigella* sp. had the highest percentage frequency of occurrence (23.81%) followed by *Esherichia* and *Salmonella* (14.29%), then *Enterobacter* and *Vibrio* (9.52%). Table 2 shows the result of the microbiological analysis of the borehole water samples from near dumpsite and non-dumpsite areas. THB count for boreholes near dumpsites ranged from 3.7×10^5 to 6.6×10^5 cfu/ml, while boreholes in non-dumpsite areas had THB counts that ranged from 3.1×10^5 to 4.4×10^5 cfu/ml for non dumpsite borehole water samples. Coliforms which are indicators of pollutions in drinking water ranged from 47 to 1,100 MPN/100 ml for near dumpsite samples and from 43 to 210 MPN/100 ml for non-dumpsite samples. Faecal coliform counts ranged from 2.5×10^2 to 4.5×10^2 cfu/ml for near dumpsite samples and 2.1×10^2 to 3.5×10^2 cfu/ml for non-dumpsite water samples. There were high counts of *Salmonella, Shigella and Vibrio* species in only the near dumpsite water samples as shown in Table 2

The physico-chemical assessment results as shown in Table 3 showed that water samples from near dumpsite had mean concentrations that were high in TDS, TSS and colour, and were acidic as compared to non-dumpsite water samples.

DISCUSSION

The WHO standard for heterotrophic bacteria in potable water supplies states that the total heterotrophic bacterial count should not be more than 100 cfu/ml (WHO, 1986a). Based on the WHO standards, the borehole water samples from near dumpsite and non dumpsite areas are unacceptable for human consumption because of their high bacterial loads. According to US EPA standards, water samples in which coliforms are detected should be considered unacceptable for drinking water as they are regarded as the principal indicators of water pollution. The WHO standards for total and faecal coliforms are 1 to 10/100 ml and 0/100 ml, respectively (USEPA, 1976; WHO, 1982, 2003). The results in Table 1 revealed that all the water samples from both areas had very high counts of total and faecal coliforms. According to one way analysis of variance conducted on the results, there was no significant difference on the THB, total and faecal coliforms from both study areas at $P<0.05$. Furthermore, high counts of *Shigella* sp., *Salmonella* sp. and *Vibrio* sp. were detected in some water samples from near dumpsite areas. The high count of these pathogenic bacteria in the water sources could be due to any of the following: improper disposal of sewage and wastewater from domestic activities, discharges from septic tanks and latrines close to some of the bore holes, inappropriate siting of boreholes very close to dumpsites and extraction of ground water from very shallow aquifers. This is in agreement with the work of Nwachukwu and Otokunefor (2006) which also stated a correlation between high bacterial load in borehole water supplies and discharges from septic tanks and waste materials from a nearby dumpsite.

Nine genera of microorganisms were identified (Table 1) from a total of 21 Isolates. These genera include: *Shigella, Esherichia, Salmonella, Vibrio, Enterobacter, Pseudomonas, Proteus, Staphylococus* and *Bacillus*. Out of the nine genera, *Shigella* sp. had the highest percentage frequency of occurrence (23.81%) followed by *Esherichia* and *Salmonella* (14.29%), then *Enterobacter* and *Vibrio* (9.52%). These Isolates with high frequency of occurrence are important human pathogens associated with a variety of infectious diseases such as gastroenteritis, typhoid fever, dysentery, cholera, urinary tract infection, etc (Orji et al., 2006). The high number of these pathogens in the water samples from both study areas needs public health attention. The high

Table 2. Microbiological analysis of the borehole water samples (A-F).

Water sample	THB (cfu/ml)	Total coliform (MPN/100ml)	Faecal coliform (cfu/ml)	*Vibrio* sp. (cfu/ml)	*Shigella* sp. (cfu/ml)	*Salmonella* sp. (cfu/ml)
A	5.6×10^5	240	3.8×10^2	2.5×10^2	3.2×10^2	3.5×10^2
B	3.7×10^5	47	2.5×10^2	-	3.2×10^2	-
C	6.6×10^5	1100	4.5×10^2	3.5×10^2	6.7×10^2	3.9×10^2
D	3.1×10^5	120	2.8×10^2	-	-	-
E	4.4×10^5	210	3.5×10^2	-	-	-
F	3.3×10^5	43	2.1×10^2	-	-	-

Table 3. Mean concentrations of water quality variables in near dumpsite and non-dumpsite water samples.

Parameter	Normal standard	A	B	C
Near dumpsite water samples				
TDS (mg L^{-1})	1000	1333.73	1200.30	1606.67
TSS (mgL^{-1})	50	1723.77	1494.07	1837.07
pH	6.5-7.0	4.83	4.87	4.49
Colour		63.84	49.64	74.57
Non-dumpsite water samples		**D**	**E**	**F**
TDS(mgL-1)	1000	362.13	377.20	389.78
TSS(mgL-1)	50	450.00	458.56	470.15
pH	6.5-7.0	6.38	6.84	5.67
Colour		51.14	54.80	60.75

prevalence pathogens in this study are in agreement with the findings of Kumarasamy et al. (2009) on enumeration and identification of pathogenic pollution indicators in Cauvery river in south India. This study revealed the presence of high level of bacterial pollution indicators and pathogenic bacterial groups such as *Salmonella* sp., *Shigella* sp. and *Streotococcus faecalis* in the Cauvery river which was as a result of high anthropogenic activities on the river. Nguendo-Tongsi (2011) in his studies highlighted the presence of coliforms, faecal coliforms and pathogens (*Esherichia coli, Streptococcus* and *Pseudomonas, Salmonella*) in large numbers which was attributed to the emanation of these species from some sources such as seepages from septic tanks into household drinking water supply, unhealthier latrine systems which have exceeded their expected life span or post treatment contamination along the distribution line. The presence of these indicator organisms in drinking water sources may provide an indication of water-borne problems and is a direct threat to human health and is a matter of serious concern.

The three boreholes (A, B and C) from the near dumpsite area were located at a short distance of 20, 25 and 10 m from the dumpsites, respectively and had depth of 50 m from the surface. The siting of these boreholes close to the dumpsites and their shallow depth from the surface could possibly contribute to the very high bacterial loads detected in these drinking water sources. However, the boreholes from the non-dumpsite areas were not extracted from very deep aquifer. They have a depth of 75 m from the surface which could also contribute to their high bacteria contamination from faecal and domestic wastes that leach into the shallow water table.

The physico-chemical analyses conducted showed that borehole water samples from near dumpsites were acidic and had mean concentrations that were higher in TDS, TSS and colour than non-dumpsite borehole samples.

According to the one way ANOVA, significant differences were noted for TDS and TSS in the boreholes from near dumpsite and non-dumpsite areas at ≥0.05. The high mean values of TDS and TSS in near dumpsite samples were perhaps due to the leaching of contaminants from the dumpsite toward the groundwater source or the presence of high dissolved mineral matter (Townsend, 2002). Siasu (2008) likewise in his work on the effect of a dumpsite to groundwater quality in Philippines, reported that the high mean values of TSS and TDS were perhaps due to the leaching of contaminants from the dumpsites towards the groundwater source.

These results likewise showed higher colour concentrations in the near dumpsite samples than those in

the non-dumpsite area. This is also in agreement with the work by Siasu (2008) who reported that the higher colour concentrations in the near dumpsite area could probably be due to the input of domestic sewage, coloured organic matter (humic substances), metals, coloured industrial wastes or the presence of inorganic particulate matter that leach into the shallow ground water source or broken underground distribution pipes. There were no significant difference in the colour concentrations in both study areas according to the statistical analysis at $P<0.05$.

The low pH level obtained in the near dumpsite water samples may be traced to the acidity produced by organic wastes decomposing under partial reducing condition into organic acids (Richardson, 1991).

In conclusion, this study assessed and compared the quality of boreholes used as drinking water supplies sited near dumpsites and non-dumpsite areas in Obio-Akpor and Ikwerre LGA in Port Harcourt. No significant differences were observed in terms of total heterotrophic count, total coliform, faecal coliform and colour between the near dumpsite and non-dumpsite samples. Results of the water quality analyses reveals that most of the parameters analysed in the water samples from both areas were not within the acceptable water quality standards and therefore indicate the existence of pollution in these drinking water sources from both study areas. Continuous water quality monitoring in both dumpsite and non-dumpsite areas is encouraged. Increasing the frequency of sampling and analysis is also needed to effectively monitor the impact of dumpsites, particularly on environment and human health.

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