Environmental Research Communications

PAPER

Assessing waste separation behaviour in Nigeria: implications for post-Covid-19 pandemic waste management strategies

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OPEN ACCESS

RECEIVED
22 September 2024

REVISED
8 December 2024

ACCEPTED FOR PUBLICATION
30 December 2024

PUBLISHED
11 February 2025

Keywords: waste separation behaviour, theory of planned behaviour, attitude, solid waste management, environmental policy, Nigeria

Supplementary material for this article is available online

Abstract

During medical emergencies, effective management of waste is crucial to preventing the spread of infections, protecting healthcare workers, and ensuring the safety of the broader society. The recent COVID-19 pandemic has underscored the importance of waste separation for efficient waste management and public health protection. However, Nigeria's situation has not been addressed by research investigation despite its potential to shape waste management policy implementation and citizen alignment. Therefore, the current study examines the waste separation behaviour of Nigerian residents during the pandemic, utilizing an extended Theory of Planned Behaviour framework. The authors achieve this by analyzing survey data from 726 residents in two highly populated cities (Lagos and Oyo states). All the latent variables in the theory of planned behaviour show a positive and significant effect on waste separation behaviour, with attitudes emerging as the strongest influence. Past behaviour positively correlates with the intention to separate waste. However, the results of perceived policy effectiveness indicate a significantly negative moderating effect on the relationship between intention and waste separation behaviour. This outcome suggests a continuous need for public enlightenment with greater focus on policy implementation and enforcement in Nigeria. Infrastructure for waste separation should receive more attention, as the absence of suitable waste segregation bins or disposal facilities weaken environmental policy implementation and Nigerians cultivation of waste separation behaviour. This study provides policy direction to enhance waste separation practices for day-to-day environmental safety and preparedness in the event of future health emergencies.

1. Introduction

Environmental waste generation presents a multifaceted challenge with far-reaching implications for both human health and ecological well-being. This include the soil, surface and groundwater bodies, plants, animals, human population, and other components making up the environment (Salako *et al* 2019, Aikowe and Mazancová 2021, Osotuyi *et al* 2022, Ojo *et al* 2023). Public health emergencies further compound the increasing rate of waste accumulation, which has emerged as a pressing global concern (Chen *et al* 2021, Moonsammy *et al* 2021). Prominent among of these is the COVID-19 pandemic (*hereinafter used interchangeably as a global pandemic outbreak*), which have had profound and enduring impacts across various sectors of society, including waste management. In response to the global pandemic, nations worldwide implemented a spectrum of measures encompassing hygiene protocols, travel restrictions, and widespread use of personal protective equipment (PPE) (Etim *et al* 2022). Although WHO (2023) made a declaration which

concluded the emergency phase of the outbreak, they elucidated that the pandemic continues to pose a global threat and cautioned about the potential emergence of novel variations. Despite significant vaccination efforts, the persistent threat of COVID-19 necessitates continued PPE usage. Individuals produced an increase in single-use PPE and medical wastes, which exacerbated the challenges of infectious waste management. An adequate understanding of the generation and separation behaviour of these wastes during the pandemic can aid in the development of effective policies to guide residents post-COVID-19 pandemic and in the management of future epidemic outbreaks. Post Covid-19, since cholera and Mpox cases have been reported and declared diseases of global concerns (NCDC 2024, WHO 2024)), this makes our study very relevant to present and future realities.

Previous studies conducted in countries such as Brazil (Urban and Nakada 2021), Morocco (Mejjad *et al* 2021) and Nigeria (Nzeadibe and Ejike-Alieji 2020) revealed indiscriminate disposal of waste in open landfills, water bodies, and other ecological spaces, which poses severe threats to the environment. Poor waste management not only leads to adverse environmental and health outcomes but also heightens vulnerability to infectious diseases (Nzeadibe and Ejike-Alieji 2020, Etim *et al* 2022). Developing nations like Nigeria, grapple with the additional burden of managing wastes efficiently, while having previously contended with outbreaks of infectious diseases like Ebola, Yellow fever, Lassa fever, the recent COVID-19 pandemic (Etim *et al* 2022, Elimian *et al* 2022), and most recently cholera and Mpox or MPXV clade (NCDC 2024, WHO 2024). At the height of COVID-19 outbreak, residents took proactive steps to separate medical wastes (*this study refers to nose masks, face shields, fumigation cans, and sanitizer bottles as the items under consideration*), as a crucial aspect of waste management during the pandemic. This practice not only curtail disease transmission and safeguard the environment, but also lightens the burden on municipal authorities responsible for waste management. Encouraging residents to engage in waste separation behaviour (*hereafter used interchangeably as* WSB) necessitates a profound understanding of the factors that influence their intentions. More so, scholars have shown that the collective and active participation of residents is crucial to solving environmental waste problems (Roy *et al* 2021).

Numerous studies have explored WSB and its determinants across countries before and during Covid-19 pandemic (Xu *et al* 2017, Aikowe and Mazancová 2021, Govindan *et al* 2022, Kwakye *et al* 2024) and the theory of planned behaviour (TPB) have been used to understand WSB across diverse geographical contexts. These existing studies highlighted that WSB is influenced by several factors, including awareness, attitude, social pressure, perceived behavioural control, moral norms, situational factors, perceived policy effectiveness, past behaviour, and demographic characteristics. Studies conducted before the COVID-19 outbreak (e.g. Xu *et al* 2017 and Alhassan *et al* 2018) acknowledged that past behaviour significantly impacts an individual's intention to repeat waste separation, and the perception of existing policies shapes participation in waste management activities. However, considering the importance of past behaviour and perceived policy effectiveness, no study has thoroughly investigated the roles of perceived policy effectiveness and past behaviour, alongside other influencing factors in residents' WSB during a public health crisis. Therefore, it becomes vital to have an understanding of the effect of these factors on waste separation actions in an emergency health crisis. Furthermore, research on WSB has primarily focused on European and Asian countries, leaving a significant gap about countries in Africa.

This study seeks to identify the psychological variables that shaped residents' WSB during the COVID-19 pandemic in Nigeria by utilizing an extended Theory of Planned Behaviour (TPB) framework to investigate pro-environmental behaviour. Deciphering these underlying factors, this work seeks to provide a basis for the development of targeted strategies and effective policies to enhance WSB among individuals. Owing to varying environmental policies from one geographical context to another, peculiarities in waste management systems across different countries should be expected. Thus, previous evaluations and findings from other countries might have a different perspective on Nigeria's waste management system during the pandemic, thereby necessitating the need to understand how government policies in Nigeria influence residents' actions to engage in waste sorting during a public health emergency. More so, the authors seek to introduce additional variables of past behaviour and perceived policy effectiveness, that have not been previously incorporated into a study of this nature, to better understand residents' WSB in the context of our study area. Insights into these influencing factors will give direction to policymakers and other stakeholders on managing future epidemics and suggest relevant interventions for improved public health and a sustainable environment. Likewise, the outcomes of this study present direct implications for waste management stakeholders, including government and non-governmental organizations, and will contribute to the evolving knowledge base in waste separation and environmental policy. Using extended TPB, this research presents an in-depth assessment of the factors that motivate residents' WSB in the context of a pandemic, offering a valuable contribution to the ongoing discourse surrounding sustainable environments. Considerable contributions and references for future studies to provide a more accurate prediction of WSB in preparedness for future health emergencies are also provided.

Outline of the other parts of this research are presented in the following order: section 2 highlights aspects of the background theories and hypotheses developed in the study. Section 3 discusses the methodology

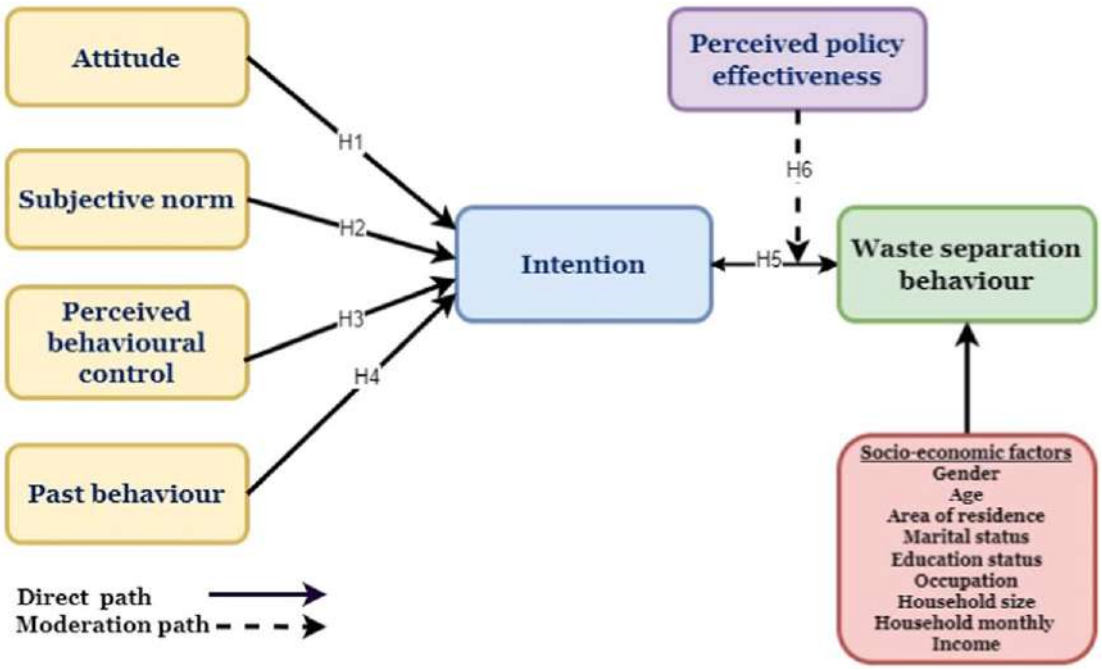

Figure 1. The conceptual model.

extensively. While section 4 presents the data analysis and results, in section 5, had a discussion on the results from the preliminary section. In conclusion, section 6 focuses on the implications, conclusion, and limitations of the study.

2. Theoretical background and hypotheses

2.1. Theory of planned behaviour

The Theory of Planned Behaviour (TPB) was introduced by Ajzen (1991) as an extension of the Theory of Reasoned Action (TRA). The theory has evolved into a robust framework within the sphere of social and behavioural sciences. By incorporating perceived behavioural control alongside attitude and subjective norm components from TRA, TPB provides a more comprehensive predictive model of human behaviour. Since its inception, TPB has been widely utilized as a theoretical framework to understand behaviour across various contexts including risky alcohol consumption, food waste, recycling, and eco-friendly transportation (Donald *et al* 2014, Caputo 2020, Lin and Guan 2021).

The first determinant under TPB is **Attitude.** It refers to a person's evaluation of an issue, which can be positive or negative, with a significant impact on shaping the intention to engage in pro-social or eco-friendly behaviours (Govindan *et al* 2022). Tang *et al* (2023) study discovered that attitude positively impacts household waste sorting intention in Ghana. Similarly, Cai *et al* (2023) study identified attitude as the most significant predictor of mask waste separation intention in China. Therefore, the current study posits that those who have a positive attitude are more likely to be involved in waste segregation, thereby contributing to environmental protection and the well-being of their communities (see figure 1).

H1: There is a positive connection between attitudes of residents and intentions towards public medical WSB during a pandemic.

Subjective norm is another psychological factor under TPB. Subjective norm refers to a person's view of the social pressure from others expecting them to engage in a specific behaviour (Arkorful *et al* 2022). The probability of an individual conforming to a specific behaviour is heightened when they experience social pressures from influential others, resulting in a positively impacted subjective norm (Oludoye *et al* 2023). While some scholars have reported the insignificance of the subjective norm in predicting intention in Malaysia (Ayob *et al* 2017); the positive impact of social influences emanating from friends, family members, neighbours, and colleagues on pro-environmental behaviour have been further highlighted in South Africa, China and Finland (Schoeman and Rampedi 2022, Huang *et al* 2022).

H2: Subjective norms have a positive impact on intention towards public medical WSB during a pandemic.

Perceived behavioural control is the third predictor under TPB. This variable pertains to an individual's assessment of the ease or challenges associated with accomplishing a task or engaging in a behaviour. It is the degree to which an individual perceive that an issue is under his or her control (Arkorful *et al* 2022). The perception of increased opportunities and facilities with lesser difficulty is likely to enhance an individual's intention and likelihood of engaging in a particular behaviour. Lin and Guan (2021) study on household food waste reduction behaviour observed that consumers who feel they have more control over food have a greater tendency to actively limit food loss. Huang *et al* (2022) survey on the influences of WSB also documented that perceived behavioural control was positively correlated with intention. In relation to this survey, a notable trajectory from perceived behavioural control to intention towards a behaviour would indicate that individuals are more inclined to engage in the sorting of waste during the pandemic when they possess a heightened sense of perceived behavioural control.

H3: Perceived behavioural control has a positive impact on intention towards public medical WSB during a pandemic.

2.2. Extension of TPB

Behaviour is a complex phenomenon influenced by numerous factors beyond TPB's scope, necessitating the integration of additional variables to enhance its predictive accuracy (Govindan *et al* 2022). Therefore, scholars advocate for augmenting the TPB model with context-specific variables to increase its robustness. Integrating supplementary variables has been shown to significantly enhance the model's predictive capacity in determining human behaviour (Xu *et al* 2017, Wang 2021, Schoeman and Rampedi 2022). Furthermore, Ajzen (1991) demonstrated the viability of incorporating additional variables, as long as the current model's constructs do not encompass them. This study investigates the TPB's psychological factors and also incorporates perceived policy effectiveness and past behaviour variables to better understand waste separation actions during the pandemic. Perceived policy is described as a person's perception of a policy's clarity, adequacy, and effectiveness in facilitating the achievement of its objectives (Wan *et al* 2014). Past behaviour is explained as an individual's knowledge and experience with waste separation (Alhassan *et al* 2018). It posits that persons with prior behaviour of separating waste are more likely to have a higher tendency to engage in waste separation activities in the future. These variables were found to be significant in previous studies conducted before the pandemic, but can the same result hold true in an epidemic situation? This unanswered question sets the motivation for their integration and examination. These two variables are important in comprehending what can drive citizens' strong commitment to waste separation in the context of Nigeria, a developing nation characterized by a low rate of waste separation (Orhorhoro and Oghoghorie 2019) (see figure 1). The outcome of this research can help the government determine what to do ahead of time and provide policy direction for a future pandemic.

Past behaviour refers to a previously performed action, which can enhance or influence such a person to carry out the same action recurrently in the future (Xu *et al* 2017). Previous research has established that people who have acquired prior experience in waste separation exhibit a heightened tendency to consistently engage in this practice (Alhassan *et al* 2018). Scholars suggest that previous recycling experience should be taken into account when predicting recycling behaviour. Similarly, results from a research on domestic waste in Glasgow showed that there is a significant and direct connection between past behaviour and recycling (Knussen and Yule 2008). This underscores the crucial role of habituation in determining waste separation practices of inhabitants. Within the framework of this study, it simply means that if an individual engages in waste separation every other day, there is every tendency that such an individual will want to do it during a public health emergency.

H4: Past WSB of residents positively influence the intention towards WSB during the COVID-19 pandemic.

Perceived policy effectiveness describes an individual's assessment of the transparency, adequacy, and efficiency of a particular policy instrument (Lin and Guan 2021). The utilization of public policy such as mandatory regulations, incentives, promotional and educational activities, and the provision of accessible facilities can enable public authorities to influence human behaviour. The perception of whether the separation policy can effectively achieve the goal of recovery and waste reduction is an important incentive or motivation to engage in WSB. Likewise, Wan *et al* (2014) study on recycling in Hong Kong proved that government recycling policies that involved adequate provision of facilities at a convenient location could be supportive in the management of solid waste. In addition, it has been demonstrated that the influence of attitude on behaviour is contingent upon the presence of motivation (Lin and Guan 2021). Hence, if residents trust and perceive government policies as effective, they are likely to be more motivated to endorse and actively participate in protective behaviour like waste separation instituted by the government, thereby promoting public health and a sustainable environment.

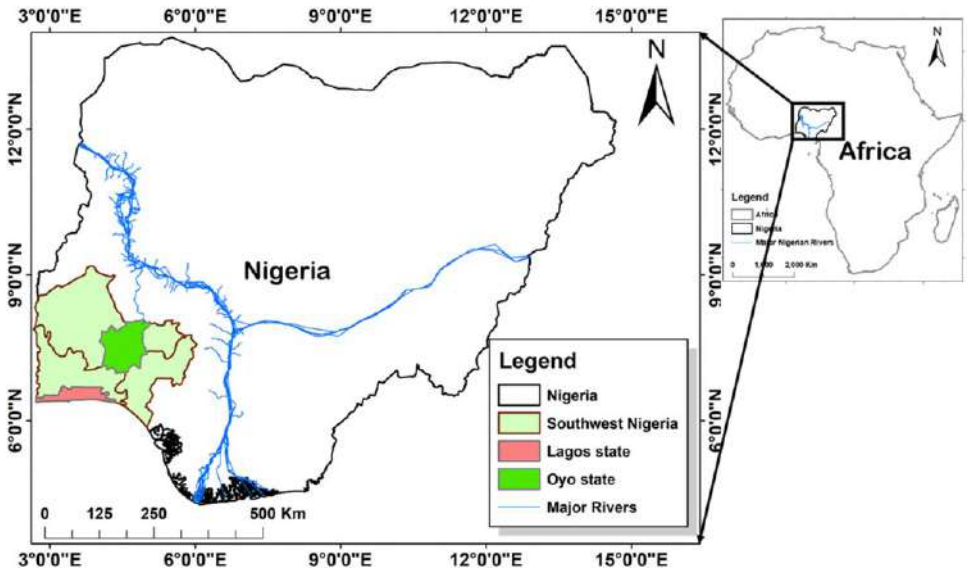

Figure 2. Map showing the study area - Oyo and Lagos states - in the western part of Nigeria.

H5: Perceived policy effectiveness moderates the relationship between intention and WSB such that, the relationship between intention and waste separation is high when perceived policy effectiveness is high as opposed to low.

The original TPB posits that intention is a crucial factor that directly predict behaviour (Ajzen 1991, Bosnjak *et al* 2020), and intention is influenced by attitudes, subjective norms, and perceived behavioural control. The concept of intention pertains to the motivating factors that influence a particular behaviour, encompassing the extent of an individual's inclination and preparedness to participate in said behaviour. Many studies has reported the positive influence of intention on WSB (see figure 1) (Xu *et al* 2017, Shi *et al* 2021).

H6: There is a positive relationship between residents' intention and WSB during a pandemic.

3. Materials and methods

3.1. Sample population

The study area for our empirical investigation is Nigeria, the West African country renowned for its demographic diversity. It has a population of approximately 219 million people, which is the highest in Africa, and a land area spanning 923,768 square kilometers (figure 2) (Oludoye *et al* 2023). The surge in medical and personal protective gear waste during the global pandemic outbreak further exacerbates Nigeria's critical challenge of waste management, despite several environmental policies in place. This empirical study addresses the pressing need for sustainable waste management solutions in Nigeria (Aikowe and Mazancová 2021) to enhance good health and well-being for residents and advance sustainable cities and communities. The discussion on waste issues and management during the pandemic era has garnered increased attention (Etim *et al* 2022, Oludoye *et al* 2023), emphasizing the importance of developing effective policies and strategies to promote efficient waste management systems for a cleaner environment and a sustainable future.

Our research focuses on Lagos and Oyo states, which rank as the first and fifth most populous states in Nigeria, respectively. Lagos, notably, stands as the largest city in Sub-Saharan Africa, with an approximate population of about 25 million people (Lagos State Government 2023). In contrast, Oyo State has about 8 million residents and is known for its vibrant economy (National Bureau of Statistics 2021). These states are chosen because of the stringent COVID-19 restrictions and regulations enforced in urban areas, which the study anticipate will significantly influence waste generation.

3.2. Sampling and data collection

The study utilized a cross-sectional survey approach to collect data between September 2022 and March 2023. The survey involved a questionnaire comprising 7 constructs and 40 items, including demographic variables. Respondents used a 5-point Likert scale to answer the questions. The survey employed purposive sampling techniques to select eligible participants, focusing on Nigerian citizens aged 18 or older who had used medical PPE (nose masks, face shields, fumigation cans and sanitizers bottles). The sample included individuals from various residential areas, including urban, peri-urban, and rural, as these regions exhibit distinct characteristics

related to population, infrastructure, income levels, and waste management facilities (Adedire 2020). These parameters were presumed to significantly influence WSB (Arkorful *et al* 2022).

The criteria for selecting participants included the use of masks and residency in the two (2) selected states. Consequentially, only individuals who confirmed their usage of masks and resided in the sample location answered the questions. The researchers decided the sample size based on guidelines provided by Kline (2010), who suggested 300 as an ideal sample sizes for SEM analysis. Also, previous environmental studies that used PLS-SEM utilized sample sizes of 324 and 146 (Govindan *et al* 2022, Ismail *et al* 2023). Going by this validation, sample size of this research is set and increased to 800 to enhance the replicability and generalizability of the study findings.

To ensure the questionnaire's validity, the study drew items from previously validated constructs (see appendix). An environmental management expert conducted a thorough review and the authors also conducted a pilot study involving ten residents to refine the questionnaire for clarity, content, and user-friendliness. Introductory descriptions and instructions preceded each section to minimize response bias, using the approach of Podsakoff *et al* (2012). The study used a cross-sectional e-survey platform to administer the questionnaire online. Initially, the authors used geo-referencing (GPS) to verify respondents' locations and ensure data accuracy. However, the geo-referencing was later made optional due to concerns about privacy and device limitations. The researchers retrieved 780 questionnaires from respondents, 726 valid responses (93%) was used for statistical analysis after excluding incomplete, highly similar, and rapidly completed responses. More so, the 726 sample size used exceeded the required thresholds, surpassing G*Power's minimum of 109 (80% power, $\alpha = 0.05$, effect size = 0.15, 8 predictors) and PLS-SEM's benchmark of 111 (Faul *et al* 2009, Hair Jr *et al* 2017).

3.3. Measurement of variables

The questionnaire employed a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). All measures were adapted from previous studies. Attitude was measured with five items, subjective norm, six items and perceived behavioural control, seven items. Past behaviour was assessed with five items. Perceived policy effectiveness was measured with five items and intention was assessed using six items. The current study measure WSB using five items. Demographic data items included age, marital status, occupation, education, residence, gender, monthly household income, household size, and area of residence. Respondents selected the appropriate options applicable to them. For details on construct and measurement items, see **appendix**.

3.4. Procedures for data analysis

The study used the Partial Least Squares Structural equation Modelling (PLS-SEM) technique via SmartPLS version 4 software to assess the constructs' effectiveness. The researchers selected PLS-SEM for its versatility with different data types and suitability for exploring initial theories. Previous TPB framework studies (Xu *et al* 2017, Lin and Guan 2021) have widely used it. Moreover, PLS-SEM aids in identifying the factors with the most significant impact on the dependent variable. Thereafter, a preliminary analysis was conducted to ensure data accuracy and reliability, assessing the validity and reliability of the measurement model. Various tests were employed, including outer loadings, Cronbach's alpha (CA), average variance extracted (AVE), and composite reliability (CR) analysis, following Hair Jr *et al* (2020) recommendations.

3.5. Descriptive statistics

The gender distribution in the sample has a slight majority of females (51.5%). The majority of respondents, accounting for 51.9%, fall within the age range of 18 to 35. Most of the surveyed population has tertiary education, with only 1.4% having primary school certificates. Additionally, the majority of the population either works or engages in self-employment. The findings suggest that most homes are relatively small in size, with 514 respondents (70.8%) having a household size of less than or equal to 5 members. Furthermore, many households have a relatively high monthly income, with the highest proportion of households, accounting for 54.1%, reporting an income greater than or equal to 81,000 Naira (Naira is hereafter written as ₦ before each income). Table 1 provides details of the descriptive statistics.

4. Results

4.1. Measurement models

4.1.1. Reliability and validity of the study variables

Data validity was confirmed by applying Fornell Larcker's Criterion and the Heterotrait-Monotrait (HTMT) ratio, as suggested by Henseler *et al* (2015) towards ensuring robust and accurate results. Additionally, a collinearity test assessment using Variance Inflation Factor (VIF) and the correlation matrix are employed to prevent highly correlated variables or items, reducing the risk of biased results.

Table 1. Socio-economic factors (demographics).

Demographics	Indicators	Frequency	%
Gender	Male	352	48.5
	Female	374	51.5
Age	18–35	377	51.9
	36–45	220	30.3
	46–55	86	11.8
	56–65	35	4.8
	66 and above	8	1.1
Area of residence	Rural	59	8.1
	Urban	559	77.0
	Peri-urban	108	14.9
Marital status	Single	304	41.9
	Married	398	54.8
	Widowed	16	2.2
	Divorced	8	1.1
Education status	Primary School	10	1.4
	Secondary School	75	10.3
	Diploma	118	16.3
	Bachelor's degree	331	45.6
	Post-graduate (Masters, PhD)	192	26.4
Occupation	Student	139	19.1
	Public/privately employed	332	45.7
	Self-employed	213	29.3
	Artisans	31	4.3
	Retiree	11	1.5
Household size	Less than or equal to 5	514	70.8
	Greater than or equal to 6	212	29.2
Household monthly income	Less than or equal to ₦30,000	114	15.7
	₦31,000–₦80,000	219	30.2
	More than or equal to ₦81,000	393	54.1

Table 2 shows the outcomes of assessments for internal consistency reliability, featuring factor loadings, average variance extracted (AVE), composite reliability, and Cronbach alpha values for latent constructs. Hair Jr *et al* (2020) recommend a Cronbach alpha and composite reliability threshold of 0.70, with an AVE threshold of 0.50 considered acceptable and factor loadings should surpass 0.7. From table 2, all factor loadings surpass the 0.7 threshold recommended by Hair Jr *et al* (2020), affirming the findings of Kaur and Kaur (2023). All variables meet the minimum requirements for AVE, composite reliability, and Cronbach alpha, aligning with Hair Jr *et al* (2020) criteria for internal consistency and reliability assessments. Meeting these established thresholds ensure the model's accuracy for further investigation, which is consistent with Mishra *et al* (2023).

4.2. Test of collinearity and common method bias

Variance Inflation Factor (VIF) values for collinearity assessment is presented in Supplementary T1. Kim (2019) suggests a VIF threshold of 5 for detecting collinearity. In our study, all constructs exhibit VIF scores below 5, confirming the absence of collinearity issues and supporting Salem *et al* (2023) findings. Kock (2017) recommends VIF values at or below 3.3 to rule out common method bias. VIF values fall below 3.3, demonstrating the absence of common method bias and aligning with Yin *et al* (2023) observations. According to Bagozzi and Phillips (1982) correlation coefficients exceeding 0.9 between variables indicate common method bias issues. However, as shown in the Supplementary T2, all constructs in our study exhibit correlation coefficients below 0.9, confirming the absence of common method bias and reinforcing the observations of Bagozzi and Phillips (1982).

4.3. Discriminant validity test

The study assesses discriminant validity using Fornell-Larcker's and Henseler *et al* (2015) HTMT ratio criteria. Fornell-Larcker's test results reveal that diagonal values, representing the square root of each construct's AVE, surpass their respective correlation coefficients (table 3) affirming the absence of discriminant validity concerns,

Table 2. Construct reliability and validity.

Variables	Indicators	Indicator loading (⩾0.70)	Cronbach alpha (⩾0.70)	Composite reliability (⩾0.70)	AVE (⩾0.50)
Attitude	ATT1	0.806			
	ATT2	0.829			
	ATT3	0.828	0.884	0.884	0.683
	ATT4	0.831			
	ATT5	0.838			
Intention	INT1	0.831			
	INT2	0.810			
	INT3	0.821	0.904	0.904	0.675
	INT4	0.832			
	INT5	0.825			
	INT6	0.809			
Past behaviour	PB1	0.833			
	PB2	0.830			
	PB3	0.814	0.868	0.869	0.654
	PB4	0.770			
	PB5	0.793			
Perceived behavioural control	PBC1	0.820			
	PBC2	0.816			
	PBC3	0.805			
	PBC4	0.820	0.917	0.917	0.668
	PBC5	0.820			
	PBC6	0.810			
	PBC7	0.830			
Perceived policy effectiveness	PPE1	0.801			
	PPE2	0.828			
	PPE3	0.835	0.877	0.878	0.671
	PPE4	0.810			
	PPE5	0.821			
Subjective norm	SN 1	0.826			
	SN 2	0.812			
	SN 3	0.799			
	SN 4	0.800	0.897	0.898	0.661
	SN 5	0.816			
	SN 6	0.825			
Waste separation behaviour	WSB1	0.787			
	WSB2	0.809			
	WSB3	0.830	0.872	0.874	0.660
	WSB4	0.822			
	WSB5	0.811			

which is consistent with Elshaer *et al* (2023). Henseler *et al* (2015) questioned the reliability of Fornell-Larcker's criterion for discerning the absence of discriminant validity in ordinary research. Utilizing the HTMT ratio of correlations (table 4), which is a more robust and reliable method, all construct discriminant validity values fall below the threshold of 0.85, following Kline (2011) guidelines. This outcome reaffirms the absence of discriminant validity issues in our analysis, corroborating Cheah *et al* (2023).

4.4. Structural model's result

Path coefficients (β) is used to assess the structural model, the p-values, and the corresponding t-statistics, which employ 5000-resample bootstrapping process (figure 3) recommended by Hair Jr *et al* (2020). Additionally, Hair Jr *et al* (2020) advised researchers to evaluate the predictive importance involving the study model using Q^2, R^2, F^2, RMSE, and SRMR. Consequently, all of these methods are evaluated in the model analyses conducted in this research.

4.5. Model diagnosis

The predictive relevance of the model is evaluated using various diagnostic assessments, with their corresponding outcomes table 5. According to Henseler *et al* (2016), a sample size larger than 100 should have an SRMR cutoff of 0.08 or less. From the analysis, the SRMR value is 0.064, corresponding to an acceptable level of model fitness.

Similarly, Schermelleh-Engel *et al* (2003) suggested that the RMSE value should be below 0.8. The current study's RMSE values for intention and WSB are 0.453 and 0.571, respectively, indicating a relatively accurate prediction of the data by the model (figure 3). Furthermore, R^2 estimates of 0.802 and 0.666 are obtained, which indicate that the independent variables explain 80.2% and 66.1% of the total variance in intention and WSB, respectively. These R^2 values surpass threshold of 0.26 Cohen (1988), suggesting that the model has significant predictive ability. Additionally, for a model to possess predictive relevance, its Q^2 value should be higher than zero. The Q^2 values of 0.796 and 0.697 obtained from our analysis indicate high predictive relevance, which aligns with the results reported from the works Foroughi *et al* (2023). Cohen (1988) reported that effect sizes (F^2) of 0.02, 0.15, and 0.35, respectively indicate weak, average, and firm effects, while a value below 0.02 implies 'no effect'. This study's F^2 values of 0.070 and 0.134 signify significant effects between the variables (figure 3 above).

4.6. Hypothesis testing

The p-values, path coefficients, and t-statistics obtained from the model are presented in table 6. The table reveals that individuals' attitude toward waste separation significantly and positively affects individuals' waste separation intention ($\beta = 0.398$; t-statistics = 7.508; $p<0.01$), which supports H1. Additionally, subjective norms positively and significantly affect individual intentions towards WSB ($\beta = 0.125$; t-statistics = 2.222; $p<0.01$), which means that H2 is supported. Conversely, perceived behaviour significantly control and positively affect individual intentions towards WSB ($\beta = 0.337$; t-statistics = 4.621; $p<0.01$), which supports H3. Past behaviour has significant effect on and positively control individuals' waste separation intention ($\beta = 0.088$; t-statistics = 2.287; $p<0.01$), which supports H4. Furthermore, perceived policy effectiveness significantly and negatively moderate the relationship between individual intention and WSB ($\beta = -0.102$; t-statistics = 4.882; $p< 0.01$), supporting H5, and figure 4 clearly displays the interaction effects of perceived policy effectiveness. Finally, individual intention significantly controls and positively affect WSB ($\beta = 0.339$; t-statistics = 6.019; $p<0.01$), which supports H6.

4.6.1. Control variables

The study examined the significance of socio-economic factors—including gender, age, education, marital status, area of residence, occupation, household size, and household monthly income—in examining waste separation behavior. The findings indicated that gender ($\beta = 0.043$, $t = 0.960$, $p > 0.05$), age ($\beta = -0.028$, $t = 1.369$, $p > 0.05$), education ($\beta = 0.062$, $t = 0.414$, $p > 0.05$), marital status ($\beta = -0.071$, $t = 0.619$, $p > 0.05$), occupation ($\beta = -0.050$, $t = 0.571$, $p > 0.05$), household size ($\beta = -0.043$, $t = 0.852$, $p > 0.05$), and household monthly income ($\beta = -0.065$, $t = 0.717$, $p > .05$) were not significant predictors of waste separation behavior. In contrast, area of residence was a significant predictor ($\beta = 0.195$, $t = 2.085$, $p < 0.05$).

5. Discussion

In this study, attempt addressing the gaps in the understanding of psychological factors influencing WSB during the recent Covid-19 pandemic, and the impact of government policies and past behaviour on WSB. Given the heightened risk of disease transmission associated with improper handling of medical waste during an epidemic (Arkorful *et al* 2021, Zhou *et al* 2022) and exploring how residents' waste separation practices can contribute to curbing the spread of infections, mitigating secondary infections has become pertinent. The identification of behavioural intentions among respondents is crucial for the successful handling of municipal solid waste (MSW) during public health emergencies, making it necessary to examine WSB using the extended TPB.

Table 6 presented the result on the significance of socio-economic factors (gender, age, education, marital status, area of residence, occupation, household size, and household monthly income) on WSB, albeit, only area of residence was significant. This outcome suggests that it is important to consider the areas of residence (urban, peri-urban and rural) when formulating policies and providing interventions. On the same table 6, the results of our structural equation analysis show that people's attitudes towards waste separation have a significant and positive effect on their intentions to separate their trash. This supports our first hypothesis. This finding is consistent with prior research on pro-environmental behaviour conducted both before and during the COVID-19 global emergency. For example, Labib *et al* (2021) found that attitudes have a positive impact on waste sorting behaviour in Saudi Arabia and Heidrich and Harvey (2018) observed a similar trend in the UK. These results underscore the significance of fostering a positive attitude through educational and promotional initiatives,

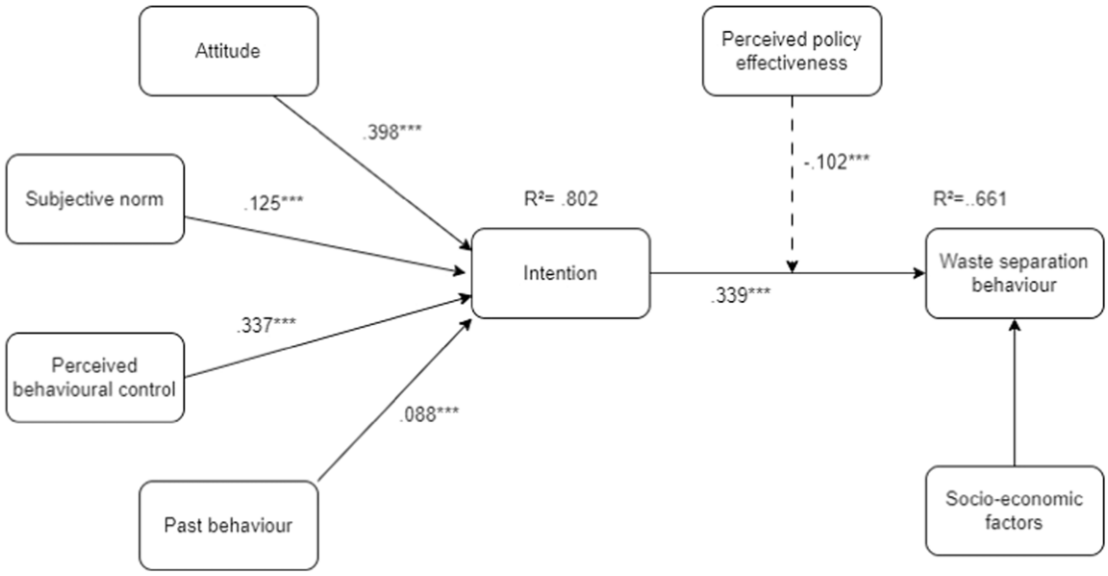

Figure 3. SEM-PLS estimated model.

Table 3. Fornell-Larcker discriminant validity.

Variable	ATT	INT	PB	PBC	PPE	SN	WSB
ATT	**0.720**						
INT	0.681	**0.824**					
PB	0.236	0.465	**0.652**				
PBC	0.611	0.692	0.630	**0.737**			
PPE	0.378	0.443	0.604	0.510	**0.715**		
SN	0.539	0.562	0.493	0.593	0.504	**0.694**	
WSB	0.318	0.763	0.637	0.502	0.484	0.443	**0.568**

Note: Values on the diagonal (bolded) are the AVE's square root, while the off-diagonals are correlations; Attitude (ATT), Intention (INT), Past behaviour (PB), Perceived behavioural control (PBC), Perceived policy effectiveness (PPE), Subjective norm (SN), and Waste separation behaviour (WSB).

Table 4. Heterotrait-Monotrait Ratio (HTMT) for discriminant validity.

Variable	ATT	INT	PB	PBC	PPE	SN	WSB
ATT							
INT	0.680						
PB	0.489	0.580					
PBC	0.602	0.548	0.812				
PPE	0.459	0.567	0.654	0.530			
SN	0.659	0.644	0.687	0.719	0.670		
WSB	0.455	0.468	0.848	0.463	0.459	0.469	

Note: Shaded boxes are the standard reporting format for the HTMT procedure; Attitude (ATT), Intention (INT), Past behaviour (PB), Perceived behavioural control (PBC), Perceived policy effectiveness (PPE), Subjective norm (SN), and Waste separation behaviour (WSB).

Table 5. Predictive relevance.

Variable	R^2	Adjusted R^2	Q^2	F^2	SRMR	RMSE
Intention	0.802	0.801	0.796	0.070	—	0.453
WSB	0.661	0.656	0.697	0.134	0.064	0.571

Note: SRMS (standardized root mean square); RMSE (root mean squared error).

Table 6. Testing for hypothesis.

Hypothesis	Relationships	β	t-statistics	p-value	Decision
H1	Attitude → Intention	0.398	7.508	0.000***	Supported
H2	Subjective norm → Intention	0.125	2.222	0.026***	Supported
H3	Perceived behavioural control → Intention	0.337	4.621	0.000***	Supported
H4	Past behaviour → Intention	0.088	2.287	0.022***	Supported
H5	Perceived policy effectiveness * Intention → WSB	−0.102	4.882	0.000***	Supported
H6	Intention → WSB	0.339	6.019	0.000***	Supported
	Control Variables				
	Gender	0.043	0.960	0.337	Not Significant
	Age	−0.280	1.369	0.171	Not Significant
	Area of residence	0.195	2.085	0.037*	Supported
	Marital status	−0.071	0.619	0.536	Not Significant
	Education status	0.062	0.414	0.679	Not Significant
	Occupation	−0.050	0.571	0.568	Not Significant
	Household size	−0.043	0.852	0.394	Not Significant
	Household monthly income	−0.065	0.717	0.473	Not Significant

Note: *** indicates significance at the 1% level; Critical t-value is 1.96.

which can raise individuals' awareness of the significance of medical waste separation in reducing landfill utilization and waste management burdens during pandemics.

Furthermore, the data analysis revealed that subjective norms positively influence individuals' intentions towards WSB, providing support for our second hypothesis. This aligns with previous research conducted in various cultural contexts, both before and during the pandemic, such as in Hong Kong, Thailand, and Ghana (Wan *et al* 2014, Vassanadumrongdee and Kittipongvises 2018, Arkorful *et al* 2021) Social norms and the influence of significant individuals, including relatives and friends, play a significant part in shaping a person's inclination towards participating in waste separation and recycling practices. Our results on perceived behavioural control supported our third hypothesis, indicating that it significantly and positively affects individuals' intentions towards WSB. This outcome agrees with Aikowe and Mazancová (2021) study in Nigeria, and the Goh *et al* (2022) observation in Australia, underscoring the importance of providing individuals with the tools, knowledge, and conditions necessary to facilitate waste separation practices.

In addition, a strong correlation was found between individuals' past WSB and their intentions to separate waste during health emergencies, which supports our fourth hypothesis. This finding highlights the role of habitual behaviour in framing residents' waste separation practices during an epidemic as evident in studies conducted before COVID-19 pandemic (Xu *et al* 2017, Alhassan *et al* 2018). Past behaviour strongly predicts future WSB, as individuals with prior experience in separating waste tend to exhibit a higher tendency to repeat this behaviour (Xu *et al* 2017). This study also observed a significant moderating impact but negative effect of perceived policy effectiveness on the relationship between intention and WSB, supporting hypothesis five. Previous empirical studies conducted before the COVID-19 global outbreak and during the pandemic (Lin and Guan 2021, Wan *et al* 2014) also found a significant influence of perceived policy effectiveness on intention but not a negative moderation effect as shown in this research. The negative effect suggests that those who believe the policies are less effective or ineffective are less likely to separate waste. In other words, when residents perceive waste management policies, such as waste collection and disposal, as less effective or ineffective, they are demotivated to participate in waste separation, presuming that the waste authority will handle it adequately. This aligns with findings from Lagos, where many residents generate mixed waste without sorting, relying on waste managers to do the work (Allen-Taylor 2023). They might even think their efforts would not make a difference or the separated waste might still end up been disposed of together at the open dumpsite as evident in many cities (Adeniyi 2023, Alaka and Osman 2023).

Finally, our study confirmed that individual intention significantly and positively affects WSB, supporting the sixth hypothesis. This aligns with previous studies carried out in China, Saudi Arabia, Russia, and Finland (Xu *et al* 2017, Labib *et al* 2021, Zaikova *et al* 2022), highlighting the critical impact of intention towards facilitating WSB. Enhancing the factors that influence intention can lead to improved waste-sorting practices, not only during a pandemic but also in everyday life.

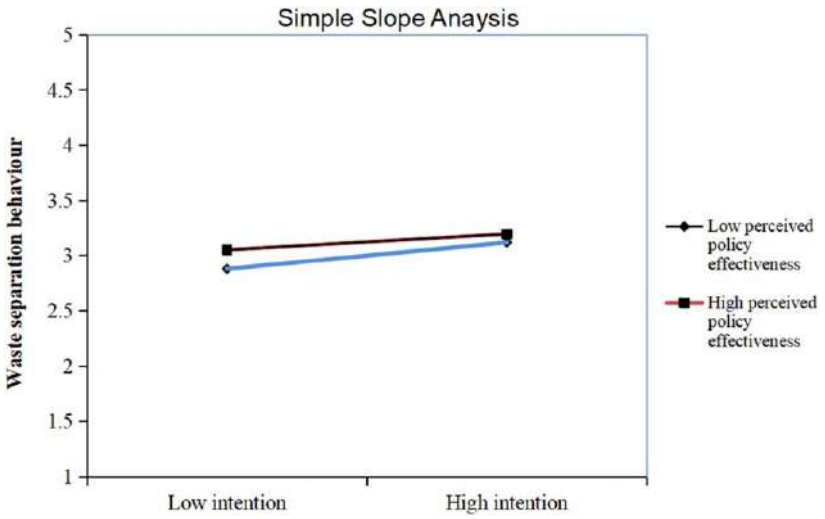

Figure 4. The interaction effect of perceived policy effectiveness on intention and WSB.

5.1. Implications

From the research findings, several implications are presented and are hereafter highlighted. Theoretically, an extended TPB model is employed to elucidate the WSB of Nigerian residents during the COVID-19 outbreak. This enhances the existing body of waste separation studies by reaffirming the applicability of TPB in investigating positive environmental actions, especially with regards to public health crises. Additionally, to better predict the determinants of residents' WSB during a global disease outbreak, this study introduces two novel variables which include; (i) perceived policy effectiveness and (ii) past behaviour. The validation of these additional factors underscores their predictive power and underscores the importance of habit formation in shaping residents' WSB during a health emergency. Consequently, our inclusion of past behaviour and perceived policy effectiveness presents an update to the conceptual model for explaining WSB in pandemic scenarios.

In more practical terms, proactive, periodic, and collaborative public awareness lectures on health protection and environmental management, which specifically focus on medical waste separation can be initiated. These should aim at raising awareness and a sense of collective accountability regarding the advantages of medical waste sorting, the risks associated with its negligence, and the necessity of fostering a positive attitude towards its implementation. With current trends in digital awareness, leveraging social media and other online platforms can be highly effective for educating the public on the importance of waste separation. Collaboration between educational institutions and waste managers for specialized environmental protection courses or clubs could be fostered, enabling students to disseminate knowledge and advocacy to their communities for waste separation at the source. In addition, comprehensive training for healthcare professionals, frontline workers, and waste handlers is crucial in ensuring the proper collection, separation, and discarding wastes generated during health emergencies. Epidemics often come with economic challenges, therefore, waste management strategies that could foster recycling activities should be put in place, and waste handlers should be properly trained on managing recyclable-infectious waste. For effectiveness, considerations should be given to community-specific demographics and classifications, e.g., education, age, language, and residence area, when developing waste management campaigns and interventions. Moreover, focus should be on the youthful population in sub-Saharan Africa, as ~60% are below 25 years.

Perceptions of the effectiveness of policies has been emphasized to influence residents' intentions to separate waste during a pandemic. Policymakers and other stakeholders can leverage this to design campaigns that not only encourage recycling, but also address public concerns about policy effectiveness. Campaigns could focus on educating the public about the effectiveness of existing waste separation programs or implementing more transparent waste separation processes. Media dissemination of epidemic updates, and government efforts in managing waste during pandemic is paramout.to promote people's trust in government policies.

Collaborations with influential individuals in society, including those in the entertainment, community, and religious sectors, can help expand the reach of pandemic preparedness strategies. Establishing neighbourhood-based waste sorting centers, with trained personnel, can facilitate the accurate sorting of waste materials during the pandemic. Government-private sector partnerships can help entrench the implementation of these strategies effectively. The government should also provide the necessary infrastructure and facilities for waste segregation, which should include colour-coded or labelled waste bins in various languages and waste collection vehicles with compartments for medical waste. The current research also advocates for a comprehensive

municipal waste management policy tailored to pandemics. This policy should address waste separation and guide the appropriate management of novel waste types associated with health crises. Regulatory frameworks should be established to oversee and enforce proper waste separation practices, and it should include sanctions and penalties for non-compliance. Regular inspections and the enforcement of environmental regulations are vital. Moreover, implementing incentivized programs offering rewards such as coupons, waste disposal fee discounts, and healthcare services can encourage individuals to adhere to medical waste separation protocols. This approach can foster community engagement and social pressure to promote waste separation.

Research on WSB has primarily focused on European and Asian countries, leaving a significant gap about countries in Africa. Knowing the fact that environmental policies and its implementation have been emphasized as very effective in many Asian and European countries (Gradus *et al* 2019, Hao *et al* 2023), it essential to investigate whether countries within the Africa have similar effectiveness drawing on recent calls about Africa's peculiar policy and it implementation challenges (Obialor 2023, Ole *et al* 2024).

Given that the current study found a negative moderating impact of policy effectiveness on Nigerians' intention to separation waste, an empirical contribution is made confirming past research assertion of the differential effect of environmental policy and its implementation in Asian and European countries (i.e., enabling effect) (Gradus *et al* 2019, Hao *et al* 2023) as well as the Africa's context (i.e., burdening effect in Nigeria) (Obialor 2023, Ole *et al* 2024). Ultimately, the study affirms that when citizens (i.e., in Nigeria) perceive environmental policy and its implementation as ineffective, they become demotivated to align to cultivating WSB. This finding highlights the importance of public enlightenment, policy implementation and enforcement which can be beneficial to other countries, particularly, those within the same Western Africa region Nigeria is embedded. Furthermore, simply encouraging people to separate waste might not be enough if there are no adequate provision for waste separation and disposal infrastructure.

6. Conclusions and limitations

In conclusion, this research offers significant insights into understanding the factors influencing waste separation practices during a public health crisis, like the COVID-19 pandemic, and how policy preparedness could help in shaping WSB in the event of future occurrences. By examining the role of TPB psychological factors and other additional factors (i.e. subjective norm, perceived behavioural control attitude, past behaviour, and perceived policy effectiveness), the current study has enhanced our understanding of waste separation behaviour (WSB) during a recent global health crisis. Our results emphasize the significance of attitude and need to adopt a multifaceted strategy to address education, infrastructure, and policy measures to facilitate residents' continuous engagement in waste separation. With proper WSB, cities can decrease landfill waste, reduce environmental pollution, and support a circular economy for a sustainable city and future. The findings from this study are applicable not only in Nigeria, but can also be adopted to benchmark policy programs in other sub-Saharan African countries and similar demographics facing similar challenges across the world. The outcome of the study gives insights into those countries that are densely populated giving a clue of what could be their behaviour during an epidemic period. It offers implications for urban, peri-urban and rural area. However, in countries with different culture, they may exhibit a different behaviour.

Collaboration among residents, government entities, environmental health stakeholders, and private institutions is essential for addressing waste management challenges effectively and ensuring long-term sustainability in waste separation practices. The policy recommendations derived from this research have the potential to improve waste management governance and mitigate the spread of infectious diseases in the event of future health crises.

Having examined waste separation behaviour (WSB) in two highly populated states in southern Nigeria, it is important to bear in mind the differences and intricacies in the behaviour of those living in other regions. Future research could use time series data focusing on specific geographical areas. Previous works have revealed the nexus between those who possess higher levels of education and income as people who are more aware of environmental protection and inclined towards participating in activities that promote environmental sustainability, this study found that most respondents have higher education levels and good incomes as well. The current study suggest future research should investigate the correlation between education, income, and waste separation participation in Nigeria and other similar demographics in sub-Saharan Africa.

Acknowledgments

The authors acknowledge the anonymous reviewers and the academic community, in USTC and Nigeria, for their thorough feedbacks which has improved the quality of this work.

Conflicts of interest

The authors declare no competing interest either directly or indirectly related to the work submitted.

Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: https://doi.org/10.7910/DVN/GAXEYY .

Statements and declarations

Funding

No funding was received for this work.

Ethics statement

Consent was gained from the participants who provided information for the survey used for this study. No participant was below the age of 16.

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