British Journal of Applied Science & Technology
4(3): 440-449, 2014

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Impact of Pit Latrines on Groundwater Quality of Fokoslum, Ibadan, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author IEA, designed and supervised the execution of the project and handled the statistical analysis aspect of the research. He also supervised the writing of the manuscript and edited the final copy before it was sent out for consideration for publication. Author PAA joined the local residents in Fokoto collect the water samples and was in the laboratory for the water analysis. He wrote the laboratory reports and prepared the first draft of the manuscript which was edited by author IEA. All authors read and approved the final manuscript.

Original Research Article

Received 31st May 2013
Accepted 28th September 2013
Published 26th October 2013

ABSTRACT

Insufficient supply of treated water in most of the rural and peri-urban areas of Nigeria has made groundwater a major source of water supply for domestic and other purposes. In theseareas,water demand is fulfilled from shallow wells. The shallow wells are commonly constructed close to pit latrines.A study was therefore conducted to determine the impact of pit latrines on groundwater quality in Foko slum, Southwestern Nigeria. Water quality of shallow wells was assessed within the slum with respect to their distance from fivepit latrines. Water samples were collected from the shallow wells and analyzed for determination of total and faecal coliforms (FC), alkalinity, total dissolved solids (TDS), total suspended solids (TSS), nitrates, electrical conductivity, turbidity and pH.The faecal coliform values were regressed with distance between the pit latrines and the wells. The resulting equation was evaluated to obtain a minimum lateral distance between a pit latrine and shallow well for zero value of microbiological parameters in the wells.

Results showed that the physico-chemical parameters of the water samples were within the World Health Organization (WHO) guidelines for drinking water quality. Nevertheless,

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biological contaminants exceeded the recommendation of WHO drinking water quality guidelines. Maximum coliform counts enumerated were9300cfu/100ml of water. This study shows that there is an indicator gradient in faecal bacteria with distance from pit latrines, and that pit latrines whichimpact on shallow well water at lateral distances of 19.75m.

Keywords: Contamination; water quality; pit latrines; shallow wells; Urbanslums.

1. 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 [1]. In Nigeria, rapid growth and 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 [2] estimated that 65 million Nigerians had no access to safe water. The situation is worse in 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 [3].

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 drinking water source.In such a situation, the use of pit latrines is not recommended unless the water table is extremely low and soil characteristics are not likely to contribute to susceptibility of groundwater pollution. According to [4], the key factor that affects the removal and elimination of pathogenic organisms from groundwater is maximization of the effluent residence time between the source of contamination and the point of water abstraction. Because of very low velocities of unsaturated flow, the unsaturated zone holds the key to defence against faecal pollution of aquifers. Although it is difficult to give a general rule for all soil conditions, commonly used guideline is that water well should be located in an area topographically higher than pit latrine site and at least 15m away from pit latrine and it should be at least 2m above water table [5,1]. As reported by Cave and Kolsky[4] such criteria may not guarantee groundwater protection as it may not apply in all areas with different soil conditions. According to Hunter et al.[6]increased lateral separation between the source of pollution and groundwater supply reduces risk of faecal pollution.Kimani and

Ngindu[7]suggested that the coexistence of pit latrines and shallow wells has in the past been mainly confined to rural areas where land was not limiting 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. This may lead to its contamination and associated water- borne diseases. Cases of water-borne diseases have been reported in Ibadan especially in FokobySangodoyin[8].

The qualities of dug well water are largely dependent on the presence of biological, chemical and physical contaminants as well as environmental and human activities in such environment. Evidences from literature [8,9,10,11] indicate that most of the 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 in respect to 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 aimed at assessing effect of proximity of pit latrines to shallow wells in Foko slum on groundwater quality; to determine the minimum lateral distance of attenuation betweenpit latrines and shallow wells that will guarantee water potability; and recommend appropriate intervention measures aimed at enhancing groundwater protection.

1.1Study Area

Foko slum (latitude 7°23’ and longitude 3°55’) is in Ibadan South-West Local Government Area of Oyo State, Nigeria (Fig. 1). The slum has a population of 35,659 people [12] with an area of 180 square kilometres and average annual temperature and rainfall of 26°C, 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 [13]. Foko area has a gentle sloping topography with groundwater flow rate of about 2.0×10^{-2}m/s [4] and flow direction from southwest to northwest [13], thereby putting majority of the wells assessed at the downstream end of the pit latrines. The major sources of water in the area are shallow wells (protected and unprotected) and borehole.

The area has a total of twenty six shallow wells having depths ranging from 5-9 metersand one borehole. Foko slum has a total of seventeen pit latrines with depth ranging from 6-11 meters, each of which is being shared by three to four households (Personal interview).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.

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

2. MATERIALS AND METHODS

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 pit latrine and were labelled as A_1, A_2 to E_1 and E_2. However, two of the wells (A_2 and E_1) were not covered and the sources of contamination to the two wells cannot be attributed to the pit latrines located within their vicinity as contaminants may also be introduced into the wells from surface due to lack of cover and therefore were not included in results presented in Tables 1a and 1b. 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. Thirty (30) water samples were collected from the ten wells, 3 samples from each well at four months intervals starting from April through December, 2010. Pre-sampling activities include pumping stagnant water out for 90 seconds and the well allowed to recharge for about 15 minutes. Sterilized sampling bottle, capped with a metal bob was then used to take the water samples. It was inserted into the well to a water depth of about 0.3m before the bob was removed. This was done to make sure the sample taken is representative of water from the shallow aquifers [1]. All the water samples collected from the wells (Well A_1, Well B_1, Well B_2, Well C_1, Well C_2, Well D_1, Well D_2, and Well E_2) were carried to the laboratory for analysis. Physical parameters (temperature, pH, TDS, electrical conductivity, turbidity and TSS) were determined in-situ. Temperature and pH were determined using Ohaus S2000 bench pH/ temperature meter, while the Total Dissolved Solid (TDS), electrical conductivity (EC), turbidity and Total Suspended Solids (TSS) were determined usingJenway M470 portable conductivity/ TDS meter. The samples for chemical and bacteriological analysis were stored in ice pack at about 4ºC while transporting them to the laboratory. For chemical analysis, the reagent bottles used were rinsed with distilled water and then with the water samples. For the analysis, the water samples collected were stored in sterile 500mL container which was washed three times with the sample water prior to collection. The water samples were analyzed for chemical and bacteriological parameters using [14] methods. Membrane filtration technique was used for bacteriological analysis, while Inductively

Coupled Plasma (ICP) spectrophotometer was used for hydro chemical analysis. Total coliform and faecal coliform tests were carried out by filtering 100ml of the sample through 0.45µ Millipore membrane filter and using vacuum pump. After one hour recovery period, the membrane was incubated on Slantez and Bartley media at 37°C and 45°C for 24hours for faecal and total coliform, respectively and on Membrane Lauryl Sulphate broth (MLSB-OXOID MM0616) at 45°C for 48hours for faecal streptococci. Bacteria that were present on the membrane grew into visible colonies [15]. These colonies were counted with membrane counter and converted to represent a count per 100ml.Cations and anions 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-5300, DV, USA) [16].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.

3. RESULTS AND DISCUSSION

4.1 Physico-Chemical Quality

The maximum, minimum and average results of physico-chemical and bacteriological analysis is presented in Tables 1a and 1b. The results indicate that generally, the physico-chemical properties of the samples followed the WHO guidelines for drinking water quality. Turbidity was not observed except in the sample collected from E_2 (Table1b) 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 [6].The nitrate values were within WHO guideline value for nitrate in drinking water of 50 mg/l. High concentration of nitrate in both surface and shallow groundwater can probably be due to poor sanitation and latrine constructionand often points towards contamination [3].

The pH ranged from 6.7 to 7.6 (Table 1a). The maximum pH value was observed in the sample collected from the wells which were properly covered at the top. However, the observed pH values were within the permissible limit for drinking water quality guidelines [16]. Nitrate was detected in the samples which would probably emanate from the nitrogen coming from the pit latrines. The results of electrical conductivity and total dissolved solids are presented in Table 1b. The electrical conductivity values ranged from 867-1321µS/cm. The lowest value of electrical conductivity was observed in the sample collected fromC_1which was laterally 16.3m far from the pit latrine, while the maximum value was observed in the sample collected from D_2 which was located at a lateral distance of 9.4m from the pit latrines and the shallowest depth to the bottom of the wells (5.8m). Electrical conductivity is a function of the type and quantity of dissolved substances in water. As the concentration of dissolved ions increase, electrical conductivity of water increases. The maximum values of TDS observed could possibly explain the corresponding high values of electrical conductivity in the water samples. In Foko, 50% of the well water samples had TDS above the WHO guideline value of 1000mg/l. The water may therefore not be good for drinking purpose as high TDS makes water unpalatable for drinking [15].

Table 1a. Results of the physico-chemical and bacteriological parameters analysis

Parameters		Well names								WHO guideline
		A_1	B_1	B_2	C_1	C_2	D_1	D_2	E_2	
Distance to latrine (m)		10.9	11.8	13.1	16.3	13.3	17.9	9.4	6.1	
pH	Min	6.5	6.3	6.6	6.0	6.0	6.3	7.1	6.4	6.5-8.5
	Max	8.4	8.9	8.2	8.1	8.1	7.9	8.9	8.1	
	ave	7.0	7.5	7.1	6.7	7.6	7.1	7.1	7.3	
Alkalinity (mg/L)	Min	100	176	139	89	201	130	271	243	NS
	Max	180	211	186	136	225	156	316	308	
	ave	150	207	156	110	218	149	292	299	
TH(mg/L)	Min	250	300	287	331	306	306	381	304	150
	Max	297	351	311	412	356	414	433	380	
	ave	281	326	305	393	332	357	409	353	
CH (mg/L)	Min	164	174	184	274	177	251	184	134	NS
	Max	214	209	233	296	231	303	215	189	
	ave	193	204	212	280	212	269	209	164	
MH (mg/L)	Min	61.9	102	71.3	102	100	79.3	135	155	NS
	Max	96.4	146	94.6	145	133	96.4	214	213	
	ave	87.8	122	82.3	113	119	88.2	187	189	
Calcium (mg/L)	Min	70.6	70.2	66.7	103	77.4	96	37.9	54.1	NS
	Max	92.4	99.3	89.6	135	96.9	124	54.6	80.3	
	ave	77.4	81.6	84.8	112	84.8	108	43.7	65.4	
Magnesium (mg/L)	Min	14.5	21.3	14.3	21.4	23.2	15.4	40.1	39.9	0.2
	Max	36.2	36.9	27.4	39.0	40.1	24.6	57.3	57.2	
	ave	20.2	28.0	18.9	26.0	27.5	20.3	45.9	43.6	
TDS (mg/L)	Min	961	950	943	821	853	933	1133	996	1000
	Max	1122	1144	1080	969	1143	1269	1521	1211	
	ave	1047	1027	980	895	908	1136	1363	1053	
TSS (mg/L)	Min	43	8.1	9.0	6.0	ND	6.4	10.1	112	NS
	Max	91	15.2	17.2	13.3	ND	13.1	16.3	146	
	ave	65.0	10.0	12.0	10.0	ND	11.0	14.0	120	

Table 1b. Results of the physico-chemical and bacteriological parameters analysis

Parameters		Wells								WHO Guideline
		A_1	B_1	B_2	C_1	C_2	D_1	D_2	E_2	
Distance to latrine (m)		10.9	11.8	13.1	16.3	13.3	17.9	9.4	6.1	
Nitrite (mg/L)	Min	0.11	0.04	0.10	0.16	0.15	0.11	0.16	0.22	3
	Max	0.19	0.09	0.18	0.27	0.27	0.22	0.30	0.41	
	ave	0.12	0.05	0.12	0.21	0.22	0.19	0.23	0.32	
Turbidity (NTU)	Min	ND	ND	ND	ND	ND	ND	ND	0.06	5
	Max	ND	ND	ND	ND	ND	ND	ND	0.15	
	ave	ND	ND	ND	ND	ND	ND	ND	0.12	
Nitrate (mg/L)	Min	0.29	0.04	0.22	0.26	0.35	0.44	0.29	0.56	50
	Max	0.48	0.18	0.49	0.41	0.51	0.69	0.38	0.88	
	ave	0.34	0.11	0.32	0.32	0.45	0.53	0.32	0.73	
Sulphate (mg/L)	Min	26.3	54.9	43.0	14.2	20.1	20.0	59.4	22.9	100
	Max	38.6	77.1	71.9	33.1	37.4	43.0	88.6	38.6	
	ave	34.4	64.1	54.2	26.0	27.5	35.9	82.0	29.9	
ECw (mg/L)	Min	1044	1104	1130	802	873	1028	1128	994	1000
	Max	1209	1249	1258	904	1045	1305	1385	1210	
	ave	1196	1220	1210	867	980	1200	1321	1090	
Iron (µS/cm)	Min	0.39	0.43	0.38	0.19	0.24	0.22	0.27	0.28	0.3
	Max	0.61	0.61	0.55	0.36	0.33	0.28	0.38	0.39	
	ave	0.47	0.53	0.43	0.29	0.31	0.25	0.31	0.31	
TC (cfu/100ml)	Min	4906	6618	7428	4980	8946	5210	9017	7944	0
	Max	5201	6783	7817	5207	9402	5701	9385	8431	
	ave	5100	6700	7700	5100	9300	5500	9300	8300	
FC (cfu/100ml)	Min	213	1179	558	190	1549	196	1254	1107	0
	Max	243	1286	658	237	1732	248	1659	1423	
	ave	240	1201	600	210	1601	230	1600	1200	

ND – Non-Detectable; TH – Total Hardness; CH – Calcium Hardness; MH – Magnesium Hardness; ECw – Electrical Conductivity; TC – Total Coliform, FC- Faecal Coliform, Min – Minimum Value, Max – maximum value, Ave – Average value, NS- Not specified.

Alkalinity ranged from 104-299mg/l. (Table 1a). The highest value(299mg/l) being observed in well E_2 which has the shortest lateral distance from the pit latrines, while the lowest value (150mg/l) was observed in well A_1.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 pit latrines had greater impact on alkalinity than the depth of the shallow wells. There is no health implication for high or low alkalinity values in drinking water.However, high values of alkalinity give undesirable taste to water. These results are in agreement with the findings of [17].

3.2 Bacteriological Quality

Zero values are recommended for total coliform and faecal coliform in drinking water [18]. Results from the study indicate that thesamples analysed had their bacteriological parameters (total and faecal matter) far above the recommended limit (Table 1b) and are therefore not fit for drinking without treatment. Maximum total coliform and faecal coliform bacteria enumerated in the sample were9300cfu/100ml and 1600cfu/100ml respectively. Analysis showed that proximity of pit latrines to shallow wells contributed highly to the bacteriological contamination to groundwater. However, the possibility of contamination is less with the sources which are properly covered at the top and lined from outside of the well. The high coliform count could be attributed to the proximity of the wells to pollution sources such as open defecation, pit latrines and waste dumps which encouraged quick migration of contaminants, especially those located upstream of the shallow wells. Our finding is in agreement with the study carried out by Dzwairo et al[1]. In the study, it has been recommended that the distance up to 25m between pit latrine and groundwater source improve groundwater quality.Research shows that these bacteria cannot withstand high temperature [19].Therefore, boiling of contaminated water is a cheap but effective option for slum dwellers before use.

3.3 Minimum Distance between PIT Latrine and Shallow Wells

Fig. 2 shows the graph of distance between shallow wells and pit latrines against faecal coliform while (the resulting regression equation of the relationship is as follows:

$$\mathrm{E.coli} = -87.578 * \mathrm{distance} + 1729.2 \qquad R^2 = 0.979 \qquad (1)$$

Equation (1) is a negative linear function. This implies that as distance from the pit latrine increases, FC decreases and vice-versa.For a shallow well to be FCfree, it follows that FChas to be taken as zero [18]. Therefore, setting equation (1) to zero, we have,

$$-87.578 * \mathrm{distance} + 1729.2 = 0 \qquad (2)$$

Equation 2 shows that in the Foko slum, a minimum distance of 19.75 meters is required between pit latrines and shallow wells to achieve FCfree water. This result is at variance with the recommendation of [5] that a minimum distance of 15meters should be allowed between pit latrines and groundwater. The higher distance of 19.75 meters obtained in the study area may be ascribed to the poor sanitary practices of the slum dwellers. From Table 1, shows that none of the samples is maintaining the minimum distance responsible for the elevation of microbiological parameters.Furthermore, poorly designed pit latrines and inadequate protective measures followed during construction of wells may again lead to accelerated contamination of groundwater sources. Such situations constantly increase the risk of water borne diseases, especially diarrhea and typhoid [8].

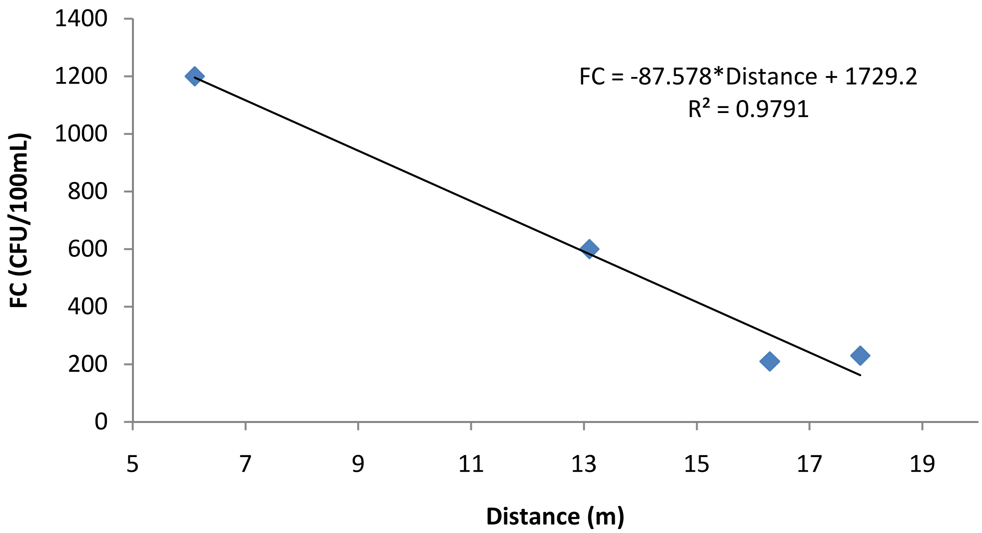

Fig. 2. Graph of distance between shallow wells and pit latrines against FC

4. CONCLUSIONS AND RECOMMENDATIONS

Results show that most of the shallow wells in Foko area are contaminated due to presence of coliform bacteria percolated from pit latrines. The findings revealed that a minimum lateral distance of 19.75m is required between pit latrines and shallow wells to minimise the threat of faecal contamination of the groundwater.

Based on the findings,it is recommended that the environmental quality in Foko area should be improved by educating people about the importance of environmental sanitation and improving water supply situation in the area. This can help to prevent the hazard of water borne diseases and improve life span of the people. Further study is needed in the area to investigate pollution level of entire groundwater sources.

ACKNOWLEDGEMENT

We acknowledge the assistance rendered by Mr.AbiodunAkande during the field work.

COMPETING INTERESTS

Authors declare that there are no competing interests.

REFERENCES

1. Dzwairo B, Hoko Z, Love D, Guzha E. Assessment of the impacts of pit latrines on groundwater quality in rural areas: A case study from Mawendera District, Zimbabwe. Physics and Chemistry of the Earth. 2006;31:779-788.

2. Majuru B, Michael MM, Jagals P, Hunter PR. Health impact of small-community water supply reliability. Int. J. Hyg. and Env. Health. 2011;214(2);162-166.
3. Schafer AI, Rossiter HMA, Owusu PA, Richards BS, Awuah E. Physico-chemical water quality in Ghana: Prospects for water supply technology implementation. Desalination. 2009;248(1-3):193-203.
4. Cave B, KolskyP. Well Study: Groundwater, latrines and health. Task No. 163. Task Management and Quality Assurance.London School of Hygiene and Tropical Medicine, U.K. WEDC, Loughborough University, UK. Available: http://www.iboro.ac.uk/well/1999.
5. WHO/UNICEF, Global Water Supply and Sanitation Assessment, Geneva World 2000.
6. Hunter PR, Zmirou-Navier D, Hartemann P. Estimating the impact on health of poor reliability of drinking water interventions in developing countries. Science of the Total Environment. 2009;407(8):2621-2624.
7. Kimani EW, NginduAM. Quality of water the Slum Dwellers Use: The case of a Kenyan Slum. J. Urban Health. 2007;84(6):829-838.
8. Sangodoyin AY. Consideration on contamination of groundwater by waste disposal systems in Nigeria. Environmental Technology. 1993;14:957-964.
9. Ugboaja, AN. Groundwater pollution near shallow dumps in Southern Calabar, South-eastern Nigeria. Global Journal of Geological Sciences. 2004;2(2):199-206.
10. Adekunle IM., Adetunji, MT Gbadebo AM BanjokoOB.Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria.Int. J. Env.l Res. and Pub. Health; 2007;4(*4)*:307-318.
11. Abdulrafiu OM, Kasali AA, Ghaniyu LO. Quality assessment of groundwater in the vicinity of dumpsites in Ifo and Lagos, South-western Nigeria. Adv.Appl. Sci. Res. 2011;2(11):289-298.
12. NPC. National Population Census Report, for Nigeria; 2006.
13. Akintola FO. Geology and hydrology of the Ibadan region. In Filani, M.O. et al. (eds). Ibadan Region. Chapter 3, Rex Charles Pub., Nigeria; 1994.
14. APHA. Standard Methods for the Examination of Water and Wastewater. American Public Health Association water quality Bulletin. 2005;Issue 46.
15. Pritchard M, Nkandawire T, O'Neill JG. Biological, chemical and physical drinking water quality from shallow wells in Malawi: Case study of Blantyre, Chiradzulu and Mulanje. Physics and Chemistry of the Earth, 2007;32:1167–1177.
16. Nkandawire T. Quality of groundwater from shallow wells of selected villages in Blantyre district, Malawi. Physics and Chemistry of the Earth. 2008;33:807 – 811.
17. Kumar M, Singh Y. Interpretation of water quality parameters for villages of Sanganer Tehsil by using Multivariate Statistical Analysis. J. Water res. and Protection. 2010;2:860-863.
18. WHO. Guidelines for Drinking Water Quality, Volume1.Third Edition.World Health Organization, Geneva, Switzerland; 2004.
19. Schmidt WP, Caircross S. Household water treatment in poor population: Is there enough evidence for scaling up now? Environmental Science and Technology. 2008.43(4):985-992.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=307&id=5&aid=2390