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Community perceptions and practices of household solid-waste separation in informal settlements along the Nullah Leh, Rawalpindi, Pakistan: a convergent mixed-methods study

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Abstract

Background.

Source separation of household solid waste underpins sustainable waste management but remains uncommon in low-income, peri-urban South Asian settlements, and evidence on why is limited for Pakistan. This study examined the practices, determinants and perceived barriers to household waste separation in informal settlements along the Nullah Leh, Rawalpindi.

Methods.

A convergent mixed methods design was used. A 38-item, pilot tested questionnaire was administered to 357 household heads, covering sociodemographic characteristics, waste handling practices, service access and theory based behavioural items (five-point Likert scales). Multi item indices were assessed with Cronbach's alpha and related to sociodemographic factors using Mann Whitney and Kruskal Wallis tests; the intention to segregate was modelled by multivariable logistic regression. Five gender stratified focus group discussions (28 participants) were analysed by Braun and Clarke's reflexive thematic analysis. The two strands were integrated using a joint display.

Results.

Awareness was moderate to high (59.1% agreed separation is useful; 70.6% knew what it is), yet disposal occurred entirely through unmanaged channels open dumping (49.6%), burning (27.7%) and dumping into the Nullah (22.7%) with 27.7% lacking regular collection and no separation scheme available. The subjective norms index ($\alpha = 0.69$) was associated with education, occupation, household size and income ($p < 0.001$; $\varepsilon^2 = 0.10–0.15$); attitude and perceived control indices had low reliability ($\alpha = 0.39$ and 0.46; exploratory). In multivariable analysis, intention to segregate was independently associated with knowledge (adjusted odds ratio 3.50, 95% CI 2.07–5.93) and collection access (1.92, 1.13–3.25), not with sociodemographic factors or bin proximity. Five themes Practices, Cultural beliefs, Behavioural patterns, Perceived barriers and Motivators explained the awareness practice gap: absent infrastructure, unpredictable collection, perceived futility, time and cost, and the gendered, low status framing of waste work. Schoolchildren, lady health workers, religious leaders, small incentives and social recognition were identified as credible levers for change.

Conclusions.

Awareness alone does not translate into practice. Sustained separation will require pairing infrastructure (colour coded bins, reliable collection) with culturally grounded, gender sensitive behaviour change

delivered through trusted community channels, offering transferable guidance for similar low resource urban settings.

Trial registration

Clinical trial number: not applicable.

Background

Municipal solid waste (MSW) generation is rising rapidly in low and middle income countries, where collection and treatment systems frequently fail to keep pace with urbanisation and population growth [1, 2]. In these settings, large fractions of waste remain uncollected and are managed through open dumping and open burning, with well documented consequences for environmental quality and public health, including water and soil contamination, vector proliferation and respiratory and gastrointestinal illness [2–4]. Source separation the sorting of waste into dry, wet and recyclable streams at the household level is widely regarded as a prerequisite for resource recovery, safe disposal and circular economy approaches, yet it remains the exception rather than the norm across much of South Asia [5, 6].

Pakistan exemplifies these challenges. Rapid urban growth, constrained municipal budgets and fragmented collection systems have produced persistent service gaps, particularly in the informal settlements that house a substantial share of the urban population [7, 8]. Rawalpindi, part of the Islamabad Rawalpindi metropolitan area, is bisected by the Nullah Leh, a heavily polluted urban stream whose banks support dense, low income settlements with limited formal waste services [8, 9]. Improper disposal in such areas has been linked to measurable health and property costs in the twin cities [9].

Behavioural research consistently shows that household separation is shaped not only by knowledge but by attitudes, social norms, perceived behavioural control and the availability of enabling infrastructure and services [6, 10, 11]. A recurring finding across South Asia and sub-Saharan Africa is a “knowledge action gap”, in which residents recognise the value of separation but do not practise it because of structural and social constraints [10, 12, 13]. In many communities, waste handling is also gendered and socially stigmatised, which further conditions who participates and how [14]. However, much of the available evidence is either purely quantitative (documenting prevalence and correlates) or purely qualitative (describing experience), and relatively few studies integrate both to explain why awareness fails to translate into practice in a specific local context.

To our knowledge, no previous mixed-methods study has examined household waste separation in the informal settlements along the Nullah Leh. This study addresses that gap. Its objectives were: (i) to assess current waste separation practices, knowledge and attitudes among household heads; (ii) to examine the association of sociodemographic characteristics with attitudes, subjective norms, perceived behavioural control and perceived moral obligation; and (iii) to explore, through focus group

discussions, the enablers and barriers shaping separation behaviour, in order to inform context appropriate intervention design.

Methods

Study design

A convergent (parallel) mixed-methods design was adopted, in which quantitative and qualitative data were collected over the same period, analysed separately and then integrated at the interpretation stage to compare and corroborate findings (Fig. 1) [15]. This design was selected because household waste separation is shaped jointly by measurable behavioural determinants and by contextual, social and economic factors that are not readily captured by a survey alone; the qualitative strand was intended to explain and contextualise the survey findings rather than to generate hypotheses for a subsequent phase. The study is reported in line with the Good Reporting of A Mixed Methods Study (GRAMMS) framework [22], with the quantitative strand reported in accordance with STROBE for cross-sectional studies and the qualitative strand in accordance with COREQ.

Setting

The study was conducted in a densely populated informal settlement on the banks of the Nullah Leh in Rawalpindi, Pakistan, bordered by Chaklala Scheme III to the east and Ayub National Park to the west. The settlement lacks a household level waste separation and collection system, and residents commonly rely on communal dumping points, informal collectors and the adjacent watercourse for disposal (Fig. 2).

Quantitative strand

Population, sampling and sample size

The target population comprised heads of household and adult members responsible for managing household waste in the settlement. Eligible participants were adults (the eligibility window was specified as 18–60 years), resident in the settlement for at least six months, primarily responsible for handling household waste, and Urdu or Punjabi speaking. Temporary visitors, seasonal workers and individuals with cognitive or sensory impairment that precluded participation were excluded. The sample size was estimated using the Raosoft calculator (5% margin of error, 95% confidence level, assumed response proportion 52%), yielding a target of 357. Non-random convenience sampling was used, supported by a community social mapping exercise undertaken with a local gatekeeper to divide the settlement into residential clusters and ensure even coverage.

Data collection tool and procedure

Data were collected using a 38-item questionnaire adapted from validated instruments used in previous household environmental behaviour research and calibrated to the local context [6, 11]. The instrument comprised (i) sociodemographic items (gender, age, education, occupation, household size, monthly income); (ii) household waste handling characteristics (disposal practices, service access, proximity to disposal facilities); and (iii) four behavioural constructs attitudes toward separation, subjective norms, perceived behavioural control and perceived moral obligation rated on five-point Likert scales (1 = strongly disagree to 5 = strongly agree). The survey was piloted in late October 2024 and administered between 29 October and 18 November 2024; the FGDs were conducted in April 2025. The questionnaire was administered in Urdu by four trained field workers able to read and write Urdu and English; a female enumerator interviewed female respondents at home and male enumerators engaged male respondents in community spaces, to respect local norms. Of 400 questionnaires distributed, those that were incomplete, completed by ineligible respondents (for example, by students' parents at a tuition centre) or submitted with missing data via an online form were removed during data cleaning, leaving 357 complete and valid responses for analysis.

Quantitative analysis

Data were analysed in SPSS and cross checked in Python (pandas, SciPy). Sociodemographic characteristics, waste handling practices and item level responses were summarised using frequencies and percentages. Theory-based items were assigned a priori to three multi-item indices using the study coding scheme attitudes (5 items), subjective norms (11 items) and perceived behavioural control (8 items); each item was assigned to a single index to avoid double counting, and the full item-to-index mapping is provided as an additional file. A planned fourth construct, perceived moral obligation, was represented by a single non-overlapping item ("segregation is essential for hygiene") and was therefore analysed at the item level rather than as a scale. Likert responses were scored 1 (strongly disagree) to 5 (strongly agree) and summed within each index. Internal consistency was assessed using Cronbach's alpha. Because the summed indices were ordinal and non-normally distributed, their associations with sociodemographic factors were tested using the Mann Whitney U test (for gender) and the Kruskal Wallis test (for education, occupation, household size and income), with epsilon-squared (ε^2) reported as the effect size; $p < 0.05$ was considered statistically significant. Because the survey did not capture observed separation practice, the intention to segregate (the intention item dichotomised as agreement vs neutral/disagreement) was modelled as a proximal behavioural outcome in a multivariable binary logistic regression, with gender, education, employment, income, household size, knowledge of segregation, collection access and residential proximity to a waste bin (≤ 200 m vs > 200 m) entered simultaneously; adjusted odds ratios (aOR) with 95% confidence intervals are reported, and model fit is summarised by the McFadden pseudo-R^2 and the likelihood-ratio test. Given the number of comparisons and the exploratory nature of indices with low reliability, associations are interpreted with corresponding caution.

Qualitative strand

Sampling and participants

Purposive, gender-stratified sampling was used to recruit participants for focus group discussions (FGDs). Following the social-mapping exercise, residents from each cluster were invited through posters at local shops and public announcements. Five FGDs were conducted three male groups (six participants each) and two female groups (five participants each) for a total of 28 participants. A small number of invited women declined to participate because they were uncomfortable with their voices and views being audio recorded; no other refusals were recorded. Gender stratification was used to enable open discussion of gendered aspects of waste work; male groups met in a public school and female groups met in a home.

Data collection

FGDs were guided by a topic guide adapted from prior research and reviewed by the academic supervisor and senior public health professionals, organised around four domains: existing waste sorting practices; opportunity (accessibility, availability and social support); ability (skills, technology, efficacy and coping); and motivation (outcome expectancies, perceived benefits and threats, and goal setting). Two community moderators one man and one woman were trained by the principal investigator to facilitate the discussions; the male moderator facilitated the male groups and the female moderator the female groups, and neither moderator had any prior relationship with the participants. Participants were informed of the purpose of the study and of the recording before each session. In keeping with the community setting, the local gatekeeper and a photographer were present at the sessions, and some women attended with their children; the potential influence of these third parties on openness is acknowledged in the limitations. Each session lasted approximately 30 to 35 minutes and was audio recorded, transcribed verbatim in Urdu and translated into English for analysis; brief contextual notes were made, with the audio recordings serving as the primary record. A trained interpreter assisted during the focus group discussions and with the subsequent Urdu–English translation of the recordings; the interpreter was prepared and supervised for this role by members of the study team (MI and KU), and translation was checked for fidelity by the bilingual research team.

Qualitative analysis

Transcripts were analysed using Braun and Clarke's six phase reflexive thematic analysis [16]: familiarisation; generation of initial codes; searching for themes; reviewing themes; defining and naming themes; and producing the report. Coding was conducted manually (without qualitative software) by the principal investigator, and the senior author independently verified the codes against the audio recordings; discrepancies were resolved by discussion. Themes were developed inductively, while a capability opportunity motivation behaviour orientation informed the topic guide and the organisation of findings [17]. Consistent with a reflexive thematic analysis orientation, data saturation was not formally assessed, and transcripts and findings were not returned to participants for comment, reflecting feasibility constraints in this population. Analysis focused on social drivers, capability constraints and environmental conditions influencing waste behaviour.

Reflexivity

The principal investigator is a physician and public health postgraduate trainee, an Urdu speaker, and an outsider to the study settlement. Recruitment and facilitation were therefore mediated through a community gatekeeper and trained local moderators to reduce social distance, and gender matched facilitation was used in line with community norms. The research team's clinical and public health orientation shaped the framing of waste as a health issue, which was reflected on during coding to keep participant meanings including economic and cultural framings foregrounded in the analysis.

Integration

The quantitative and qualitative findings were integrated at the interpretation stage using a joint display (Table 8) that aligned survey results and themes against each study objective, allowing convergence and divergence between the two strands to be examined and supporting a more complete interpretation than either strand alone.

Ethical considerations

Ethical approval

was granted by the Institutional Review Board / Ethical Review Committee of the Armed Forces Postgraduate Medical Institute (AFPGMI), Rawalpindi (reference 551-AAA-ERC-AFPGMI; valid September 2024 to September 2025). All participants provided informed consent before data collection. Participation was voluntary, participants were informed of the study's aims, procedures, risks and benefits, and personal data were de-identified and stored securely with access limited to the research team. The study was conducted in accordance with institutional ethical standards.

Results

Quantitative findings

Sociodemographic characteristics

Of 357 respondents, 191 (53.5%) were men and 166 (46.5%) were women (Table 1). The sample was relatively young (mean age 32.5 years; range 18–78), with most respondents aged 18 to 40 years. Educational attainment was mixed (higher education 37.3%, college 22.7%, school 12.6%, other 27.5%), and the head of household was most often retired (28.6%) or unemployed (26.9%). Household size was large in most cases (71.4% lived in households of seven or more), and monthly income was concentrated in the lower and middle bands, with 13.1% of households reporting incomes below PKR 10,235.

Table 1
Sociodemographic characteristics of survey respondents (N = 357)

Characteristic	Category	n	%
Gender	Male	191	53.5
	Female	166	46.5
Education	School	45	12.6
	College	81	22.7
	Higher education	133	37.3
	Other	98	27.5
Occupation of household head	Employed	84	23.5
	Self-employed	75	21.0
	Retired	102	28.6
	Unemployed	96	26.9
Household size	1–3	45	12.6
	4–6	125	35.0
	7–10	130	36.4
	> 10	57	16.0
Monthly household income (PKR)	> 68,241	64	17.9
	34,121–68,240	78	21.8
	25,591–34,120	61	17.1
	17,060–25,590	66	18.5
	10,236–17,059	41	11.5
	3,445–10,235	23	6.4
	< 3,445	24	6.7

PKR, Pakistani rupees. Percentages may not sum to 100 owing to rounding. Figures verified against the primary dataset (N = 357).

Waste handling practices, service access and disposal

Most respondents (70.6%) reported knowing what waste segregation is, and 59.1% agreed or strongly agreed that separation is useful. Despite this awareness, reported disposal occurred entirely through unmanaged channels open-space dumping (49.6%), burning (27.7%) and dumping into the Nullah

(22.7%) and over a quarter of households (99/357, 27.7%) lacked regular collection (Table 2). No respondent reported access to a household source separation or separated collection scheme, and more than one-third of households (129/357, 36.1%) lived over 300 m from the nearest waste bin or container. The contrast between widespread awareness and the apparent absence of any separation practice or supporting infrastructure is examined further in the qualitative findings and in the analysis of intention below.

Table 2
Self-reported waste knowledge, practices, service access and disposal (N = 357)

Indicator	Category	n	%
Knows what waste segregation is	Yes	252	70.6
	Maybe	53	14.8
	No	52	14.6
Access to regular waste collection	Yes	258	72.3
	No	99	27.7
Primary disposal method used	Open-space dumping	177	49.6
	Burning	99	27.7
	Dumping into the Nullah	81	22.7
Distance from residence to nearest waste bin/container	< 100 m	84	23.5
	101–200 m	61	17.1
	201–300 m	83	23.2
	301–400 m	76	21.3
	> 500 m	53	14.8

Figures verified against the primary dataset. Additional item-level responses are summarised in Table 3.

Item-level responses

The distribution of responses across the behavioural model statements is shown in Table 3. Agreement was highest for general environmental concern and intention items (for example, 67.8% agreed or strongly agreed that they think about improving Pakistan's environment, and 67.8% intended to separate waste to avoid environmental harm), and lower for items reflecting ease, time and resource availability consistent with attitudes being more favourable than perceived control.

Table 3
Distribution of responses to behavioural-model statements (N = 357)

Statement	SD	D	N	A	SA
1. Waste segregation is useful	10.4	17.6	12.9	46.2	12.9
2. Segregation is essential for hygiene	8.4	21.8	17.9	35.9	16.0
3. Segregation helps conserve resources/environment	9.8	21.0	12.0	36.4	20.7
4. Family thinks segregation minimises environmental effects	10.4	13.4	12.3	42.6	21.3
5. I value family opinion on segregation	8.9	32.8	14.0	26.6	17.6
6. Solid-waste segregation is effortless	8.7	34.2	15.7	22.4	19.0
7. I have enough time for segregation	8.9	35.0	13.4	25.8	16.8
8. I have complete awareness of what to segregate	10.4	15.4	14.3	40.9	19.0
9. I have all necessary resources for segregation	10.1	17.4	12.3	39.5	20.7
10. Segregation can bring economic benefits	11.8	31.1	12.3	26.6	18.2
11. Segregation enhances landfill life	7.6	27.7	14.8	31.9	17.9
12. Segregation decreases morbidity	11.8	15.4	14.8	39.2	18.8
13. Segregation minimises environmental damage	9.5	23.8	16.2	34.5	16.0
14. Aware of need to reduce waste long-term	11.8	23.3	15.4	32.2	17.4
15. Aware of disease symptoms from poor disposal	11.8	23.8	9.5	36.7	18.2
16. Environmental change is my concern	8.9	16.8	13.4	42.6	18.2
17. Dumpsite near house is a concern	8.9	30.5	12.3	28.0	20.2
18. Waste blocking affects aesthetic sense	10.4	14.3	13.4	42.6	19.3
19. Concerned about water contamination from dumping	10.4	27.7	11.2	33.3	17.4
20. Think about improving Pakistan’s environment	10.9	10.6	12.0	45.4	21.0
21. Support incentivising segregation	10.6	31.7	12.6	27.2	17.9
22. Three-bin facilities are sufficient	12.6	34.2	17.6	20.2	15.4
23. Support laws for segregation awareness	11.2	31.9	11.8	30.5	14.6
24. Intend to segregate to avoid environmental effects	11.5	10.9	9.8	49.3	18.5
25. Having suffered waste-related illness, intend to segregate	12.0	11.2	12.3	44.0	20.4

Values are column percentages. SD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree. Verified against the primary dataset.

Behavioural indices and their associations with sociodemographic factors

Of the three multi-item indices, only the subjective norms index showed acceptable internal consistency (Cronbach's α = 0.69); the attitude and perceived behavioural control indices showed low internal consistency (α = 0.39 and 0.46, respectively), indicating that their constituent items did not cohere well and that associations involving them should be regarded as exploratory (Table 4). In Kruskal Wallis analyses, the subjective norms index was significantly associated with education, occupation, household size and income ($p < 0.001$ for each), with small to moderate effect sizes ($\varepsilon^2 = 0.10–0.15$); scores were highest among more educated, employed and higher income respondents. The attitude and perceived behavioural control indices showed broadly concordant but weaker associations ($\varepsilon^2 = 0.02–0.09$), with income and household size the most consistent correlates. Gender was not significantly associated with subjective norms ($p = 0.179$) or perceived behavioural control ($p = 0.060$) and was only weakly associated with attitudes ($p = 0.019$, $r = 0.12$). Overall, socioeconomic position rather than gender was the more consistent correlate of the behavioural indices, although the magnitude of these associations was modest.

Table 4
Internal consistency of the behavioural indices and their associations with sociodemographic factors (N = 357)

Index	k	α	Gender (p)	Education p (ε^2)	Occupation p (ε^2)	Income p (ε^2)
Subjective norms	11	0.69	0.179	< 0.001 (0.14)	< 0.001 (0.15)	< 0.001 (0.11)
Perceived behavioural control	8	0.46	0.060	< 0.001 (0.07)	< 0.001 (0.06)	< 0.001 (0.09)
Attitudes	5	0.39	0.019	0.020 (0.03)	0.143 (0.02)	< 0.001 (0.07)

k, number of items; α, Cronbach's alpha; ε^2, epsilon-squared effect size. Gender tested by Mann Whitney U; education, occupation and income tested by Kruskal Wallis. Household size (not shown) was significantly associated with all three indices ($p \le 0.003$; $\varepsilon^2 = 0.04–0.10$). Indices computed from the primary dataset using the documented item mapping (additional file). The attitude and perceived behavioural control indices had low internal consistency; their associations are exploratory. Perceived moral obligation was represented by a single item and not analysed as a scale.

Factors associated with the intention to segregate

Because the survey did not include a direct measure of separation practice, the intention to segregate (the proportion agreeing or strongly agreeing with the intention statement; 242/357, 67.8%) was modelled as a proximal behavioural outcome. In a multivariable logistic regression adjusting for gender, education, employment, income, household size and proximity to a bin, intention was independently and

strongly associated with knowledge of waste segregation (adjusted odds ratio [aOR] 3.50, 95% confidence interval [CI] 2.07–5.93; $p < 0.001$) and with having access to a waste collection service (aOR 1.92, 95% CI 1.13–3.25; $p = 0.015$). Distance to the nearest bin was associated with intention in unadjusted analysis (χ^2 $p < 0.001$) but living within 200 m of a bin was not independently associated once service access was taken into account (aOR 1.26, 95% CI 0.76–2.10; $p = 0.367$), suggesting that reliable collection service, rather than physical proximity alone, underpins intention. None of the sociodemographic variables was independently associated with intention (Table 5). The model was statistically significant overall (likelihood ratio $p < 0.001$) but explained only a modest share of the variance (McFadden pseudo-$R^2 = 0.10$), consistent with intention being shaped by additional contextual factors explored in the qualitative strand.

Table 5
Multivariable logistic regression of factors associated with the intention to segregate waste (N = 357)

Predictor	aOR	95% CI	p
Knows what waste segregation is (vs not)	3.50	2.07–5.93	< 0.001
Has waste-collection access (vs none)	1.92	1.13–3.25	0.015
Lives ≤ 200 m from a bin (vs > 200 m)	1.26	0.76–2.10	0.367
Female (vs male)	0.98	0.61–1.59	0.945
Higher education (vs other)	0.71	0.42–1.20	0.199
Employed/self-employed (vs not)	0.67	0.41–1.10	0.112
Higher income, ≥ 25,591 PKR (vs lower)	1.08	0.65–1.80	0.772
Large household, ≥ 7 members (vs smaller)	0.78	0.47–1.28	0.320

aOR, adjusted odds ratio; CI, confidence interval; PKR, Pakistani rupees. Outcome: intention to segregate (agreement vs neutral/disagreement). All predictors entered simultaneously. McFadden pseudo-$R^2 = 0.10$; likelihood-ratio $p < 0.001$. Intention is a proximal proxy for behaviour; the survey did not capture observed separation practice.

Qualitative findings

The 28 FGD participants reflected the settlement's social profile (Table 6). Male participants reported diverse, often insecure occupations (labourer, driver, shopkeeper, electrician, cleaner, vendor), while all female participants identified as homemakers; educational attainment ranged from no formal schooling to graduate level, and most households reported incomes below the national living wage. Five interrelated themes were constructed (Table 7; Fig. 3): Practices, Cultural beliefs, Behavioural patterns, Perceived barriers and Motivators.

Table 6
Sociodemographic characteristics of focus group discussion participants (n = 28)

FGD	Gender	Age	Education	Occupation	Monthly income (PKR)
1	Male	25	Illiterate	Labourer	17,060–25,590
1	Male	33	Primary	Driver	> 68,241
1	Male	42	Intermediate	Shopkeeper	> 68,241
1	Male	30	Technical	Electrician	10,236–17,059
1	Male	47	Graduate	Cleaner	25,591–34,120
1	Male	29	Intermediate	Peon	34,121–68,240
2	Male	26	Illiterate	Labourer	34,121–68,240
2	Male	38	Primary	Cleaner	10,236–17,059
2	Male	40	Middle	Shopkeeper	25,591–34,120
2	Male	24	Matric	Mechanic	< 3,445
2	Male	27	Intermediate	Vendor	3,445–10,235
2	Male	30	Graduate	Teacher	25,591–34,120
3	Male	45	Illiterate	Labourer	3,445–10,235
3	Male	26	Primary	Driver	34,121–68,240
3	Male	52	Middle	Shopkeeper	> 68,241
3	Male	28	Matric	Electrician	17,060–25,590
3	Male	29	Intermediate	Cleaner	10,236–17,059
3	Male	30	Graduate	Assistant	> 68,241
4	Female	43	Illiterate	Homemaker	34,121–68,240
4	Female	49	Primary	Homemaker	25,591–34,120
4	Female	53	Middle	Homemaker	34,121–68,240
4	Female	40	Matric	Homemaker	< 3,445
4	Female	32	Intermediate	Homemaker	> 68,241
5	Female	28	Illiterate	Homemaker	17,060–25,590
5	Female	29	Primary	Homemaker	25,591–34,120
5	Female	39	Middle	Homemaker	> 68,241
5	Female	44	Matric	Homemaker	> 68,241

FGD	Gender	Age	Education	Occupation	Monthly income (PKR)
5	Female	50	Intermediate	Homemaker	17,060–25,590

FGDs 1–3 were male groups (six participants each) and FGDs 4–5 were female groups (five participants each).

Table 7
Themes and subthemes derived from the focus group discussions

Theme	Subthemes
1. Practices	Relevance to daily life; misconceptions; single-stream disposal; drain dumping; open burning of dry waste
2. Cultural beliefs	Cultural norms; stigma; responsibility for waste; social acceptance
3. Behavioural patterns	Use of bins/containers; role of family members
4. Perceived barriers	Lack of infrastructure; time constraints; economic constraints; perceived futility
5. Motivators	Willingness to participate; health and environmental drivers; economic and social incentives; role of community leaders

Theme 1: Practices

Households described separation as a low priority relative to immediate survival needs, and reported disposing of mixed waste through a single stream, often supplemented by drain dumping and open burning when collection failed. Misconceptions particularly the belief that all collected waste is ultimately mixed eroded any incentive to sort.

"By the time I've cooked, washed dishes, and got kids ready for school, who has the time to think about separating waste?" — Male, 25 years (FGD 1)

"Our kabari wala (scrap dealer) comes on Sunday; we save bottles for him. Beyond that, everything vegetable peels, plastics, broken glass goes into one bag. That's just how life is here." — Male, 42 years (FGD 1)

"We dump bags into the drain (nullah). There's no other option bins are rare and far away, and stray animals pull the bags out so it ends up all over the streets." — Female, 32 years (FGD 4)

"Whenever our piles of paper and plastic get too high, we light a small fire at the compound's edge it's faster than waiting for the truck, though the smoke gives us headaches." — Female, 44 years (FGD 5)

Theme 2: Cultural beliefs

Waste work was strongly gendered and socially stigmatised, framed as the responsibility of women or of municipal sweepers. Several participants located responsibility with the municipality, and many felt that change would require a critical mass of households to adopt separation first.

“In our culture, waste work is considered women’s duty. Men say, ‘Leave it to the housewives,’ so if a man handles trash, people question his respect.” — Male, 45 years (FGD 3)

“Sorting garbage is seen as sweeper’s work. My father says, ‘We pay sweepers why should we lower ourselves to that level?’” — Male, 47 years (FGD 1)

“As long as only one or two families bother to separate their kachra, the rest will just watch and wait. Here, change happens slowly first a few neighbours must lead, then the whole mohalla will follow.” — Male, 52 years (FGD 3)

Theme 3: Behavioural patterns

At the household level, residents improvised storage with reused tins and buckets but lacked space and dedicated containers for structured sorting. Children who had received environmental education at school were frequently described as encouraging separation, whereas older household members tended to resist change.

“Our two room home has no space for extra bins. We sometimes use old paint cans, but that’s hardly a permanent fix.” — Male, 30 years (FGD 1)

“My children come home from school with lessons on recycling. They nag me: ‘Ammi, separate the plastic!’ Their enthusiasm is contagious.” — Male, 33 years (FGD 1)

“My mother-in-law says, ‘Waste will go where it will go.’ Her doubts make me hesitate.” — Female, 40 years (FGD 4)

Theme 4: Perceived barriers

Participants described an absence of enabling infrastructure no colour-coded bins, signage or Urdulanguage guidance compounded by unpredictable collection, time and financial constraints, and a pervasive sense that individual effort was futile when waste was recombined at collection.

“We’ve never seen a colour-coded bin or signboard in Urdu here. Without them, how are we supposed to know what to do?” — Female, 28 years (FGD 5)

“After cooking, cleaning, and chauffeuring kids, I barely have energy left. Separating waste is just another chore I can’t squeeze in.” — Female, 29 years (FGD 5)

“I sorted once, but the collector threw them all together in the same truck. Why bother when nothing changes?” — Male, 26 years (FGD 2)

“Separate bags cost money more than we can afford. If NGOs donated bins and sacks, many would start.” — Female, 28 years (FGD 5)

Theme 5: Motivators

Despite these constraints, participants expressed willingness to separate waste under enabling conditions. Personal experience of waste related illness, small financial returns from recyclables, public recognition, and demonstrations delivered by trusted figures such as lady health workers were identified as credible levers for change.

“Many of us don’t even know how to start. If someone came to our mohalla with a live sorting demo step by step we’d line up to learn.” — Male, 42 years (FGD 1)

“Whenever drains are blocked, my children get skin rashes and diarrhoea. Stagnant garbage breeds mosquitoes that fear motivates me to keep our surroundings clean.” — Female, 32 years (FGD 4)

“If our local lady health worker added a 10 minute sorting demo, we’d all follow her. They could train us, and we’d teach the rest of the mohalla.” — Female, 43 years (FGD 4)

“If our lane got a ‘Cleanest Street’ award with a small cash prize, everyone here would scramble to sort their kachra.” — Male, 52 years (FGD 3)

Integration of quantitative and qualitative findings

The joint display (Table 8) shows convergence between the two strands: survey documented awareness coexisted with disposal occurring entirely through unmanaged channels, and the qualitative data identified the infrastructural, service and social mechanisms absent bins, unreliable collection, perceived futility, gendered stigma and competing demands on time that account for this gap. The strands also converged on potential levers: trusted community channels, personal experience of health risk, and modest economic or social incentives.

Table 8
Joint display integrating quantitative and qualitative findings by objective

Objective	Quantitative finding	Qualitative insight	Integrated interpretation
Awareness vs practice	59.1% found separation useful and 70.6% knew what it is, yet disposal was entirely via dumping/burning/Nullah with no separation scheme	High awareness undermined by absent bins and unreliable service	Awareness is necessary but insufficient; education must be paired with infrastructure
Sociodemographic correlates	Education, occupation, income and household size associated with the behavioural indices, most strongly subjective norms ($p < 0.001$)	Educated/employed participants expressed more confidence; low-income households cited cost and stigma	Socioeconomic status enhances self-efficacy, but social norms and financial barriers mediate practice
Service access vs disposal	27.7% lacked regular collection; disposal via dumping (49.6%), burning (27.7%), Nullah (22.7%)	Drain dumping and burning described as responses to service failure and futility	Service gaps directly drive unsafe disposal; reliable collection is a precondition for change
Motivators for change	Awareness of health risk and intention to separate were comparatively high	Lady health workers, religious leaders, children, incentives and recognition cited as levers	Trusted local channels and lived experience of risk can catalyse action when enabling support exists

Discussion

This convergent mixed-methods study of informal settlements along the Nullah Leh found a clear gap between awareness and practice: most residents valued waste separation, but few practised it. Integrating survey and focus group data showed that this gap is sustained less by ignorance than by absent infrastructure, unreliable municipal service, perceived futility, financial and time constraints, and the gendered, lowstatus framing of waste work. These findings align with a substantial body of evidence from South Asia and sub-Saharan Africa describing a persistent knowledgeaction gap in low-resource urban settings [10, 12, 13].

Among sociodemographic factors, education, formal employment, household size and income were associated with stronger subjective norms and, less consistently, with more favourable attitudes and greater perceived control. The associations with subjective norms were the most robust, though their magnitude was small to moderate ($\varepsilon^2 = 0.10–0.15$), and the attitude and perceived control indices had low internal consistency, so their correlates should be regarded as exploratory. These patterns are nonetheless consistent with prior work linking socioeconomic position and formal or workplace

exposure to pro-environmental orientation and self-efficacy [10, 11, 18, 19], and with intention focused and perceived control models of household separation in Pakistan's twin cities and elsewhere [6, 21]. The observation that the intention to segregate was expressed more often by those concerned about nearby health risks or who had experienced waste related illness echoes findings that proximity to risk can strengthen protective behaviour [9].

The qualitative data explain why awareness does not translate into action. Service failure unpredictable collection and the belief that sorted waste is recombined at the truck was repeatedly cited as a reason not to sort; consistent with this, intention in the survey was tied to having a collection service rather than to physical proximity to a bin, mirroring observations from informal settlements in Kampala, where scarce space and service gaps drive burning and drain disposal [13]. Gender norms framed waste work as women's or sweepers' work, constraining male participation and stigmatising sorting, consistent with gendered patterns of domestic waste responsibility documented in Nepal [14]. Even motivated households were limited by a lack of space, containers and time. These convergent findings indicate that interventions targeting knowledge alone are unlikely to succeed; enabling infrastructure and reliable service are prerequisites, and behaviour change messaging must be culturally grounded and gender sensitive [11, 20].

Participants themselves identified plausible, context appropriate levers: demonstrations and reminders delivered by trusted figures (lady health workers, teachers and religious leaders), engagement of schoolchildren as household influencers, small financial returns for recyclables building on existing informal scrap networks, and social recognition such as "cleanest street" competitions. These align with community based approaches that pair health framing with social and economic incentives delivered through credible local actors [20]. Integrating informal waste collectors into formal systems may simultaneously improve separation and protect livelihoods [12].

Strengths and limitations

The principal strength of this study is its integration of quantitative prevalence and correlates with qualitative explanation in an understudied, highrisk setting, allowing the awarenesspractice gap to be both measured and explained. Several limitations should be acknowledged. First, the quantitative sample was recruited by non-random convenience sampling, which limits generalisability beyond this settlement. Second, outcomes were self-reported and may be subject to socialdesirability bias; no direct observation of disposal was undertaken, and the survey did not include a direct measure of separation practice, so the intention to segregate was modelled as a proximal proxy; intention does not always translate into behaviour. Third, the cross-sectional design precludes inference about temporal change or causation, and the inferential analyses were bivariate and unadjusted for confounding. The behavioural indices were derived from a studyspecific instrument; two of the three multi-item indices showed low internal consistency (Cronbach's $\alpha = 0.39$ and 0.46), and a planned fourth construct could not be operationalised as a reliable scale, so the indexbased associations are exploratory. Future work should employ validated, single loading scales and a confirmatory measurement model, and should adjust for

confounding using multivariable methods. Fourth, although gender stratified FGDs were intended to support open discussion, group settings and some moderator prompting may have constrained the expression of dissenting views, particularly among women; the presence of third parties (the community gatekeeper, a photographer and, in the female groups, accompanying children) may have further moderated openness, and the discomfort with audio recording reported by some invited women suggests that the most privacyconscious voices may be underrepresented. Finally, the qualitative findings are specific to one settlement and are intended to be analytically, rather than statistically, transferable. In addition, the involvement of an interpreter and the translation of data from Urdu into English, although necessary in this setting, may have introduced subtle shifts in meaning during cross-language interpretation.

Conclusions

In informal settlements along the Nullah Leh, awareness of the value of waste separation is widespread but is not matched by practice. Reported separation was low and unsafe disposal common, driven by absent infrastructure, unreliable collection, perceived futility and gendered social norms rather than by lack of knowledge. Sustained behaviour change is therefore likely to require a multi-level response that pairs basic infrastructure colour-coded bins, reliable scheduled collection and accessible drop off points with culturally grounded, gender sensitive behaviour change delivered through trusted community channels, and that integrates informal collectors into formal systems. These findings provide context specific, transferable guidance for similar low resource urban settings, and point to a clear agenda for longitudinal and intervention research.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Institutional Review Board / Ethical Review Committee of the Armed Forces Postgraduate Medical Institute (AFPGMI), Rawalpindi (reference 551-AAA-ERC-AFPGMI). All methods were carried out in accordance with relevant guidelines and regulations. Written informed consent to participate was obtained from all survey respondents on the questionnaire prior to data collection. For the focus group discussions, verbal informed consent was obtained from all participants before each session; verbal consent was considered appropriate for this low-risk, group-based component and to accommodate participants with limited literacy, and was documented by the research team. The use of verbal consent for the focus group discussions was approved by the AFPGMI Ethical Review Committee.

Trial registration

Clinical trial number: not applicable.

Consent for publication

Participants consented to the use and publication of their anonymised responses and quotations as part of the consent process described above. No individually identifiable information or images are presented in this manuscript.

Availability of data and materials

The quantitative dataset analysed during the current study is available from the corresponding author on reasonable request. Qualitative transcripts are not publicly available in order to protect participant confidentiality but may be available from the corresponding author on reasonable request, subject to ethical approval.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AS conceived and designed the study, obtained ethical approval, collected the data, contributed to analysis and interpretation, and drafted and revised the manuscript. MI and KU contributed to participant recruitment and field data collection and to the training and supervision of the focus group discussion interpreter, and reviewed the manuscript. MH performed the data analysis and contributed to interpretation of the data and critically reviewed the manuscript. SM supervised the study, contributed to its design and to interpretation of the findings, and critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Figures

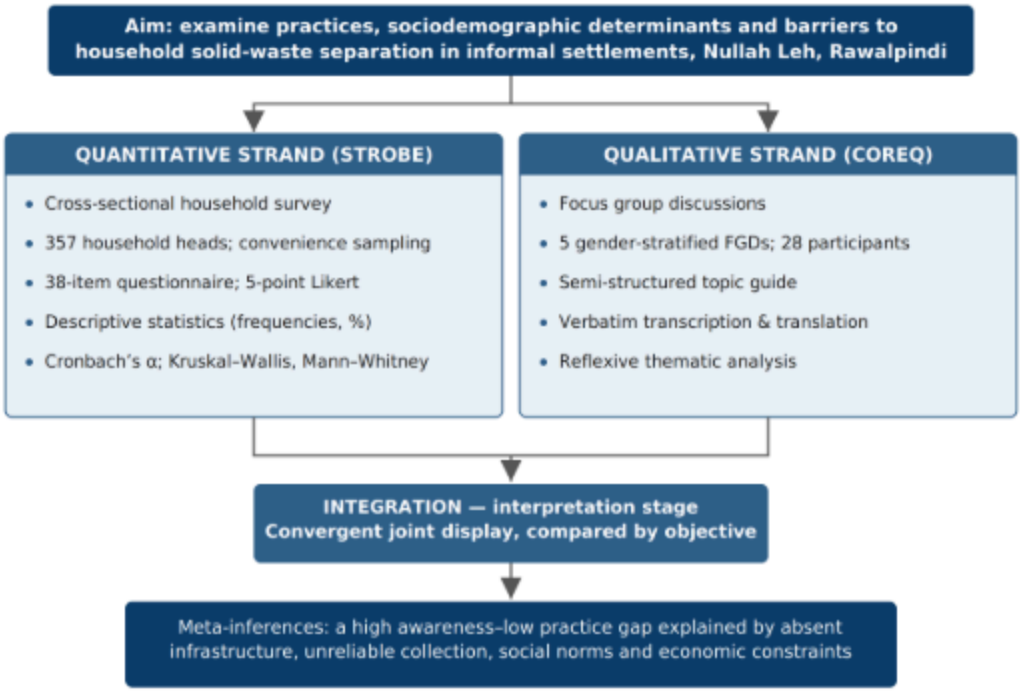


Figure 1

Convergent parallel mixed-methods study design.



Figure 2

The study setting: the Nullah Leh and the adjacent informal settlement, showing accumulated solid waste along the watercourse and banks. Photographs taken by the study team.

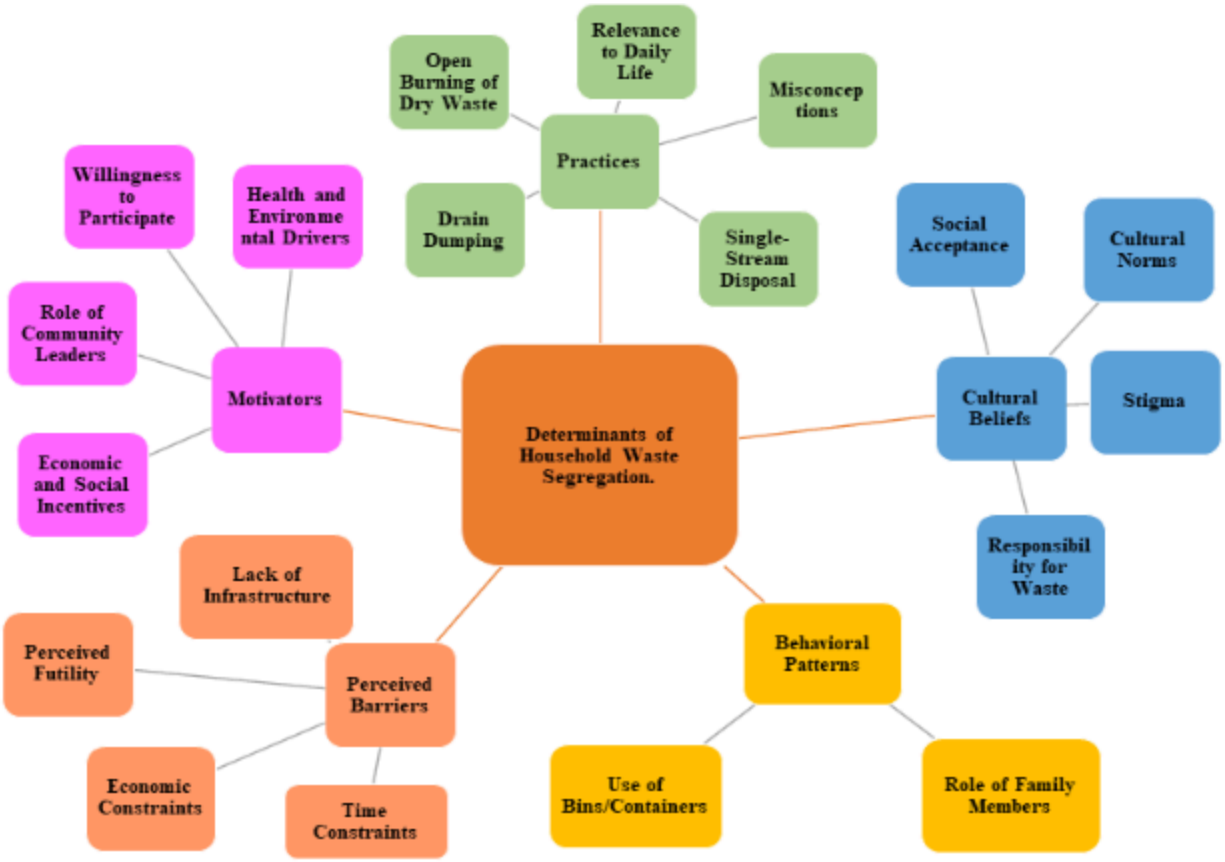


Figure 3

Thematic framework: the five themes and nineteen subthemes constructed from the focus group discussions.