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Research paper

The impact of pit latrines on groundwater quality in Foko-slum, Ibadan, Southwestern Nigeria.

Abstract

A study was conducted to determine the impact of pit latrines (privies) on groundwater quality in Foko slum, Southwestern Nigeria. Ten shallow wells were assessed within the slum with respect to their distance from privies. Water samples were collected from the shallow wells and analyzed. Parameters analyzed were total and faecal coliforms, alkalinity, total dissolved solids (TDS), total suspended solids (TSS), nitrates, electrical conductivity, turbidity and pH. Results show that the physico-chemical parameters of the water samples were within the World Health Organization (WHO) guidelines for drinking water quality. However, the microbiological parameters had elevated values indicating faecal contamination and the presence of disease pathogens in the water. The faecal coliform (FC) data were regressed with distance between the privies and the wells. The resulting equation was evaluated to obtain a minimum lateral distance of 20m between a privy and shallow well for zero value of microbiological parameters in Foko.

Keywords: contamination; water quality; privies; shallow wells; urban slums.

Introduction

Adequate supply of safe drinking water is universally recognized as a basic human need and one of the most essential factors of civilisation. Because water is a non-renewable natural resource, it should be conserved and preserved. It is on this premise that developed nations have continually been monitoring and classifying water in relation to quality. Millions of people in unplanned environments such as slums in developing countries do not have access to adequate and safe water supply. The number is rising greatly as a result of rapid growth in population, much of which is occurring in peri-urban and rural areas. The United Nations projected a rapid population growth in the urban areas between 2000 and 2030, indicating that access to safe drinking water and adequate sanitation in urban areas is likely to worsen (Dzwaizo et al. 2006). In Nigeria, rapid growth and

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economic degradation has resulted in an increase in the number of people living in abject poverty in informal settlements with serious consequences on the environmental health resources. Slums do not enjoy government services such as potable water supply, sewage and waste collection and disposal systems. Consequently, informal settlements are characterized by poor environmental and sanitary conditions that expose the inhabitants to poor health conditions. It is public knowledge that children of poor families exhibit poor health conditions than those of the rich in the urban or developed areas. Recent survey by Majuru et al. (2011) estimated that 65 million Nigerians had no access to safe water. The situation is worse in the rural areas where only 24% of the population have access to potable water. Provision of clean, reliable and potable water in rural areas and urban slums remains therefore a challenge considering the fact that larger percentage of the population live in the areas. When provision of clean water is inadequate, people are compelled to use contaminated water that later result into outbreak of water related diseases (Schafer et al. 2009).

Faeces and urine as well as poor personal and domestic hygiene have been identified as major factors that spread many water-borne diseases including cholera, typhoid, hepatitis, polio, cryptosporidiosis, ascariasis, and schistosomiasis. Pit latrines belong to on-plot sanitation systems that dispose of human excreta without treatment. The use of pit latrines naturally raises concern about pollution of groundwater and especially shallow wells sited within the plot which are being used as source of drinking water. In such a situation, the use of pit latrines or privies is not recommended unless the water table is extremely low and soil characteristics are not likely to contribute to susceptibility of groundwater to pollution. According to Cave and Kolsky (1999), the key factor that affects the removal and elimination of pathogenic organisms from groundwater is the maximization of the effluent residence time between the source of contamination and the point of water abstraction. Because of the very low velocities of unsaturated flow, the unsaturated zone holds the key to the defence against faecal pollution of aquifers. Although it is difficult to give a general rule for all soil conditions, the commonly used guideline is that the well should be located in an area topographically higher than the privy site and at least 15m away from the privy and it should be at least 2m above the

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water table (WHO/UNICEF, 2000; Dzwaizo et al.2006). As reported by Cave and Kolsky (1999), such criteria may not guarantee groundwater protection as it may not apply in all areas and soil conditions. According to Hunter *et al*. (2009) increased lateral separation between the source of pollution and groundwater supply reduces the risk of faecal pollution. Kimani and Ngindu (2007) opined that the coexistence of on-site sanitation and shallow wells has in the past been mainly confined to the rural areas where land was not a limiting to allow for adequate distance between pit latrines and shallow wells. The short lateral distance between pit latrines and wells in urban slums and poor sanitary practices such as open defecation by children and dumping of wastes near wells allow bacteria and other microorganisms to migrate from faecal contents into the underground water which may lead to its contamination and associated water- borne diseases, a situation which is prevalent in Foko. The problem is further exacerbated by illiteracy, poverty and poor personal hygiene of the inhabitants.

The qualities of dug well water are largely dependent on the concentration of biological, chemical and physical contaminants as well as environmental and human activities in such environment. Evidences from literature (Sangodoyin 1993; Ugbaja 2004; Adekunle et al. 2007; Abdulrafiu et al.2011) indicate that most previous studies on groundwater quality in Nigeria are centred on effect of leachate from waste dump sites with little or no reference to other on-site sanitary conditions especially the impact of pit latrines. There exist no clear-cut guidelines as to the location of wells where they co-exist with pit latrines. Because of the dynamics of different contaminants in varying sub-surface soils, there is the need to determine safe distances for each situation. This study is aimed at assessing the effect of proximity of privies to shallow wells in Foko slum on groundwater quality; to determine the minimum lateral distance of attenuation between privies and shallow wells in Foko that will guarantee water potability; and recommend appropriate intervention measures aimed at enhancing groundwater protection.

Study area

Foko slum (latitude 7^0 23’ and longitude 3^0 55’) is in Ibadan South-West Local Government Area of Oyo State, Nigeria (Figure 1).

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Figure 1: Map of Oyo State in Nigeria showing the study area (arrowed).

The slum has a population of 35,659 people (NPC 2006); with an area of 180 square kilometres and average annual temperature and rainfall of 26^0C, and 1320mm, respectively. The soils in the study area are predominantly sandy loam and classified as Alfisols. The major rock types found in the area are the basement complex of Precambrian age. The rocks may be further sub-divided into the meta-sedimentary series comprising mainly quartzites and magmatites complex (Akintola 1994). Foko area has a gentle sloping topography. The major sources of water in the area are shallow wells and boreholes. The area has a total of thirty eight shallow wells having depths ranging from 5-9 meters and one borehole. There is no public water supply in Foko and household water treatment is not practised. The major method of excreta disposal in the area is the use of pit latrines. Due to limited land availability in Foko, wells and toilets are privately owned assets or self-supplied within owned landed properties. The shallow aquifer of the area is susceptible to pervasive contamination due to poor sanitary practices like open defecation by children and indiscriminate dumping of refuse. Water abstraction from wells is done manually using fetchers which may lead to contamination at point of abstraction.

Methodology

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Five pit latrines were randomly selected from different households in the area and were labelled Pit Latrine A to E. Two wells were also marked for assessment within the vicinity of each privy and were labelled as A1, A2 to E1 and E2.The distances between the pit latrines and the respective selected wells within their vicinity were measured with measuring tape. Well parameters like diameter, well head, depth to water and depth to bottom of the wells were measured. The wells were sampled over a period of two years (2010-2011) with three replicates for each well at each sampling occasion.

Thirty (30) water samples were collected from the ten wells, 3 samples from each well at different time intervals. All the samples of water that were taken from the selected wells (Well A1, Well A2, Well B1, Well B2, Well C1, Well C2, Well D1, Well D2, Well E1, and Well E2) were taken to the laboratory for physical, chemical and biological analysis. For the analysis, the water samples collected were stored in sterile 500mL container which was washed three times with the sample water prior collection. Thirty (30mL) of the collected samples were filtered through a 0.45μm syringe filter and stored in a 20ml polypropylene container. It was stored under 4^0C using ice blocks and taken for laboratory analysis within 6 hours of collection. The pH and conductivity of the water samples were measured on-site using Multiline p4 Multimeter and turbidity was measured with Turbidimeter (TN-100 Eutech) instruments. The water samples were analyzed for chemical and bacteriological parameters using APHA (2005) methods. Total bacteria and coliform count tests were performed in duplicate using 50ml samples after filtering the sample portion through individual 0.45μm membrane filter papers as stipulated in the Membrane Filtration Technique. For chemical analysis, the water samples were divided into two, the first portion was acidified to pH less than 2 with concentrated Nitric acid (HNO_3) and left for 4 days to equilibrate before taking it for Inductively Coupled Plasma(ICP) mass spectrometry analysis. The second portion (untreated) was used for Ion Chromatography (IC) analysis. Purified water using a Millipore Milli-q laboratory water system was used to prepare the laboratory blanks and was treated in the same way with the samples. Cations of low concentrations (≤ 0.01μg/L) were analyzed with coupled plasma- mass spectrography (ICP-MS-Japan 7500). Major cations (≥ 0.1mg/L) were determined by coupled Plasma Optical Emission spectrography (ICP-OES-

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5300, DV, USA). Anions were analyzed using IC Diomex CA, USA. Simple regression analysis was used to determine the minimum distance between privies and shallow wells.

Results and discussion

Shallow wells profiles and proximity to privies

The profiles of the sampled shallow wells are presented in Table 1. The distance from the wells to the pit latrines ranged from 6.1m (Ateere/ LG) to 18.2m for Atinu/LG

Table 1: Shallow wells profiles with respect to privy location in Foko-slum, Ibadan, Nigeria.

Well symbol	Owner/donor	Distance of wells to privy (m)	Depth to water (m)	Depth to bottom (m)	Well Diameter(m)	Well features
A1	Atinu/UBS	10.9	5.4	6.9	0.9	Covered, lined with concrete
A2	Atinu/LG	18.2	4.3	6.8	0.94	Uncovered, unlined
B1	Jascolly/LG	11.8	4.5	7.1	0.86	Covered, lined with stone
B2	Jascolly/P	13.1	6.3	8.2	1.3	Covered, lined with pre-cast concrete
C1	Oguntosin/LG	16.3	5.4	8.7	1.2	Unlined, uncovered
C2	Oguntosin/P	13.3	2.7	6.8	1.3	Unlined, covered
D1	Abioko/LG	17.9	6.3	8.3	1.1	Lined with stone, covered
D2	Abioko/P	9.4	3.6	5.8	0.95	Covered, lined with pre-cast concrete
E1	Ateere/P	17.1	4.5	6.6	0.94	Unlined, covered
E2	Ateere/LG	6.1	3.6	5.8	1.0	Lined with concrete, covered

P- Private; LG- Constructed by the Local Government; UBS- Constructed by Universal Basic Services

well (Table 1). Sixty percent (60%) of the wells are at distances far below the WHO/UNICEF (2000) recommended minimum distance of 15m.

Water quality status

Physico-chemical quality

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The average values of the concentration of the physico-chemical parameters analysed from the ten wells are presented in Table 2. The results indicate that generally, the physico-chemical properties of the shallow wells water were within WHO limits for drinking water quality. The water samples from all wells except well E2 were so clear that no turbidity value was detected (Table 2). Therefore, some form of primary treatment like flocculation and coagulation need only be carried out on the water from well E2 before any disinfection treatment can be done. Turbidity in drinking-water is caused by particulate matter that may be present from water source as a consequence of inadequate filtration. These particulates can protect microorganisms from the effects of disinfection and can stimulate bacterial growth (Hunter et al.2009). Nitrate is a nitrogenous compound that when it is in excess in drinking water can cause reduction of oxygen capacity of blood, shortness of breath and blueness of skin. The WHO guideline value for nitrate in drinking water is 50 mg/l and if exceeded, is regarded as one of the causes of methaemoglobinaemia (Blue Baby Syndrome). High concentration of nitrate in both surface and shallow groundwater can probably be due to poor sanitation and latrine construction and often points towards contamination (Schafer et al.2009).

The pH ranged from 6.7 to 7.6 for the shallow wells as indicated in Table 2. Both the lowest and the highest values of pH were observed in unlined wells. The highest value was observed in the covered well. The lower value of pH observed in the uncovered well may be due to dilution from direct rainfall into the well. However, the observed pH values were within the permissible limit for drinking water quality (WHO 2004). With a few exceptions, it was generally observed that the nearer a well is to a privy, the higher the alkalinity level and hence their elevated pH. These observations were not unexpected since nitrates were detected in the wells which would probably emanate from the nitrogen coming from the pit latrines. The depth of the well did not adversely affect the pH.

The conductivity and total dissolved solids values are presented in Table 2. The conductivity values ranged from 882-1321µS/cm. The lowest value was observed in well

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Table 2:Average values of the physico-chemical and bacteriological parameters analysed.

	Wells									
Parameter	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**	**D1**	**D2**	**E1**	**E2**
pH	7.0	6.8	7.5	7.1	6.7	7.6	7.1	7.1	7.3	7.3
Alkalinity(mg/l)	150	104	207	156	110	218	149	292	170	299
T H (mg/l)	281	382	326	305	393	332	357	409	340	353
C H (mg/l)	193	271	204	212	280	212	269	209	238	164
M H (mg/l)	87.8	111	122	82.3	113	119	88.2	187	103	189
Calcium (mg/l)	77.4	108	81.6	84.8	112	84.8	108	43.7	95.2	65.4
Magnesium(mg/l)	20.2	25.4	28.0	18.9	26.0	27.5	20.3	45.9	23.6	43.6
TDS (mg/l)	1047	913	1027	980	895	908	1136	1363	925	1053
TSS (mg/l)	65.0	21.0	10.0	12.0	10.0	ND	11.0	14.0	ND	120
Nitrite (mg/l)	0.12	0.10	0.05	0.12	0.21	0.22	0.19	0.23	0.12	0.32
Turbidity (NTU)	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.12
Nitrate (mg/l)	0.34	0.23	0.11	0.32	0.32	0.45	0.53	0.32	0.54	0.73
Sulphate (mg/l)	34.4	45.6	64.1	24.2	56.0	67.5	32.9	32.0	53.1	59.9
ECw (µS/cm)	1196	822	1220	1210	867	980	1200	1321	976	1090
Iron (mg/l)	0.470	0.303	0.532	0.431	0.297	0.312	0.254	0.312	0.210	0.311
TB C (cfu/100ml)	5100	5100	6700	7700	5100	9300	5500	9300	8500	8300
Coliform count (CFU/100ml)	240	201	1201	600	210	1601	230	1600	200	1200

ND – Non-Detectable; TH – Total Hardness; CH – Calcium Hardness; MH – Magnesium Hardness; ECw – Electrical Conductivity; TBC – Total Bacterial Count

A_2 with the highest lateral distance of 18.2m from the privies, while the highest value was observed in well D_2 which was next to the lowest lateral distance from the privies (9.4m) and the shallowest depth to the bottom of the wells (5.8m). Electrical conductivity is a function of the types and quantities of dissolved substances in water. As concentration of dissolved ions increase, conductivity increases.

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Thus, the high values of TDS observed could possibly explain the corresponding high values of conductivity in the water samples. In Foko, 50% of the well water samples had TDS above the WHO guideline value of 1000mg/l. High TDS makes water unpalatable for drinking. It could be adduced that the nitrate from the pit latrines and other salts such as calcium, magnesium and sulphate further enhanced the high conductivity values. The result is consistent with those reported by Dzwairo et al. (2006).

Alkalinity ranged from 104-299 mg/l. (Table 2). The highest being observed in well E2 which has the shortest lateral distance from the pit latrines, while the lowest value of alkalinity was observed in well A_2 with the highest lateral distance from the pit latrines. Except for wells B_1, C_2, D_2 and E_2 which had shorter distances from the pit latrines, all other six wells had alkalinity values below the WHO permissible limit of 200mg/l. Like conductivity, lateral distance from privies had greater impact on alkalinity than the depth of the shallow wells. High values of alkalinity give undesirable taste to water. These results are in agreement with the findings of Kumar and Singh (2010).

Bacteriological quality

WHO (2004) recommends zero values for total coliform and E-coli. Results from the study indicate that all the well water samples tested had their bacteriological parameters (total and faecal matter) far above the recommended limit (Table 2) and are therefore not fit for drinking without treatment. The presence of E-coli provides evidence of faecal contamination. Total coliform figures as high as 9300cfu/100ml and faecal coliform figures as high as 1600cfu/100ml were recorded in the shallow wells. Analysis showed that proximity of pit latrines to shallow wells contributed highly to the bacteriological contamination of the wells waters than well features such as covering and lining. The high coliform count could be attributed to the proximity to pollution sources such as open defecation, pit latrines and waste dumps near the shallow wells which encouraged quick migration of contaminants, especially those located upstream of the shallow wells. Our finding is similar to those of Dzwaizo et al. (2006) who found out that pit latrines had an impact on groundwater quality for

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distances of up to 25m from pit latrines in Mawendera district of Zimbabwe. Research has shown that these bacteria cannot withstand high temperature (Schmidt and Caircross 2008). It is therefore necessary to encourage the water user to always boil it before drinking.

Minimum Distance between Pit Latrine and Shallow Wells

To establish the minimum distance that should exist between the pit latrines and the shallow wells, the faecal coliform (FC) values were regressed against the measured distances from the shallow wells to the pit latrines after the out-liars were removed (Figure 2).

The resulting regression equation is:

$$\text{E. coli} = -86.16 * \text{distance} + 1714 \qquad R^2 = 0.977 \qquad (1)$$

The equation is a negative linear function. This implies that as distance from the pit latrine increases, E-coli decreases and vice-versa. For a shallow well to be E. Coli free, it follows that E. Coli has to be taken as zero (WHO, 2004). Therefore, setting equation (1) to zero, we have,

$$-86.16 * \text{distance} + 1714 = 0 \qquad (2)$$

The result of the evaluation of equation 2 shows that for Foko slum, a minimum distance of 20 meters is required between pit latrines and shallow wells to achieve E. Coli free water. This result is at variance with the recommendation of WHO/UNICEF (2000) that a minimum distance of 15meters should be allowed between pit latrines and groundwater. The higher distance of 20 meters obtained in the study area may be ascribed to the poor sanitary practices of the slum dwellers. From Table 1, none of the ten wells sampled is maintaining the minimum distance which may be a major factor responsible for the elevated microbiological parameters in the tested water samples. Furthermore, the preponderance of poorly designed pit latrines (associated with the poverty status of the people) as well as inadequate protection of the shallow wells may lead to the observed contamination of the shallow wells, resulting in frequent outbreak of water borne diseases especially diarrhea and typhoid in Foko as attested to by the residents.

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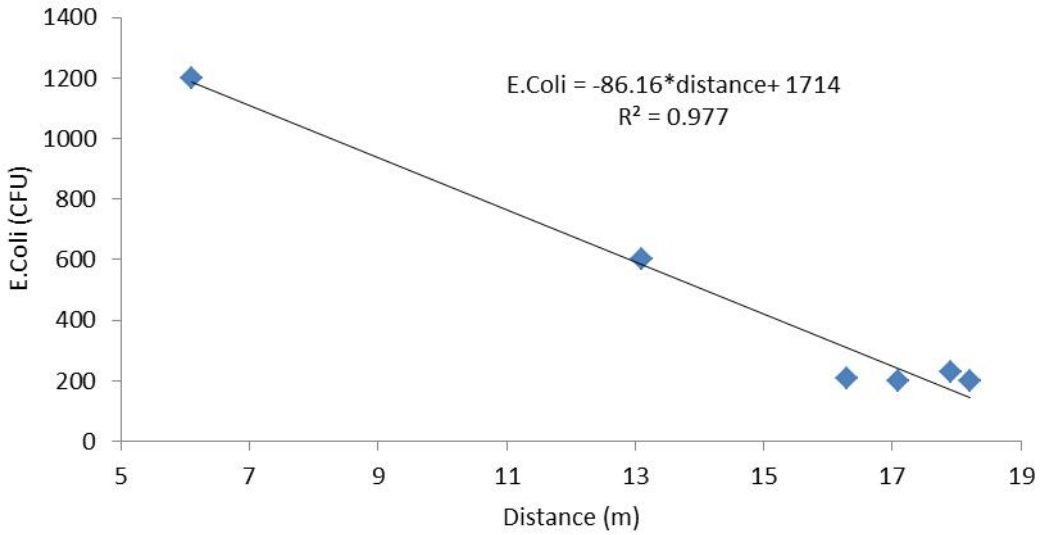

Figure 2: Graph of distance between shallow wells and pit latrines against E-coli.

Conclusions and recommendations

Results from the study shows that shallow wells in Foko were not polluted with respect to physico-chemical properties. However, bacteriological tests indicate that pit latrines impacted negatively on groundwater quality from the shallow wells due to elevated coliform count that do not meet the WHO guidelines for drinking water quality, thus rendering the water unsafe for human consumption without treatment. Analysis of the data generated in the study area for distances between pit latrines and shallow wells and their associated faecal coliform counts indicate that a minimum lateral distance of 20m is required between pit latrines and shallow wells to minimise threat of faecal contamination of the groundwater.

It is recommended that appropriate intervention measures should be taken in terms of the provision of adequate pipe borne water in the area for both domestic use and human consumption. This may however take some time, therefore, short term measures such as basic environmental sanitation and improvement in the existing wells like covering and lining may help. Also, basic treatment of the water at both the community and at the household levels by chemical disinfection with chlorine, filtration using simple household filters and boiling of water before its consumption is

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encouraged. To guarantee water potability and avert further outbreak of water borne diseases in Foko, it is further recommended that future shallow wells be located upstream of the privy of every household so that leachates from the pit latrines will not drain into the wells. Lastly, the wells should have concrete platforms with proper drainage made around each well to prevent recirculation of dirty water at well head into the well.

ACKNOWLEDGEMENT

We acknowledge the assistance rendered by Mr. Abiodun Akande during the field work.

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