Review Article

Waste Management Knowledge, Attitudes, and Practices: Determinants, Gaps, and Pathways to Sustainable Behavior Across Diverse Socio-Economic Contexts

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ABSTRACT

Background: Solid waste management (SWM) is a LMIC challenge. This review synthesizes evidence and field-survey data from Charsadda, Pakistan, integrating TPB, VBN, KAP, and ISWM frameworks.

Objective: To identify patterns in SWM knowledge, attitudes, and behavioral determinants and illustrate Pakistani conditions using evidence.

Methods: A narrative synthesis of five studies published between 2020 and 2024, including cross-sectional surveys, mixed methods, and secondary data benchmarking, was supplemented by two structured questionnaires administered face-to-face at four sites in Charsadda district. Descriptive statistics and percentage frequency distributions were used for analysis.

Results: Knowledge gaps were more consistently associated with improper SWM practices than attitudinal barriers; subjective norms were strong behavioral predictors in collectivistic contexts; and infrastructure access was a stronger predictor of improper disposal than individual knowledge or attitudes. Charsadda data showed 92.86% willingness to act, 90.48% non-participation, and severe infrastructure deficits. Economic modelling for 11 Pakistani cities estimated 11.6 million tons of MSW and approximately 29% operational cost recovery through recycling, composting, and carbon credits.

Conclusion: Effective SWM interventions must address cognitive, normative, and structural determinants simultaneously. Campus-based programs show promise for behavioral change. Estimated methane emissions from the 11 cities reach 179.7 Gg/year, highlighting climate relevance of SWM governance.

INTRODUCTION

Solid waste management (SWM) has become a critical environmental, public-health, and governance challenge in the twenty-first century. Rapid urbanization, population growth, changing consumption patterns, and economic development are driving substantial increases in the generation of municipal solid waste (MSW), placing growing pressure on collection, transportation, treatment, recycling, and disposal systems. Global MSW generation is projected to reach approximately 3.4 billion tonnes annually by 2050, emphasizing the need for effective and sustainable waste-management strategies (Kaza et al., 2018). Beyond the direct environmental consequences of uncontrolled disposal, inefficient SWM results in resource loss, environmental pollution, greenhouse-gas emissions, and increased pressure on already constrained municipal services. Consequently, contemporary SWM increasingly requires an integrated perspective that incorporates environmental protection, resource recovery, behavioural change, institutional capacity, and economic sustainability.

Solid waste comprises diverse material streams, including organic and food waste, paper, glass, plastics, and other residual materials. Each stream has different characteristics and recovery potential and therefore requires appropriate handling from the point of generation through collection, treatment, recycling, and final disposal. Source separation is particularly important because contamination between waste streams can reduce the feasibility and economic value of subsequent recovery processes. The major waste categories considered within sustainable source-separation systems are illustrated in Figure 1.

HIGHLIGHTS	
Research insights	Knowledge gaps and infrastructure deficits are stronger determinants of improper solid waste management practices than attitudes alone.
Practical insights	Effective SWM interventions should integrate behavioral, social, and infrastructure-based approaches, with campus-based programs offering promising settings for behavioral change.
Industry insights	Integrated recycling, composting, and carbon-credit systems could recover approximately 29% of operational costs while reducing methane emissions and strengthening sustainable waste governance.

Figure 1. Principal solid waste streams requiring source-separated management.

The figure illustrates four major waste categories—paper, glass, organic/food waste, and plastics—and emphasizes source separation as an important prerequisite for effective recovery, recycling, and sustainable downstream waste management.

The challenge is particularly pronounced in developing countries, where population growth and urban expansion may outpace the development of adequate waste-management infrastructure and governance systems. In Pakistan, SWM remains characterized by substantial variation in waste generation, collection efficiency, disposal practices, and institutional performance across urban centres. Iqbal et al. (2022) demonstrated considerable differences in SWM conditions across major Pakistani cities and emphasized the need to integrate environmental and economic considerations into sustainable waste-management planning. Their assessment of 11 major cities provides an important illustration of the scale and spatial distribution of the national urban waste burden. As shown in Figure 2, Karachi and Lahore account for particularly large quantities of daily MSW generation, while substantial volumes are also generated by other major urban centres.

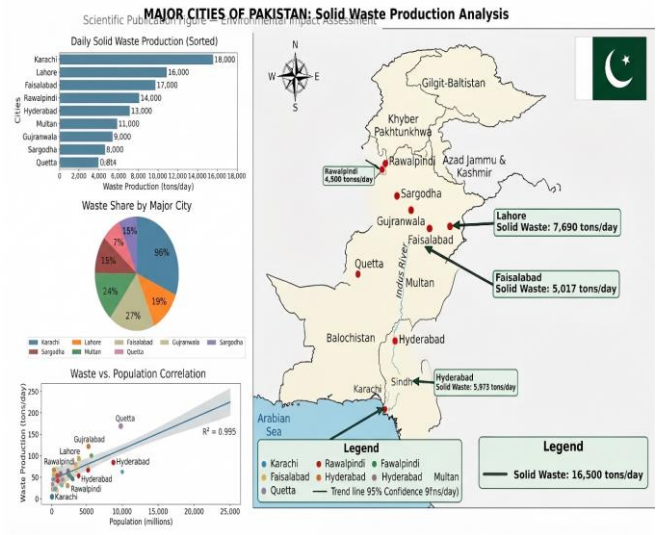

Figure 2. Estimated daily municipal solid waste generation in 11 major Pakistani cities.

Source: Iqbal et al. (2022). The figure presents estimated daily municipal solid waste generation in the 11 major Pakistani cities assessed using the Waste-aware Integrated Sustainable Waste Management framework. Collectively, these cities generate approximately 11.6 million tonnes of MSW annually, representing a substantial proportion of the national waste burden.

However, the SWM challenge cannot be explained solely by deficiencies in physical infrastructure. The effectiveness of waste-management systems is also strongly influenced by individual and collective behaviour. Decisions concerning waste reduction, segregation, recycling, reuse, and disposal are shaped by environmental knowledge, attitudes, perceived social expectations, personal norms, perceived behavioural control, and the availability of appropriate facilities. Consequently, increasing environmental knowledge does not necessarily guarantee corresponding behavioural change. This discrepancy between what people know and believe and what they actually do has been described across different forms of pro-environmental behaviour and represents an important barrier to achieving sustainable SWM (Hines et al., 1987; Bamberg & Möser, 2007; Geiger et al., 2019).

The relationship between environmental knowledge and behaviour is therefore complex. Knowledge can provide individuals with an understanding of environmental problems and appropriate responses, but its translation into practice may depend on attitudes, social norms, perceived responsibility, perceived control, and contextual opportunities. The Theory of Planned Behavior (TPB) provides an established framework for explaining such behavioural processes. According to TPB, behavioural intention is influenced by attitude toward the behaviour, subjective norms, and perceived behavioural control, while intention and perceived control contribute to the prediction of actual behaviour (Ajzen, 1991). The framework has subsequently been applied to environmental and waste-related behaviours, including recycling and waste-management practices (Geiger et al., 2019). Although TPB provides an important explanation of behavioural intention, environmentally responsible waste practices may also involve moral and normative considerations. The Value-Belief-Norm (VBN) perspective proposes that environmentally significant behaviour can arise through a sequence involving environmental values, ecological beliefs, awareness of consequences, responsibility, and personal norms (Stern, 2000). Personal norms may therefore provide an additional explanation for why individuals undertake environmentally responsible behaviours even when immediate personal benefits are limited. Evidence from environmental-behaviour research further demonstrates the importance of normative and psychosocial factors in explaining pro-environmental action (Bamberg & Möser, 2007; Morren & Grinstein, 2021). The Knowledge–Attitude–Practice (KAP) framework provides a complementary approach by examining how knowledge and attitudes relate to observable practices. KAP-based research is particularly relevant to SWM because individuals may report favourable environmental attitudes while continuing to engage in inappropriate disposal or inadequate source separation. Studies among university students and households have demonstrated that waste-related knowledge, attitudes, and practices may not develop uniformly and that demographic, social, and contextual characteristics can influence these dimensions (Eshete et al., 2023; Liu et al., 2024). Research among university students has also shown that environmental knowledge and behavioural engagement can differ according to educational and disciplinary contexts (Yusuf & Fajri, 2022). Recent evidence further supports the need to move beyond simple knowledge-deficit explanations. Wu et al. (2022) integrated environmental knowledge with TPB and VBN constructs to examine waste-management behaviour among university students. Their framework incorporates environmental concern and personal norms alongside attitude, subjective norms, and perceived behavioural control, thereby recognizing that sustainable waste behaviour may result from multiple interacting psychological pathways. Figure 3 presents this integrated conceptual structure and provides the theoretical basis for examining the behavioural determinants synthesized in the present review.

ENVIRONMENTAL KNOWLEDGE	H3e → Attitude H3c → Env. Concern	Attitude (H1b) Env. Concern (H2b) Personal	→	WASTE MANAGEMENT BEHAVIOR (WMB)

	H3d → Personal Norms H3b → PBC H3a → Direct WMB	Norms (H2a) PBC (H1c) [Moderator H4] Subj. Norms (H1a / H2c)		

Figure 3. Expanded TPB–VBN–Knowledge integrated conceptual framework for waste-management behaviour.

Adapted from Wu et al. (2022). The framework integrates environmental knowledge with Theory of Planned Behavior and Value-Belief-Norm constructs, incorporating attitude, subjective norms, perceived behavioural control, environmental concern, and personal norms as interconnected determinants of waste-management behaviour.

Importantly, individual behaviour occurs within a broader waste-management system. Even when individuals possess adequate knowledge and favourable environmental attitudes, sustainable practices may be difficult to maintain when appropriate collection services, segregation facilities, recycling infrastructure, institutional coordination, or enforcement mechanisms are absent. Thus, behavioural determinants and structural conditions should not be considered independently. The Waste-aware Integrated Sustainable Waste Management (ISWM) framework provides a systems-level perspective by evaluating physical and governance components of waste-management systems. Its application across major Pakistani cities demonstrated that SWM performance involves interconnected environmental, institutional, and economic dimensions (Iqbal et al., 2022). The interaction between behavioural and structural determinants is particularly important in developing-country contexts. Informal-sector participation, municipal capacity, service availability, and local governance can influence how waste is collected, recovered, and disposed of, while household and community practices determine the quality and quantity of waste entering these systems. The role of informal recycling systems is especially relevant in developing countries, where informal actors may make substantial contributions to material recovery despite operating outside formal municipal structures (Wilson et al., 2009). Similarly, the circular-economy perspective emphasizes the importance of retaining materials and resources within productive systems rather than treating waste solely as a disposal problem (Ellen MacArthur Foundation, 2019). Against this background, a comprehensive understanding of sustainable SWM requires integration of individual-level behavioural determinants with household, community, institutional, and system-level factors. The available evidence spans different populations and settings, including university students, households, and municipal systems in China, Ethiopia, Indonesia, and Pakistan. Although these studies differ in design and analytical approach, collectively they provide an opportunity to examine recurring patterns in environmental knowledge, attitudes, norms, perceived control, engagement, and waste-management practices across diverse socioeconomic contexts. The present narrative review therefore synthesizes evidence on the determinants, gaps, and pathways associated with sustainable SWM behaviour. Particular attention is given to environmental knowledge, environmental concern, attitudes, personal norms, subjective norms, perceived behavioural control, and observable waste-management practices. The review also considers how educational interventions, social influences, institutional arrangements, and infrastructure may contribute to narrowing the persistent gap between environmental awareness and actual behaviour. By integrating behavioural theories with KAP evidence and systems-level SWM assessment, the review seeks to provide a multidimensional understanding of why environmentally favourable orientations do not consistently translate into sustainable waste practices.

Research Objectives

The review was guided by the following objectives:

1.To synthesize evidence on the direct and indirect influence of environmental knowledge, environmental concern, personal norms, subjective norms, attitude, and perceived behavioural control on waste-management behaviour within an integrated TPB–VBN–knowledge framework.

2.To examine knowledge, attitudes, and practices related to garbage sorting among university students and identify demographic and behavioural factors associated with these dimensions.

3.To evaluate household-level KAP related to SWM and identify factors associated with inappropriate waste-management practices.

4.To examine differences in environmental knowledge, engagement, and behaviour across university academic disciplines within campus-based environmental programmes.

5.To assess the environmental, institutional, and economic dimensions of SWM systems across major Pakistani cities using the Waste-aware ISWM framework.

6.To synthesize evidence-based educational, behavioural, infrastructural, and policy strategies capable of strengthening sustainable SWM across diverse socioeconomic settings.

Scope and Rationale

The review encompasses evidence from China, Ethiopia, Indonesia, and Pakistan, incorporating university-based, household-level, and municipal-system perspectives. This geographical and population diversity allows behavioural patterns to be considered alongside differences in institutional and infrastructural contexts. The inclusion of a Pakistan-specific field survey from Charsadda further provides contextual evidence relevant to local perceptions of waste-management services, environmental conditions, and willingness to engage in pro-environmental practices.

The central premise of this review is that sustainable SWM is unlikely to be achieved through awareness campaigns or infrastructure development alone. Rather, durable improvement requires alignment between knowledge, attitudes, norms, perceived behavioural control, social expectations, service infrastructure, and institutional capacity. Integrating these dimensions provides a stronger basis for identifying the determinants of sustainable waste behaviour and for developing interventions that address both the individual and structural causes of inadequate SWM.

METHODOLOGY

The methodological characteristics of the five included studies were examined with respect to research design, study population, sampling strategy, sample size, setting, measurement instruments, and analytical approaches. The included evidence demonstrates considerable methodological diversity, ranging from primary cross-sectional surveys of students and households to secondary-data analysis and city-level waste-management modelling. This diversity enabled the review to consider waste-management knowledge, attitudes, practices, behavioural determinants, and system-level sustainability from complementary perspectives.

Research Designs and Study Settings

Four studies used quantitative cross-sectional survey designs to assess waste-management knowledge, attitudes, practices, environmental behaviour, or their associated determinants (Wu et al., 2022; Liu et al., 2024; Eshete et al., 2023; Yusuf & Fajri, 2022). These designs are appropriate for characterizing population-level patterns and examining associations between psychosocial or demographic variables and waste-related behaviours. However, because measurements were generally collected at a single point in time, temporal relationships and causal pathways cannot be established. Wu et al. (2022) investigated waste-management behaviour among university students in China using a theory-based survey and structural equation modelling. Liu et al. (2024)

conducted a multicampus cross-sectional study among undergraduate and postgraduate students in Beijing to examine knowledge, attitudes, and practices related to garbage sorting. Eshete et al. (2023) adopted a mixed-methods design among urban households in Gelemso, Ethiopia, combining a structured household survey with qualitative inquiry and direct observation. This approach provided complementary information regarding household practices and the local waste-management environment. Yusuf and Fajri (2022) examined differences in environmental knowledge, engagement, and behaviour among university students from different academic disciplines in Banda Aceh, Indonesia. In contrast, Iqbal et al. (2022) used secondary data and system-level analysis to evaluate solid waste-management performance across 11 major Pakistani cities. The study incorporated Waste-aware Integrated Sustainable Waste Management (ISWM) benchmarking, greenhouse-gas estimation, and economic modelling to develop city-specific sustainability and revenue scenarios. Consequently, this study operated at the municipal rather than individual or household level.

Sampling Strategies and Participants

The five studies covered diverse populations and geographical contexts, including university students, urban households, and municipal institutions across China, Ethiopia, Indonesia, and Pakistan. Sample sizes for the primary survey studies ranged from 279 to 1,282 participants, providing substantial variation in population coverage. Wu et al. (2022) used online convenience sampling among 434 undergraduate students, whereas Liu et al. (2024) employed stratified random sampling across five universities, resulting in a sample of 1,282 students. Eshete et al. (2023) recruited 390 urban households using systematic random sampling. Yusuf and Fajri (2022) included 279 university students using proportional sampling. Iqbal et al. (2022) analyzed 11 major Pakistani cities using a census-based city-level approach rather than individual participant sampling.

Table 1. Summary of Study Samples, Settings, and Analytical Designs

Study	Country /City	Population	n	Sampling/ Selection	Analytical Design
Wu et al. (2022)	China – Jiangsu Province	Undergraduate students, 18–25 years	434	Online convenience sampling	PLS-SEM
Liu et al. (2024)	China – Beijing	Undergraduate and postgraduate students	1,282	Stratified random sampling across five universities	ANOVA; stepwise regression
Eshete et al. (2023)	Ethiopia – Gelemso	Urban households	390	Systematic random sampling	Mixed methods; binary logistic regression
Yusuf & Fajri (2022)	Indonesia – Banda Aceh	University students	279	Proportional sampling	One-way MANOVA
Iqbal et al. (2022)	Pakistan – 11 major cities	Municipal institutions/city-level systems	11 cities	Census of selected cities	ISWM benchmarking; GHG and economic modelling

Note: PLS-SEM = partial least squares structural equation modelling; ANOVA = analysis of variance; MANOVA = multivariate analysis of variance; ISWM = integrated sustainable waste management; GHG = greenhouse gas.

Instrumentation and Analytical Procedures

The studies employed analytical techniques appropriate to their respective research questions. Wu et al. (2022) measured multiple Likert-scale constructs and applied PLS-SEM using SmartPLS, including bootstrap estimation to evaluate path relationships and interaction effects. Measurement quality was assessed using established convergent and discriminant validity criteria. Liu et al. (2024) used a structured 39-item KAP questionnaire with reported reliability and sampling adequacy statistics and subsequently applied regression-based analyses to identify factors associated with waste-sorting knowledge, attitudes, and practices.

Eshete et al. (2023) combined quantitative survey data with qualitative evidence and applied multivariable binary logistic regression, reporting adjusted odds ratios with 95% confidence intervals. This enabled assessment of independent factors associated with household waste-management practices while accounting for multiple explanatory variables. Yusuf and Fajri (2022) used one-way MANOVA to compare environmental knowledge, engagement, and behaviour across academic disciplines, followed by pairwise comparisons at a 5% significance level. Iqbal et al. (2022) differed substantially from the primary survey studies by integrating ISWM benchmarking with GHG estimation and economic equations to assess environmental and economic dimensions of municipal waste management.

Overall, the methodological evidence demonstrates a progression from individual-level KAP assessment to behavioural modelling and system-level sustainability analysis. While the predominance of cross-sectional designs limits causal interpretation, the combination of quantitative, mixed-methods, and modelling approaches provides a broader basis for understanding the behavioural and structural determinants of sustainable waste management.

RESULTS

Expanded TPB Structural Model

The structural model tested six direct and moderation effects on waste management behavior (WMB). Four of five direct paths were statistically significant (Table 2). The attitude-to-WMB path was not significant ($\beta = -0.035$, $p = 0.521$). This non-significant finding may reflect a ceiling effect attitude scores were uniformly high in a context where waste classification is mandated which would reduce the variance available for attitude to predict behavior. This interpretation is consistent with the ceiling-effect explanation and warrants further investigation in future studies.

Table 2. Structural Model: Direct and Moderation Effects on Waste Management Behavior (Wu et al., 2022)

Hyp.	Path	β	p-value	95% CI	Result
H1a	Subjective Norms → WMB	0.276	<0.001	[0.143, 0.404]	✓ **Supported**
H1b	Attitude → WMB	−0.035	0.521	[−0.141, 0.072]	✗ **Not Supported**
H1c	PBC → WMB	0.172	0.005	[0.052, 0.291]	✓ **Supported**
H2a	Personal Norms → WMB	0.132	0.018	[0.023, 0.241]	✓ **Supported**
H3a	Environmental Knowledge → WMB	0.216	<0.001	[0.108, 0.323]	✓ **Supported**
H4	**Personal Norms × PBC → WMB (Moderation)**	**0.106**	**0.003**	**[0.036, 0.176]**	✓ **Supported**

Note. WMB = Waste Management Behavior; PBC = Perceived Behavioral Control. β = standardized path coefficients from PLS-SEM bootstrapping (5,000 subsamples). R^2(WMB) = 0.318; GoF = 0.34. Hypotheses H2b (Env. Concern → WMB) and H2c (Subjective Norms → Personal Norms) and H3b–H3e (knowledge indirect paths) are reported in Wu et al. (2022) but are not listed above as they target mediating constructs rather than WMB directly.

Environmental knowledge exerted pervasive multi-path influence: it was a significant predictor of PBC ($\beta = 0.253$, $p < 0.001$),

environmental concern (β = 0.195, p < 0.001), personal norms (β = 0.108, p = 0.010), and attitude (β = 0.244, p < 0.001). Among social-influence variables, subjective norms were the strongest predictor of personal norms (β = 0.487, p < 0.001), supporting the applicability of VBN theory in collectivistic cultural contexts.

KAP Scores of University Students: Beijing, China

Figure 6 presents KAP scores for 1,282 Beijing University students. Attitude scores (69.2%) substantially exceeded both knowledge scores (55.6%) and practice scores (54.8%), illustrating the characteristic KAP gap in which positive attitudes do not translate into proportionate knowledge or practice. Only 35.4% of students consistently practiced waste classification, and 13.6% had never practiced. The knowledge score (55.6%) fell in the 'borderline' range (60–65% threshold) described as 'barely acceptable.'

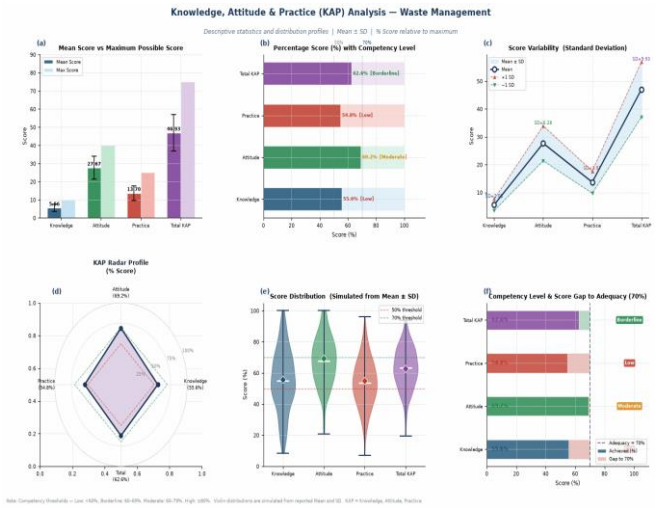

Figure 6. KAP scores (percentage) for 1,282 university students across five Beijing universities (Liu et al., 2024). Attitude scores substantially exceed both knowledge and practice scores, illustrating the KAP gap. The knowledge score falls in the borderline range; only 35.4% of students consistently practised waste classification. Note. Knowledge scored 0–10 (objective test).

Household KAP and Improper SWM Predictors: Gelemso, Ethiopia (Eshete et al., 2023)

Ethiopian households in Gelemso town demonstrated paradoxically high knowledge (96% identified solid waste as an environmental pollutant) and strongly positive attitudes (87.4% agreed solid waste poses an environmental problem), yet 79.4% disposed of waste through illegal means. The multivariate logistic regression (Figure 7) identified infrastructure access specifically landfill access (AOR = 0.084) and door-to-door collection availability (AOR = 0.105) as the dominant predictors of improper disposal, outweighing individual knowledge and attitude variables. These associations suggest that infrastructure access is a more proximate structural correlate of compliant behavior than attitudinal or cognitive factors in this context.

Figure 7. Multivariate logistic regression: adjusted odds ratios (AOR) for predictors of improper SWM practice, Gelemso, Ethiopia. AOR values below 1.0 indicate protective factors (i.e., reduced likelihood of improper disposal). Note. Reference category: households with adequate infrastructure access and 3R (reduce, reuse, recycle) knowledge. AOR = Adjusted Odds Ratio; 95% CI reported; p < 0.05 for all listed predictors. Disciplinary Differences in Environmental KAP: Banda Aceh, Indonesia (Yusuf & Fajri, 2022)

MANOVA revealed a significant multivariate group difference [$F(3, 275) = 11.877$, $p < 0.001$; Wilks' $\Lambda = 0.885$; $\eta^2 = 0.115$]. Science students reported significantly higher scores on environmental knowledge (M = 3.67 vs. M = 3.43; p < 0.001) and environmental engagement (M = 3.51 vs. M = 3.39; p = 0.010) than social science students, while science students also showed higher environmental behavior scores (M = 3.71 vs. M = 3.61; p = 0.026). These findings are attributed to the effect of mandatory environmental coursework and practical laboratory exposure in science curricula.

SWM System Assessment in Pakistan: 11 Major Cities

Using Waste-aware ISWM benchmarking, the study assessed SWM systems across 11 major Pakistani cities. Waste collection capacity ranged from approximately 34% (Hyderabad) to approximately 90% (Lahore), reflecting wide inter-city variation in service coverage. Total methane (CH_4) emissions from the 11 cities were estimated at 179.7 Gg/year using the IGES GHG estimation tool. Two economically sustainable SWM scenarios were modeled. Scenario 1 projected annual revenue of approximately Rs. 1,431 million for Lahore through an integrated approach combining recyclable recovery, composting, and carbon credit revenues, corresponding to approximately 22% operational cost recovery. Scenario 2 projected revenue of approximately Rs. 1,901 million per year for Lahore via expanded recycling, composting, and carbon credit streams, corresponding to approximately 29% operational cost recovery. These projections indicate that economically partially self-sufficient SWM is technically feasible in a major Pakistani city, though full cost recovery would require additional governance and investment measures.

Field Survey Results: Charsadda District, Pakistan

Primary data from Charsadda district reveal a stark gap between environmental attitudes and SWM participation, consistent with the patterns observed in the reviewed literature.

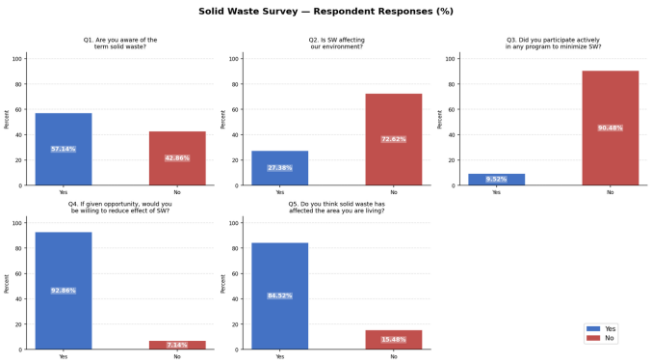

Figure 8. Community Survey respondent responses (n = 84), Charsadda district, Pakistan. The chart shows percentage-frequency responses across five survey items (Q1–Q5). Q1: awareness of the term 'solid waste' (57.14% aware). Q3: participation in waste minimisation programs (9.52% have participated). Q4: willingness to take action to reduce SWM impacts (92.86% willing). Q5: perception that solid waste has affected their local living area (84.52%). The contrast between Q4 (high willingness) and Q3 (near-zero participation) illustrates the attitude–behavior gap in the absence of enabling infrastructure and programs.

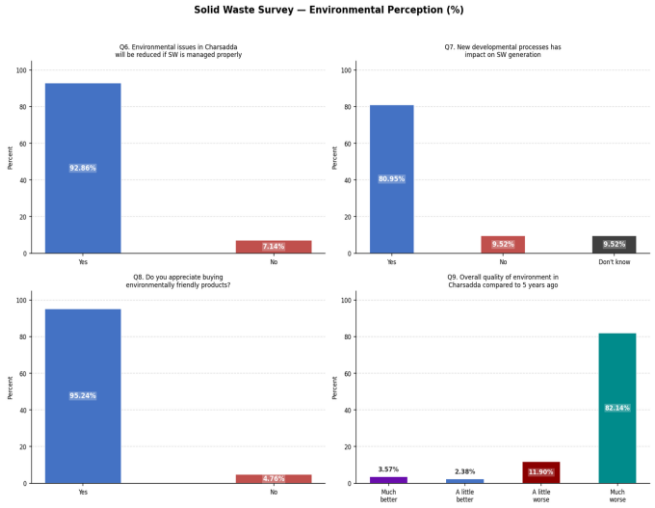

Figure 9. Community Survey environmental perception responses (n = 84), Charsadda district, Pakistan. Q6: proportion recognizing proper SWM as a solution to local environmental problems (92.86%). Q9: proportion reporting that local environmental quality has become 'much worse' over the past five years (82.14%). These findings indicate high environmental concern and near-universal recognition of SWM as a priority, alongside perceived deterioration in local environmental conditions.

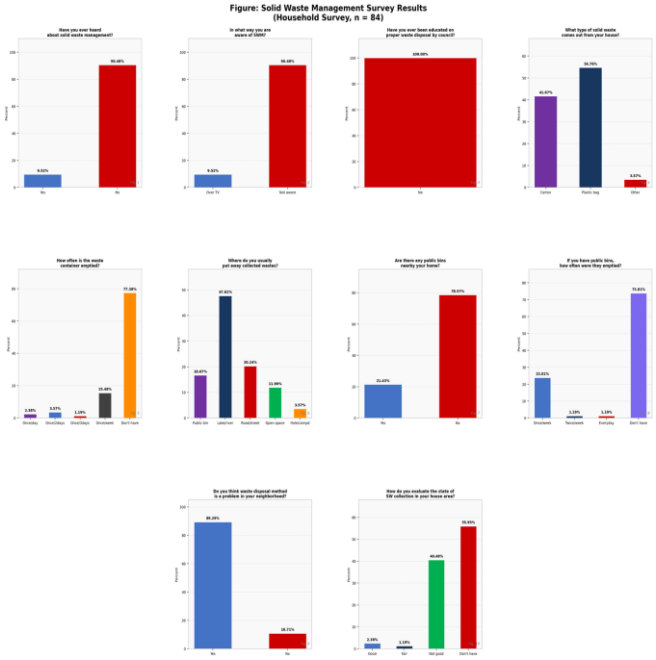

Figure 10. Household Survey results (n = 84), Charsadda district, Pakistan. Six infrastructure and service dimensions are presented: SWM program awareness (90.48% unaware), receipt of council education on proper disposal (100% have never received any), availability of household waste container (77.38% have none), primary waste disposal location (47.62% use lakes or rivers), proximity of public bins (78.57% report none nearby), and evaluation of local SWM collection service (55.95% rate it as non-existent). These data collectively indicate severe infrastructure deficits that constrain compliance with proper SWM practices irrespective of knowledge or attitudinal factors.

DISCUSSION

The most consistent finding across all five included studies corroborated by the Charsadda field survey is that the primary barrier to proper SWM is knowledge deficit rather than attitudinal resistance. Across the Beijing sample, average objective knowledge scored 55.6% against 69.2% for attitude, indicating that positive attitudes are more prevalent than the knowledge required to act on them (Liu et al., 2024). Eshete et al. (2023) observed that 79.4% of Ethiopian households disposed of waste illegally even when they were aware of its environmental impact. In Charsadda, 92.86% of respondents expressed willingness to reduce SWM impacts (Figure 8, Q4), and 92.86% recognized proper SWM as a solution to local environmental problems (Figure 9, Q6), yet 90.48% had no awareness of any SWM programs (Figure 10), and 100% had never received council education on proper waste disposal (Figure 10). This pattern across all four countries supports the interpretation, consistent with Wu et al. (2022), that environmental knowledge functions as a pivotal trigger for the entire motivational system, activating attitudes, environmental concern, personal norms, and PBC through multiple pathways (β = 0.216 direct effect; indirect effects β = 0.108–0.253).

The significant contribution of personal norms (β = 0.132) over standard TPB variables in the Wu et al. (2022) model is consistent with the 'altruistic–rational' model of pro-environmental behavior (Stern, 2000; Thøgersen, 2006). The finding that subjective norms were the strongest predictor of personal norms (β = 0.487) supports the collectivism hypothesis, which predicts that social influence pathways are especially prominent in collectivistic cultural contexts (Morren & Grinstein, 2021; Tang et al., 2011). The Charsadda data further illustrate this: 92.86% of respondents indicated willingness to participate in waste management initiatives when given the opportunity (Figure 8, Q4), yet only 9.52% had ever participated (Figure 8, Q3), suggesting that motivational potential exists but social platforms and institutional mandates to activate it are absent.

Ethiopian findings showed that infrastructure access landfill proximity (AOR = 0.084) and door-to-door collection availability (AOR = 0.105) was more strongly associated with improper disposal than individual knowledge or attitude variables (Eshete et al., 2023). The Charsadda data provide convergent evidence: 78.57% of households reported no public bins nearby, 77.38% had no household waste container, and 47.62% used lakes or rivers as their primary disposal site (Figure 10). These structural deficits make behavioral compliance difficult regardless of attitudinal or motivational factors, consistent with the attitude–context–behavior model of Guagnano et al. (1995). The low collection coverage observed in Hyderabad (approximately 34%) by Iqbal et al. (2022) using the Waste-aware benchmark corroborates this infrastructure gap at the city scale.

The MANOVA results from Yusuf and Fajri (2022) reveal a disciplinary specialization pattern: science students demonstrate higher environmental knowledge (M = 3.67 vs. M = 3.43) while also showing higher behavioral and engagement scores. This pattern is consistent with Kolb's (1984) experiential learning theory and highlights the complementary value of concept-oriented and action-oriented curricula. These findings suggest that campus institutions can provide structured behavioral change environments through mandatory coursework, practical laboratory exposure, and peer norm activation, as demonstrated in the science cohort at Syiah Kuala University. Liu et al. (2024) similarly identified that social media engagement (used by 77.7% of Beijing students) and practical classification training are effective knowledge-dissemination platforms within university settings.

Economic modelling by Iqbal et al. (2022) challenges the perception that sustainable SWM is cost-prohibitive in low- and middle-income country settings. Scenario 2 projects that integrated revenue streams from recycling, composting, and carbon credit markets could generate approximately Rs. 1,901 million per year for Lahore, covering approximately 29% of operational costs. This finding is contextually significant given that 89.29% of Charsadda households reported waste disposal as a neighbourhood problem (Figure 10) and 55.95% rated their local collection service as non-existent

(Figure 10). These data indicate that governance and institutional capacity, not resource availability alone, are the binding constraints on SWM improvement.

Implications and Recommendations

Given the multi-path influence of environmental knowledge documented by Wu et al. (2022), knowledge enhancement represents the highest-leverage entry point for SWM behavior change. Effective environmental education should address both system-level knowledge (understanding waste as an environmental problem) and procedural knowledge (practical waste classification skills), as recommended by Geiger et al. (2019). Even basic awareness campaigns would be impactful in Charsadda, where 100% of households have never received council education on waste disposal (Figure 10). Mandatory waste classification modules, practical laboratory components modeled on campus programs such as the PKL program at Syiah Kuala University (Yusuf & Fajri, 2022), and social media campaigns used by approximately 77.7% of Beijing students (Liu et al., 2024) offer scalable pathways for knowledge dissemination.

The significant roles of personal norms (β = 0.132) and subjective norms (β = 0.276) as behavioral predictors (Wu et al., 2022) support norm-activation approaches at the campus and community level. Given the high latent motivation in Charsadda (92.86% willingness; Figure 8, Q4) contrasted with low participation (9.52%; Figure 8, Q3), the challenge is to create enabling platforms rather than to build motivation. Community waste banks, local volunteer coordinator networks, and co-residential dormitory sorting programs represent feasible interventions to convert latent motivation into active participation.

The Ethiopian and Charsadda findings converge on the principle that infrastructure investment must accompany or precede behavioral campaigns. Priority measures include door-to-door waste collection expansion, public bin installation, and provision of household waste containers. The Charsadda data indicate that 47.62% of households currently discharge waste to water bodies (Figure 10), necessitating source-based infrastructure to prevent continued water contamination. Simultaneous policy measures recommended include developing a legal SWM framework with enforcement mechanisms in Khyber Pakhtunkhwa (where no SWM Act is currently in force); formalizing the informal recycling sector; establishing Public-Private Partnership (Build-Operate-Own) models for materials recovery facilities and composting; and linking Pakistani cities with carbon credit markets to generate supplementary SWM revenue (Iqbal et al., 2022; Wilson et al., 2009).

Limitations and Future Research Directions

Methodological Limitations

The cross-sectional designs used in four of the five included studies preclude causal inference and do not control for common method bias (Bamberg & Möser, 2007). Self-reported behavioral measures are susceptible to social desirability bias, acknowledged by all four survey-based studies. Geographic representativeness is limited: Wu et al. (2022) and Yusuf and Fajri (2022) each sampled from a single province or city, restricting generalizability to national populations. The Charsadda field survey, while providing valuable contextual grounding, is limited by its purposive sampling approach, small sample size (n = 84 per instrument), and coverage of only two sub-district areas, which precludes district-level extrapolation.

Future Research Directions

The following future research priorities are identified. First, longitudinal studies are needed to track knowledge and behavior change following campus or community SWM interventions over sustained periods (Liu et al., 2024; Eshete et al., 2023). Second, objective behavioral measurement, including waste audits and direct observation of sorting compliance, should supplement self-report surveys. Third, experimental pre-post designs are required to establish causal claims regarding educational, infrastructure, and normative interventions (Bamberg & Möser, 2007). Fourth, a district-wide probability-sampled study in Charsadda or broader Khyber Pakhtunkhwa would enable regression-based identification of SWM determinants specific to this socio-cultural context. Fifth, the economic modelling framework of Iqbal et al. (2022) should be developed into open-access decision tools accessible to municipal governments across Pakistan. Sixth, ethnographic research is needed to understand and facilitate the transition from informal scavenging to formal materials recovery employment.

CONCLUSION

This synthesis demonstrates that solid waste management behavior (SWMB) is shaped by interconnected cognitive, normative, volitional, and structural factors. Knowledge emerges as a key driver of behavioral change, influencing environmental concern, attitudes, personal norms, and perceived behavioral control. However, a persistent knowledge–attitude–practice gap indicates that willingness alone does not ensure compliant behavior. Social and personal norms are particularly influential within collectivistic contexts, while access to waste collection, disposal facilities, and institutional platforms remains essential for translating intentions into action. Evidence also supports universities as effective intervention settings through curricula, waste banks, and peer networks. In Charsadda, 92.86% expressed willingness to act, yet 90.48% reported non-participation, primarily due to inadequate infrastructure and programs. Sustainable improvement therefore requires integrated investment in knowledge, social structures, institutions, and physical infrastructure.

Ethical Considerations

This study was based exclusively on previously published literature and secondary data and did not involve the collection of data from human participants. Therefore, ethical approval and informed consent were not applicable.

Data Availability

Available from corresponding author on request.

Author Contributions

Conceptualization: Naji Ullah and Kashif; Methodology: Naji Ullah, Laiba Salman; Formal analysis: Wajiha Bilal, Muhammad Hussam ul Haq; Investigation: Muhammad Junaid Khan; Writing – original draft: Naji Ullah, Kashif; Writing – review and editing: all authors; Supervision: Naji Ullah. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

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Declaration of AI Use

Grammarly AI was used for language correction.

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