frontiers in Environmental Health

TYPE Original Research
PUBLISHED 29 June 2026
DOI 10.3389/fenvh.2026.1828143

Check for updates

OPEN ACCESS

EDITED BY
Rakesh Kumar,
Auburn University, United States

REVIEWED BY
Sunday Olutayo Fakunle,
Redeemer's University, Nigeria
Turin Afroz,
Bangladesh University of Health Sciences, Bangladesh
Khoiron Khoiron,
University of Jember, Indonesia

*CORRESPONDENCE
Sonali Kar
sonsam72@yahoo.co.uk

RECEIVED 11 March 2026
REVISED 06 April 2026
ACCEPTED 10 April 2026
PUBLISHED 29 June 2026

CITATION
Mohapatra N, Kar S, Verma V, Ray A, Rath GK and Mishra K (2026) Environmental risk scoring of household solid waste practices and its association with infectious morbidity: a community-based mixed-methods study in urban and rural Odisha, India.
Front. Environ. Health 5:1828143.
doi: 10.3389/fenvh.2026.1828143

COPYRIGHT
© 2026 Mohapatra, Kar, Verma, Ray, Rath and Mishra. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Environmental risk scoring of household solid waste practices and its association with infectious morbidity: a community-based mixed-methods study in urban and rural Odisha, India

Nirmalya Mohapatra[1], Sonali Kar[1]*, Vivek Verma[2], Angana Ray[1], Gouri Kumar Rath[1] and Krishna Mishra[1]

[1]Department of Community Medicine, Kalinga Institute of Medical Sciences (KIMS), KIIT University, Bhubaneswar, India, [2]Department of Statistics, Assam University, Silchar, India

Background: Inadequate household solid waste management remains a critical environmental health challenge in low- and middle- income countries, contributing to infectious disease transmission through vector breeding, water contamination, and unsafe disposal practices. Evidence linking quantified environmental risk practices to household morbidity remains limited, particularly in urban–rural comparative settings.

Methods: A community- based mixed- methods descriptive study was conducted among 219 households across urban slums and rural villages in Odisha, India. Quantitative data were collected using interviewer- administered questionnaires, observational checklists, and waste quantification through colour- coded bag weighing. Eight waste categories were assessed for segregation and disposal practices. An environmental risk score (0–8) was developed based on the appropriateness of disposal. Infectious morbidity (gastrointestinal, respiratory, dermatological, and vector- borne diseases) reported within the preceding 3 months was recorded. Qualitative insights were obtained through focus group discussions and in- depth stakeholder interviews. Associations were analysed using chi- square tests, odds ratios, and thematic analysis.

Results: A total of 219 households participated (urban = 110; rural = 109). Appropriate waste segregation practices were significantly higher in urban households. Dustbin use for kitchen waste was reported by 75% (95% CI: 66.1–82.3) in urban areas compared to 65% (95% CI: 55.5–73.4) in rural areas ($p < 0.001$), while indiscriminate disposal was observed only in rural households (20%; 95% CI: 13.3–28.5). Safe thin- plastic collection was higher in urban settings (78%; 95% CI: 69.5–84.7) than rural (64%; 95% CI: 1.54.5–72.6) ($p < 0.001$). Mean daily kitchen waste generation was greater in rural households (2.38 ± 0.60 kg) than in urban households (1.38 ± 0.50 kg; $p < 0.001$). Skin infections were significantly higher in rural households (46%; 95% CI: 36.7–55.6) than in urban households (18%; 95% CI: 11.7–26.4), whereas vector- borne diseases were more prevalent in urban areas (21%; 95% CI: 14.2–29.7). Higher environmental risk scores were positively associated with increased reporting of infectious morbidity.

Conclusion: Environmental risk scoring provides an actionable household- level metric linking waste practices to infectious morbidity. Strengthening segregation behaviour, decentralised waste systems, and risk communication strategies is essential for infection prevention and environmental health equity.

KEYWORDS

environmental health, environmental risk score, India, infectious morbidity, mixed methods, rural households, solid waste management, urban slums

Highlights

- An eight-component environmental risk score provided a quantifiable household- level metric to assess exposure from unsafe waste disposal.
- Urban households showed higher compliance with segregation and safer disposal practices, reflecting stronger municipal waste service coverage.
- Rural households exhibited higher organic waste generation and greater reliance on open dumping, delayed disposal, and informal waste disposal pathways.
- Distinct epidemiological patterns emerged: dermatological infections were higher in rural households, whereas vector-borne diseases were more prevalent in urban areas.
- Higher environmental risk scores (indicating safer disposal practices) were significantly protective against infectious morbidity in multivariable analysis. Governance gaps, irregular waste collection, stigma around sanitary waste, and informal recycling systems were key behavioural and structural drivers identified qualitatively.
- Mixed-methods integration strengthened causal interpretation by linking statistical associations to lived community experiences.
- Environmental risk scoring has potential utility as a primary health care surveillance and risk-stratification tool.
- Convergence among the Swachh Bharat Mission, municipal waste governance, and Comprehensive Primary Health Care is essential to reduce the risk of environmentally mediated infections.

Introduction

Safe management of household solid waste is a foundational environmental health service and a recognised determinant of infectious disease prevention. Globally, an estimated 2 billion people lack access to safe waste collection systems, disproportionately affecting populations in low- and middle-income countries (1). Poor segregation, open dumping, and unsafe disposal create ecological niches for pathogens and vectors, facilitating transmission of gastrointestinal, dermatological, respiratory, and vector-borne infections (2). The burden is particularly pronounced in rapidly urbanising settlements and underserved rural regions where infrastructure expansion has not kept pace with waste generation (3).

India generates over 160,000 metric tonnes of municipal solid waste daily, with household waste accounting for a major share (4). Despite national missions such as Swachh Bharat Abhiyan and Solid Waste Management Rules (2016), implementation gaps persist at the household level, especially in peri-urban slums and agrarian communities (5). Studies have documented associations between unsegregated waste, open burning, and adverse health outcomes, including diarrhoeal diseases, skin infections, and vector proliferation (6–8).

However, most evidence relies on descriptive assessments rather than composite environmental risk metrics.

Environmental risk scoring offers a pragmatic approach to quantify exposure from household waste practices and link it to health outcomes. Mixed-methods inquiry further enables triangulation of behavioural, infrastructural, and governance determinants. Regional evidence from eastern India remains sparse. A recent review from Odisha by Mohapatra and Kar highlighted systemic gaps in segregation behaviour, municipal coverage, and infection vulnerability in vulnerable settlements (9).

Against this backdrop, the present study developed a household environmental risk score based on disposal practices across multiple waste streams and examined its association with infectious morbidity in urban and rural communities. Infectious morbidity differed significantly between settings, with dermatological infections higher in rural households (46% vs. 18%) and vector-borne diseases higher in urban households (21% vs. 2%), indicating environment-specific exposure pathways (10). The findings aim to inform decentralised waste governance, risk communication, and primary health care–linked environmental interventions.

Aims and objectives

General objective

To evaluate the environmental risk associated with household solid waste practices and their relationship with infectious morbidity in urban and rural Odisha.

Specific

1. Assess waste segregation and disposal practices and compare urban–rural risk differentials.
2. Quantify waste generation and disposal timelines, rural vs. urban.
3. Examine the association between infectious diseases and the risk score.
4. Explore behavioural and governance determinants qualitatively.

Materials and methods

Study design

A community-based mixed-methods descriptive study using an Embedded design (QUAN → QUAL) was conducted to evaluate environmental risks associated with household solid waste practices and their relationship with infectious morbidity in urban and rural Odisha, India. The quantitative component formed the primary dataset, while a qualitative inquiry was conducted in a subset to explain the behavioural, infrastructural, and governance determinants underlying observed practice patterns. The location maps and the detailed stratified study design charts are provided in the Supplementary Material.

Study period: The study was conducted between March 2023 and April 2025.

Study setting and participants

The study was conducted in the urban and rural field practice areas attached to a tertiary care teaching institution in Odisha. Urban participants were drawn from selected slums under the Urban Health and Training Centre (UHTC), while rural participants were selected from villages under the Rural Health and Training Centre (RHTC).

A total of 219 households participated (Urban = 110; Rural = 109). The study respondent was the head of the household or an adult member (≥18 years) directly involved in daily waste handling and disposal.

Inclusion criteria

- Resident household member ≥18 years
- Actively involved in waste segregation/disposal
- Provided informed consent

Exclusion criteria

- Locked household after two visits
- Non-consenting respondents
- Uncooperative households

Sampling technique

A stratified two-stage random sampling design was employed.

Stage 1: Selection of primary sampling units.

Rural: One panchayat selected randomly → three villages selected.

Urban: Three slums selected randomly from the wards which are a part of the catchment area.

Stage 2: Household selection.

Line-listing obtained from frontline health workers (Auxiliary Nurse Midwife- ANM/Aanganwadi Worker-AWW); households were selected using a simple random (lottery) method, ensuring at least 100 households per stratum.

Data collection

Quantitative data

Data were collected using an interviewer-administered semi-structured questionnaire that included socio-demographics, waste segregation and disposal practices, environmental conditions, and infectious morbidity (past 3 months). An observational checklist was used to evaluate waste storage containers, segregation behaviour, and proximity to dumping sites or ponds. A waste quantification exercise was conducted in a subset of households, where colour-coded, labelled polybags were provided; category-wise waste was retained for 1 week and weighed with a calibrated scale, with food waste measured thrice weekly for averaging.

The Exposure Variable is the Environmental Risk Score (0–8), which was developed based on the appropriateness of disposal across 8 waste categories: Kitchen waste, Paper/cardboard, Thin plastic, Thick plastic, Glass, Sanitary waste, Sick/biomedical waste, and E-waste.

Appropriate disposal = 1; inappropriate = 0; summed to create a composite score.

Outcome Variable was Infectious morbidity (reported at the sampled household level over the last 3 months): Gastrointestinal infections, Dermatological infections, Respiratory infections in urban households, and vector-borne diseases such as Malaria and Dengue, which were endemic in certain regions, were explored in rural areas.

The Covariates were Socio-demographics, Environmental characteristics, Household composition, Waste generation quantity as well as disposal timelines.

Statistical analysis

Data were entered in MS Excel and analysed using SPSS 25.0.

Segregation and disposal practices (Urban vs. Rural) were reported using the Chi-square test or Fisher's exact test (expected cell count <5), with odds ratios and 95% CI. Waste generation and disposal timelines were measured with the Independent samples *t*-test, expressed as Mean ± SD, with comparisons using the mean difference and 95% CI. Risk score vs. infectious morbidity was analysed using Chi-square (categorised risk bands), the Independent *t*-test (continuous score), and Binary logistic regression (if adjusted analysis was conducted), with Crude/Adjusted OR and 95% CI; statistical significance was set at $p < 0.05$.

For qualitative analysis: Qualitative data were collected through six focus group discussions (FGDs) and in-depth interviews (IDIs) to explore behavioural and governance determinants of household waste practices. Three FGDs were conducted in urban areas and three in rural villages. Each FGD involved approximately six participants purposively selected from surveyed households to ensure representation of primary waste handlers. A total of 36 participants took part (urban = 18; rural = 18). The mean age of participants was 39.6 ± 11.7 years

(range: 21–68 years). Most participants were female household members responsible for waste handling (61%), followed by male household heads (39%). Educational status included no formal schooling (28%), primary education (33%), secondary education (27%), and higher secondary or above (12%). Predominant occupations included homemakers (44%), daily wage workers (22%), agriculture-related work (18%), small business owners (8%), and service workers (8%).

FGDs were conducted at community meeting points in the local Odia language by the principal investigator with two trained research interns. One researcher facilitated the discussion, one documented field notes, and another audio-recorded the sessions. An inductive FGD checklist was developed based on preliminary quantitative findings, focusing on segregation practices, storage behaviours, service access, and disease perceptions. Each discussion lasted approximately 35–45 min. Verbal probes were used to clarify emerging responses. Audio recordings were transcribed verbatim and translated into English for analysis.

A total of eight in-depth interviews were conducted with key stakeholders. These included two municipal waste workers, two urban corporators from urban areas, and two village sarpanch representatives, along with two youth volunteers involved in waste disposal activities in rural areas. Participants were purposely selected based on their involvement in waste governance or community-level waste management. The interviews lasted 20–30 min and explored collection infrastructure, governance barriers, behaviour change strategies, and perceived health risks. Interviews were conducted in Odia, recorded, transcribed, and translated.

Thematic analysis followed a six-step inductive framework: familiarisation, initial coding, code refinement, theme development, sub-theme clustering, and triangulation with quantitative findings. Transcripts were read repeatedly to generate initial open codes. Codes were grouped into categories and then organised into themes and subthemes. Verbatim quotations supported the interpretation. Triangulation was performed across FGDs, IDIs, and quantitative results to enhance credibility.

Coding and organisation were conducted manually and using Taguette (open-source qualitative analysis software) to assist in code indexing, retrieval, and thematic grouping which are freely available and commonly used for qualitative public health research.

The thematic domains explored included: Waste knowledge and awareness; Segregation behaviour; Storage practices; Disposal barriers; Governance gaps; Service delivery reliability; Informal recycling practices; Sanitary waste stigma; Perceived health risks.

Results include a tabulated version of integration of findings of Quant to Qual findings.

Ethics statement

Ethical approval was obtained from the Institutional Ethics Committee by letter No. KIIT/KIMS/IEC/1138/2023. Written informed consent was obtained from all participants.

Confidentiality, anonymity, and voluntary participation were maintained in accordance with the Declaration of Helsinki.

Results

Table 1 shows that Urban households demonstrated significantly safer practices for disposing of kitchen waste. Indiscriminate dumping was exclusively rural, indicating infrastructural and behavioural gaps.

In Table 2 Rural households generated significantly more organic waste, while plastic waste generation was comparable, reflecting differences in consumption and livelihoods.

Rural households had higher dermatological morbidity, whereas urban households demonstrated greater vector-borne disease burden, suggesting ecological and density-driven risks as is evident from Table 3 and Figures 1A,B.

The overlay histogram in Figure 2A shows a clear rightward shift in environmental risk scores among urban households compared to rural households. Urban households mostly cluster in higher score categories (6–8), indicating safer waste segregation and disposal practices, while rural households are concentrated in lower score categories (0–5), reflecting unsafe disposal behaviours. The distributional difference was statistically significant ($\chi^2 = 198.72$, $p < 0.001$), confirming notable urban–rural disparities in environmental risk exposure. Risk score distribution differed significantly between urban and rural households ($\chi^2 = 198.72$, $p < 0.001$), with urban households mainly at higher scores (6–8) and rural households at lower scores (0–5).

The side-by-side histograms in Figure 2B highlight distinct distribution patterns across settings. Urban households show a peaked distribution at scores 7 and 8, indicating widespread compliance with proper disposal practices. In contrast, rural households display a broader distribution, skewed toward lower

TABLE 1 Kitchen waste disposal practices (urban vs. rural).

Practice	Urban % (95% CI)	Rural % (95% CI)	*p*-value
Dustbin use	75% (66.1–82.3)	65% (55.5–73.4)	<0.001
Indiscriminate disposal	0%	20% (13.3–28.5)	<0.001

TABLE 2 Waste generation comparison.

Waste type	Urban mean ± SD	Rural mean ± SD	*p*-value
Kitchen waste (kg/day)	1.38 ± 0.50	2.38 ± 0.60	<0.001
Thick plastic (kg/week)	0.89 ± 0.23	0.063	

TABLE 3 Infectious morbidity profile.

Disease	Urban % (95% CI)	Rural % (95% CI)	*p*-value
Skin infections	18% (11.7–26.4)	46% (36.7–55.6)	<0.001
Vector-borne diseases	21% (14.2–29.7)	2% (0.5–7.0)	<0.001

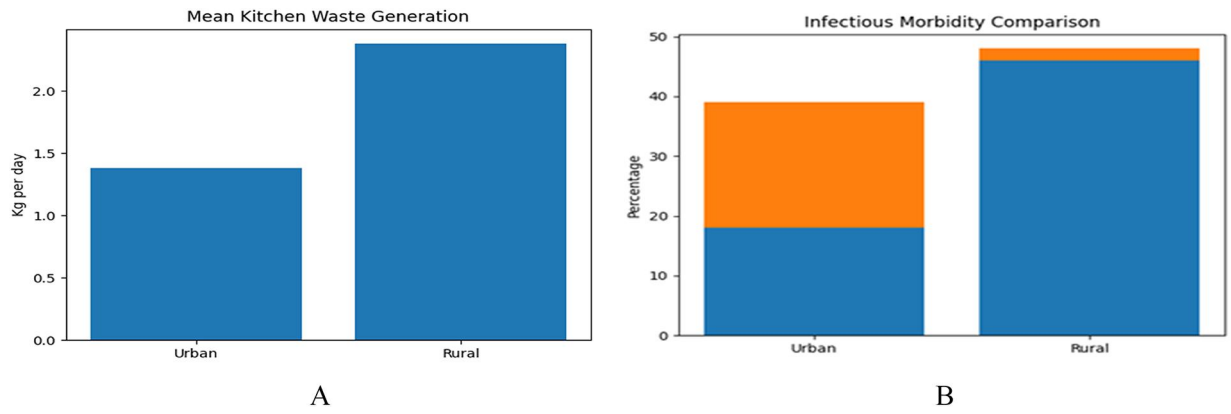

FIGURE 1
(A) Mean household kitchen waste generation in urban and rural areas (kg/day). **(B)** Comparison of infectious morbidity patterns in urban and rural households.

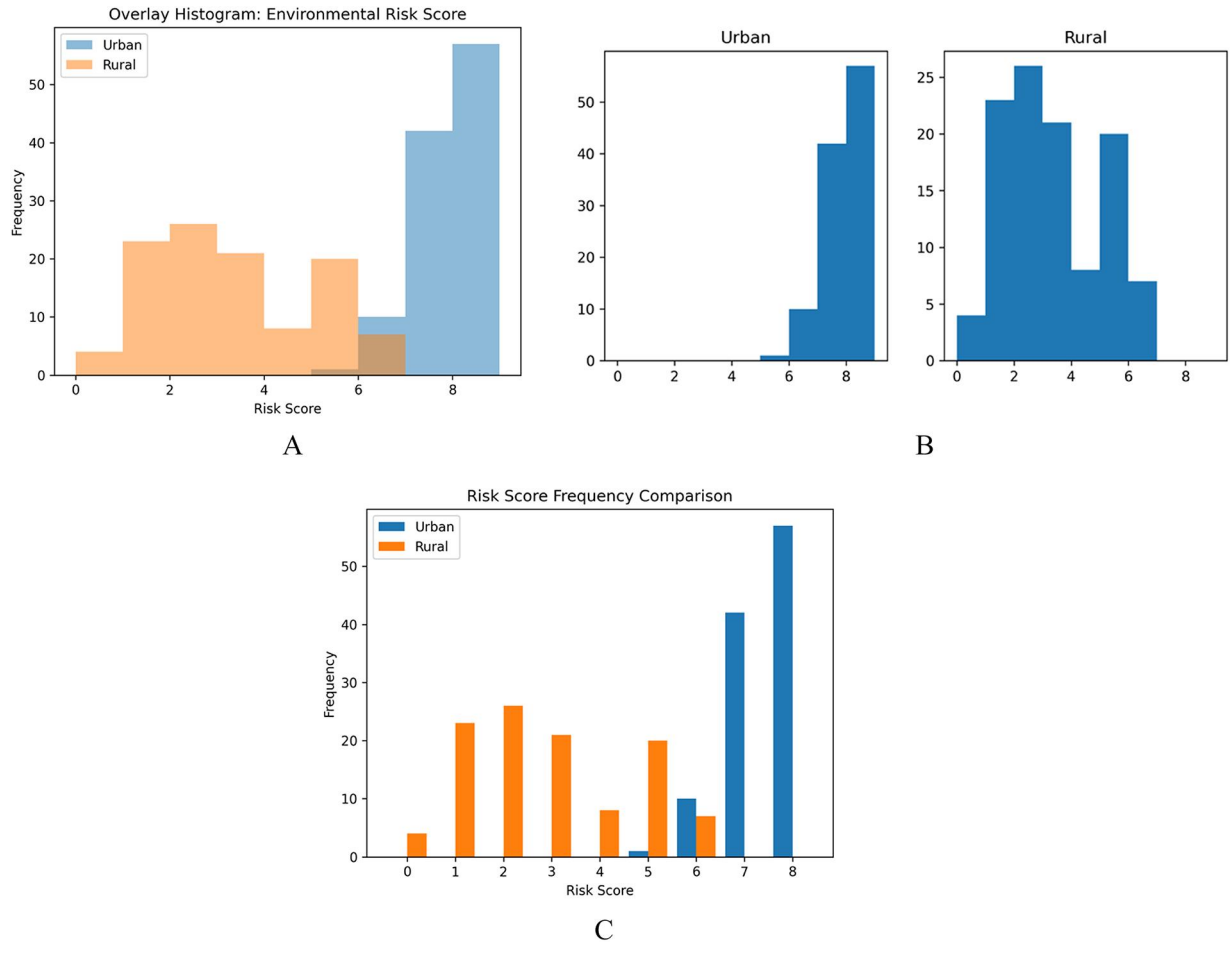

FIGURE 2
Environmental risk score visualizations. **(A)** Overlay histogram (urban vs. rural). **(B)** Side-by-side panel histogram. **(C)** Risk score frequency comparison.

scores (1–4), suggesting varied, mostly unsafe disposal behaviours. The minimal overlap between distributions further emphasises important structural and behavioural differences in waste management practices between urban and rural communities.

The bar chart in Figure 2C compares the frequency of environmental risk scores between urban and rural households. Urban households mainly fall into higher score categories (6–8), while rural households are mostly in lower categories (0–5). No rural households reached the maximum score of 8, but most urban households did. This pattern shows that better waste segregation, collection infrastructure, and service availability in urban areas are linked with lower environmental risks.

10.3389/fenvh.2026.1828143

Multivariable logistic regression in Table 4 showed that higher environmental risk scores (indicating safer waste disposal practices) were significantly protective against infectious morbidity (AOR = 0.74; 95% CI: 0.62–0.88; $p < 0.001$). Rural residence independently increased infection odds (AOR = 1.89; $p = 0.017$), even after adjusting for household size and landfill proximity. Model diagnostics indicated acceptable explanatory power, with a pseudo- R^2 (Nagelkerke) of 0.28, suggesting moderate variance explained. The Hosmer–Lemeshow goodness-of-fit test was not statistically significant ($p > 0.05$), indicating adequate calibration and validity of the model. The forest plot (Figure 3) shows adjusted effect sizes and confidence intervals.

Focus group discussions identified three main themes explaining segregation patterns. Participants reported irregular rural waste collection, which led to prolonged storage and open dumping. Stigma around sanitary waste disposal caused households to conceal mixed waste storage practices. Households also relied on informal recycling networks, resulting in temporary buildup of plastic waste (Figure 4B). In contrast, areas with consistent municipal collection and awareness campaigns showed segregated, covered-bin storage (Figure 4A). These qualitative findings aligned with quantitative results linking lower environmental risk scores to unsafe waste handling behaviours (Table 5).

TABLE 4 Logistic regression—environmental risk score predicting infectious morbidity.

Predictor	Adjusted OR	95% CI	*p*-value
Environmental risk score (continuous)	0.74	0.62–0.88	<0.001
Rural residence	1.89	1.12–3.21	0.017
Presence of landfill/dump nearby	1.56	0.94–2.61	0.081
Household size (>5 members)	1.42	0.88–2.30	0.142

Note: The Supplementary Material includes images depicting various waste practices in rural and urban areas, details of the COREQ study design, and illustrative quotes to support comprehension.

Table 6 presents an integrated mixed-methods matrix that connects statistical findings with thematic insights. Higher safe disposal practices in urban areas correspond with qualitative narratives of regular municipal collection services. Rural open dumping aligns with reported service gaps and irregular waste pickup. Greater rural organic waste generation reflects agrarian consumption and livestock-feeding practices. Delayed plastic disposal in rural areas results from reliance on informal recycling chains (kabadiwala systems).

Elevated urban vector-borne disease prevalence corresponds with qualitative reports of stagnant waste and drainage congestion. Higher rural skin infection rates are explained by occupational exposure and barefoot waste handling.

Sanitary waste mismanagement highlights stigma, privacy issues, and the lack of gender- sensitive disposal infrastructure. Informal e-waste handling shows awareness gaps and weak enforcement of extended producer responsibility. Overall, the display illustrates how behavioural norms, service delivery inequalities, and governance weaknesses shape environmental risks and infectious disease outcomes.

Discussion

Qualitative insights showed that governance gaps, irregular waste collection, stigma around sanitary waste, and dependence on informal recycling systems shape household behaviour. These structural and socio-cultural factors influence environmental exposure and disease risk (9). This mixed-methods study finds a strong connection between household solid-waste practices and infectious diseases

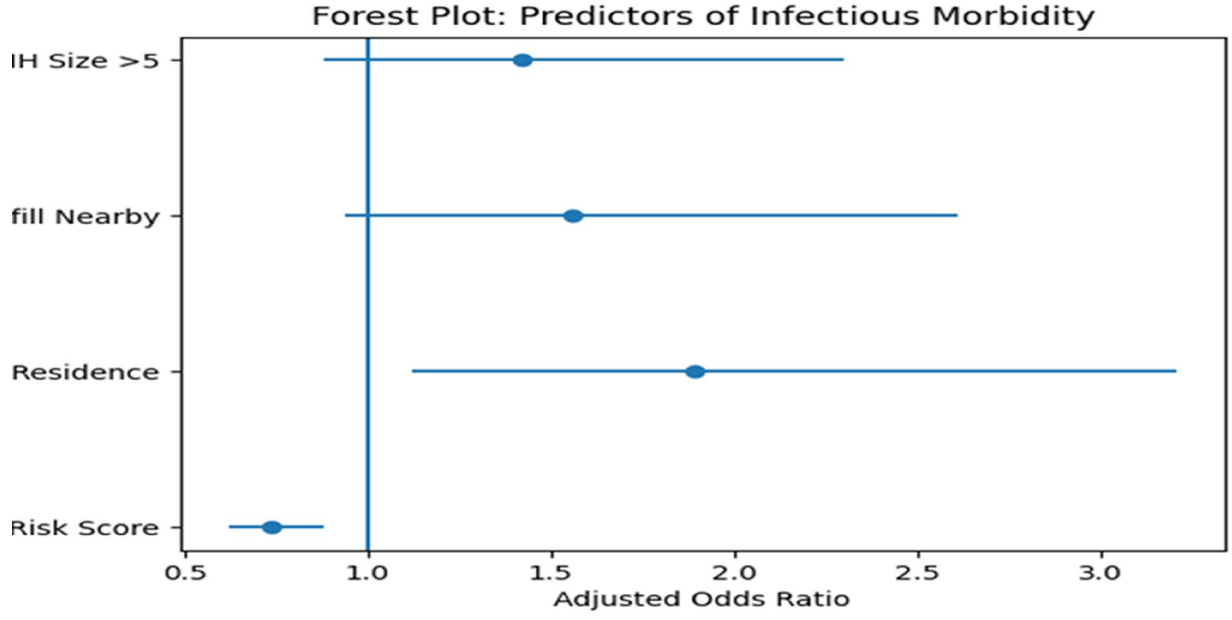

FIGURE 3
Forest plot showing results of multiple regression.

FIGURE 4
(**A**) Solid waste management in urban communities: wet-dry segregation, public bins, and BMC collection services. (**B**) Plastic waste dumping.

using a composite environmental risk score. Urban households exhibited better waste segregation and safer disposal methods compared to rural households, reflecting differences in infrastructure, service delivery, and behaviour. Similar urban–rural differences have been observed in Indian municipal waste studies, where organised door-to-door collection and segregation campaigns improved urban compliance, while rural areas still rely on open dumping and informal disposal methods (4, 6, 11). Evidence from Odisha and eastern India also highlights gaps in decentralised waste governance, limited transportation options, and weak monitoring under rural sanitation programs, which increase environmental exposure risks (9).

The present study observed higher organic waste generation in rural households, which aligns with agrarian consumption patterns and livestock-related waste streams.

Comparable findings have been reported in Nepal and Bangladesh, where biodegradable waste accounted for more than 60% of rural household waste, increasing microbial contamination risks (12, 13). In contrast, urban areas showed relatively higher plastic waste accumulation, consistent with consumption transitions driven by packaged goods and market penetration in LMIC urban settlements (14). Such dual waste streams create different ecological risk environments, with organic waste promoting bacterial proliferation and plastic waste contributing to vector breeding.

The epidemiological differences observed in this study further support environment- specific risk pathways. Rural households reported significantly higher dermatological infections, which may be linked to occupational exposure, barefoot handling

TABLE 5 Mixed-methods integration was seen with integration followed embedded design logic in the construct given below.

Integration stage	Approach
Connecting	QUAN findings informed QUAL sampling
Building	Interview guides derived from risk/practice gaps
Merging	Joint interpretation through mixed display

TABLE 6 Joint display table (QUAN ↔ QUAL integration).

Quantitative finding	Statistical evidence	Qualitative theme	Illustrative insight	Integrated interpretation
Higher safe disposal in urban households	Higher segregation %, $p < 0.001$	Municipal service access	"BMC carts collect daily"	Infrastructure drives safer practices
Open dumping in rural areas	20% indiscriminate disposal	Service gaps	"We dump roadside weekly"	Lack of collection systems elevates risk
Higher rural kitchen waste generation	Mean 2.38 vs. 1.38 kg	Household food patterns	"Peels fed to animals"	Agrarian lifestyle increases organic waste
Delayed plastic disposal rural	Longer retention time, $p < 0.01$	Storage and recycling gaps	"We keep plastics till kabadiwala comes"	Informal recycling delays disposal
Urban VBD higher	21% vs. 2%	Urban ecology	"Water stagnates near dumps"	Dense settlements → vector breeding
Rural skin infections higher	46% vs. 18%	Occupational exposure	"We work barefoot near waste"	Environmental + occupational risk synergy
Poor sanitary waste handling	Disposal variation $p < 0.001$	Stigma and privacy	"Pads thrown secretly"	Cultural barriers affect safe disposal
E-waste informal handling	Scrap dealer reliance	Awareness gaps	"Old gadgets kept or sold"	Weak formal recycling chains

of waste, and contact with contaminated soil. Similar links between improper waste disposal and skin infections have been reported in rural Tamil Nadu and Uttar Pradesh (15, 16). Conversely, vector-borne diseases were more common in urban households, likely due to dense urban settlements, stagnant water, and the accumulation of plastic containers. Studies from Kolkata, Dhaka, and Nairobi have shown clustering of dengue and chikungunya cases around unmanaged waste sites (17–19).

A major contribution of this study is the development of an environmental risk score that quantifies exposure across multiple waste streams. Regression analysis showed that higher risk scores (indicating safer disposal practices) were protective against infectious morbidity. Similar composite environmental indices have been used in Brazil and Indonesia, where sanitation risk scoring predicted diarrhoeal and vector-borne disease burden (7, 20). The moderate pseudo-R^2 observed in this study suggests that, while waste practices significantly influence infection risk, other factors, such as water quality, housing density, and sanitation coverage, also contribute to disease transmission.

Qualitative findings strengthened interpretation by identifying governance and behavioural barriers. Rural participants reported irregular waste collection and a lack of transport infrastructure, consistent with Panchayati Raj evaluations of waste governance in India (21). Stigma surrounding sanitary waste disposal and the absence of gender-sensitive infrastructure were also identified, echoing findings from South Asian WASH research (22). Informal recycling networks (kabadiwala systems) contributed to delayed plastic disposal, a phenomenon documented in LMIC circular-economy studies, where informal sectors dominate recycling but increase temporary environmental exposure (23).

The integration of mixed methods further enhanced causal plausibility. Statistical findings of higher urban vector-borne disease prevalence were supported by qualitative reports of stagnant waste and drainage congestion. Similarly, increased rural dermatological morbidity was associated with occupational exposure and unsafe waste-handling practices. These convergent findings highlight the usefulness of environmental risk scoring as a household-level surveillance and intervention tool.

From a policy perspective, the findings align with the Swachh Bharat Mission indicators, which emphasise segregation at source, door-to-door collection, and decentralised waste processing. Integrating environmental risk scoring into Health and Wellness Centre outreach under Comprehensive Primary Health Care could enable risk-stratified environmental interventions. Such convergence between sanitation governance and primary health care is essential to reduce environmentally mediated infectious diseases and enhance community health outcomes.

Recommendations

1. Integrate household environmental risk scoring into primary health outreach and SBM monitoring.
2. Strengthen decentralised rural waste collection and transport systems.
3. Promote behaviour change communication on segregation and sanitary waste disposal.
4. Formalise informal recycling chains to reduce storage-related exposure.
5. Develop gender-sensitive sanitary waste infrastructure.
6. Embed environmental surveillance within Health and Wellness Centres under CPHC.

Collectively, multi-sectoral convergence between sanitation, primary health care, and municipal governance is essential to reduce environmentally mediated infectious disease risk and advance sustainable community health outcomes.

Public health and policy implications

The findings have direct programmatic relevance. Environmental risk scoring can serve as a household vulnerability screening tool, a key health care environmental assessment metric, and a framework for behaviour change communication targeting. Incorporating it into Health and Wellness Centre outreach and Swachh Bharat surveillance could facilitate risk-based environmental interventions.

Strengths

The study used mixed-methods triangulation and composite environmental risk scoring to create an urban–rural comparative design. It could also perform waste quantification and model morbidity linkage.

Limitations

Self-reported morbidity (recall bias); field-practice-area sampling limits generalisability. The cross-sectional design precludes establishing temporality, and some waste categories are excluded from weighing, such as construction waste.

Future research directions

Longitudinal environmental surveillance and microbiological waste profiling can enhance exposure–disease linking. Incorporating WASH and climate data would improve predictive modelling.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the corresponding author upon reasonable request, subject to discussion and approval by all authors.

Author contributions

NM: Conceptualization, Data curation, Investigation, Resources, Supervision, Writing – original draft, Writing – review & editing. SK: Conceptualization, Methodology, Supervision, Visualization, Writing – original draft, Writing – review & editing. VV: Formal analysis, Methodology, Software, Writing – review & editing. AR: Investigation, Supervision, Writing – review & editing. GR: Data curation, Writing – review & editing. KM: Conceptualization, Methodology, Supervision, Writing – review & editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. Author VV is supported with Department of Health Research, Indian Council of Medical Research, New Delhi [grant number R.12016/16/2023-HR dated 26 . 03.2024] and Indian Council of Social Science Research, New Delhi [grant number 19/LSS/2024-1054/HS&SP/SCD Dated 23.09.2024].

Acknowledgments

The authors would like to acknowledge the support of the Department of Community Medicine, Kalinga Institute of Medical Sciences (KIMS), KIIT University, Bhubaneswar, for facilitating the fieldwork. We sincerely thank the community participants from the urban and rural field practice areas for their cooperation and valuable time. We also acknowledge the contributions of frontline health workers and local stakeholders who assisted during data collection and community engagement activities.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvh.2026.1828143/full#supplementary-material

SUPPLEMENTARY FIGURE 1
Google. Location on Google Maps [Internet]. Google Maps; [cited 2026 May 20] Available from: maps.app.goo.gl.

References

1. World Bank. *What a Waste 2.0: A Global Snapshot of Solid Waste Management*. Washington DC: World Bank (2018).

2. WHO. *Safe Management of Wastes from Health-Care Activities*. Geneva: World Health Organization (2014).

3. UNEP. Global waste management outlook. Nairobi: United Nations Environment Programme (2015).

4. Central Pollution Control Board. Annual report on solid waste management in India. New Delhi: CPCB; (2022).

5. Ministry of Housing and Urban Affairs. Solid waste management rules (2016). Government of India.

6. Gupta N, Yadav KK, Kumar V. A review on current status of municipal solid waste management in India. *J Environ Sci*. (2015) 37:206–17. doi: 10.1016/j.jes.2015.01.034

7. Ferronato N, Torretta V. Waste mismanagement in developing countries. *Int J Environ Res Public Health*. (2019) 16:1060. doi: 10.3390/ijerph16061060

8. Kaza S, Yao L, Bhada-Tata P, Van Woerden F. *What a Waste 2.0*. Washington, DC: World Bank (2018).

9. Kar S, Mohapatra N, Mishra K. Burden of solid waste and control measures for health hazards emanating from its mismanagement in a populous country like India, with special reference to Odisha slums and rural areas. *Int J Multidiscip Res*. (2023) 5(6):1–10. doi: 10.36948/ijfmr.2023.v05i06.9359

10. NFHS IT. NFHS. Mumbai: International Institute for Population Sciences. Available online at: https://www.nfhsiips.in/nfhs5.php (Accessed May 20, 2026).

11. Joshi R, Ahmed S. Status and challenges of municipal solid waste management in India. *Cogent Environ Sci*. (2016) 2:1139434. doi: 10.1080/23311843.2016.1139434

12. Dangi MB, Urynowicz MA, Belbase S. Household solid waste generation in Nepal. *Waste Manag*. (2011) 31:1935–43.

13. Afroz R, Hanaki K. Waste management in Bangladesh. *Waste Manag*. (2009) 29:1395–402.

14. Kaza S, Yao L, Bhada-Tata P. *What a Waste 2.0: Global Snapshot of Solid Waste Management*. Washington, DC: World Bank (2018).

15. Sivaranjini R, Senthilkumaran S. Occupational skin disorders among waste handlers. *Indian J Dermatol*. (2014) 59:548.

16. Kumar S, Smith SR. Waste exposure and skin infection risk in rural India. *Waste Manag*. (2020) 102:361–9.

17. Paul KK, Dhar-Chowdhury P. Dengue ecology in urban slums. *PLoS Negl Trop Dis*. (2018) 12:e0006427.

18. Ebi KL, Nealon J. Dengue in urban environments. *Trop Med Int Health*. (2016) 21:889–98.

19. Mboera LEG, Rumisha SF. Vector-borne diseases in urban settings. *Parasit Vectors*. (2020) 13:1–10.

20. Teixeira JC, Oliveira GS. Environmental sanitation index and diarrhoea. *Cad Saude Publica*. (2012) 28:1653–64.

21. Gupta K, Arora NK. Panchayati raj and waste governance in India. *Indian J Public Adm*. (2016) 62:258–70.

22. Sommer M, Phillips-Howard P. Menstrual hygiene and waste disposal challenges. *PLoS Med*. (2015) 12:e1001962.

23. Wilson DC, Velis C. Informal recycling in developing countries. *Waste Manag Res*. (2009) 27:797–808.

24. Kar S, Mohapatra N, Mishra K. Burden of solid waste and control measures for health hazards in India with reference to Odisha. *Int J Multidiscip Res*. (2023) 5(6):1–8.