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Analysis of sanitation and waterborne disease occurrence in Ondo State, Nigeria

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Abstract
Waterborne diseases (i.e., diarrhea, dracunculiasis, dysentery, typhoid fever, malaria, scabies, ringworm, cholera, hepatitis B, streptococci, and onchocerciasis) are linked to a significant disease burden worldwide. This work has thus established a relationship between access to improved sanitation, potable water supply, and waterborne disease occurrence in Ondo State, Nigeria, by analyzing the data sourced from the Federal Ministry of Water Resources, Federal Republic of Nigeria. The results showed that there was water scarcity (< 42% access) in the southern part of Ondo State. There was inadequate access to improved sanitation (< 30% access) in both the southern and northern parts of the State. Meanwhile, Southern Ondo State had the highest (> 320%) prevalence of waterborne diseases. There also existed a *negatively moderate correlation*: a *substantial relationship* between the access to a potable water supply (APW) (%) and the occurrence of waterborne diseases (WBD) (%) in Ondo State and between the occurrence of WBD (%) and improved sanitation (IS) (%) in the State. There existed a *low correlation: definite but small relationship* between the percentage of people with APW and the percentage of people with IS (%). This study has used the multiple linear regression model to develop a relationship equation using WBD as a dependent variable and APW and IS as independent variables. The first twelve elements (or LGAs) of Ondo State were used for modeling, while the last six were used to validate the results obtained. Equations generated were validated through residuals by observing the conditions of homoscedasticity, normality, and autocorrelation. The Nash–Sutcliffe efficiency was estimated to be about 80%. The spatial variability analysis was also done using inverse distance weighting. Therefore, it can be said that the modeled equation was quite good in predicting past and future waterborne diseases in Ondo State.

Keywords Improved sanitation · Potable water access · Sustainable Development Goal 6 · Waterborne diseases

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1 Introduction

The deprivation of people from Water and Sanitation Services (WSS) or the lack of relevant structures for effective service delivery could increase the rate of waterborne disease spread (Medeiros et al., 2021). According to Ferreira et al. (2021), though the percentage of people without access to water, sanitation, and hygiene (WASH) may have decreased, there is still a need to pay attention to the increasing number of people with no basic toilets. The unhygienic practice of open defecation and the use of unimproved sanitation systems are critical factors influencing the spread of waterborne infections.

The Sustainable Development Goals, also known as the SDGs, are targeted at maintaining the quality of water and hygiene, reducing poverty, protecting biodiversity, and achieving peace and prosperity in the world by the year 2030. They were introduced by the United Nations in 2015 (Alshomali & Gulseven, 2020). The agenda emphasized on the need for potable water and adequate sanitation for human survival. SDG 6, which is one of the 17 set targets of the UN to be reached by 2030, will improve basic water accessibility and hygiene while reducing the gaps in their service delivery.

According to the United Nations (2018), the percentage of people in the world having access to basic sanitation increased from 59% in 2000 to 68% in 2015. In 2017, 92 countries representing six out of eight SDG regions had good estimates for safely managed sanitation; this makes 54% of the global population (UNICEF and WHO, 2019). A safely managed sanitation refers to the situation of bringing about the presence of an improved facility in every household where excreta are disposed safely or transported off-site for treatment.

According to Ferreira et al. (2021), 600 million people frequently use shared toilets and bathrooms, and about 892 million people (the majority of whom are in the rural areas) engage in open defecation. To abolish this practice, there is a need for the government to identify this problem and provide adequate facilities working with the information provided in various research works.

As indicated by Centrulo et al. (2020), there is hardly any study yet that has adequately defined a model to explain the right of every man to water. Because of this, data concerning WASH in Ondo State, Nigeria, were sourced from the Federal Ministry of Water Resources in Abuja, Nigeria, for analysis. Information concerning the three variables of potable water, improved sanitation and waterborne diseases in the State were correlated, and modeled equations were used to show the interdependence of each variable and how it was validated.

In this study, an attempt was made to answer some research questions which include: the relationship existing between the three variables considered, i.e., potable water supply, improved sanitation, and waterborne disease occurrence; the statistical analysis problem involving a multiple linear regression model (and this was useful in proving that there is a statistically significant relationship between the three variables considered); and the validation of a modeled equation using both the predicted and the measured outcome variables.

This study analyzed the data on sanitation and waterborne disease occurrence in Ondo State, Nigeria. The data on potable water supply, waterborne disease occurrence, and access to improved sanitation were correlated. The modeled equation was used in predicting the occurrence of waterborne disease in six LGAs of Ondo State while using the information available for both potable water and improved sanitation. This equation was validated by estimating the Nash–Sutcliff efficiency (NSE) and conducting a through residual analysis to confirm the three assumptions of the multiple linear regression model.

This study has highlighted the factors responsible for the prevalence of waterborne diseases in Ondo State. It is expected that the study will help the government in policy formulation and facility improvement, especially for the residents of the study area. It will assist future researchers to formulate models to predict the relationship existing between the variables adopted for their various studies. It will help future researchers in conserving time and energy needed for both data collection and their analyses.

2 Literature review

The basic needs of man go around access to a safe drinking water, improved sanitation, and hygiene (WASH) for his well-being and survival (IWA/WHO, 2011). Deficiency in these vital areas of life is detrimental to the health of many, especially children (Yaya et al., 2018). According to the World Health Organization (2018), about 1.8 million people in the world are estimated to die from diarrhea-related diseases caused by the consumption of unclean water and contaminated foods. As such, the relationship between hygiene and infection cannot be overemphasized.

The state of health of every individual determines his resistance to disease ailments. Persons living with one ailment, or the other are even more susceptible to waterborne diseases that are ordinarily harmless to healthy individuals (Kgalushi et al., 2008; Laurent, 2005). In the less developed parts of the world, the number of people indulging in the use of undrinkable water has reduced significantly but it is just uncertain if all these people will eventually adopt potable water (Mintz et al., 2001). If all persons leaving the consumption of unsafe drinking water would indulge in the use of potable water, several people will gain good body resistance to fight diseases.

According to UNDESA (2009), the developing world of about 6 billion has almost half of its population facing the challenge of unimproved sanitation. Seventy percent of people who are deprived of the access to improved sanitation live in the rural areas and 80% of this same population (who are denied access to improved sanitation) are those denied access to potable water (DID, 2008). Both sanitation and clean water are menace to people outside major cities upon the vast area of land yet untapped and the enormous water bodies existing.

According to Sridhov (2020), 9% of the world's ravaging diseases can be controlled by employing the use of adequate water, sanitation, and hygiene (WASH) facilities. The most susceptible people to diseases are the young people who are not privileged to access safe water, sanitation, and hygiene facilities (Yaya et al., 2018). The spate of death in children below the age of five resulting from diarrhea disease is due to a non-compliance with WASH (Yaya et al., 2018; Pruss-Ustun et al., 2019). The challenges of health can be solved by maintaining proper hygiene and following health guidelines.

Again, the lack of infrastructures needed for the proper maintenance of hygiene has contributed to ill health. According to Hothur et al. (2019), there is a shortfall in the number of facilities needed to dispose excreta (i.e., toilet) in both households and in public places like schools (Hothur et al., 2019), and hospitals (WHO, 2016). In most African countries, people are inclined to urinate in places that are not appropriate, thereby polluting the environment and encouraging disease spread.

Over the years, people have had a no better choice than to defecate openly and/or in water bodies (Okullo et al., 2017) using no soap or disinfection afterward (Shrestha, 2018). Moreover, people use the toilet indiscriminately and give no special attention to women's

needs and integrity. The failure of the government has led to the intervention of UNICEF and WHO, responsible for the introduction of WASH to more than a hundred countries (UNICEF, 2020). WASH programs have provided most underdeveloped countries supports to cater for hygiene thus addressing this most crucial need of all.

When poorly treated water is consumed, people are prone infections. According to Biu et al. (2009); Adekunle et al. (2007), there have been incident reports about infections arising from the drinking of contaminated water in many towns. Outbreaks of waterborne diseases occur when surface water containing enteric pathogens is adopted for drinking and for domestic and sporting purposes (Johnson et al., 2003). In Sokoto, Shunni, and Tambuwal towns, the drinking water sampled had *Salmonella, E. coli, Shigella,* and *Vibrio* species that were more than WHO's tolerance for water potability (Raji et al., 2010). The presence of microbes in drinking water is one prominent cause of disease infection.

2.1 Impacts of water supply, sanitation, and waterborne diseases on the individual and the economy

There must exist a relationship between our environment, consumption, and infection. Many researchers have demonstrated a significant correspondence between non-potable water, sanitation, and maternal mortality (Benova et al., 2014; Hutton & Chase, 2017). The most susceptible age group to diseases are the children below the age of five. Frequent exposure to fecal matter causes nutritional deficiencies, leading to growth stunting and mental retardment (Humphery, 2009; Petri et al., 2008). There is a huge unawareness about child mortality and unhygienic environments that dispose him to ailments.

At times, when water is not readily available, users are discouraged from maintaining health consciousness. According to Pickering and Davis (2012), a significant reduction in the distance of travel to get water bears a direct impact on the prevalence of diarrhea; it yields a healthy food and prevents death in children below 5 years. This encourages better hygiene practices (Curtis & Cairncross, 2003) and brings improvement to time allotted for child-care, personal growth, and investment (Illahi, 2000). Inadequate water available for consumption leads to dehydration which affects both mental and physical functions of the body (Popkin et al., 2010). Water readily made available to the inhabitants of a place would ensure safe health and compliance with best hygiene.

It is quite unsafe to use water arbitrarily for the purpose of the drinking. According to Atia and Bunchman (2009), oral rehydration salts are premised upon the use of safe drinking water. In the use of groundwater that contains deleterious elements like arsenic, 226 million people have died in more than a hundred different countries (Murcott, 2012). It is thus inadequate to allow people rely on artificial wells for domestic use let alone for drinking purposes.

When poorly treated water is consumed, people are prone infections. According to Lim et al. (2012), poor water and sanitation are responsible for 0.9% of global disability-adjusted life years (DALY), or 300,000 mortality per year. Also, 842,000 deaths worldwide are due to the prevalence of diarrhea disease (Pruss-Ustun et al., 2014) and of which 43% constitute children below the age of five. According to Ali et al. (2015), about 2.9 million cases of deaths were due to cholera and its prevalence in 69 countries. We can do better to reduce this number by containing the spread and encouraging people to maintain proper hygiene.

Overall, with water made available, our economy is improved, and the status of women (as individuals) becomes elevated within the society as they are less troubled by water scarcity. When water supply and sanitation are improved, they offer comfort, safety, convenience, status, and dignity to people and optimally influence their habitat (Hutton et al., 2014). All these are particularly beneficial to women (Fisher, 2006). Although water availability does not automatically translate into women's employment (Lokshin & Yemstov, 2005), it has been proven to reduce time spent on water collection by women and thus promote gender equity (Koolwal et al., 2013). There is no gainsaying that water, sanitation, and hygiene holds a tripartite influence on both the economy of the country and the individuals.

2.2 Managerial or policy implications of the study

People are disposed to poor hygiene for the lack of strict guidelines and adequate policies set to curtail the menace. There is hardly any urban area in Nigeria that is quite equipped with sewerage systems (USAID, 2010). According to Akpabio (2012a) , the factors that affect human behaviors and their perception of water, sanitation, and hygiene (WASH) are: one, their cultural values and two, their religious inclinations. Since various national and sub-national governmental bodies have different interests and overlapping agendas, they are less coordinated thus resulting in the poorly structured nature of WASH (Akpabio, 2012b). If everyone would put their differences aside and become compliant with stricter governmental policies set in place, the issues with WASH would have become solved.

According to Akpabio and Rowan (2021), governmental policies are structured from the top down to the bottom and so, at times, they fail to represent the local interests and their realities. Due to poor bureaucratic control, socio-economic interest, and interagency competition, the major goal of delivering improved WASH services by coordinated means is seriously affected. But as the governmental and institutional-based problems of WASH are barely confronted, this study has addressed the challenge using Ondo State as a case study. The study area is in dire need of attention.

3 Materials and methods

3.1 Description of the study area

Ondo State is favored by varying degrees of ecology and climate as its vegetation transverses from mangrove swamps to rainforest and to the derived savannah that is most prevalent in the northern part of the state. The southern part of the state supports the growing of cash crops such as cashew, oil palm, cocoa, and teak.

According to Owoeye and Adedeji (2013), the environmental challenges being faced by the capital city of Ondo State, Akure, are largely due to the absence of a physical developmental plan, save the land use act inherited from the colonial years. According to Olanrewaju and Akinbamijo (2002), the city is challenged by the persistent rise in slum and squalid places, overcrowding, waste mismanagement, epileptic power supply, environmental pollution, and water scarcity. The sanitation coverage is thus not adequate for the teeming population around.

According to Adedeji (2005), the overall well-being of individuals and families may be dictated by the quality of their environment. It is expected that when the lives of the

inhabitants of a place are improved, their health and living conditions become insured (Owoeye, 2013). Thus, this study aims at generating awareness around sanitation, potable water, and waterborne disease problems in Ondo State. Figure 1 demonstrates the map of the study area.

3.2 Sampling and sampling procedures

The sampling procedure that has been adopted by the Federal Ministry of Water Resources, Federal Republic of Nigeria, and used to prepare the National Water Supply and Sanitation Baseline Survey Forms in this study is the stratified sampling procedure.

The objective of this assignment is to document the proportion of Nigerians that have access to safe water and sanitation facilities and those who, on the other hand, are deprived of access to them. In line with the definition of sanitation, i.e., the availability of improved disposal facilities of human wastes that can effectively prevent human, animal, and insect contact with the human wastes, forms were distributed to gather information about the location, types, and conditions of sanitation facilities. The forms specified the types of healthcare facilities available in urban, small towns, and the rural areas of Ondo State.

They have as well captured the incident cases of diseases that are caused by lack of access to safe water, the use of contaminated water, the practice of poor hygiene, and exposure to water-based disease vectors. In other parts of the form, the types of toilet facilities used in some selected households were investigated. And this had informed

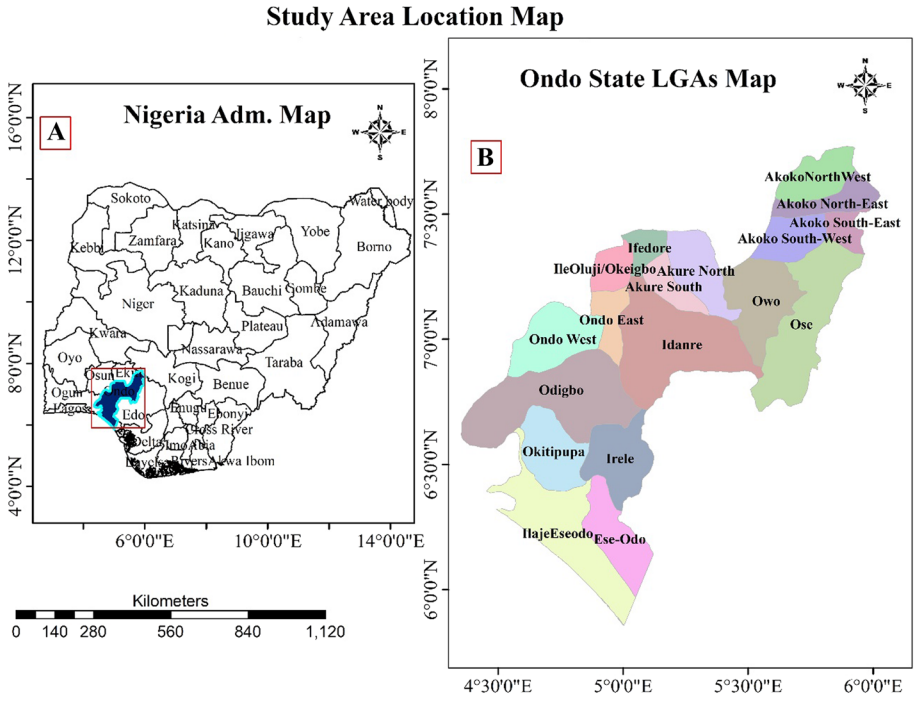


Fig. 1 Map of Ondo State showing the eighteen local government areas in the State (developed by the author)

the kind of sanitation, improved or unimproved, in the households. Part C of the forms stated the probable diseases challenging each of the households considered.

The summary of the instruments used in gathering information for this study includes Form 01 (Sanitation Facility Survey) used in capturing the location, types, and conditions of sanitation facilities; Form 02 (Water-Related Disease Survey) used in collecting data on reported cases of water-related diseases from health institutions; Form 03 (Household Survey) used while capturing data on the proportion of households that have access to safe drinking water and sanitation facilities and the prevalence of water-related diseases in each community. Forms were randomly administered by trained enumerators to a minimum of fifteen households in each political council ward.

3.3 Data preparation and analysis methods

The collected secondary data were processed while following some established methods as described in the sub-sections below. The percentage of access to potable water, improved sanitation, and waterborne diseases in the study area were estimated as described in Sect. 3.3.1. Different water-related diseases were sampled. They included diarrhea, guinea worm, dysentery, typhoid fever, malaria, scabies, ringworm, cholera, trachoma, hepatitis B, streptococci, and onchocerciasis.

3.3.1 Data preparation

3.3.1.1 Estimation of the percentage of people with access to potable water In Ondo State, there was more than one source of potable water. The various means through which potable water was made available to the people of the state were represented as the total percentage of access to potable water. This includes the percentage of people with access to House Connection; Hand-Pump Borehole; Motorized Borehole; Dug Well; Standpipe; Rainwater; and Spring. They were cumulated in the same way it was found in a study by Solihu and Bilewu (2021), where the percentage of access to potable water in Oyo State, Nigeria, was estimated.

3.3.1.2 Estimation of the percentage of people with access to improved sanitation In Ondo State, there were more than one means of access to improved sanitation. The various means through which improved sanitation was made available to the people of the state were given as the total percentage of access to improved sanitation. This was the summation of the percentage of people with access to simple latrine; latrine sanplat; latrine VIP; water closet; hand wash; septic system; public server; sullage system; and storm water.

3.3.1.3 Estimation of the percentage of people with various waterborne diseases Similarly, there was more than one waterborne disease occurrence. Waterborne disease among the residents of Ondo State was represented as the total percentage affected with waterborne diseases. This included the percentage of people with diarrhea; guinea worm; dysentery; typhoid fever; Malaria; schistosomiasis; scabies; ringworm; trachoma; hepatitis B; streptococci; onchocerciasis; and others.

3.3.2 Statistical methods

This study used both correlation and regression analyses as the statistical methods to analyze the data for this work. They were successful in showing the relationship existing between sanitation and disease occurrence in Ondo State, as well as the relationships existing between other similar variables. In the correlation of the percentages of people with access to potable water and the percentages of people with various waterborne diseases in Ondo State, the percentages of people with access to potable water served as the predictor (or the independent) variable, while the percentages of people with waterborne diseases served as the dependent variable.

Meanwhile, in the correlation of the percentages of people with waterborne diseases and the percentages of people with improved sanitation in Ondo State, the percentages of people with improved sanitation were the independent variable and the percentages of people with waterborne diseases were the dependent variable. Also, in the correlation of the percentages of people with access to potable water and the percentages of people with improved sanitation, the percentages of people with access to potable water were the independent variable and the percentages of people with improved sanitation were the dependent variable.

To determine the strength of the relationships between the variables, Guilford's rule of thumb with the following statistical ranges $r<0.2$ (almost negligible relationship); $0.2<r<0.4$ (low correlation; definite but small relationship); $0.4<r<0.7$ (moderate correlation; substantial relationship); $0.7<r<0.9$ (high correlation; marked relationship), and $r>0.9$ (very high correlation; very dependable relationship) were used.

3.3.3 Relationship equation development and validation

3.3.3.1 Relationship development To establish the relationship between the three variables, the linear regression model was used, and the modeled equations were developed using SPSS version 25. About twelve LGAs data were used for relationship equation modeling, and it comprised the first 12 Local Governments of Ondo State as they come in alphabetical order (Akoko N/W, Akoko N/E, Akoko S/E, Akoko S/W, Akure North, Akure South, Ese Odo, Idanre, Ifedore, Ilaje, Ile-Oluji/Okeigbo, and Irele).

3.3.3.2 Relationship validation This study validated the modeled equations by estimating the Nash–Sutcliff efficiency (NSE) using the modeled and observed values as the inputs in Eq. 5. Also, the modeled equation was validated through the residuals by observing three conditions as normality, homoscedasticity, and no autocorrelation over the residuals while using the residual plots. The last six LGAs of Ondo State, however, were used for the validation. They include Odigbo, Okitipupa, Ondo East, Ondo West, Ose, and Owo. The data from these LGAs were used to check for the modeled equation's appropriateness to know if they were fair representations of the relationship that exists between the variables involved.

$$\mathrm{ME} = \frac{\text{Measured Value} - \text{Modeled Value}}{\text{Measured Value}} \times 100 \tag{1}$$

$$\mathrm{NSE} = 1 - \left(\frac{\left[\left(\sum_{i=1}^{n} (\text{Measured Value} - \text{Modeled Value} \right)^2 \right]}{\left[\sum_{i=1}^{n} (\text{Measured Value} - \overline{\text{Measured Value}} \right)^2]} \right) \tag{2}$$

where "ME" represents the mean error, and "NSE" represents the Nash–Sutcliffe efficiency.

4 Results and discussion

Figures 2, 3, 4, and 5 provide a summary of the results obtained for the access to potable water, improved sanitation, and the occurrence of waterborne diseases. They are the plots representing the percentages of people having access to a potable water supply; the percentages of people with waterborne diseases; and the percentages of people with an improved (level of) sanitation in Ondo State.

In Fig. 2, the percentages of people with access to drinkable water are shown. It can be inferred from the table that Irele and Ese Odo LGAs have the highest and lowest accesses of about 80% and 23%, respectively, to potable water amongst all the sampled populations within the LGAs of Ondo State. Also, the percentages of the sampled population with the occurrence of waterborne diseases were estimated using Eq. 3, and the results are shown in Fig. 2.

Again, from Fig. 2, Ese Odo and Ondo West LGAs have the highest (452%) and the least (108%) occurrences of waterborne diseases. It is important to note that some of the sampled populations have had one or more waterborne infections. Therefore, the percentages of diseases are more than 100%. For example, while the sampled population in Akoko LGA is 295, the occurrence of waterborne infection has been more than 295 because some of the sampled populations have had multiple infections.

From Fig. 2, it is understood that access to the potable water supply is inversely proportional to the level of waterborne disease (%) in Ondo State. As seen in Fig. 2, Ese Odo LGA has the highest percentage of the sampled population affected by the waterborne disease (about 453%) with the corresponding lowest access to potable water supply (about 23%).

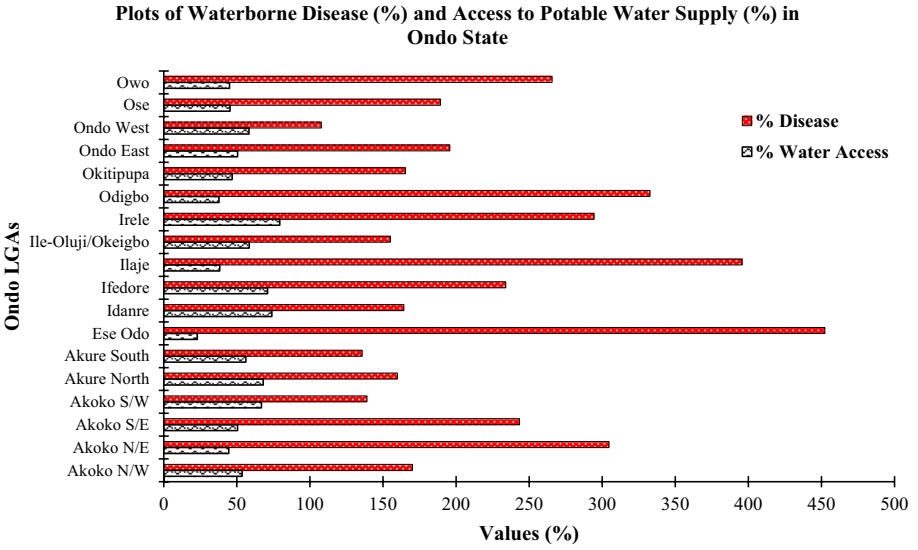


Fig. 2 A clustered bar chart showing the plots of access to potable water (%) and waterborne disease (%) in Ondo State

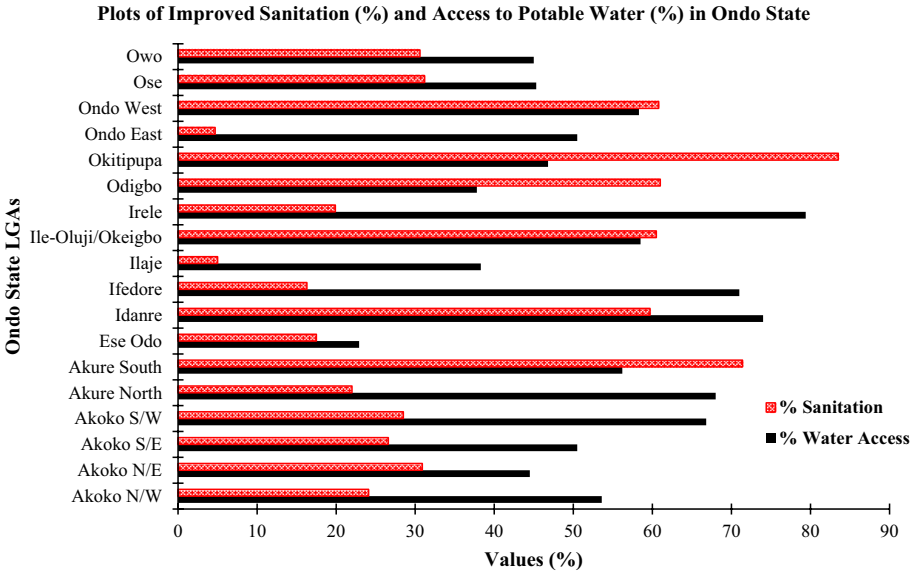


Fig. 3 A Clustered bar chart showing the plots of access to potable water (%) and improved sanitation (%) in Ondo State

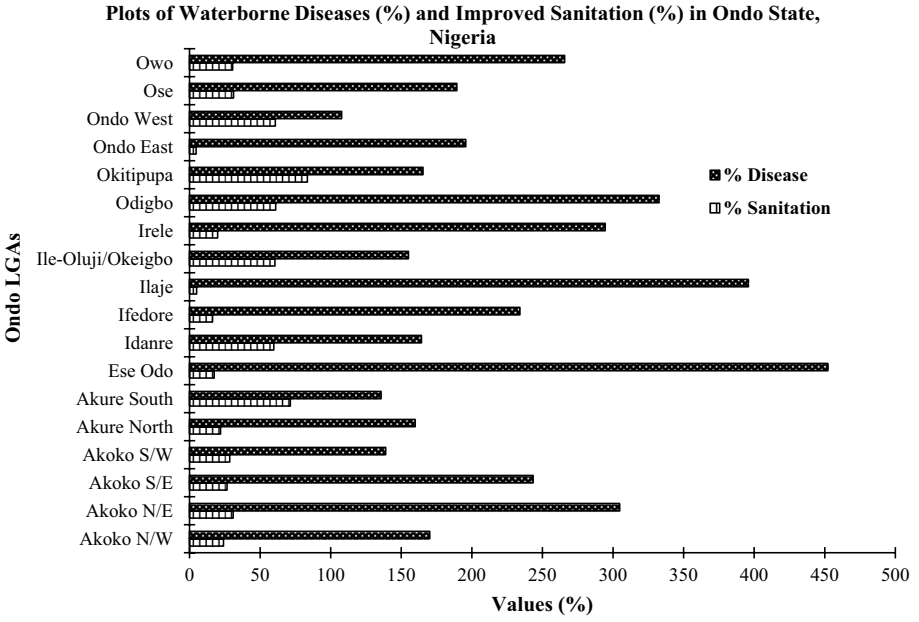


Fig. 4 A Clustered bar chart showing the plots of access to potable water (%) and improved sanitation (%) in Ondo State

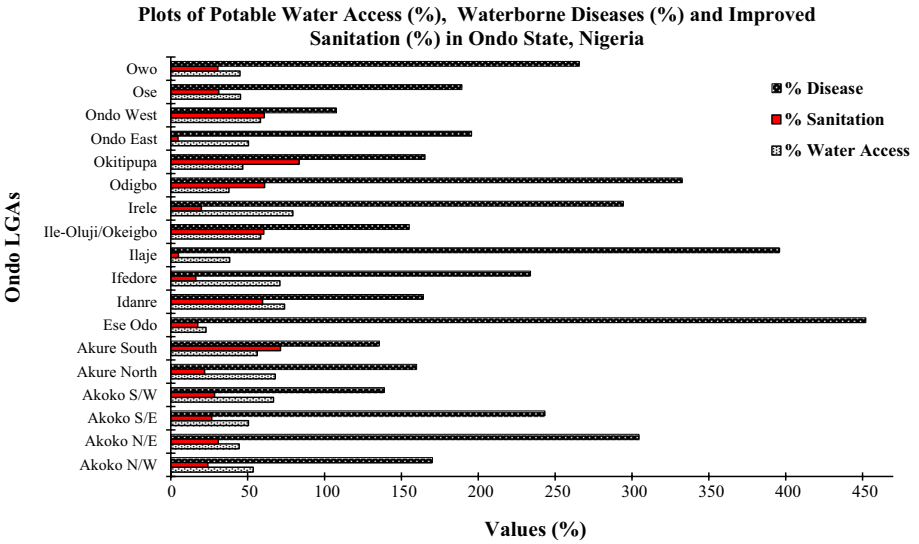


Fig. 5 A clustered bar chart showing the plots of access to potable water (%), improved sanitation (%), and waterborne diseases (%) in Ondo State

Similarly, using Eq. 2, the access to improved sanitation was estimated as shown in Fig. 3. So, from Fig. 3, Okitipupa and Ilaje LGAs have the highest (about 84%) and the least (about 5%) access to improved sanitation in the sampled population of the LGAs of Ondo State. It can thus be seen that the majority of the LGAs in Ondo State have access to improved sanitation. As seen in Fig. 3, it is safe to conclude that access to water supply in about 85% of the LGAs in Ondo contributed to having an improved sanitation facility.

Figures 4 and 5, therefore, reveal that lack of water and improved sanitation facility (WASH) in Ondo State is a factor contributing to the occurrences of waterborne diseases. This cuts across about 95% of the LGAs in Ondo State and is more severe in LGAs such as Akoko N/E, Akoko S/E, Ese Odo, Ifedore, Ilaje, Irele, Odigbo, Ondo East, and Owo.

4.1 Spatial analysis

The result of the spatial variability of the sampled population (%) with access to potable water, improved sanitation, and waterborne disease occurrence is shown in Fig. 6. The spatial variability map was developed with ArcMap using the inverse distance weighted (IDW) method of deterministic interpolation. Maps A, B, and C represent the spatial variability maps of the sampled population of Ondo State with access to potable water, occurrence of waterborne diseases, and access to improved sanitation, respectively. From this figure, there was water scarcity (< 42% access) in the southern part of Ondo State; inadequate access to improved sanitation (< 30% access) both in the southern and northern parts of the state, while the southern part had the highest (> 320%) prevalence of waterborne diseases.

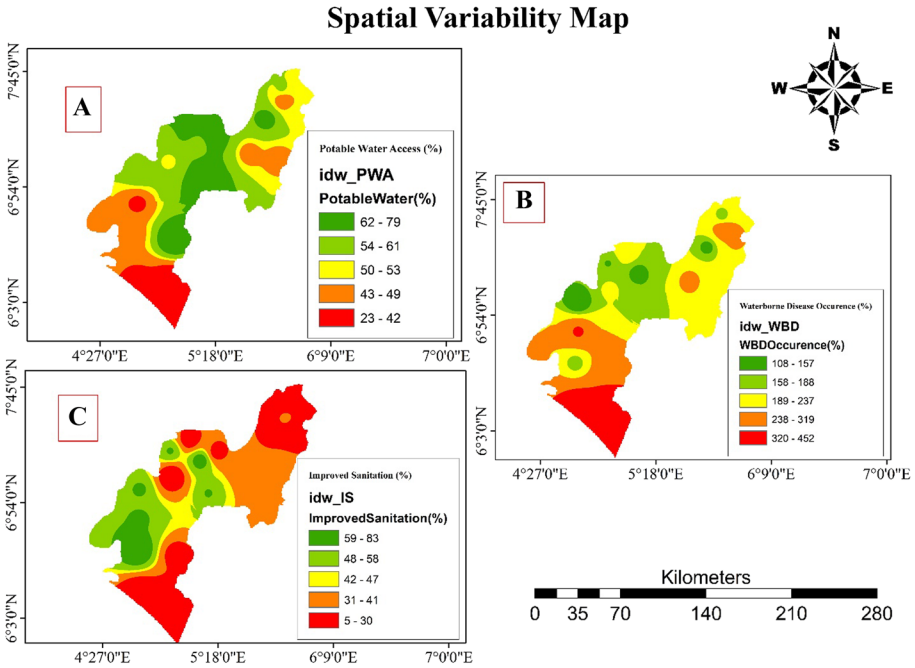


Fig. 6 Spatial variability map

4.2 Statistical analysis of variables

The data of the first twelve LGAs of Ondo State are contained in Table 1. Table 1 summarizes the information regarding the access to potable water, improved sanitation, and waterborne disease occurrence in Ondo State. The first twelve LGAs of Ondo State were used to model Eq. 3.

Table 2 shows that there existed a *negatively moderate correlation*: *substantial relationship* between the access to a potable water supply (APW) (%) and waterborne diseases (WBD); and between waterborne diseases (%) and improved sanitation (IS) (%) in Ondo State. However, it is safe to infer that there existed a *low correlation, definite but small relationship* between the percentages of people with access to a potable water (APW) (%) and those with improved sanitation (IS) (%) in the state.

From Table 3, the R^2 value indicated about 62% (Table 4). Hence, it can be said that the movement of the outcome (dependent) variables was explained by the movement of the predictor (independent) variables by 62%. Table 5 reveals that there was a linear relationship between the occurrence of waterborne diseases, access to a potable water supply, and access to improved sanitation in Ondo State. These linear relationships can be represented by Eq. 3.

$$W_{\mathrm{BD}}(\%) = 520.9966 - 3.59458P_{\mathrm{WA}} - 2.47318I_{\mathrm{S}} \tag{3}$$

where W_{BD} (%) = waterborne disease occurrences in Ondo State (outcome variable), $\mathrm{P_{WA}}$ = access to potable water in Ondo State (predictor variable 1) with a

Table 1 Summary of the study variables for the statistical analysis

S/N	LGA name	% Potable water access	% Improved sanitation	% Water-borne disease
1	Akoko N/W	53.6	24.1	170.2
2	Akoko N/E	44.5	30.9	304.6
3	Akoko S/E	50.5	26.6	243.4
4	Akoko S/W	66.8	28.5	139.0
5	Akure North	68.0	22.0	159.9
6	Akure South	56.2	71.4	135.7
7	Ese Odo	22.9	17.5	452.2
8	Idanre	74.0	59.7	164.3
9	Ifedore	71.0	16.3	234.0
10	Ilaje	38.3	5.0	395.8
11	Ile-Oluji/Okeigbo	58.5	60.5	155.1
12	Irele	79.4	19.9	294.4
13	Odigbo	37.8	61.0	332.6
14	Okitipupa	46.8	83.5	165.4
15	Ondo East	50.5	4.7	195.7
16	Ondo West	58.3	60.8	107.8
17	Ose	45.3	31.2	189.4
18	Owo	45.0	30.6	265.7

Table 2 Correlations amongst the study variables

	APW (%)	WBD (%)	IS (%)
APW (%)			
Pearson Corr	1	− .678*	0.249
Sig. (2-tailed)		0.015	0.435
WBD (%)			
Pearson Corr	− .678*	1	− .623*
Sig. (2-tailed)	0.015		0.03
IS (%)			
Pearson Corr	0.249	− .623*	
Sig. (2-tailed)	0.435	0.03	1

*Correlation is significant at the 0.05 level (2-tailed)

Table 3 Change statistics

Mode	R	R^2	Adjusted R^2	SE Estimate	Obs
WBD (%), APW (%) and IS (%)	0.82	0.68	0.61	65.75	12

Table 4 ANOVA

	df	SS	MS	*F*	Sig. *F*
Regression	2	82799.87	41399.94	9.577	0.006
Residual	9	38906.57	4322.95		
Total	11	121706.44			

Table 5 Correlation coefficients

	Coefficients	St. Error	*t*-Stat	*P*-value
Intercept	521.00	73.09	7.13	0.0001
% Potable water access (PWA %)	− 3.59	1.25	− 2.87	0.0186
% Improved sanitation (IS %)	− 2.47	0.99	− 2.49	0.0345

coefficient − 3.59458, I_S = improved sanitation (predictor variable II) with a coefficient − 2.47318, intercept or constant on the vertical axis = (520.9966). In Table 4, the analysis of variance shows that the significant F value (0.006) is less than the p-value (0.05) which is a strong evidence against the null hypothesis. Since there is less than 5% probability that the null hypothesis is correct, we fail to accept the null hypothesis.

It follows that using Eq. 3, it might be possible to predict the level of occurrence of waterborne diseases in Ondo State if information regarding the access to potable water supply and improved sanitation is available.

4.3 Modeled relationship equations validation

While the first twelve in the eighteen LGAs of Ondo State were selected for training, the remaining six were used for validation. Modeled equation (Eq. 3) was used to estimate the occurrence of waterborne diseases in the remaining six LGAs using the information available for their predictor variables (i.e., potable water access and improved sanitation). The outcome variable values were compared with the original measured outcome variables. The equation was revalidated by estimating the Nash–Sutcliffe efficiency (NSE) and using residual analysis.

$$\mathbf{NSEWBD} = 1 - \left(\frac{394046.6}{198915.4}\right) = 0.8 = 80\% \tag{4}$$

Since the NSE was greater than 50%, this meant that the modeled equation is very good in predicting the past and the future waterborne diseases in the state. Thus, with good-quality raw data, it is possible to reduce these error values. However, it is reasonable to conclude that the model can achieve its purpose in Ondo State.

4.3.1 Residual analysis

The model was validated through residuals. The three conditions over residuals such as homoscedasticity, normality, and no autocorrelation were observed as shown in Figs. 7, 8, and 9, respectively.

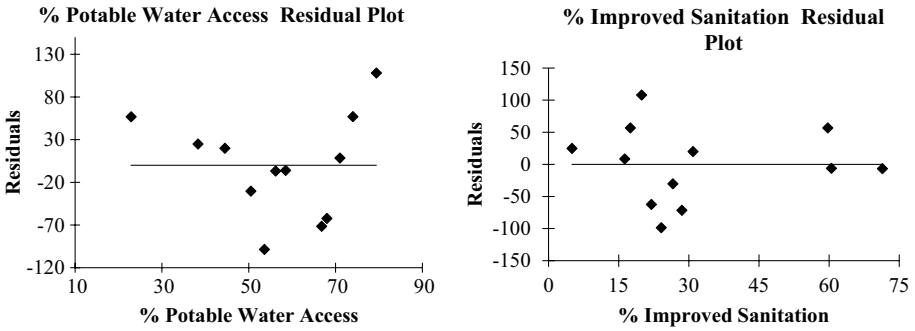


Fig. 7 Residual plots for the homoscedasticity check

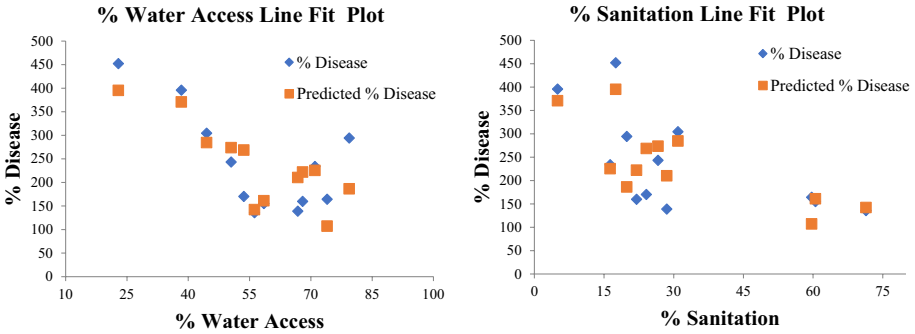


Fig. 8 Line fit plots for the auto-correlation check

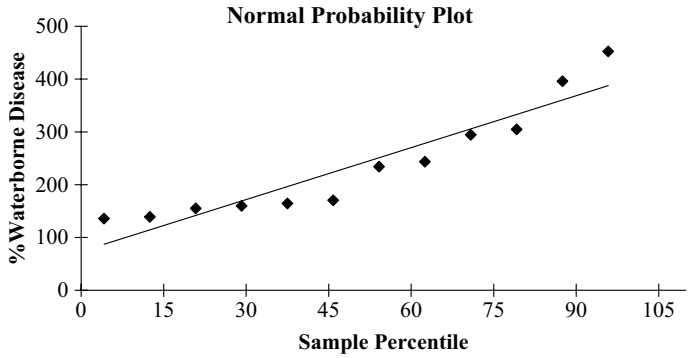


Fig. 9 Normal probability plot for the normality check

Figures 7, 8 and 9 reveal that the modeled equation (Eq. 3) met all the assumptions of the linear regression model, and it can predict the level of occurrence of waterborne diseases while using the information on the percentage access to potable water and improved sanitation.

5 Conclusions

The level of access to potable water in Ondo State has less significance on the prevalence of waterborne diseases when compared to the impact of improved sanitation on the diseases in the state. Waterborne diseases in Ondo State are best attributed to the unhygienic practices of the people of the state since the least average error was generated when the prevalence of diseases in the state was estimated using information available on improved sanitation.

This study may be adopted for future planning and implementation of SDG 6, Target 1, i.e., 'by 2030, we may come to achieve universal and equitable access to safe and affordable drinking water for all.' The study has helped in identifying the problem of water accessibility in Ondo State. Since the study has distinguished between improved and unimproved sanitation and has also identified the parameters of assessments, SDG 6, Target 2 which specifies that 'by 2030, we may come to achieve access to adequate and equitable sanitation and hygiene for all,' may become achievable.

A linear relationship was established between access to potable water and waterborne disease occurrence, and between improved sanitation and waterborne diseases in Ondo State. It is now possible to predict any of the observed parameters (i.e., access to potable water, waterborne disease occurrence, and improved sanitation) if information about other variables is readily known. The prediction or modeling of each of the identified variables, i.e., improved sanitation, access to potable water, and waterborne diseases with another variable that the study has adopted, will help in saving time and energy needed in future data sourcing.

6 Availability of data and approval

The datasets used for the analysis of the study are available from the corresponding author upon any considerable request.

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Declarations

Conflict of interest The authors declare no competing interest in this research paper.

Ethical approval The authors of this work ensured that all ethical standards were complied with throughout the work and that no human or animal rights were violated.

Consent to participate All author (s) and co-authors who collaborated on the project have consented to participate in the work.

Consent for publication The permission to publish this article has been sought and obtained from all contributing authors.

Authors' comments Meanwhile, a preliminary version of the manuscript is available on Research Square. The preprint only serves to provide the community with the work ahead of its acceptance by this journal. This is to receive critiques and gain more insights into the work ahead of publication.

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