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Assessing the influence of solid waste knowledge and concern on pro-environmental action in South Africa: Implications for waste management and circular economy strategies

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ABSTRACT

This study investigates public awareness, concern, personal pro-environmental norms, and household recycling behaviour in South Africa using data from the 2022 and 2024 rounds of the South African Social Attitudes Survey. The findings indicate that recycling behaviour remains limited, with approximately 30% reporting that they "always" or "often" recycle. Regression analyses show that environmental knowledge and waste-specific concern are positively associated with recycling behaviour, although these relationships explain only a modest proportion of the variation in behaviour. Environmental knowledge shows a relatively stronger association, while concern plays a more limited role once knowledge is accounted for, suggesting that awareness of recycling is an important, but not sufficient, influence on action. The association between personal pro-environmental norms and recycling behaviour is weak and inconsistent across survey years, indicating a context-dependent role. The results highlight a persistent gap between environmental awareness and consistent pro-environmental behaviour. In the South African context, this gap is shaped not only by behavioural factors but also by structural constraints, including uneven access to waste collection services, variability in municipal infrastructure, and differences in service delivery capacity across municipalities. The findings provide support for the Theory of Planned Behaviour and Value-Belief-Norm frameworks, while also showing that psychological drivers such as knowledge, concern, and norms are mediated by real-world conditions that influence perceived behavioural control and the translation of environmental values into action. Improving recycling outcomes in South Africa requires an integrated approach that combines behavioural interventions, such as strengthening environmental literacy and reinforcing pro-environmental norms, with systemic improvements in waste management infrastructure and service delivery.

1. Introduction

Solid waste leakage into the environment remains one of the most persistent environmental and social challenges in South Africa, as in many developing nations [1]. Although current policy and legislative interventions being implemented in the country, including extended producer responsibility (EPR), may slow down waste leakage over time, they will not fully solve these environmental and social challenges [2]. Yet, waste is not an unavoidable consequence; it is a distinctly human problem. It arises from human consumption and production patterns, resulting from perceptions that waste materials are "useless," and should be discarded when no longer wanted, without consideration of the potential value of products and materials as secondary resources in the economy. Waste is ultimately the consequence of uninformed perceptions and the consequential collective behaviour of people. What we call "waste" is not inherent to the materials themselves but rather a reflection of societal choices, knowledge, and norms. Littering is an example of this as it is a conscious choice that contributes to pollution and environmental degradation (Rockström et al., 2009; [3]). The everyday action of littering, multiplied across millions, transform local negligence into a global ecological crisis.

Waste mismanagement through indiscriminate dumping and the

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improper handling of collected waste at formal disposal sites exacerbates this challenge [2]. Rapid population growth, rising consumption, excessive packaging, and under-resourced municipal systems have placed significant pressure on South Africa's waste management capacity (Gu et al., 2024; Kannankai and Devipriya, 2024; Seif et al., 2024; Sharma et al., 2024). Municipalities face persistent capacity constraints, including limited staff and funding, inadequate vehicles and infrastructure, weak organisational structures, and poor route planning [4]; [5–8]. These systemic gaps are compounded by ineffective law enforcement, corruption, low public awareness, and political inertia [9–12].

The consequences are far-reaching. Waste leakage contaminates soils and water resources, releasing persistent pollutants that threaten ecosystems and human health (Iravanian and Ravari, 2020; [13]; Stafford et al., 2022). Open burning of waste releases greenhouse gases, toxic pollutants, and harmful particulates, while marine litter threatens biodiversity and disrupts ecosystem services critical to human well-being [14]; [15,16]. These outcomes reflect a combination of structural limitations, governance challenges, and behavioural factors, including how responsibility for waste management is distributed across society.

Addressing solid waste leakage requires not only improvements in services and infrastructure, but also changes in knowledge, attitudes, and behavioural norms. Behavioural change is influenced by individuals' environmental knowledge, levels of concern, and pro-environmental norms. Environmental knowledge refers to an individual's understanding of environmental issues and their causes and consequences. Waste-specific concern refers to the degree to which individuals perceive waste management as an important environmental issue requiring attention. Personal pro-environmental norms refer to an individual's internalised sense of responsibility or moral obligation to act in environmentally responsible ways. Environmental education is foundational to behavioural change, as individuals with ecological knowledge are more likely to recognise environmental problems, feel concern for their consequences, and engage in actions that mitigate harm [17]; [18]. Recycling behaviour refers to the actual practice of separating and disposing of waste in a manner that enables material recovery.

Recycling is a widely practiced activity that plays a crucial role in conserving natural resources and reducing waste. By collecting and processing waste materials, recycling transforms items that would otherwise be discarded into valuable raw materials, for new products thereby helping lower the demand for virgin resources, saves energy, reduces pollution, and minimises the volume of waste sent to landfills. Over the past three decades, South Africa has promoted recycling and the circular economy through legislation and awareness campaigns [1]. Despite these efforts, only about 10% of solid waste is recycled, largely driven by informal waste collectors [19]. The persistence of low recycling rates suggests a gap between awareness of waste-related issues and participation in recycling practices.

Understanding the relationship between knowledge, concern, and behaviour is critical for shaping effective waste management and circular economy interventions. While waste management challenges are often framed as infrastructural issues, behavioural and social factors play a key role in influencing outcomes. In the South African context, disparities in service delivery, varying levels of environmental awareness, and differing social norms may influence how individuals engage with waste management practices such as recycling. This study uses national survey data to examine how South Africans' knowledge and concern about solid waste and pro-environmental actions, particularly that of recycling, have evolved over time. It further examines the relationships between environmental knowledge, waste-specific concern, personal norms, and recycling behaviour.

This research addresses a key gap in the literature by providing a national-level analysis of waste-related behaviours in South Africa. Previous studies have largely focused on localised contexts, resulting in fragmented insights into behavioural drivers. This paper contributes a broader, systemic understanding of waste behaviour in South Africa, and provides an evidence base for informing public education, policy interventions, and behavioural change strategies aimed at improving waste management and supporting a transition towards a circular economy.

2. Theoretical background

The relationship between environmental knowledge, concern, and pro-environmental action is a concept in environmental psychology and behaviour change theory [20]. This study draws on the Theory of Planned Behaviour (TPB) and the Value-Belief-Norm (VBN) theory as interpretive frameworks to contextualise and make sense of observed relationships between environmental awareness, concern, norms, and that of recycling behaviour.

The TPB, developed by Ajzen [21], is widely used to interpret patterns of pro-environmental behaviour. The theory proposes that behaviour is associated with behavioural intentions, which are shaped by attitudes, subjective norms, and perceived behavioural control. Within this interpretive framework, environmental knowledge is understood as informing attitudes toward environmental issues, including waste management. These attitudes, together with perceptions of social expectations and perceived capability, help explain why individuals may be more inclined to engage in behaviours such as recycling [22]. In this study, TPB is used to interpret how attitudes, social influence, and perceived feasibility shape recycling behaviour, without assuming a linear or predictive causal sequence among these constructs.

The VBN theory [3] offers a complementary perspective by emphasising moral and normative dimensions of pro-environmental behaviour. This theory interprets behaviours such as recycling as being associated with underlying values, environmental beliefs, and personal norms. Within this framework, environmental concern reflects beliefs about environmental conditions and human–environment relationships, while personal norms represent an internalised sense of moral responsibility to act. In this study, VBN is applied as an interpretive lens to understand how waste-related concern and personal norms relate to recycling behaviour.

Together, these theories highlight that pro-environmental behaviour emerges from interrelated cognitive, affective, and social processes. Environmental knowledge contributes to awareness of environmental issues such as waste accumulation and pollution, which can support the development of concern, particularly when connected to personal values and lived or vicarious experiences of environmental harm [3,23,24]. Knowledge encompasses both objective understanding and subjective engagement [17], and while it is widely recognised as an important precursor to pro-environmental action, it is insufficient on its own to motivate behaviour.

Environmental concern functions as a motivational orientation, reflecting a sense of urgency and responsibility regarding environmental degradation [25]. Within the VBN framework, concern is shaped by beliefs about environmental risks and the perceived effectiveness of individual action, and it activates feelings of moral obligation that are strong correlates of pro-environmental behaviour [3]. Individuals holding strong biospheric or altruistic values are more likely to experience heightened concern, which reinforces internal norms supportive of recycling and responsible waste practices.

Pro-environmental actions, including recycling, responsible waste disposal, and support for waste management initiatives, are understood here as behavioural outcomes shaped by the interaction of these factors. TPB highlights that concern and positive attitudes must be accompanied by perceived behavioural control and supportive social norms for behaviour to occur [21]. Individuals are more likely to act when they perceive sustainable behaviours as both feasible and socially endorsed. As such, environmental education and communication efforts that enhance knowledge and awareness provide a foundation through which concern and norms can translate into action.

Together, TPB and VBN provide complementary perspectives for interpreting the behavioural dimensions of waste management. TPB emphasises the role of attitudes, social influences, and perceived control, while VBN highlights the importance of moral obligations and environmental concern. In this study, environmental knowledge is interpreted as shaping attitudes (TPB), waste-specific concern as reflecting environmental beliefs (VBN), personal norms as internalised obligations (VBN), and recycling behaviour as the observed outcome of these interacting factors.

3. Methodology

3.1. Data collection

This study was part of a collaborative research initiative involving the South African Department of Fisheries, Forestry and the Environment (DFFE), the Human Sciences Research Council (HSRC), and the Council for Scientific and Industrial Research (CSIR). The overarching aim is to use the South African Social Attitudes Survey (SASAS) research infrastructure to explore South African citizens' environmental literacy by unpacking their knowledge, interests, and concerns across a variety of priority environmental themes. For this paper, detailed analysis was restricted specifically to the components of SASAS addressing litter and rubbish, enabling an examination of changes in public perceptions and behaviours over time. This focus yielded a unique and comprehensive output that advances understanding of public perceptions and behaviours related to waste management and recycling in South Africa.

SASAS is an annual, nationally representative survey of South Africans aged 16 years and older living in private households, hostels, and other residential structures. Administered by the HSRC since 2003, the survey aims to track and explain public attitudes, beliefs, behaviours, and values across a diverse range of topics, providing an empirical foundation for social research and policy development. SASAS employs a multi-stage, probability-based sample design using Statistics South Africa's statistical geography as a sampling frame to ensure randomness and representativeness. This involves firstly drawing a random sample of 500 Small Area Layers (SALs) as primary sampling units (PSUs), stratified by province, type of geographic area, and dominant population group. Secondly, from the estimated dwelling units within SALs, seven visiting points are randomly chosen as secondary sampling units (SSUs). In the final sampling stage, all adults that meet the eligibility criteria (aged 16+ years and residing 15 out of the last 30 days on the property) within selected visiting points are listed, after which one individual is randomly selected as a respondent. Interviewing was conducted by means of computer-assisted personal interviewing (CAPI).

The realised sample size for the 2022 SASAS round was 3105, and 3095 in the 2024 round. The data collected in each survey round was benchmarked and weighted using the latest mid-year population estimates by Statistics South Africa to correct for sampling and non-response biases and ensure representativeness of the broader South African population. All analyses presented are based on the weighted data and reflect the views and opinions of adult South Africans. Based on these sample sizes, the estimated margin of sampling error for national-level estimates is approximately ±2 percentage points at the 95% confidence level. The analysis was conducted with Stata version 18, and the analytical approach incorporated descriptive statistics and inferential modelling techniques to identify patterns and changes in public perceptions and behaviours concerning waste over time.

Ethics approval was obtained from the HSRC Research Ethics Committee (REC), in compliance with national and international ethical guidelines. The study adhered to strict ethical standards throughout the fieldwork process. Informed consent was obtained from each participant prior to proceeding with interviewing. No identifying information was recorded, and all data were stored and managed in accordance with HSRC data protection protocols and the requirements of South Africa's Protection of Personal Information Act (POPIA).

3.2. Analytical approach

All analyses were conducted using weighted data to account for the survey design. Regression models accounted for the complex survey design, including clustering and stratification, in the estimation of standard errors. This approach ensures that statistical inferences are robust to the multi-stage sampling structure of SASAS and that standard errors are not underestimated.

The analysis focused on examining associations between environmental knowledge, waste-specific concern, personal pro-environmental norms, and recycling behaviour. Given the repeated cross-sectional nature of the data, the analysis does not attempt to infer causal or temporal relationships, but rather to identify statistically significant associations between variables.

The study employed multiple linear regression models to assess the relationships between the key constructs. Self-assessed knowledge of recycling and frequency of recycling behaviours, which were both measured using a four-point scale, were reverse-coded and rescaled to a 0–100 scale, with higher values indicating greater knowledge and more frequent engagement in recycling activities. Levels of concern about litter and rubbish was captured using a five-point response scale ranging from 'not concerned at all' to 'extremely concerned'. This was transformed into a 0-100 scale, with higher scores representing greater concern. Personal pro-environmental norms were measured using the question 'To what extent do you feel a personal responsibility to try and protect the environment?', with responses capture using an 11-point end-anchored scale where 0 represented 'not at all' and 10 'a great deal'. The measure was again converted to a 0-100 scale. Across all four measures, the small share (1-2%) of 'don't know' responses were coded as 0. Separate models were estimated to examine.

- the association between environmental knowledge and waste-specific concern,
- the association between waste-specific concern and personal norms, and
- the association between personal norms and recycling behaviour.

Standardised beta coefficients are reported to allow comparison of the relative strength of associations between variables, while adjusted R^2 values are used to assess overall model fit.

4. Results

4.1. Environmental understanding, interest and knowledge

Respondents were asked to describe what they understood by the term "the environment." In both survey rounds, pre-coded response options were provided, allowing respondents to select one or more answers. These options included "animals and plants," "water, air and soil," "people," and "buildings and residential areas (man-made environments)." The aim was to assess whether public conceptions of the environment extend beyond the natural environment to include human and built components.

The pattern of responses in the 2022 and 2024 survey rounds is broadly similar, with only minimal variation observed (Table 1). This suggests that public perceptions of the environment remained relatively stable over the two-year period. Most respondents associate the environment primarily with natural elements. A smaller proportion included people and fewer than one-third identified built or man-made environments as part of their definition. Fewer than one-fifth of respondents identified all four components, suggesting that comprehensive environmental understanding is limited. These findings suggest that the environment is predominantly understood in natural terms, with less recognition of the interconnected roles of human and built systems.

Interest in the environment is shaped by a combination of value orientations, lived experiences of local environmental conditions,

Table 1
Public conceptions of what constitutes the environment in South Africa, 2022 and 2024 compared (% mentioning each aspect).

Which of the following aspects do you regard as part of the environment? [MULTIPLE RESPONSE TABLE]	% 2022	% 2024	Percentage point difference
a. Animals and plants	73.5	73.1	−0.3
b. Water, air, soil	72.1	70.4	−1.7
c. People	55.2	52.6	−2.6
d. Buildings, residential areas (man-made environment)	28.6	26.8	−1.8
e. (Don't know)	3.5	4.6	+1.1
f. (Refusal)	0.0	0.0	+0.0
% selecting (a) + (b) + (c) + (d)	18.7	16.8	−1.9
N	3105	3095	…

education, and socialisation, and is often linked to an awareness of how environmental conditions and associated risks influence health and the economy [26]. To explore this in the South African context, respondents were asked to indicate their level of interest in the environment with the results indicating a moderately high level of environmental interest, with close to three-quarters of respondents reporting that they were either "very" or "somewhat" interested in environmental issues in 2022 (Table 2). The distribution of responses in 2024 shows some variation compared to 2022, including a six-percentage point decline in the share of respondents indicating that they were "very interested". This difference is relatively modest in magnitude and given the descriptive nature of the data, no conclusions are drawn regarding changes in interest over time beyond the observed differences in proportions.

Promoting knowledge and awareness of environmental problems remains crucial for encouraging pro-environmental norms and actions. In 2024, half of South Africans (52%) reported a moderate to high level of awareness of environmental problems, while 47% displaying low awareness (Table 3). As observed with environmental interest, there are indications of a slight decline in self-reported awareness of environmental challenges between the 2022 and 2024 survey rounds. While relatively modest, this fluctuating tendency is a cause for concern given the degree of media attention devoted to environmental issues as well as ongoing initiatives designed to promote awareness of environmental issues among the public.

In the 2022 survey, respondents were presented with a list of environmental problems currently affecting South Africa and were asked to indicate those they were concerned about (Fig. 1). The most frequently cited concerns were water pollution and air pollution both of which are strongly linked to inadequate waste management practices and the leakage of waste into the environment. Solid waste, commonly described as rubbish, litter, or waste, was identified as a concern by 43% of respondents. In addition, 22% of the public expressed concern about pollution of oceans and beaches, a problem largely driven by the accumulation of mismanaged waste in coastal and marine environments. All four of these concerns are directly attributable to waste leakage, underscoring the central role of poor waste management in shaping

Table 2
Interest in the environment in South Africa, 2022 and 2024 (%). Lower and upper 95% confidence intervals on point estimates are displayed in brackets.

How interested are you the environment?	% 2022	% 2024	Percentage point difference
Very interested	31.0	25.2	−5.8
Something interested	43.3	43.8	0.6
Not very interested	15.9	17.7	1.8
Not interested at all	9.0	11.7	2.7
(Don't know)	1.0	1.6	0.6
Total	100.0	100.0	…
% very/somewhat interested	74.2	69.0	−5.2
% not very/not at all interested	24.8	29.4	4.6
N	3105	3095	…

Table 3
Awareness of environmental problems in South Africa, 2022 and 2024 (%).

How much, if any, would you say you know about environmental problems? Do you know …	% 2022	% 2024	Percentage point difference
A lot	14.7	15.3	0.7
A fair amount	42.7	36.7	−6.1
A little	31.8	35.0	3.2
Nothing at all	9.9	11.5	1.6
(Don't know)	0.9	1.5	0.6
Total	100.0	100.0	…
% A lot/a fair amount	57.4	52.0	−5.4
% A little/nothing at all	41.7	46.5	4.9
N	3105	3095	…

environmental impacts of concern to South Africans.

4.2. Litter and rubbish: Concern among the South African public

Respondents were presented with a range of commonly cited reasons for South Africa's litter and rubbish problem and asked to select all factors they believed contributed to solid waste pollution in the country (Fig. 2). The pattern of responses provides insight into how the public understands the drivers of waste leakage. Respondents identified a mix of structural and behavioural factors, indicating a relatively nuanced appreciation of the problem. Taken together, these perceptions frame waste pollution as the outcome of interconnected service delivery shortcomings, weak regulation and enforcement, and everyday disposal behaviours, underscoring the need for integrated interventions that simultaneously address infrastructure, governance, and public awareness.

Levels of concern about litter and rubbish were further examined by asking respondents to indicate their overall degree of concern (Table 4). Although concern remained widespread, the 2024 results indicate a sizeable change in intensity compared with 2022, with an 11-percentage-point decline in the proportion of respondents reporting that they were very or extremely concerned. Despite this reduction, the overall distribution of responses remains largely unchanged, with high levels of concern continuing to predominate. These findings emphasise that litter and rubbish persist as a significant issue of concern for the South African public.

Concern about the removal and disposal of refuse, rubbish, and waste was also examined, with both survey rounds showing only minor variation over time. The findings suggest that solid waste management remains an issue of concern for a clear majority of the population. In both survey rounds, more than half of respondents reported being either 'very' or 'extremely' concerned about waste management in the country. A further quarter indicated that they were 'somewhat' concerned, while fewer than one-fifth reported low or no concern (Table 5).

In the 2022 survey respondents were presented with several serious problems affecting coastal and marine environments in the county and were asked to identify those they believed to be the most serious (Fig. 3). Plastic pollution in oceans and on beaches was regarded as the leading concern, cited by more than half of the public followed by sewage entering rivers, estuaries and oceans and oil spills. These findings emphasise strong public recognition of marine pollution risks, particularly those linked to solid waste, combined with a degree of uncertainty or disengagement among a minority share of South Africans.

4.3. Recycling: knowledge and behaviour

Recycling is a pro-environmental behaviour in which an individual consciously decides to engage in the process of gathering and treating waste materials so they can be reused to create new products instead of being discarded. Moderate and improving levels of self-reported knowledge about recycling are evident (Table 6). In both survey

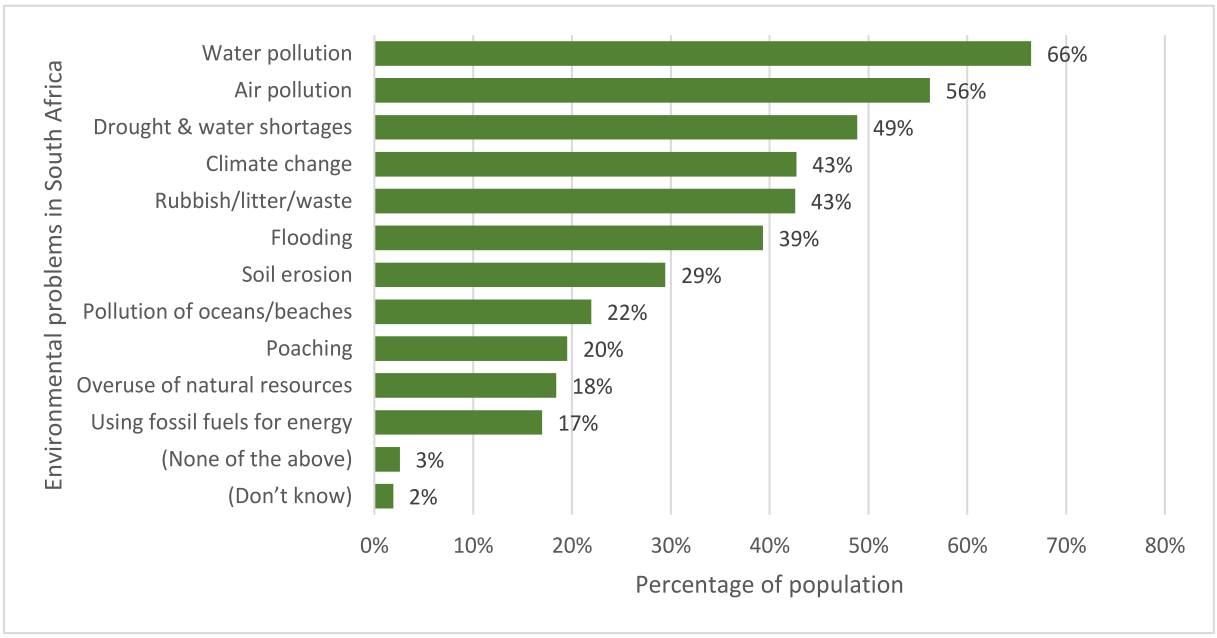

Fig. 1. Concern about specific environmental problems in South Africa, 2022 (% mentioning each concern, N = 3105). The results are ranked in descending order.

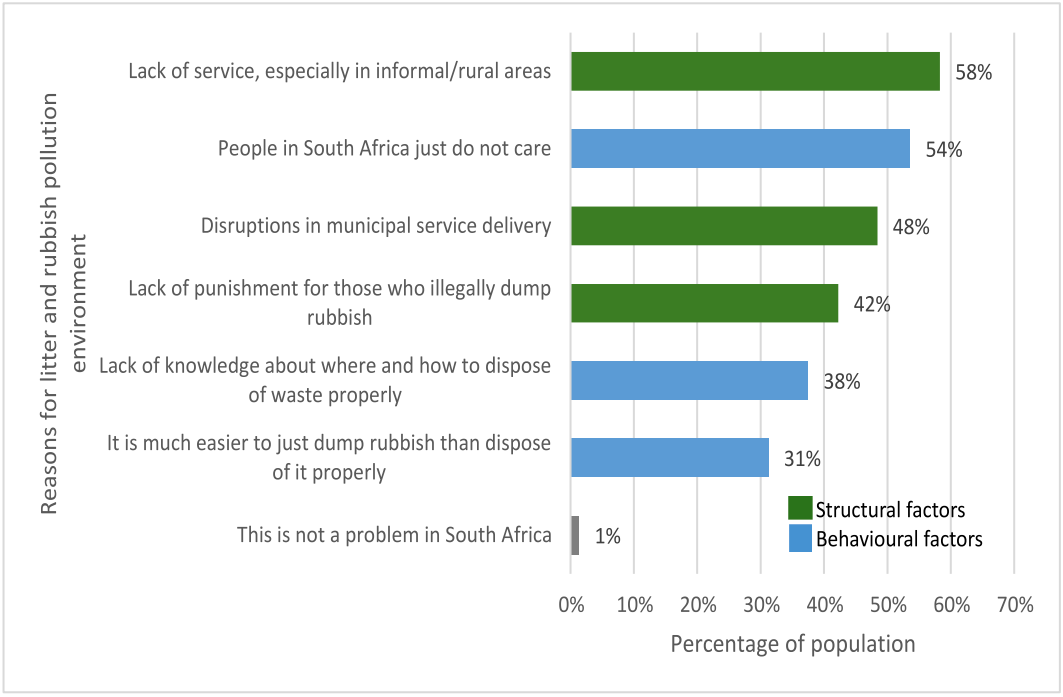

Fig. 2. Main reasons for litter and rubbish polluting the environment, 2022 (% mentioning each concern, N = 3105). The results are ranked in descending order.

rounds, most South Africans indicated that they knew 'a lot' or 'a fair amount' about the recycling of solid waste, with the share increasing from 54% to 63% over the two-year period.

Despite these levels of knowledge, recycling behaviour remains limited. To assess public recycling behaviours, respondents to the 2022 and 2024 surveys were asked: 'How often do you make a special effort to sort glass, tins, plastic, newspapers, and similar items for recycling?'. In the two survey years, a low level of self-reported recycling behaviour is evident, with slightly less than a third of the public 'always' or 'often' participating in the recycling of glass, tin, plastic, or newspaper items (Fig. 4). The reported recycling frequency has remained consistent between the survey rounds, with similar shares reporting infrequent recycling and never engaging in this practice. It is important to note that these measures are based on self-reported behaviour and may reflect both actual practices and social desirability effects so the results should be interpreted with appropriate caution.

4.4. Relationships between recycling knowledge, concern about litter, pro-environmental norms and recycling behaviour

This section presents the results of regression analyses examining the relationships between environmental knowledge, waste-specific

Table 4
Concern about litter and rubbish in South Africa, 2022 and 2024 (%).

Generally speaking, how concerned are you about litter and rubbish? Are you …	% 2022	% 2024	Percentage point difference
Not concerned at all	4.0	6.0	1.9
Not very concerned	7.6	11.9	4.4
Somewhat concerned	24.7	27.4	2.8
Very concerned	43.7	32.5	−11.2
Extremely concerned	19.2	19.6	0.5
(Refusal)	0.2	0.3	0.1
(Don't know)	0.8	2.3	1.6
Total	100.0	100.0	0.0
% Not at all/not very concerned	11.6	17.9	6.3
% Somewhat concerned	24.7	27.4	2.8
% Very/extremely concerned	62.8	52.1	−10.8
% Uncertain/refusal	0.9	2.6	1.7
N	3105	3095	…

Table 5
Concern about the removal and disposal of refuse, rubbish and waste, 2022 and 2024 (%).

How concerned are you about the removal and disposal of refuse, rubbish and waste (i.e., solid waste management) in South Africa? Are you …	% 2022	% 2024	Percentage point difference
Not concerned at all	4.6	5.4	0.8
Not very concerned	9.0	11.3	2.3
Somewhat concerned	27.1	28.8	1.6
Very concerned	43.1	35.7	−7.4
Extremely concerned	15.3	16.3	1.0
(Refusal)	0.1	0.6	0.5
(Don't know)	0.8	2.1	1.3
Total	100.0	100.0	0.0
% Not at all/not very concerned	13.6	16.7	3.1
% Somewhat concerned	27.1	28.8	1.6
% Very/extremely concerned	58.4	51.9	−6.5
% Uncertain/refusal	0.9	2.6	1.8
N	3105	3095	…

concern, personal pro-environmental norms, and recycling behaviour. All models are estimated using weighted data and account for the complex survey design. The results are reported using standardised coefficients (β) to allow comparison across variables.

The 2022 regression analysis (Table 7, Panel A) shows that recycling knowledge is a significant positive predictor of concern about waste-related issues (Model I, $\beta = 0.184$, $p < 0\ 0.001$). However, the adjusted R^2 value of the model is 0.033, indicating that approximately 3.3% of the variation in concern is explained by recycling knowledge. In Model II of Panel A, both concern and knowledge predict personal pro-environmental norms ($\beta = 0.243$ and $\beta = 0.135$ respectively, $p < 0\ 0.001$), indicating that a greater level of understanding and concern about waste is associated with a stronger sense of personal responsibility to protect the environment. These factors explain approximately 9% of variance in norms.

When modelled alone, knowledge accounts for 13% of the variance in recycling behaviour (Model III, $\beta = 0.363$, $p < 0\ 0.001$). This suggests that, in South Africa, knowledge is strongly associated with recycling behaviour on whether individuals make a special effort to recycle. When modelled independently, concern (Model IV, $\beta = 0.081$, $p < 0\ 0.001$) and pro-environmental norms (Model V, $\beta = 0.075$, $p < 0\ 0.001$) were found to statistically correlates with recycling behaviour, although the scale of effect is small, with each explaining less than 1% of the variance in recycling behaviour (Adj. $R^2 = 0.006$ and 0.005 respectively). While a sense of environmental concern and responsibility matter, their influence on recycling behaviour is limited. In contrast, recycling knowledge was a much stronger predictor of behavioural action.

In the full model that jointly includes knowledge, concern and personal norms (Model VI), knowledge remains the strongest predictor of action ($\beta = 0.361$, $p < 0.001$), while the effects of concern and personal norms become statistically non-significant. The combined model

Table 6
Knowledge of recycling, 2022 and 2024 (%).

How much would you say you know about recycling? Do you know …	% 2022	% 2024	Percentage point difference
A lot	18.6	25.9	7.3
A fair amount	35.4	37.0	1.7
A little	33.8	27.9	−5.9
Nothing at all	11.1	7.8	−3.3
(Don't know)	1.1	1.4	0.3
(Refusal)	0.0	0.0	0.0
Total	100.0	100.0	0.0
% A lot/a fair amount	53.9	62.9	8.9
% A little/nothing at all	45.0	35.7	−9.2
% Uncertain/refusal	1.1	1.4	0.3
N	3105	3095	…

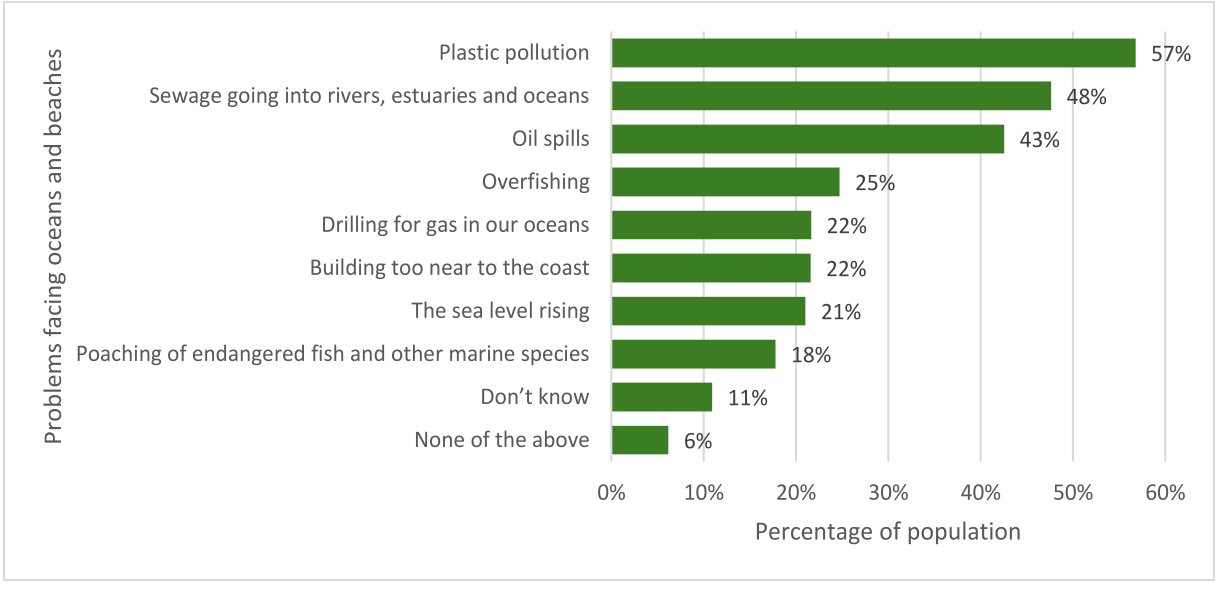

Fig. 3. Most serious problems facing oceans and beaches, 2022 (% mentioning each problem).

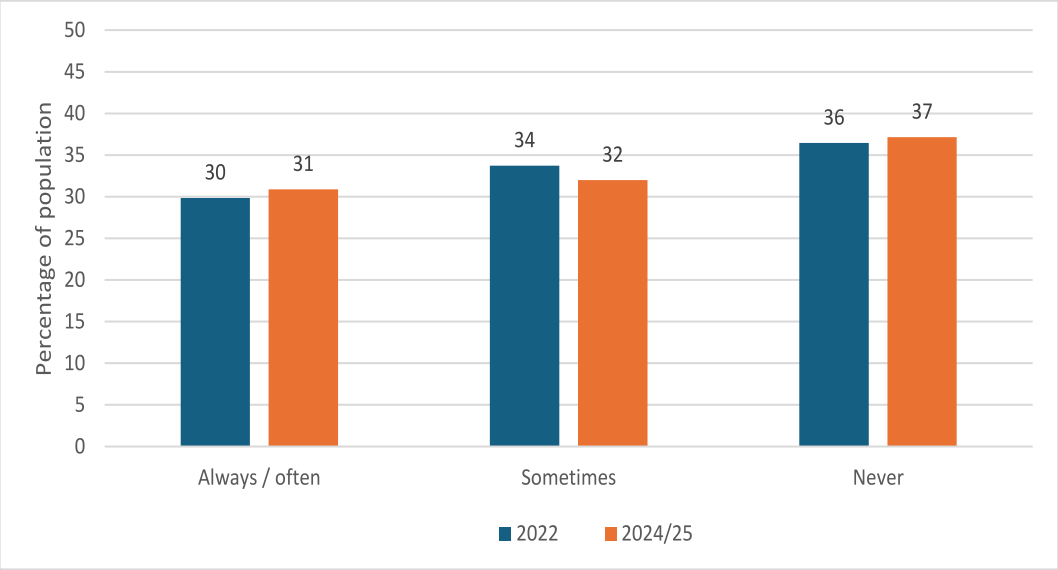

Fig. 4. Frequency of recycling amongst the South African populations by survey year (%).

Table 7
Regression analysis displaying the relationship between knowledge, concern, norms and behaviour.

	I Concern	II Norms	III Action	IV Action	V Action	VI Action
PANEL A: 2022						
Recycling knowledge	0.184***	0.135***	0.363***	…	…	0.361***
Concern about litter	…	0.243***	…	0.081***	…	0.014$^{n.s.}$
Pro-environmental norms	…	…	…	…	0.075***	0.007$^{n.s.}$
Adj. R^2	0.033	0.089	0.131	0.006	0.005	0.133
N	3095	3089	3105	3095	3099	3089
PANEL B: 2024						
Recycling knowledge	0.317***	0.215***	0.309***	…	…	0.285***
Concern about litter	…	0.198***	…	0.104***	…	−0.012$^{n.s.}$
Pro-environmental norms	…	…	…	…	0.169***	0.093***
Adj. R^2	0.100	0.112	0.095	0.011	0.028	0.101
N	3082	3077	3095	3082	3088	3077

Notes: Significance is denoted as follows: n.s. = not significant, *p < 0.05, **p < 0.01, ***p < 0.001; Standardised betas are presented. Number of observations varies across models due to a small number of refusals to the concern and personal pro-environmental norms questions > This does not materially affect the results.

explains 13% of the variance in action (Adj. $R^2 = 0.133$), a marginal improvement over knowledge alone.

The 2022 results suggest that while recycling knowledge is associated with increased concern and a sense of pro-environmental responsibility, its influence on recycling behaviour is largely direct rather than mediated through concern or norms. This is reflected in the larger standardised beta values and higher proportion of variance explained when knowledge is included.

The 2024 regression results (Table 7, Panel B) reinforce the central role of recycling knowledge in shaping both attitudes and behaviour, while revealing a stronger role for pro-environmental norms than observed in 2022. Recycling knowledge is more strongly associated with concern about waste issues than in the earlier survey round ($\beta = 0.317$, Adj. $R^2 = 0.100$). Concern and knowledge are again found to be significant predictors of personal pro-environmental norms ($\beta = 0.198$ and 0.215 respectively), explaining 11% in variance. Unlike the 2022 results, in the 2024 survey the effect of knowledge on norms was slightly stronger than the effect of concern.

Examined separately, concern (Model IV, $\beta = 0.104$, $p < 0.001$) and personal norms (Model V, $\beta = 0.169$, $p < 0.001$) significantly predict recycling behaviour, with personal norms displaying a stronger effect than in 2022. As previously observed, knowledge remains a more salient direct predictor of recycling behaviour (Model III, $\beta = 0.309$, Adj. $R^2 = 0.095$). When knowledge, concern and personal norms are entered together in Model VI, knowledge ($\beta = 0.285$, $p < 0.001$) and norms ($\beta = 0.093$, $p < 0.001$) both remain significant predictors of recycling behaviour, while concern becomes non-significant ($\beta = -0.012$). The combined model explains 10% of the variance in recycling behaviour (Adj. $R^2 = 0.101$), with knowledge remaining the dominant factor of the three tested in predicting action, with personal norms playing a more meaningful secondary role than in 2022.

Comparing the regression results from the two survey rounds highlights some variation in the relationships between knowledge, concern, norms and recycling behaviour. First, the association between knowledge and concern considerably stronger in 2024 relative to 2022, with standardised betas of 0.307 and 0.184 respectively. The variance explained in 2024 was also 10.0% compared to 3.3% in 2022. Second, the behavioural influence of personal pro-environmental norms was similarly stronger in 2024 than 2022, emerging as a significant predictor of recycling behaviour in the fully specified 2024 model. Third, the effect of concern on recycling behaviour also marginally stronger in 2024 than 2022 when tested independently (2022: $\beta = 0.081$, Adj. $R^2 = 0.005$); 2024: $\beta = 0.104$, Adj. $R^2 = 0.028$), although it remains a non-significant predictor overall in the joint models once knowledge and norms are added. Fourth, the direct effect of knowledge on action was somewhat weaker in 2024, with the standardised beta declining from 0.363 in 2022 to 0.309 in 2024, and the variance explained falling from 13.1% to 9.5% when individually tested. The combined model in both

survey rounds suggests that knowledge remains the strongest and most consistent predictor overall. However, it is important to note that the relatively low explanatory power of the models in the table suggests that additional factors not included in the model are likely to influence levels of concern, pro-environmental norms and the frequency of recycling activities, typically the structural and behaviour challenges highlighted by the respondents. Literature supports this highlighting a complex interplay of personal values, environmental knowledge, attitudes, perceived social norms, and contextual factors all of which influence levels of concern, pro-environmental norms, and the frequency of recycling behaviour [27]; Shultz et al., 1995).

5. Discussion

The purpose of this study was to analyse nationally representative survey data on environmental literacy collected in South Africa in 2022 and 2024, with a focus on public knowledge, concern, norms, and behaviour relating to solid waste and recycling. The study examined how these dimensions of environmental engagement are related and identified gaps between awareness and reported behaviour.

The descriptive results indicate that public understanding of the environment is uneven. While much of the South African public associate the environment with natural elements such as plants, animals, water, air, and soil, fewer recognise the inclusion of human and built systems. This suggests that environmental knowledge is predominantly framed in ecological terms, with less emphasis on the interconnectedness between environmental, social, and economic systems. This distinction is important, as broader conceptualisations of the environment may influence how individuals understand environmental problems, including waste management, and their role within these systems (Price, 2008).

Levels of environmental interest were found to be moderately high, with a substantial proportion of the public expressing some degree of interest in environmental issues. This interest is not uniform across the population, and observed changes over time are relatively modest. These findings suggest that while environmental issues are salient to many South African, the depth and consistency of engagement vary.

In relation to waste, the results indicate that it is not among the most prominent environmental concerns, with fewer than half of the public identify it as a serious issue. This suggests that waste does not yet occupy the same level of public concern as environmental issues with direct links to human health and well-being, such as water and air pollution. This pattern points to potential gaps in public understanding of the links between waste mismanagement and broader environmental and health outcomes. The suggested lack of knowledge is a concern given that knowledge remains a significant positive predictor of action, and that action at household level, is required for moving South Africa up the waste management hierarchy and towards a circular economy.

Findings highlight of both behavioural and structural dimensions of waste management. Respondents attribute waste leakage to both individual behaviours such as lack of care or awareness and structural factors, including inadequate service delivery and infrastructure. The co-existence of these explanations suggests that waste management challenges cannot be attributed to a single set of drivers.

Previous research indicates that littering is often attributed to individual traits such as inattentiveness or lack of care, while also being shaped by broader social-economic and contextual influences [28]. Littering can be further understood through socially constructed meanings, including associations with income generation or prevailing social norms [28]; [29]. These insights align with the findings of this study, which suggest that moderate levels of environmental interest may not be sufficient to support consistent pro-environmental behaviour. Instead, higher levels of environmental concern and a stronger sense of personal responsibility are associated with an increased likelihood of pro-environmental action [21]; [3].

In terms of the structural explanations, respondents frequently attributing the prevalence of litter and waste to limitations in service delivery, particularly in informal settlements and rural areas. These perceptions reflect real institutional and infrastructural constraints that shape waste management outcomes. They may also indicate a tendency to externalise responsibility, as waste generation and disposal ultimately involve individual practices within these structural contexts [28]. In rural areas, waste management practices are further influenced by local traditions, cultural norms, and community-level dynamics [29].

From a holistic perspective these findings suggest that behavioural practices and structural conditions are closely interconnected. Waste management outcomes are shaped not only by individual attitudes and actions, but also by the systems and contexts within which these behaviours occur. This reinforces the importance of adopting an integrated perspective that considers both behavioural and structural dimensions when interpreting recycling behaviour and designing interventions to address waste management challenges.

Although public concern about rubbish and litter is relatively high, with over two-thirds of the population expressing some level of concern, the intensity of this concern appears to be variable over time. This finding is relevant as it is the strength of concern rather than mere awareness that strongly predicts pro-environmental action [3]. Temporal variation in the intensity of concern may signal an element of complacency towards the waste situation in the country while waste management challenges persist nationwide. It could also point to acceptance that poor service delivery is a manifestation of corruption in South Africa which is not being actively addressed [28]. These patterns should be interpreted cautiously as the data is descriptive and only has two survey time points, which does not allow for conclusions about underlying drivers or trends to be derived.

Limited public knowledge about the impact of waste on human and environmental health may be a contributing factor to the varying intensity of concern observed between 2022 and 2024. The apparent change amongst those expressing most concern may indicate a possible weakening in public motivation to demand improved waste services or to act individually to reduce waste pollution, though this should be interpreted cautiously given that the evidence is based on only two survey time points. If this pattern continues, it could undermine citizen-led initiatives and reduce community pressure on municipalities to deliver better waste management services. Continuous monitoring through repeat surveys is essential to assess the extent to which changes in concern are associated with shifts in behavioural commitment and civic engagement in relation to waste-related issues.

Recycling behaviour remains relatively limited, despite moderate levels of environmental knowledge and interest. This finding is consistent with the broader observation that awareness and interest do not necessarily translate into sustained behavioural change. To achieve meaningful progress in national waste diversion towards a circular economy, it will be essential to accelerate behavioural change by addressing barriers to recycling, and perceived efficacy of individual action, while continuing to reinforce public education and awareness efforts [30].

From a behavioural perspective, the regression results suggest environmental knowledge, waste-specific concern, and personal pro-environmental norms have a positive association with recycling behaviour. While concern and personal pro-environmental norms serve as mediating variables between knowledge and action, most of the effect of knowledge on behaviour appears to be direct. The combined model indicates that personal norms may be becoming an increasingly important pathway through which knowledge translates into pro-environmental action, even though knowledge itself remains the stronger predictor. The analysis does not demonstrate a sequential or causal relationship between knowledge, concern, norms, and behaviour. The findings indicate that these factors are interrelated, with their associations varying across contexts. While knowledge shows an association with recycling behaviour, this should not be interpreted as a direct causal effect, nor as evidence of mediation through concern or norms.

Instead, the results suggest that multiple dimensions of environmental engagement operate simultaneously and interactively.

These findings are consistent with the TPB and the VBN frameworks when interpreted within the South African context. From a TPB perspective, environmental knowledge, attitudes, and personal norms contribute to behavioural intention, but their translation into actual recycling behaviour is shaped by perceived behavioural control. In South Africa, this perceived control is strongly conditioned by structural realities such as uneven access to waste collection services, variability in municipal infrastructure, and differences in local service delivery capacity. These constraints can limit the extent to which favourable attitudes and intentions are expressed in practice. From a VBN perspective, environmental concern and personal norms provide important motivational foundations for pro-environmental behaviour, but their activation into action depends on enabling external conditions. In contexts where recycling systems are inconsistent or inaccessible, even strong environmental concern and personal responsibility norms may not consistently result in behaviour change.

The results imply that efforts to improve recycling behaviour in South Africa may benefit from an integrated approach that considers both behavioural and structural factors. Interventions that focus solely on increasing awareness or concern may have limited impact if not accompanied by improvements in infrastructure, service delivery, and enabling conditions. The variation in environmental understanding observed in the study highlights the potential value of strengthening environmental literacy, particularly in relation to the interconnected nature of environmental systems and human activity.

To operationalise education and infrastructure integration in South Africa's waste management based on the findings from this study, the National Waste Management strategy (NWMS) must be strengthened by embedding comprehensive educational programmes that raise awareness about waste hierarchy principles, and environmental impacts at all levels of society. This includes integrating waste education into school curricula, community programmes, and public campaigns, aiming to foster pro-environmental norms and behaviours. Infrastructure development must be prioritised, especially in rural and underserved areas, to improve access to waste collection and recycling facilities. Implementing integrated waste management planning using a bottom-up approach, supported by clear legislative mandates, will promote sustainable practices. Regular monitoring and evaluation, coupled with inclusive stakeholder collaborations, are essential for continuous improvement and accountability in waste management systems.

Several limitations should be considered when interpreting these findings. First, the analysis is based on cross-sectional survey data collected at two time points that a relatively closely spaced, which limits the ability to draw conclusions about temporal or causal relationships. Second, recycling behaviour is self-reported and may be influenced by social desirability bias or differences in interpretation. The results should be understood as indicative of reported behaviour rather than precise measures of actual practices. Despite these limitations, the study provides a national-level perspective on environmental attitudes and behaviours in South Africa. By highlighting both the relationships and gaps between knowledge, concern, norms and behaviour, the findings contribute to a more nuanced understanding of waste-related practices and provide a basis for informing future research and interventions.

6. Conclusion

This study provides the first nationally representative evidence on environmental knowledge, concern, personal norms, and recycling behaviour in South Africa, offering a system-level perspective to inform waste management policy and practice. The findings reveal a persistent gap between awareness and consistent pro-environmental behaviour: while public interest in environmental issues is moderate, consistent recycling behaviour remains limited.

Environmental knowledge emerges as a strong and consistent predictor of recycling behaviour, with a largely direct influence. This knowledge does not reliably translate into action in the absence of enabling conditions. Structural constraints, particularly uneven access to waste services, inadequate infrastructure, and variability in municipal service delivery, significantly limit the ability of households to act on pro-environmental intentions. This highlights a critical policy insight: behaviour change interventions alone are unlikely to deliver meaningful improvements without parallel investments in service delivery systems. The findings provide partial support for the Theory of Planned Behaviour and Value-Belief-Norm frameworks, particularly in highlighting the importance of knowledge and perceived behavioural control, while also demonstrating the limitations of these frameworks in contexts characterised by structural constraints.

These findings underscore the need for systemic solutions that combine behavioural interventions with structural support. The results point to the need for an integrated policy approach. Environmental literacy must be strengthened through targeted education and communication, but this must be aligned with expanded and reliable waste collection services, accessible recycling infrastructure, and clearer guidance to households on how to participate. Embedding waste education within school curricula, community programmes, and national campaigns can support longer-term behavioural shifts, while infrastructure investments, particularly in underserved and rural areas, are essential to enable action.

Future research should support policy design by identifying causal pathways, linking behavioural data with service delivery conditions, and evaluating the effectiveness of specific interventions. Continued national monitoring of public attitudes and behaviours will be critical for tracking progress and refining strategies aimed at advancing South Africa's circular economy and improving waste management outcomes.

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CRediT authorship contribution statement

Lorren K. Haywood: Conceptualization, Formal analysis, Visualization, Writing – original draft. **Shanaaz Dunn:** Data curation, Formal analysis, Methodology, Visualization, Writing – original draft. **Suzan HH. Oelofse:** Writing – original draft. **Benjamin J. Roberts:** Formal analysis, Methodology, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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