

Research Paper

Freshwater requirement to attain open-defecation-free status in Nigeria by 2025

O. Adeoti, F. F. Akinola, S. A. Ogundare and B. S. Awe

ABSTRACT

Nigeria is a signatory to the United Nations Sustainable Development Goals (SDGs). Target 6.2 of Goal 6 has requested countries who are parties to the SDGs to end open defecation by 2030. Notwithstanding this, the Government of Nigeria launched a far more ambitious National Road Map in 2016 to end open defecation in the country by 2025. Since water and sanitation are inextricably linked, this paper estimates Nigeria's freshwater requirement to attain open-defecation-free status by 2025. The analysis revealed that the quantity of freshwater required amounted to between 2.74 and 2.94×10^6 cubic metres (m^3) per day or between 1.0 and $1.1 \times 10^9 m^3$ per year under the assumptions made. This amount is relatively less than Nigeria's total water resources potential estimated at $375.1 \times 10^9 m^3$ /year. The data presented will help increase the reliability of estimates of water for sanitation in Nigeria.

Key words | freshwater requirement, Nigeria, open defecation, sanitation, SDGs

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HIGHLIGHTS

- Evaluates water requirement to attain open-defecation-free status in Nigeria by 2025.
- Draws on data sources from the Nigerian perspectives.
- The amount of freshwater required amounted to between 1.0 and $1.1 \times 10^9 m^3$ /year.
- Less than Nigeria's water resources potential estimated at $375.1 \times 10^9 m^3$ /year.

INTRODUCTION

As a follow up to the Millennium Development Goals (MDGs) that ended in 2015, the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs), adopted by countries on 25 September 2015, officially came into force on 1 January 2016 (United Nations 2019a). The 2030 Agenda has 17 goals and 169 specific targets addressing social, economic and environmental aspects of development, and seeks to end poverty, protect the Earth and ensure prosperity for all (WHO and UNICEF 2017).

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SDG target 6.2 is far more ambitious than the previous MDG target 7c, which aimed to halve the proportion of the population without access to sanitation by 2015. In an explicit term, target 6.2 has called on countries who are parties to the SDGs to end open defecation by 2030. Notwithstanding this, the Government of Nigeria has set a far more ambitious commitment to end open defecation in the country by 2025 through the formulation of a National Road Map (FMWR 2016a) and the Partnership for Expanded Water Supply, Sanitation and Hygiene (PEWASH) (FGN 2016). To reinforce this ambition, a state of emergency was declared on the water supply, sanitation and hygiene (WASH) sector on 8 November 2018 to eliminate the business as usual approach

(Premium Times 2018), while an executive order 009 targeted towards making Nigeria open-defecation-free by 2025 was signed on 20 November 2019. These attempts suggest that Nigeria is committed to ending open defecation by 2025. The National Water and Sanitation Policy of 2004 has also emphasised achieving 100% sanitation coverage by 2025. Although the National Water Resources Policy of 2016 does not specify a timeline, it also supports universal coverage in sanitation provision. In monetary terms, open defecation costs Nigeria over US\$1.0 billion per year (FMWR 2016a). Globally, about 892 million people defecated in the open in 2017 (United Nations 2019b). In the case of Nigeria, over 47 million people excreted in the open in 2019 (Odogwu 2019). While various sanitation facilities are in use in Nigeria (Table 1), under the do-nothing approach about 102 million people are expected to defecate in the open in Nigeria by 2025 (FMWR 2016a).

Nigeria's water resources potential is estimated at 332.7×10^9 cubic metres (m^3) of surface and $155.8 \times 10^9 m^3$ of groundwater (FRN 2014). Despite this relatively abundant water resource, there are still cases of freshwater shortage during the dry season, especially from December to April, when some streams and rivers run dry. The total water use (for irrigation, freshwater aquaculture, livestock, and municipal) is projected to increase from 5.93 in 2010 to $16.59 \times 10^9 m^3$ /year in 2030. The municipal component, 3.1×10^9 in 2010, is expected to rise to $8.9 \times 10^9 m^3$ /year in 2030 (FMWR 2016b). In Nigeria, the provision of drinking water falls within the constitutional responsibility of the State Governments (Adeoti & Fati 2019). Available data indicated that country-wide access to piped water was 11% in 2017. Roughly 8% of the rural

population and 15% of the urban population had access to piped water in 2017 (UNICEF and WHO 2019). Water and sanitation are positively linked. Water is needed to flush, for anal cleansing, handwashing and toilet cleaning. As one of the major indicators of extreme poverty (Abubakar 2018), eliminating open defecation has benefits from the health, nutrition, learning, social and economic perspectives (FMWR 2016a). To realise this still poses some challenges on water resources management, especially in developing economies.

Literature investigating the amount of water needed for human faeces disposal remains sparse, at least from the Nigerian perspective. Studies related to water and sanitation in Nigeria have focused on inequalities in households' environmental sanitation practices, looking at the case of Ile Ife (Faniran & Ojo 2019), impact and sustainability of community water supply and sanitation programmes in Nigeria (Ademiluyi & Odugbesan 2008), spatial variations in access to improved sanitation and water, using the local government areas in Lagos state as a case study (Kunnuji 2014), drinking water quality, household sanitation, and hygiene practices in Tunga Magaji, a rural community in Sokoto state (Kaoje et al. 2019), determinants of access to sanitation facilities in Nigeria (Abubakar 2017), factors associated with safe disposal practices of children's faeces in Nigeria (Aliyu & Dahiru 2019), water meanings, sanitation practices and hygiene behaviours from a cultural perspective in Akwa Ibom state (Akpabio 2012), possibility of water and sanitation shortfalls exacerbating SARS-CoV-2 transmission risks in Nigeria (Odih et al. 2020), review of the past, current and future status of urban sanitation in Nigeria in terms of access coverage, policies, institutions, future challenges and opportunities

Table 1 | Use of sanitation facilities in Nigeria, 1990–2018

Sanitation facility	Percentage of the population in:									
	1990	2000	2008	2010	2011	2012	2013	2015	2017	2018
Open defecation ^a	24	23	22	22	23	23	29	25	20	24
Unimproved ^b	14	18	20	22	22	23	17	22	21	18
Shared ^c	24	27	26	25	24	26	20	24	21	16
Improved ^d	38	32	32	31	31	28	34	29	39	42

Sources: FMWR (2016a); NBS (2018); UNICEF and WHO (2019).

^aIncludes the use of open fields, forests, open bodies of water, or other open spaces, beaches, or disposed with solid waste.

^bIncludes the use of pit latrines without a platform, hanging latrines, or bucket toilets.

^cIncludes the use of acceptable sanitation facilities but shared between two or more households.

^dIncludes the use of flush/pour toilets, ventilated improved pit (VIP) latrines, pit latrines with slab, and composting toilets (FMWR 2016a).

(Ezeudu 2019), association between oral hygiene practices and WASH practices among street-involved young people in southwest Nigeria (Folayan *et al.* 2020), factors influencing growing-city pollution and sanitation in Ibadan, Ogbomoso (Oyo state) and Ajegunle (Lagos state) (Apata *et al.* 2019), factors influencing the practice of open defecation among Nigerian households (Abubakar 2018), sources of water supply, sanitation facilities and hygiene practices in Amassoma, Bayelsa State (Olalekan *et al.* 2019), geo-spatial modelling of access to water and sanitation in Nigeria (Ajisegiri *et al.* 2019), access to sanitation facilities and handwashing practices among physically challenged persons in homes for the disabled in Ibadan (Oyo state) (Olorunfoba *et al.* 2020), impact of water and sanitation on childhood mortality in Nigeria (Ezeh *et al.* 2014), and inequalities in access to water and sanitation in some rural settlements in southwestern Nigeria (Akoteyon 2019).

Therefore, the main question addressed by this paper is: how much freshwater is needed to attain open defecation free status in Nigeria by 2025? One of the key issues constraining the effective implementation of WASH programmes in Nigeria has been traced to a lack of data (FGN 2016). The finding of this paper is useful to the government, practitioners, development partners (such as UNICEF, African Development Bank, World Bank, European Union, Japan International Cooperation Agency, etc., and Non-Governmental Organisations such as WaterAid, and Tulsi Chanrai Foundation, etc.), and researchers in the field of water, sanitation and hygiene in Nigeria and elsewhere.

For the purpose of this study, wet toilets are defined as those toilets that operate with flush water (Tilley *et al.* 2014). These include pour-flush toilets and flush toilets either connected to piped water or connected to overhead reservoirs. It refers to dry toilets as those that operate without flush water. These include ventilated improved pit (VIP) latrines, pit latrines with(out) slab, and composting toilets. 'House', as used in this study, refers to a complete standalone residential building. Its use in this study differs from household which refers to a family unit. In Nigeria, two or more families (or households) may inhabit one house and share the same toilet. How many of these exist in Nigeria is not known. However, using the house as the unit of analysis makes it easier for data collection and analysis (for example, to quantify the amount of water used for toilet cleaning).

METHODOLOGY

Sites selection

To understand the types of sanitation facilities-in-use and the amount of freshwater required, Ado Ekiti and Osogbo, both located in the southwestern part of Nigeria, were purposely selected. The selection of these sites was favoured by ease of data collection and financial constraints. Limiting the study to two urban sites was deliberate and informed by financial constraints. The study agrees that urban and rural households, with varying spatial differences, experience sanitation water needs in different ways. However, since this study did not aim to compare urban and rural sanitation water needs, a detailed assessment of freshwater requirement for sanitation in rural areas in Nigeria is left for future investigations. Notwithstanding this, the study assumed that there may be no huge variations in the sanitation water needs of two similar houses located within the same cultural setting, one in urban and the other in a rural area, using for example the pit latrine or flush toilet of the same design. Apart from north central Nigeria (50.0%), the southwest (24.1%) had the highest number of households that defecated in the open. In terms of ethnicity of household head, the Yoruba (23.8%) had the highest proportion of open defecation (NBS and UNICEF 2017). These were the other factors that favoured the selection of the southwestern part of Nigeria. The selected sites are briefly described below.

Site descriptions

Ado Ekiti, Ekiti State, Nigeria

With a population of 463,000 people in 2019 (Macrotrends 2020a), Ado Ekiti, the capital of Ekiti State, was the largest town in Ekiti State covering 293 km². It lies on coordinates 7°38'N 5°13'E. The city has an average annual rainfall of 1,334 mm, and annual mean minimum and maximum temperature of 20.1 and 30.1 °C, respectively (Climate-Data.Org 2020).

In a 2016–2017 survey, 50.5% of the households in Ekiti State used improved sanitation facilities, 10.5% unimproved

facilities, while 39.0% defecated in the open (NBS and UNICEF 2017). A preliminary investigation revealed that roughly two in every five houses, in especially the inner part of the town, defecated in the open. Almost 50% of the population lived in the inner part of the town. At present there are no faecal sludge collection and treatment systems in Ado Ekiti and Ekiti State in general. Using an average faeces size of 0.05 m^3 per person per year and 0.43 m^3 of urine per person per year (Tilley et al. 2014), it is estimated that roughly $23.15 \times 10^3 \text{ m}^3$ of faeces and $199.09 \times 10^3 \text{ m}^3$ of urine were produced in Ado Ekiti in 2019. Although specific data on Ado Ekiti are scarce, Ekiti State Education Index in 2016 was 0.8944, higher than the national average of 0.7966. The Gross National Income was 1,897.60 Naira per capita, also slightly higher than the national average of 1,756.56 Naira per capita (UNDP 2018). Less than 10% of the population in Ado Ekiti had access to piped water (Sodamade et al. 2020). In terms of quality of residential buildings (e.g. wall and roofing materials) in Ado Ekiti, over 60% of the houses are made of concrete or cement blocks, with over 70% roofed with corrugated iron sheets.

Osogbo, Osun State, Nigeria

Osogbo, the capital city of Osun State, lies on coordinates $7^{\circ}46'N$ $4^{\circ}34'E$ with an area of 47 km^2 (Ministry of Innovation Science and Technology 2020). The city had a population of 699,000 people in 2019 (Macrotrends 2020b). Slightly drier than Ado Ekiti, the city's average annual rainfall is 1,177 mm (Deutscher Wetterdiens undated), while the annual mean minimum and maximum temperatures, comparable with that of Ado Ekiti, are 21.5 and 31.7°C , respectively (Deutscher Wetterdiens undated; NBS 2009).

In the case of Osun State, 61.8% of the households used improved sanitation facilities, 5.4% unimproved facilities, while 32.7% defecated in the open (NBS and UNICEF 2017). Similar to the situation in Ado Ekiti, almost 100% of the population in Osogbo were serviced by on-site, self-help sanitation infrastructures, with no sewer and faecal sludge collection and treatment systems. Drawing on the data of Tilley et al. (2014), faeces and urine generations were roughly estimated at 34.95×10^3 and $300.57 \times 10^3 \text{ m}^3$, respectively, in 2019. With almost 60% of the population living in the inner part of the city, roughly three in 10 houses defecated in the open

in 2019. Similar to the case of Ado Ekiti, there is a dearth of specific data on Osogbo. However, Osun State Education Index in 2016 was 0.8551, slightly lower than Ekiti State's, but higher than the national average of 0.7966. For the period, the Gross National Income was 1,225.47 Naira per capita (UNDP 2018), lower than both the Ekiti State and the national average. Similar to Ado Ekiti, residents of Osogbo obtain their water supplies from the natural sources (wells – deep or shallow, rain) and/or from treated sources (including piped network, water vendors, etc.). In terms of quality of residential buildings (e.g. wall and roofing materials) in Osogbo, over 60% of the houses are made of concrete or cement blocks, with over 70% roofed with corrugated iron sheets.

Data gathering

To identify the types of toilet facilities being used and the amount of water required, a face-to-face questionnaire survey was administered to some residents of the selected sites (Table 2). The survey was carried out between June and August 2019 under conditions of confidentiality and anonymity (the Institution has no Ethics Screening Committee. However, it is expected that researchers comply with good ethical practices when dealing with human subjects. For example, obtain informed consent, provide anonymity and confidentiality assurance). Because of the purpose of this study, houses were purposely selected. The selection criteria were that houses had the time and were willing. These houses were verbally invited to participate in the study. Purposive sampling was deliberately adopted to capture the various sanitation end-use facilities in the face of limited financial resources. Besides this, houses using two or more different types of toilets were eliminated from the survey, because they could make the script complex and data difficult to analyse. Based on this and other associated problems (coinciding with the time of the survey was

Table 2 | Questionnaire administration

Questionnaire	Site	
	Ado Ekiti	Osogbo
Administered	62	31
Received	37	29

when the issue of 'human faeces for money rituals' was high in the southwest. This made exploring issues related to human faeces very sensitive), a sampling frame could not be developed. Also, there were no databases which could have made the sampling process quite simple and easier to carry out. In this study, the survey was conducted in a semi-structured format (with some open-ended questions) to enable the emergence of new ideas. Interviewing all the house members was ruled out due to being time consuming and may result in conflicting information. Instead, any adult house members with some reasonable understanding of house size, defecation frequency, and water use for sanitation mostly served as respondents in the presence of others, while some house heads collected and completed the script at their convenience. Besides this, some houses were assisted when completing the questionnaire script. To assist when completing the script, containers of known volumes were provided. The survey aimed at identifying the types of toilet facilities being used and estimate the amount of freshwater used for faeces disposal. The issue of water losses, wastage and leakages during conveyance to the point of use is outside the scope of this study. This becomes relevant when designing water supply systems.

Prior to application, the semi-structured questionnaire script was tested using some of the expected respondents in order to remove what Pratt & Loizos (1992) refer to as sources of weakness and error and to improve the ability of the scripts to elicit the required information. Following pre-testing, improvements were made to the scripts in light of the feedback received. The restructured script consisted of 10 questions and had three sections (Supplementary material, Appendix A). The first section dealt with house location and the type of sanitation (or toilet) facility-in-use. The second section dealt with the number of persons per house, their defecation frequency, the quantity of freshwater being used per person per defecation, and water used for cleaning. The last section dealt with the case of infants (those below the age of five years) (Supplementary material, Appendix A). The script was kept simple to avoid respondent fatigue.

Despite the adopted purposive sampling, a 100% return rate could not be achieved because some questionnaire scripts could not be retrieved from some houses after repeated attempts. This may be due to the fear associated

with the rumoured 'human faeces for money rituals' and/or the unwillingness to participate. Ethical requirements dictate that houses may discontinue participation without prejudice. As illustrated in Table 2, the size of respondents for this study was not large. While small scale samples can provide rich information capable of informing policy and practice, this is an important limitation of this study. Readers should be aware of this and interpret the discussions presented within the context of this limitation.

DATA ANALYSIS

This study aimed at identifying the various onsite human faeces disposal facilities and estimating the amount of water used for faeces disposal, with the objective of conducting a quantitative analysis on the data collected. Descriptive statistics (mean, standard deviation, and percentages) was used to analyse the data collected.

In the analysis, the study adopted a four-scenario analysis (Table 3) to quantify Nigeria's freshwater requirement for sanitation and end open defecation by 2025. This is because there was no specific trend or known pattern of adoption to predict the future use of sanitation facilities in Nigeria (see Table 1). From 2015 to 2025, about 102 million people are expected to defecate in the open (FMWR 2016a). As illustrated in Table 3, the open defecation fraction of the population (25%) was distributed across the four improved sanitation facilities with different ratios for the four scenarios when compared with the base year of 2015 (some known socio-economic realities, such as all the houses in Nigeria cannot be on pour/flush systems, and the position of the National Road Map helped inform the selection of the different ratios for the selected scenarios). To illustrate: in scenario A, by 2025, 30% of the population would be expected to use pour/flush toilets, 12.6% VIP latrines, 32% pit latrines with slab, while 2% would be expected to use composting toilets. On the one hand, the National Road Map did not foreclose the possibility of moving up the sanitation ladder in achieving open-defecation-free status in Nigeria. On the other hand, the Map's underlying assumption was that between 2015 and 2025 some houses may likely upgrade their toilets in line with changing socio-economic status and life style. In the case of scenario D, all the

Table 3 | Data and assumptions

Sanitation facility	2011 ^a	2016 ^b	2015 ^c	Scenario (% of population)			
				A (2025)	B (2025)	C (2025)	D (2025)
Improved:	51.3	51.6					
– Pour/Flush	24.4	25.7	25.7	30	35	40	25.7
– Ventilated Improved Pit (VIP) latrine	1.5	1.3	1.3	12.6	14	16	1.3
– Pit latrine with slab	25.1	23.9	23.9	32	26	20	48.9
– Composting toilet	0.2	0.7	0.7	2.0	1.6	0.6	0.7
Unimproved:	48.7	48.4					
– Pit latrine without slab	18.3	23.2	23.4	23.4	23.4	23.4	23.4
– Hanging toilet	1.5	0.8					
– Bucket	0.0	0.1					
– Others	0.4	0.9					
– Open defecation	28.5	23.5	25.0				
Population ^d ($\times 10^6$)			183.524	239.874	239.874	239.874	239.874

^aNBS UNICEF & UNFPA (2013).

^bNBS and UNICEF (2018).

^cFor simplicity, the 2016 data for improved sanitation facilities were assumed for 2015.

^dFMWR (2016a).

open defecation fraction of the population were moved to the category of pit latrine with slab, translating to 48.9% when compared with that of the base year at 23.9% (Table 3). This also agrees with the assumption of the National Road Map towards making Nigeria open-defecation-free by 2025 (FMWR 2016a). However, the National Road Map was silent on the proportion of the population using other unimproved sanitation facilities such as pit latrines without slab, hanging toilets, bucket toilets, etc. (Table 3). The document only asserted that the target for 2025 was to stop open defecation in the country (FMWR 2016a). It is therefore assumed in this study that the roughly 23.4% of the population who used these other unimproved sanitation facilities in 2015 would continue with its use till 2025 (see Table 3). Nevertheless, Nigeria plans to achieve a country-wide access to safely managed (or improved) sanitation by 2030 (FMWR 2016a).

LIMITATIONS OF THE STUDY

Although the study has adopted a purposive sampling method for primary data collection to minimise data

contamination, there are some important limitations. First, the study areas were limited to a few urban sites, therefore the data obtained cannot be representative of southwestern Nigeria. Even within the selected sites, the primary sample size was not large and could not be increased due to financial and other constraints. Second, the sampled houses may have exaggerated some of the values. There is a tendency for houses to have underestimated some values due to poor judgement and to have over-estimated some others due to self-image, cultural and traditional influences. Third, it is important to highlight that data gathering was carried out during the rainy season, this may have also influenced the amount of water reported to have been used in some cases. Notwithstanding its limitation, the study offers some insights capable of informing policy and practice if applied. This study is one of the first to focus on quantifying the amount of freshwater needed for sanitation in Nigeria by 2025 in response to the National Road Map and other instruments which aim to end open defecation in the country by 2025 (FMWR 2016a). Because of this, the nature of the study was exploratory. It should be highlighted that this study has not accounted for urine flush water use (for example, in houses using wet toilets) and to maintain

personal hygiene after urinating (for example, in houses using wet toilets or dry toilets). Further study is required to determine the amount of water use associated with urinating.

RESULTS AND DISCUSSION

The results of the survey revealed that 16.2% of the houses surveyed in Ado Ekiti defecated in the open, while 13.8% defecated in the open in Osogbo (Figure 1). The sanitation facility with the highest number of users in Ado Ekiti was FT₁ (flush toilets connected to piped water) (29.7%), while PL (pit latrines with slab) and FT₁ (flush toilets connected to piped water) both had the highest number of users (20.7% each) in Osogbo (Figure 1).

According to the survey data, the number of persons (aged five and above) per house varied from one to 15. As illustrated in Figure 2, mean values varied from 4.0 to 10.0, with the overall mean (and standard deviation) translating to 6.1 ± 1.7 persons per house. The average defecation frequency varied from one to 1.8 times per person per day, while the overall mean (and standard deviation) amounted to 1.4 ± 0.2 defecations per person per day. The overall mean defecation frequency obtained in this study (1.40) is comparable with the value of 1.20 defecations per person per day reported in Rose et al. (2015). For any on-site sanitation, defecation frequency impacts water requirement and the indicator is useful in the planning

and design of sanitation systems. About 41% of the houses reported visiting the toilet twice a day on average, while others (59%) reported an average of once. Overall, about 92% of the surveyed houses washed hands after toileting (5% indicated not washing hands after defecating, while 3% reported some house members), while about 86% reported using water for anal cleansing (11% reported not using water for anal cleansing, while 3% reported some house members). Those who did not use water for anal cleansing indicated the use of dry cleansing materials such as tissue paper, etc., 100% of houses using wet toilets reported cleaning their toilets with water. In a week of 7 days, 24.2% cleaned every day, 22.3% twice a week, 23.9% cleaned three times a week, while 10.3% cleaned four times a week on average. Others cleaned once (12.2%), five times (4.9%) and six times (2.2%) a week. Per cleaning event, the quantity of water used varied from one to 40 L per house (10.8 ± 2.9 L per house). In the case of houses using dry toilets, about 76% reported the use of water to clean their toilets/containers. The quantity of water used varied from 2 to 10 L per house per cleaning event (6.4 ± 1.1 L per house per cleaning event).

While this study is not about comparing sites, Figure 2 revealed that even open defecation was not water use neutral. Although UNICEF and WHO (2015) have defined open defecation to mean when human faeces are disposed of in fields, forest, bushes, open bodies of water, or other open spaces or disposed of with solid waste, the data revealed that in some houses practising open defecation

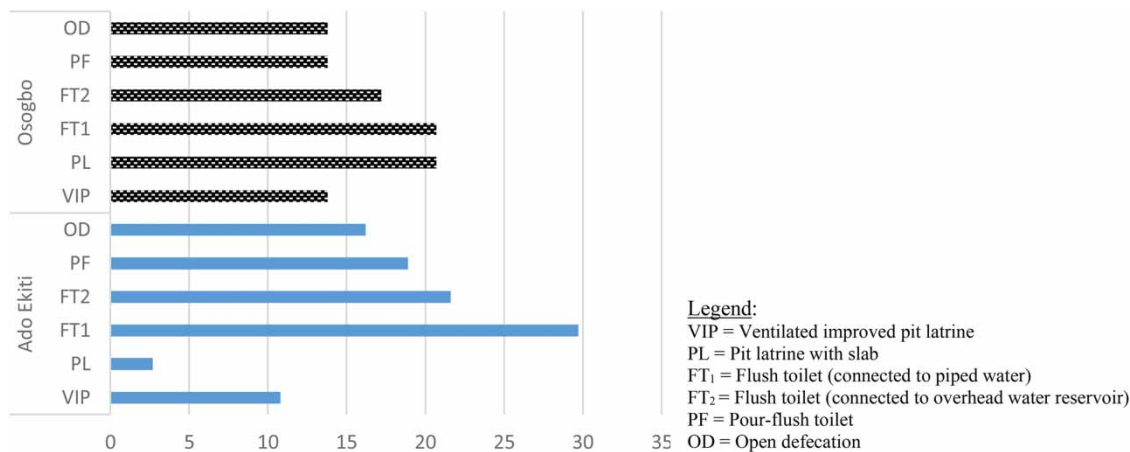


Figure 1 | Sanitation facilities-in-use (%) based on the survey data (mean values). Note: composting and unimproved (pit latrines without slab, hanging, and buckets) toilets were not popular in the surveyed sites.

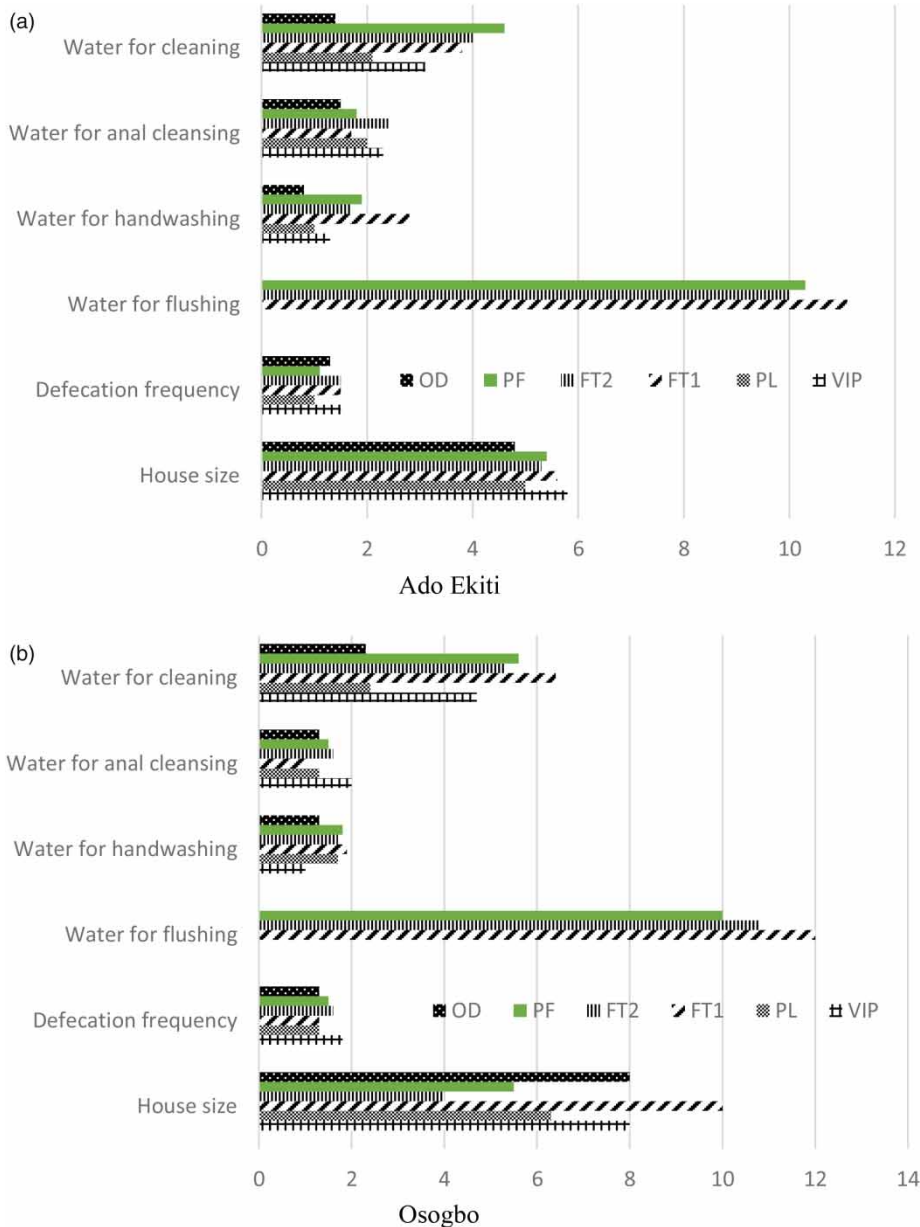


Figure 2 | Survey results on house size, defecation frequency, and water use (water use in litres) (mean values). (a) Ado Ekiti, (b) Osogbo.

water was used for handwashing, anal cleansing as well as cleaning of buckets (or containers) used for faeces disposal. On average (Figure 2), the amount of water used varied from 0.8 to 1.0 L (for handwashing), 1.3–1.5 L (for anal cleansing) per person per defecation, and 4.0–4.5 L per house per cleaning event. However, water for flushing accounted for the highest in the surveyed sites (Figure 2). Mean values varied from 10.0 (PF and FT₂) to 12.0 (FT₁) litres per

defecation per person. The quantity of water used was influenced by availability (for those using PF), type of flush toilet technologies being used (for those using flush toilets), and users' behavioural patterns.

As illustrated in Figure 3, the overall mean values per person per defecation were 10.7 ± 2.9 L for flushwater, 1.7 ± 0.4 L for anal cleansing, 1.6 ± 0.5 L for handwashing, and 3.8 ± 1.6 L for cleaning per person per day. The value

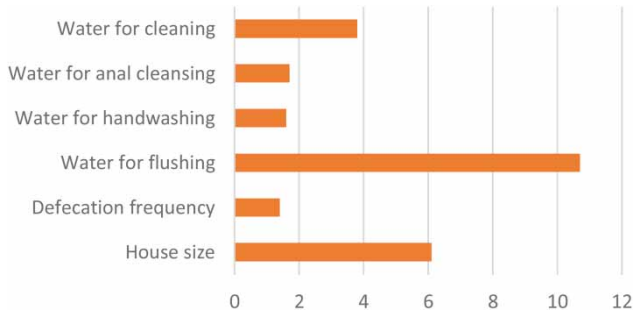


Figure 3 | Summary of survey results (water use in litres) (mean values). Note: flush water, water for handwashing, and anal cleansing are per defecation per person, while water for cleaning is per person per day.

obtained in this study for anal cleansing (1.7) is comparable with the value (1.75 L per person) reported in [Tilley *et al.* \(2014\)](#) for anal cleansing.

In the case of infant's (children below five years) water use for sanitation, the survey data revealed that water for flushing accounted for the highest (Figure 4). It varied from 12.9 to 15.7 L (14.5 ± 4.7 L) per house per day. For houses using wet toilets, children's water use varied from 27.1 (FT₂) to 34.9 (FT₁) litres per house per day, while for houses using dry toilets, it varied from 6.3 (OD) to 17.4 (PL) litres per house per day. However, about 13% of the surveyed houses in Ado Ekiti and 12% in Osogbo had children below the age of five years. Overall, the mean value for

children sanitation varied from 6.3 (OD) to 34.9 (FT₁) litres per house per day. The average defecation frequency (from the survey data) varied from one to three defecations per child per day, with the overall mean (and standard deviation) translating to 2.2 ± 0.6 defecations per day.

Combining the data in [Figures 2 and 4](#) together, overall, as shown in [Figure 5](#), houses using FT₁ accounted for the highest water use, 195.6 L per day. Besides being the highest flush water user (see also [Figures 2 and 3](#)), another reason for this is that FT₁ had the highest mean number of persons per house (8.2 ± 3.9) compared with VIP (7.5 ± 2.6), PL (7.3 ± 3.6), OD (7.0 ± 4.1), PF (6.7 ± 2.6), and FT₂ (5.5 ± 3.1). The absence of metering in most piped houses in the surveyed sites may have accounted for the high water use in FT₁. The overall average house size (including infants) obtained in this study amounted to 7.03 ± 3.32 persons per house per day.

Considering the information provided in [Figures 2 and 4](#) together, the sanitation water use tree that formed the basis of quantifying the amount of freshwater needed by 2025 under the various end-use sanitation facilities (These facilities are: pour/flush, VIP latrine, pit latrine with slab, composting toilet, and unimproved toilet (from [Table 3](#))) is shown in [Figure 6](#). Using the overall average values ([Figure 5](#)), the results of the scenario analysis revealed that

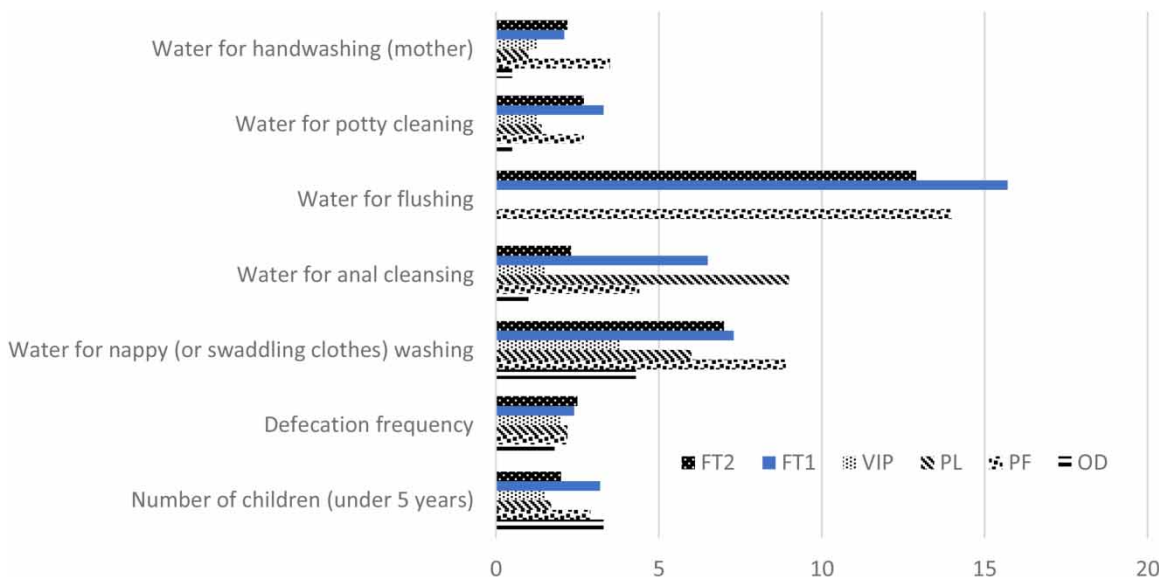


Figure 4 | Infant's (below five years) water use (in litres) for sanitation per house per day (mean values).

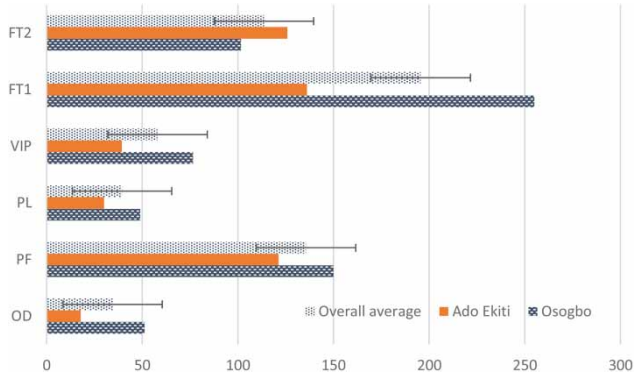


Figure 5 | Overall summary of water use per day in the surveyed sites (in litres, mean values).

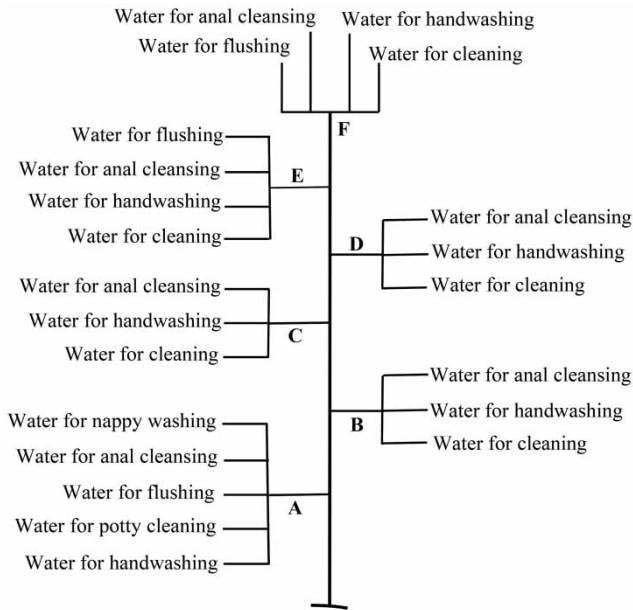


Figure 6 | Sanitation water use tree. Key: Sanitation activities involving water use: A – infant's (below five years) sanitation; B – open defecation; C – pit latrines with slab; D – VIP latrines; E – pour-flush toilets; and F – flush toilets.

by 2025 the freshwater requirement for sanitation to attain open-defecation-free status in Nigeria by 2025 amounted to between 2.74 and $2.94 \times 10^6 \text{ m}^3$ per day (Table 4), or between 1.00 and $1.07 \times 10^9 \text{ m}^3$ per year. In the analysis, the overall average defecation frequency used was 1.0. To estimate the average number of houses by 2025 (see Table 4), the overall average house size of 7.03 persons per day per house obtained in this study was used. This study assumed no significant change in the average house size by 2025. For example, the projected national average

Table 4 | Results of scenario analysis for 2025

Sanitation facility	Scenario A	Scenario B	Scenario C	Scenario D	Scenario	Amount ($\times 10^6 \text{ m}^3/\text{day}$)	Average number of houses ($\times 10^6$)	Amount ($\times 10^6 \text{ m}^3/\text{day}$)	Average number of houses ($\times 10^6$)	Scenario	Amount ($\times 10^6 \text{ m}^3/\text{day}$)
Pour/Flush ^a	30	35	40	25.7	25.7	1.52	10.24	2.02	8.77	25.7	1.30
VIP latrine	12.6	14	16	1.3	1.3	0.25	4.30	0.32	0.44	1.3	0.03
Pit latrine with slab	32	26	20	48.9	48.9	0.43	10.92	0.27	16.69	48.9	0.66
Composting toilet	2.0	1.6	0.6	0.7	0.7	0.03	0.68	0.01	0.24	0.7	0.01
Unimproved toilet	23.4	23.4	23.4	23.4	23.4	0.32	7.98	0.32	7.98	23.4	0.32
Total						2.55	2.74	2.94	2.94		2.32

^aMean value of PF₁ and FT₂ (from Figure 5) = 148.3 L per house per day.

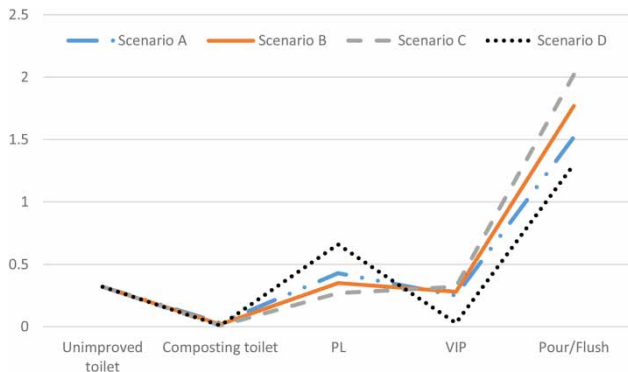


Figure 7 | Classification of water use ($\times 10^6$ m³ per day) (from Table 4).

household size by 2025 is 5.1 persons (FMWR 2016a). This value was estimated at 5.5 in 2015 (NBS 2016). Because composting and unimproved (pit latrines without slab, hanging, and bucket (see Table 1)) toilets are not water-based systems, their water use was roughly assumed to be similar to that of pit latrines with slab. The expected Nigeria's total population by 2025 used in the calculation is 239.874 million (see Table 3). The water use rate (that is, the ratio between total water demand and Nigeria's total water resources potential, estimated at 375.1×10^9 m³/year (FRN 2014)) by 2025 translated to between 0.27 and 0.29%. This reveals that the total freshwater demand to attain open-defecation-free status in Nigeria is much less than the country's total water resources potential.

However, as shown in Figure 7, pour/flush toilets represented the highest consumer of water for sanitation, majorly influenced by the flush water requirement. This indicates that climbing the sanitation ladder as suggested by the National Road Map (FMWR 2016a) would result in more water use at the national level. To cut flush water use (especially in FT₁ and FT₂ houses), policy prescriptions will need to suggest and encourage the use of low-flush toilet designs and mandate the public water utilities in Nigeria to meter piped (FT₁) houses. As a standalone measure, metering can encourage investments in low-flush toilet designs in FT₁ houses. In FT₂ houses, policy prescriptions will have to address users' behavioural patterns through educating houses on how to use a small amount of water to flush. In the case of dry toilets (see Figure 7), their water use is majorly governed by the population of users. These explanations have implications for the design of faecal sludge collection and treatment systems.

CONCLUSIONS

This study concludes that the amount of freshwater required to realise Nigeria's open-defecation-free status by 2025 amounted to between 1.0 and 1.10×10^9 m³ under the assumptions made. This represents between 0.27 and 0.29% of Nigeria's total water resources potential estimated at 375.1×10^9 m³/year. Although this requirement is not huge compared with the estimated total water resources potential, to even out water supply, especially during the dry periods when freshwater shortages are expected, will require considerable investments in water storage and supply systems. This will require the joint efforts of both the federal and the state governments in Nigeria. Notwithstanding its limitation, the outcome of this study is useful in the field of water, sanitation and hygiene (WASH) in Nigeria and elsewhere.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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