

Research paper

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

Comment [CM1]: The terms 'pit latrines' and 'privies' have been used interchangeably in the manuscript. For the purposes of consistency, kindly choose and stick to one term only.

Comment [CM2]: These are two different words and should be separated. Otherwise it gives the impression that the area is called 'Foko-slum' which I believe it is not. Rather, the area is called 'Foko' and it is a slum in Ibadan city.

Comment [CM3]: Also make reference to the 5 pit latrines.

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

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

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

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

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

77 Study area

Comment [CM4]: Need to cite data on the associated water-borne diseases and also the data sources, otherwise, as it is, it remains a blanket statement, which of course might be or might not be authentic.

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



80
81 Figure 1: Map of Oyo State in Nigeria showing the study area (arrowed).

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

Comment [CM5]: There is need to state the behaviour of groundwater flow in such soils. Such behaviour might include flow rate, etc. Thus, for similar soils in similar climate elsewhere, the results of this study could be easily generalizable.

Comment [CM6]: Clarify whether these are protected or unprotected shallow wells. The susceptibility to and degree of contamination will be different in either case.

96

97 Methodology

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

104 Thirty (30) water samples were collected from the ten wells, 3 samples from each well at
105 different time intervals. All the samples of water that were taken from the selected wells (Well A1, Well
106 A2, Well B1, Well B2, Well C1, Well C2, Well D1, Well D2, Well E1, and Well E2) were taken to the
107 laboratory for physical, chemical and biological analysis. For the analysis, the water samples collected
108 were stored in sterile 500mL container which was washed three times with the sample water prior
109 collection. Thirty (30mL) of the collected samples were filtered through a 0.45µm syringe filter and
110 stored in a 20ml polypropylene container. It was stored under 4°C using ice blocks and taken for
111 laboratory analysis within 6 hours of collection. The pH and conductivity of the water samples were
112 measured on-site using Multiline p4 Multimeter and turbidity was measured with Turbidimeter (TN-100
113 Eutech) instruments. The water samples were analyzed for chemical and bacteriological parameters
114 using APHA (2005) methods. Total bacteria and coliform count tests were performed in duplicate
115 using 50ml samples after filtering the sample portion through individual 0.45µm membrane filter
116 papers as stipulated in the Membrane Filtration Technique. For chemical analysis, the water samples
117 were divided into two, the first portion was acidified to pH less than 2 with concentrated Nitric acid
118 (HNO₃) and left for 4 days to equilibrate before taking it for Inductively Coupled Plasma(ICP) mass
119 spectrometry analysis. The second portion (untreated) was used for Ion Chromatography (IC)
120 analysis. Purified water using a Millipore Milli-q laboratory water system was used to prepare the
121 laboratory blanks and was treated in the same way with the samples. Cations of low concentrations ($\leq$

Comment [CM7]: Since Foko is a relatively small area, there is need to give an indication of the total number of pit latrines and total number of shallow wells in this area. This will give an indication of the sample size being used and help to determine whether it is suitable.

Comment [CM8]: Add the sampling frequency. i.e. at what intervals? What was the rationale for these intervals?

Comment [CM9]: Refer to comment 8 above.

Comment [CM10]: Line 102-103 and 104-105 are repetitions which need to be eliminated by rewriting into a single sentence.

Comment [CM11]: Clarify by stating the specific methods used.

Comment [CM12]: Clarify whether this means 'total coliforms' and 'faecal coliforms' as these two are the standard terminologies in bacteriological analyses of water samples. Otherwise as it is, is confusing. What does 'total bacteria' mean? And what does 'coliform' mean?

0.01µg/L) were analyzed with coupled plasma- mass spectrography (ICP-MS-Japan 7500). Major cations ($\geq 0.1\text{mg/L}$) were determined by coupled Plasma Optical Emission spectrography (ICP-OES-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

Comment [CM13]: Separate the Results from Discussions, i.e. present the results in one section and discussion in another section.

Comment [CM14]: Widen the scope of the discussion by making references to more African studies conducted on the same subject.

Comment [CM15]: Refer to comment 1.

Comment [CM16]: Remove from this table and subsequent analysis A2 and E1. These shallow wells are not covered and the potential bias of entry of contaminants through the well head need to be eliminated. The study is primarily concerned with the impact of proximity of pit latrines to shallow wells and not other sources of contamination.

137 **Physico-chemical quality**

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

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

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

163

164

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

Parameter	Wells									
	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

167 ND – Non-Detectable; TH – Total Hardness; CH – Calcium Hardness; MH – Magnesium Hardness;

168 ECw – Electrical Conductivity; TBC – Total Bacterial Count

169

Comment [CM17]: The narrative indicated that 30 samples were collected over a period of 2 years at certain intervals, i.e. 3 samples per well. What do these values in the table represent? One sample per shallow well? This table does not depict the 3 samples collected per well. Also refer to comment #14, i.e. A2 and E1 need to be excluded completely from the results and any subsequent analysis.

170 A₂ with the highest lateral distance of 18.2m from the privies, while the highest value was observed in
171 well D₂ which was next to the lowest lateral distance from the privies (9.4m) and the shallowest depth
172 to the bottom of the wells (5.8m). Electrical conductivity is a function of the types and quantities of
173 dissolved substances in water. As concentration of dissolved ions increase, conductivity increases.
174 Thus, the high values of TDS observed could possibly explain the corresponding high values of
175 conductivity in the water samples. In Foko, 50% of the well water samples had TDS above the WHO
176 guideline value of 1000mg/l. High TDS makes water unpalatable for drinking. It could be adduced that
177 the nitrate from the pit latrines and other salts such as calcium, magnesium and sulphate further
178 enhanced the high conductivity values. The result is consistent with those reported by Dzwaïro et al.
179 (2006).

180 Alkalinity ranged from 104-299 mg/l. (Table 2). The highest being observed in well E₂ which has the
181 shortest lateral distance from the pit latrines, while the lowest value of alkalinity was observed in well
182 A₂ with the highest lateral distance from the pit latrines. Except for wells B₁, C₂, D₂ and E₂ which had
183 shorter distances from the pit latrines, all other six wells had alkalinity values below the WHO
184 permissible limit of 200mg/l. Like conductivity, lateral distance from privies had greater impact on
185 alkalinity than the depth of the shallow wells. High values of alkalinity give undesirable taste to water.
186 These results are in agreement with the findings of Kumar and Singh (2010).

187 **Bacteriological quality**

188 WHO (2004) recommends zero values for total coliform and E-coli. Results from the study indicate
189 that all the well water samples tested had their bacteriological parameters (total and faecal matter) far
190 above the recommended limit (Table 2) and are therefore not fit for drinking without treatment. The
191 presence of E-coli provides evidence of faecal contamination. Total coliform figures as high as
192 9300cfu/100ml and faecal coliform figures as high as 1600cfu/100ml were recorded in the shallow
193 wells. Analysis showed that proximity of pit latrines to shallow wells contributed highly to the
194 bacteriological contamination of the wells waters than well features such as covering and lining. The

Comment [CM18]: This should be E. Coli. Maintain this consistency as the correct scientific terminology. Also note that 'E. Coli count' is synonymous to 'faecal coliform count'. There is need to maintain consistency throughout the manuscript.

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 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:

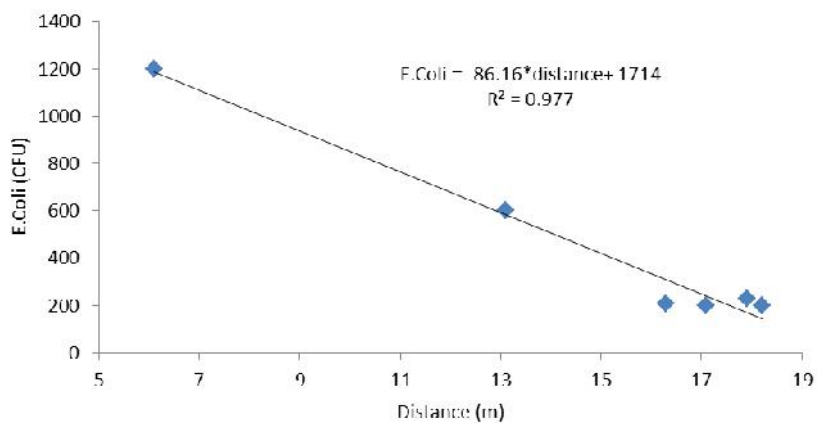
$$E.coli = -86.16 * distance + 1714 \quad R^2 = 0.977 \quad (1)$$

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,

$$-86.16 * distance + 1714 = 0 \quad (2)$$

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

220 well as inadequate protection of the shallow wells may lead to the observed contamination of the
221 shallow wells, resulting in frequent outbreak of water borne diseases especially diarrhea and typhoid
222 in Foko as attested to by the residents.



223

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

Comment [CM19]: Before fixing the regression equation, the authors should have demonstrated that relationship(s) exist between e-coli counts and distances. Scatter diagram, correlation coefficient, chi square by trend could be employed.

225 **Conclusions and recommendations**

226 Results from the study shows that shallow wells in Foko were not polluted with respect to physico-
227 chemical properties. However, bacteriological tests indicate that pit latrines impacted negatively on
228 groundwater quality from the shallow wells due to elevated coliform count that do not meet the WHO
229 guidelines for drinking water quality, thus rendering the water unsafe for human consumption without
230 treatment. Analysis of the data generated in the study area for distances between pit latrines and
231 shallow wells and their associated faecal coliform counts indicate that a minimum lateral distance of
232 20m is required between pit latrines and shallow wells to minimise threat of faecal contamination of
233 the groundwater.

234 It is recommended that appropriate intervention measures should be taken in terms of the
235 provision of adequate pipe borne water in the area for both domestic use and human consumption.
236 This may however take some time, therefore, short term measures such as basic environmental
11

237 sanitation and improvement in the existing wells like covering and lining may help. Also, basic
238 treatment of the water at both the community and at the household levels by chemical disinfection with
239 chlorine, filtration using simple household filters and boiling of water before its consumption is
240 encouraged. To guarantee water potability and avert further outbreak of water borne diseases in Foko,
241 it is further recommended that future shallow wells be located upstream of the privy of every
242 household so that leachates from the pit latrines will not drain into the wells. Lastly, the wells should
243 have concrete platforms with proper drainage made around each well to prevent recirculation of dirty
244 water at well head into the well.

245 **ACKNOWLEDGEMENT**

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

247

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Comment [CM20]: Include the study limitations before the acknowledgement.

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