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IMPACT OF SOIL AND WATER BACTERIA CONTAMINATION ON POPULATION DEMOGRAPHY OF SELECT SOUTHWEST COMMUNITIES WITH COMMUNITY LED TOTAL SANITATION IMPLEMENTATION

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Abstract

Community Led Total Sanitation (CLTS) approach was an adopted and piloted environmental intervention done at selected communities in southwest Nigeria. The impact of soil and water bacteria contamination on population demography of select communities with operational CLTS was evaluated. Water (n=64) and soil samples (n=64) collected from communities were estimated for total bacteria (TBC) and coliform counts (TCC). More than $1.50x10^6$ CFU/g TBC were estimated in soil samples and TCC >$1.5x10^6$ CFU/g were observed in all the communities. TCC indicated a fecal contamination level of more than $0.50x10^6$ CFU/g (p=0.001). More than 10% occurrence rates of Escherichia coli, Klebsiella oxytoca, Citrobacter species and Pseudomonas aeruginosa were recorded in water and soil samples from all the communities and spore formers (B. megaterium and B. subtilis) ranging from 8.0 to 16.67%. Higher rates of participants (98.0%) resided in these communities with 22.4% and 63.0% were of the age ranges 31-40 and 41 to 50 years respectively. Higher rates of 72.6% were male, predominant occupation were farming (68.5%) and trading (15.4%). Level of education and total number of occupants living in houses were significantly associated with the CLTS (p<0.05). The impact of population demography on the environmental sanitation is yet to improve the sanitation in these communities and CLTS implementation.

Key Words: *Coliforms, Population demography, Community sanitation, Environmental laws*

Introduction

The management of environment has become a major concern for the government and the populace. Over the years, the environment has been greatly threatened by human activities. This has consequently resulted into adverse and disastrous effects on human habitation and survival (Combs *et al.,* 2022). Environmental problems arising from Open Defecation (OD), untreated sewage, effluent discharge, open dumping of waste, flagrant discharges of wastewater into the streets, poor hygiene, dirty/filthy environment etc have increased the prevalent diseases in developing communities (Amin *et al.,* 2020). Insanitary environment coupled with unsafe hygiene causes 5.3% of all deaths and 6.8% of all Disability Adjusted Life Years (DALYs) (WHO, 2022). The insanitary condition of the environment was reported to have caused more than 30,000 deaths each (Amanabo-Arome *et al.,* 2021). More than a billion people are infected with diseases associated with insanitary and unhygienic environment globally (Olotupa-Adetona *et al.,* 2020; Popoola, 2023). Nigeria has been described endemic as a result of insanitary environment and unhygienic practices (Omole *et al.,* 2019; Owhonda *et al.,* 2023).

In curbing this menace, several environmental sanitation laws were promulgated to ensure the sustainable utilization and management of the environment. Despite the enactment of many environmental sanitation laws, contravention is still discernible in most towns and cities, as pollution and insanitary activities have increased tremendously. Some houses were built without latrine/sanitary conveniences, wastes are dumped in the open space and many more. Achieving the environmental sanitation goal is to simply reduce the number of people without access to a toilet by 2015 is put at $38 billion per year according to previous estimate (Paul *et al.,* 2020). In achieving the Millennium Development Goals sanitation target of 63% for Nigeria, Community Led Total Sanitation (CLTS) approach was introduced as an intervention, adopted and piloted in Nigeria (Abramovsky *et al.,* 2019). The CLTS approach has become a paradigm shift from the normal enforcement of Environmental Sanitation laws approach to environmental education, awareness, advocacy, sensitization and triggering. The CLTS has led to stepping down of Environmental Sanitation Laws, in terms of the enforcement, to achieving Millennium Development Goals target (Kouassi *et al.,* 2023). The direct impacts of intervention program on sanitation and health of community are direct link with enteric diseases caused by fecal contamination of soil and water as a result of open defecation in communities (Kouassi *et al.,* 2023). There is a need investigate the implications of fecal coliform contamination of water and soil through open defecation and prevention by CLTS process (Bakobie *et al.,* 2020). The social impacts of population demography on the CLTS in rural communities, and compliance to the environmental health standards towards effective monitoring for sustainable community needed to be assessed. It has become imperative to assess the impacts of CLTS on the environmental health of some selected communities through reduction of the faecal pathogen loads in the environment. Implementation of intervention programme, such as point of use treatment and disinfection of stored water was to reduce diarrhoea incidences and transmission via faecal oral pathogens (Islam *et al.,* 2020; Goddard *et al.,* 2020). The present study evaluates the impact of soil and water bacteria contamination on population demography of select southwest communities with Community Led Total Sanitation implementations.

Study Area

The study was conducted at selected communities (including Ilaho Olosan, Ewuji, Abule- Eta, Odo-Erin, Egbeda, Idera, Eweje, Baagbon) geographically located in Odeda District township in southwest Nigeria designated as peri-urban and rural entities with respect to land division according to boundary marks (Fig. 1). Odeda District township is situated between 7°6′ - 7°30′ N and 3°13′ - 3°45′ E (Fig.1) with a landmass of 1,560km^2 and a population of 109,449 (NPC, 2006). It has a climatic weather of wet and dry seasons between April to October and November to February respectively (Adekunle and Shittu, 2014)

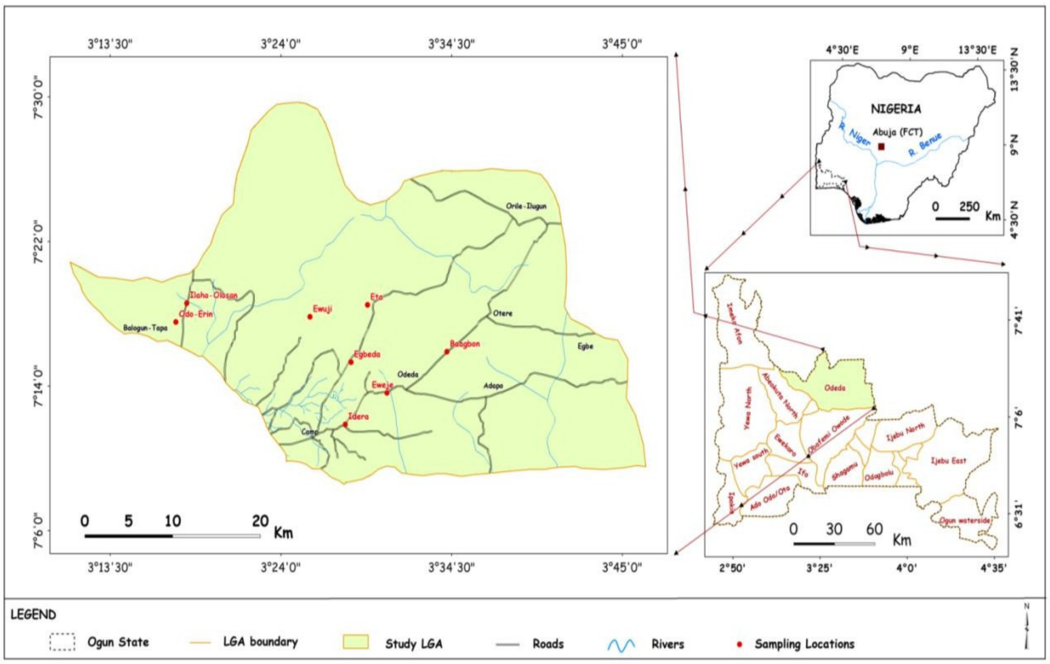

Fig. 1: Geographical location of selected communities in southwest Nigeria

Methods

Sampling

Replicates water (n=64) and soil (n=64) samples were collected from only eight communities out of over 30 communities which were previously listed in Odeda town based on their compliance to the intervention programme, Environmental Sanitation Laws and CLTS indicated by governmental selection processes and certified as Open Defecation Free (ODF) community. Soil samples were collected at the surface of the topsoil, using sterilized spoon at the different locations in proximity to surroundings of the toilets, residential buildings, dump sites, markets and other frequently locations. Water samples were collected from reservoir surface water, rivers and available water sources in the communities. All the collected water and soil samples were transferred in cold chain to the laboratory for analysis. Structured questionnaires were administered on the residents of the communities to obtain information on their socio-demographic status and compliance to the Community Led Total Sanitation (CLTS) intervention programs. However, UNICEF recommended guidelines were applied for the collation of information on Community Led Total Sanitation conditions of the selected intervention communities (Harter *et al.,* 2020).

Water and Soil Bacteria Load Estimation

Estimation of total bacteria level in water and soil samples was performed as described by method of Miles and Mistra described by Hedges (2002). Briefly, 1ml of the water sample or 1g of soil sample was aseptically and thoroughly mixed with 9 ml sterile distilled water in separate sterile tubes and serially diluted in sterile tubes containing 9 ml of sterile water each to make $1/10^2$, $1/10^3$, $1/10^4$, $1/10^5$, and $1/10^6$ respectively. One millilitre from the dilution was plated on dried prepared Nutrient agar and MacConkey agar to estimate total bacteria and coliform counts respectively. After the incubation of the plates at 37°C for 24 hours, colonies of bacteria found were counted and estimated accordingly.

Bacteria Strain Characterization

Homogenized soil and water samples were cultured on Nutrient agar and MacConkey agar and were sub-cultured after incubation at 37^{o}C for 24 hours. Obtained colonies were examined for colonial and cellular morphologies as previously described (Akinduti *et al*., 2016). Biotyping of each strain was performed with the use of Microbact Analytical Profile Index (API). Each bacteria isolate was emulsified in sterile normal saline and characterised using Microbact API for Enterobacteriaceae (Microbact 24E) which is a standardized identification system for *Enterobacteriaceae* with 21 miniaturized biochemical tests and database. The observed colour changes of the reactions were interpreted according to the reference to the Analytical Profile Index.

Data Analysis

The significance of total bacteria and coliform count from each community was determined using ANOVA taking the $p < 0.05$. Level of association of the population demography from the community with CLTS intervention program was analysed with Pearson correlation and risk factor analysis was determined using the odd ratio and confidence interval estimated at 95% taking $p > 0.05$.

Results

Implications of Bacteria Load in Water and Soil Samples

Considering the total bacteria count in water and soil samples (Table 1), more than 1.50×10^6 CFU/g significant level of bacteria isolates were estimated in soil samples from five communities while lower count was recorded in three communities (Eta, Egbeda and Eweje). In water samples from these communities, higher level of TBC $>1.5 \times 10^6$ CFU/g were observed in all the communities except in Ewuji. Total coliform count indicated a faecal contamination level and a significant level of coliform estimation was observed in all the communities with total coliform count more than 0.50×10^6 CFU/g ($p = 0.001$).

Table 1: Estimated bacteria load in water and soil samples from various communities

Communities	**Soil**		**Water sources**		**F value**	**P value**
	TBC	TCC	TBC	TCC		
	mean±SD (x 10^6 CFU/g)					
Odo erin	1.54±0.94 [a,b]	0.700±0.63 [a]	1.92±1.24 [a]	0.90±0.66 [a]		
Ilaho olosan	1.54±0.74 [a,b]	0.820±0.48 [a,b]	1.58±0.73 [a]	0.70±0.46 [a]		
Ewuji	2.44±0.66 [b]	1.340±0.18 [b]	1.48±0.65 [a]	0.52±0.27 [a]		
Eta	1.40±0.43 [a]	0.680±0.44 [a]	1.88±0.87 [a]	0.80±0.51 [a]	1.452	**0.001**
Egbeda	1.44±0.53 [a]	0.520±0.21 [a]	2.40±0.84 [a]	0.98±0.55 [a]		
Idera	1.94±0.59 [a,b]	0.760±0.46 [a,b]	2.08±1.03 [a]	0.98±0.53 [a]		
Eweje	1.36±0.83 [a]	0.600±0.33 [a]	2.20±0.90 [a]	0.84±0.42 [a]		
Baagbon	1.98±0.29 [a,b]	0.860±0.60 [a,b]	2.44±0.93 [a]	1.16±0.42 [a]		

(TBC, total bacteria count; TCC, total coliform count; CFU/g, colony forming unit per gram; $P<0.05$ is significant while superscripts a,b are not significantly different)

Distribution of Recovered Bacteria Strains from Different Communities

More than 10% occurrence rates of *Escherichia coli, Klebsiella oxytoca, Citrobacter species* and *Pseudomonas aeruginosa* were recorded in water samples from all the communities and spore formers (*Bacillus megaterium* and *B. subtilis)* ranging from 8.0 to 16.67% were found in water samples (Fig 2A). From the soil samples, more than 12.0% *Escherichia coli, Klebsiella oxytoca* and *Pseudomonas aeruginosa* were predominantly found from these communities (Fig 2B). Higher rates of *B. subtilis* and *B. megaterium* found in soil samples ranges from 12.2% to 22.22% compared to water samples.

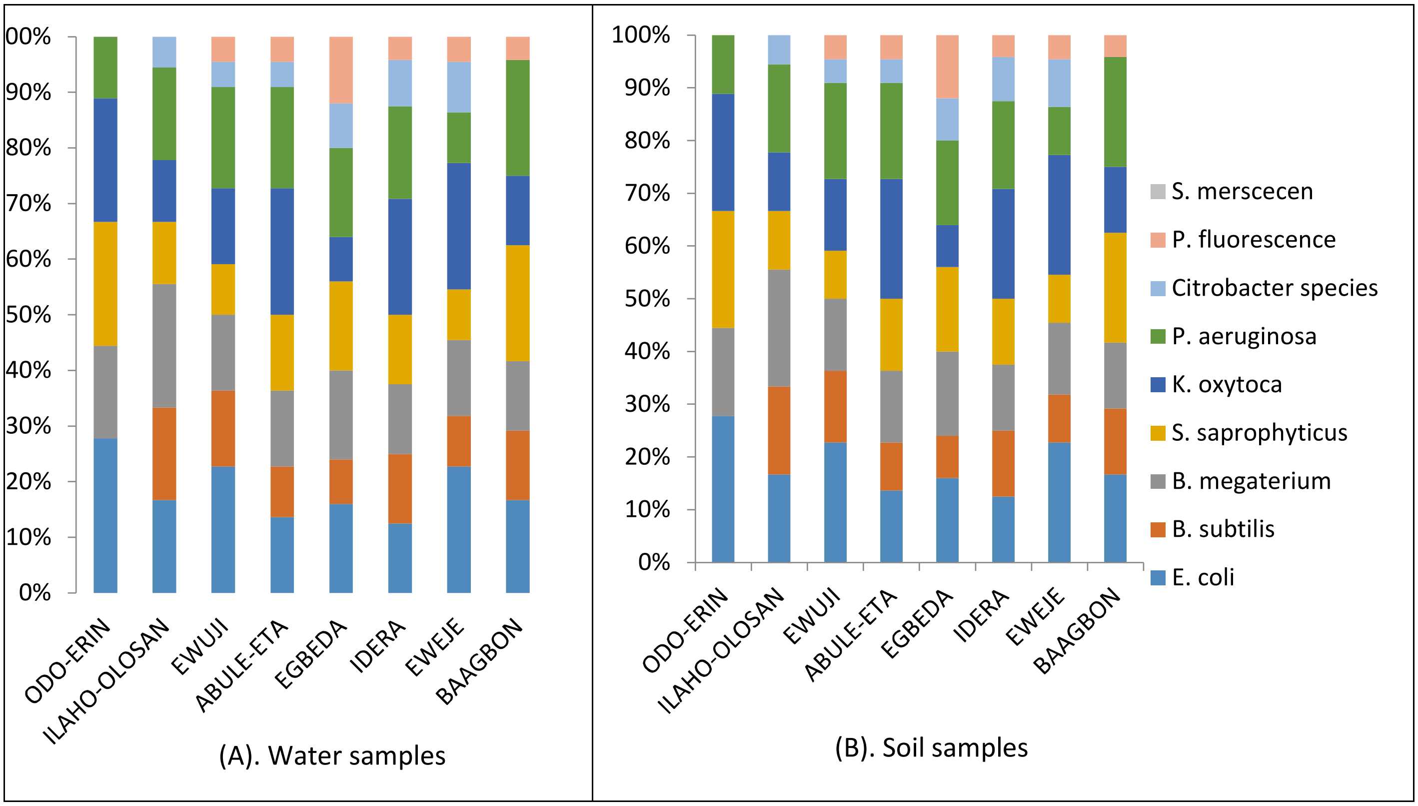

Fig. 2: Proportion of bacteria isolates recovered from soil and water samples from different communities

Impact of Population Demography on CLTS

Higher rates of participants (98.0%) resided in these communities with 22.4% and 63.0% were of the age range 31-40 and 41 to 50 years respectively. Higher rates of 72.6% were male and predominant occupation were farming (68.5%) and trading (15.4%). Higher rates of 60.3% had primary education and 37.0% had non-formal education while 79.5% of the resident lived in houses with 1 to 4 occupants and 17.8% were found to live together in number of 5 to 8 (Table 2). Estimates of participants residing in these communities, age, gender and occupation of the community residents were not significantly correlated with the CLTS with low level of risk factor in these communities ($p>0.05$). The level of education and total number of occupants living in houses were significantly associated with the CLTS showing high risk factor ($p<0.05$).

Table 2: Impact of population demography on CLTS

Characteristics	Variables			
	N (%)		OR[CI]	P value
Residential location	Yes	65(89.0)	0.339[0.31-3.712]	0.378
	No	8(11.0)		
How old are you	1-10	1(1.4)		
	11-20	3(4.1)		
	21-30	1(1.4)	0.243[0.56-4.012]	0.648
	31-40	16(22.4)		
	41-50	46(63.0)		
	51-60	1(1.4)		
	60 and above	6(8.4)		
Gender	Male	53(72.6)	0.301[0.769-4.521]	0.450
	Female	19(26.0)		
What is your occupation	Farming	50(68.5)		
	trading	11(15.4)		
	Student	5(7.0)	0.294[1.005-4.631]	0.746
	Teaching	3(4.1)		
	Civil servant	4(5.6)		
	Artisan	1(1.4)		
	others	0(0.0)		
What is your level of education	Primary	44(60.3)		
	Secondary	2(2.7)	1.86[2.962-5.821]	0.019
	Tertiary	0(0.0)		
	Non-formal	27(37.0)		
What is the number of occupants in your house	1-4	58(79.5)		
	5-8	13(17.8)		
	9-12	1(1.4)	2.913[2.943-6.318]	0.001
	13-16	1(1.4)		
	16 and above			

Discussion

The inabilities of the environmental sanitation laws to effectively tackle the problems of environmental sanitation have led the international communities to develop an intervention programme towards achieving the Millennium Development Goals target (Cernev *et al.,* 2020; Van Tulder *et al.,* 2021). The impact of population demography on the environmental sanitation is yet to improve the sanitation in Nigerian rural communities like other Sub-Saharan Africa. High bacteria load recorded in soil and water samples from the selected communities threatened the community populace. The potential presence of fecal bacteria obtained from different sources and pollutions which are coming from poor sanitation and environmental degradation as refuse dumping and open defaecation persist, this is an indication for possible disease outbreak (Mudau *et al.,* 2023; White *et al.,* 2023). Groundwater or streams are major sources of drinking water in several communities, and they play important role in improving the health and sustainability of community livelihoods and their contamination with faecal coliform is not safe for the domestic use or drinking (Adutwum *et al.,* 2022). The observation of high-level coliform estimation from the soil further indicates indiscriminate disposal of waste and refuse which could be responsible for enteric infection such as diarrhoea and dysentery particularly among children under 5 years. The estimated bacteria and coliform count from the surveyed communities showed poor quality of water which necessitates provision of affordable and sustainable interventions to improve access to clean and safe water in rural communities (Ray *et al.*, 2021).

Investigating the faecal contamination of drinking water sources is very important for effective monitoring of insanitary communities. Distribution of recovered bacteria strains from different communities indicate over 10% occurrence rate of enteric coliform including *Escherichia coli, Klebsiella oxytoca, Citrobacter* sp. and *Pseudomonas aeruginosa* from the community water sources. The detection of faecal coliform *Escherichia coli* in these communities provides indication for faecal contamination of water and soil material with potential accumulation or contamination with faecal material from humans or animals (Khan and Gupta, 2020). This further correlate to the temporal variation in *E. coli* occurrence rates (Petersen and Hubbart, 2020; Vandeputte *et al.,* 2021; Owhonda *et al.,* 2023), as a results of ground well depths, proximity to a septic tank, and population density (Ngasala *et al.,* 2019; Murphy *et al.,* 2020; Indrastuti and Takizawa, 2021). Presence of *Escherichia coli* and *Klebsiella oxytoca* in community soil and water are crucial indicator for fecal contamination that put majority of the population at risk of intestinal infection due to insanitary status of these communities. The significant level of faecal contamination of the household environment affecting the water and soil surfaces poses a health risk to the community residents. Ingestion of faecal coliform (*Escherichia coli, Klebsiella oxytoca or Citrobacter* spp) from homestead soil and untreated drinking water has high chances of community disease outbreak resulting to intestinal morbidity and occasional death mostly among children (Indrastuti and Takizawa, 2021). Recording high rates of spore formers such as *B. megaterium* and *B. subtilis* in water and soil from these communities portray a potential source of systemic infection due to insanitary environment. Inadequate sanitation and unsafe faecal sludge management with high spore formers threaten public health, socio-economy and human capacity development (Amanabo-Arome *et al.*, 2021; Fagbemi *et al.,* 2023). Exposure pathways including contaminated soil, water, farm produce, and community vended food are potential link for adverse health outcomes such as diarrhea, enteric dysfunction and stunted growth (Budge *et al.,* 2019).

Community Led Total Sanitation (CLTS) was participatory development programme design to solve problems of sanitation and recognizes individual's right to clean environment and sanitation (Amanabo-Arome *et al.,* 2021; Okumu *et al.,* 2022). Apart from CLTS discouraging open defecation and insanitary environment which has led to increasing rate of bacteria coliform and several species of bacteria causing enteric infection, population demography pose a serious risk to achieving CLTS in several communities in southwest Nigeria. The study observed higher rates of participants residing in these communities with more than 20% and 60% of ages 31-40 and 41 to 50 years respectively, and predominant occupation were farming and trading. Low level of education which was indicated by the majority attaining primary education and non-formal education further pose a risk to the achievement of CLTS. Poor implementation of CLTS has made the programme ineffective and applicable tool to reduce enteric infection mostly diarrhoea prevalence (Chirgwin *et al.,* 2021; Okumu *et al.,* 2022). The low level of education among the community populace is one of the major factors that slows down the achievement of CLTS in majority of southwest Nigeria communities. Practical implementation of community health education and awareness programmes for CLTS would facilitate improved environment, prevention of inadequate and unsafe water, lack of sanitation, and poor hygiene practices (Salecker *et al.,* 2020). Similar high population of residents living together in a single household is one major risk factor for poor implementation of CLST in many low- and medium-income settings (such as Ethiopia, Kenya, and Zimbabwe) (Kusago, 2019; Haier and Schaefers, 2022; Popoola, 2023). The collective approach for the implementations of CLTS provides a preventable and treatable measure for feco-oral disease and healthy environment (Kusago, 2019). CLTS is a participatory approach involving all members of the community to discuss their environment, sanitation, health and safety. This will create ideas in the people to identify their problems, think of solutions and assessing their initiatives to take action (Kouassi *et al.,* 2023). The adverse effect of open defecation in environment would be practically resolved to certain extent with CLTS approach and its integration in the community system of governance. To improve the implementation of CLTS in several communities, population would require strategic orientation, educational awareness, facilitation of required environmental skill towards prevention of open defecation, waste disposal and sanitary of household toilets.

Conclusion

High coliform count in water and soil from the communities provided a significant indication of faecal pollution due to poor environmental sanitation in selected communities. High occurrence of faecal indicator bacteria particularly *Escherichia coli* and other coliforms present level of faecal contamination of the household environment mostly from contamination from septic or run-off from nearby refuse dump. The evidence of significant association of poor level of education and high number of people living together contribute to poor implementation of CLTS. The impact of population demography on the environmental sanitation is yet to improve the sanitation in the rural communities and CLTS implementation. To improve CLTS in developing communities, population oriented and environmental strategy, educational awareness is urgently required to prevent potential enteric infection outbreak.

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