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Environmental and Public Health Implications of Waste Generation and Disposal in Selected Communities of Port Harcourt Metropolis, Nigeria: A Questionnaire Survey and Airborne Microbial Assessment

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ABSTRACT

Rapid urbanisation in Port Harcourt, Nigeria, has outpaced waste-management capacity, yet few studies have paired residents' reported practices with measured airborne microbial exposure. This study conducted a descriptive comparative cross-sectional investigation in four communities (Egbelu, Rumuodara, Diobu and Borokiri) and one control community with no visible waste dump. Structured questionnaires were administered face to face to 348 adult residents, and a structured checklist recorded environmental conditions. Airborne bacteria, fungi and *Staphylococcus* were sampled by passive sedimentation and expressed as CFU/m³; isolates were identified by cultural, morphological and biochemical methods. Results revealed that waste segregation was uncommon (7.1–39.7% across communities) and was lower in the four study communities combined (15.7%) than in the control community (39.7%; $p < 0.001$). Awareness that improper disposal affects community health (88.6–100%) and of its health risks (73.5–100%) was high, indicating a clear knowledge–practice gap. Between 8.8% and 42.9% of respondents reported a dumpsite near their home. Egbelu, Rumuodara and Diobu were rated dirty or very dirty by 87–97% of respondents, compared with 14.3% in the control community. Mean airborne total heterotrophic bacterial counts ranged from 98.27 to 727.20 CFU/m³, fungal counts from 15.72 to 157.29 CFU/m³ and *Staphylococcus* counts from 78.61 to 290.09 CFU/m³. Egbelu recorded the highest value for all three indicators and the control community the lowest. bacterial isolates were *Staphylococcus* spp. (32%), *Bacillus* spp. (25%), *Escherichia coli* (16%), *Streptococcus* spp. (10%), *Pseudomonas* spp. (10%) and *Micrococcus* spp. (7%). Fungal isolates were *Aspergillus* (32%), *Penicillium* (30%), *Fusarium* (16%), *Mucor* (15%) and *Rhizopus* (7%). The findings revealed that poor waste management in the study communities coincided with poorer sanitation and higher airborne microbial loads. Awareness alone is not translating into safe practice; integrated action on source segregation, reliable collection, discouraging open burning, community engagement and routine environmental monitoring is needed.

Keywords: Municipal Solid Waste, Open Dumping, Bioaerosols, Airborne Microorganisms, Environmental Sanitation.

Introduction

Global waste generation was estimated at 2.01 billion tonnes in 2016 and is projected to reach 3.40 billion tonnes by 2050, with the fastest growth in low- and middle-income countries, where waste is often dumped in unregulated sites or burned in the open (Kaza et al., 2018).

Port Harcourt, the capital of Rivers State, illustrates the problem. Rapid population growth, commercial activity and unplanned settlement have increased the volume and variety of waste produced, while collection, storage and disposal systems have not kept pace (Ayotamuno & Gobo, 2004; Ogbonna et al., 2007). An earlier household survey estimated waste generation in the metropolis at about 1.45 kg per person per day (Ogbonna et al., 2007). Waste that is uncollected or improperly disposed of affects health through several routes.

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Refuse heaps provide breeding sites for flies, rodents and mosquitoes, block drainage channels and contribute to flooding, and the open burning of waste degrades air quality (Boadi & Kuitunen, 2005; Giusti, 2009). Decomposing organic waste and disturbed refuse also release bioaerosols, airborne particles carrying bacteria, fungi and their products, which are associated with respiratory, allergic and infectious outcomes (Douwes et al., 2003). Quantitative exposure data from open dumpsites in Nigeria are scarce, which limits the design of interventions for workers and nearby residents (Akpeimeh et al., 2019). Studies in Port Harcourt have shown that dumpsite soils differ microbiologically from reference soils (Amadi et al., 2023), but residents' practices, perceptions and airborne exposure are rarely examined together.

Residents' behaviour is also central. Awareness of the dangers of improper disposal does not guarantee good practice when containers, separate collection and reliable services are unavailable. Evidence that combines what residents do and know with what is measurable in the air of their neighbourhoods can show whether the problem is mainly one of knowledge or of infrastructure (Robinson et al., 2026).

This study therefore assessed the environmental and public health implications of waste generation and disposal in selected communities of Port Harcourt metropolis. The specific objectives were to (i) identify waste generation and disposal practices among residents; (ii) determine waste segregation, proximity to dumpsites and awareness of health risks; (iii) assess environmental conditions and the adequacy of waste-collection services; and (iv) determine the microbial quality of ambient air in the study communities relative to a control community.

Materials and Methods

Ethical considerations

Ethical approval was obtained from the Research ethics committee, Faculty of basic medical Sciences, College of Medical Science, Rivers State University with approved number RSU/FBMS/REC/26/468, before data collection, and permission was obtained from community leaders where required. Participation was voluntary, written or verbal informed consent was obtained, and no personal identifiers were collected. Data were stored securely and used only for research. Standard biosafety procedures were followed in handling microbiological samples.

Study area and design

The study was conducted in Port Harcourt City Local Government Area (Diobu and Borokiri) and Obio/Akpor Local Government Area (Egbelu and Rumuodara), Rivers State. These communities were selected for their high population density, varied residential character and visible waste-disposal activity. A control location within the Government Reserved Area (GRA), with no evidence of waste dumping, was included for comparison. A descriptive comparative cross-sectional design with environmental sampling was used, combining a questionnaire survey, direct observation and microbiological air sampling over a six-month period.

Study population, sample size and sampling

Participants were adults aged 18 years or older who had lived in the community long enough to be familiar with local waste practices and who gave informed consent.

Visitors, temporary residents and those returning substantially incomplete questionnaires were excluded. The minimum sample size from Cochran's formula (Cochran, 1977),

$$n = \frac{-Z^2P(1-P)}{e^2}$$

With Z = 1.96, P = 0.50 and e = 0.05, was 384. Of 385 questionnaires administered, 348 were retrieved and analysed (response rate 90.4%): 70 in each of the four study communities and 68 in the control community.

A multistage approach was used: communities were chosen first, streets and waste-accumulation points were then identified by reconnaissance, and households were selected by systematic or simple random sampling depending on accessibility.

One eligible adult was interviewed per household. Air-sampling points were purposively placed near visible waste accumulation or disposal activity where human exposure was likely; the control point was placed in an area with minimal waste accumulation.

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Questionnaire and observation checklist

A structured, pre-tested questionnaire was administered face to face. It covered socio-demographic characteristics, types and frequency of waste generated, storage, segregation and disposal methods, proximity of dumpsites, awareness of health risks and observed environmental problems (Aleruchi et al., 2026). Face and content validity were established by review from experts in environmental health, microbiology and public health, and reliability was assessed by pre-testing among residents outside the study communities, after which ambiguous items were revised. A structured checklist recorded the condition of disposal sites, segregation, presence of flies and rodents, drainage blockage and the proximity of dumpsites to homes, schools, markets and water sources.

Air sampling and microbiological analysis

Airborne microorganisms were sampled by the passive sedimentation (settle-plate) method. Sterile Petri dishes containing Nutrient Agar, MacConkey Agar and Mannitol Salt Agar (bacteria) or Sabouraud Dextrose Agar (fungi) were exposed at 1–1.5 m above ground level for 20 minutes at each sampling points per community, then covered and transported to the laboratory. Bacterial plates were incubated at 35–37 °C for 24–48 h and fungal plates at 25–28 °C for 3–7 days. Colonies were counted and converted to CFU/m³ using the Omeliansky formula, $N = (5 \times a \times 10^4)/(b \times t)$, where N is the microbial concentration (CFU/m³), a the number of colonies per plate, b the plate surface area (cm²) and t the exposure time (minutes). Total heterotrophic bacterial count (THBC) was obtained on Nutrient Agar, *Staphylococcus* count on Mannitol Salt Agar and total fungal count (TFC) on Sabouraud Dextrose Agar. Representative colonies were sub-cultured and identified from colony morphology, Gram reaction and biochemical tests (bacteria), and from macroscopic and microscopic features (fungi). Aseptic technique and sterile materials were used throughout (Kpormon et al., 2023).

Statistical analysis

Questionnaire data were coded and entered into IBM SPSS Statistics. Categorical variables are summarised as frequencies and percentages. Pearson's chi-square test compared proportions across communities, and Fisher's exact test was used where expected cell counts were below five; significance was set at $p < 0.05$. Airborne counts are presented as community means and interpreted descriptively.

Results

The characteristics of the 348 respondents comprised 70 in each study community and 68 in the control community (Table 1). Females predominated everywhere (52.9–61.4%). The modal age group was 56 years and above in Egbelu (28.6%), 18–25 years in Rumuodara (27.1%), 36–45 years in Diobu (30.0%) and the control (30.9%), and 26–35 and 46–55 years equally in Borokiri (22.9% each). Primary education was most common in Egbelu (32.9%) and Borokiri (37.1%), secondary in Rumuodara (34.3%), while primary and secondary were equal in Diobu (28.6%). The control community had the highest educational attainment, with 41.2% each at secondary and tertiary level. Self-employment was the commonest occupation in Egbelu (41.4%), Diobu (61.4%) and Borokiri (40.0%), and civil service in Rumuodara (57.1%) and the control community (45.6%). Most respondents had lived in their community for one to ten years.

Results of waste generation and disposal practices showed that the predominant waste type differed by community (Table 2). Plastics dominated in Egbelu (72.9%), mixed waste in Diobu (54.3%), and plastics (41.4%) and food or organic waste (35.7%) in Borokiri. In Rumuodara, food or organic waste (27.1%) and mixed waste (28.6%) were the most frequent categories, and in the control community mixed (36.8%) and food or organic waste (33.8%). Daily disposal was the norm in the study communities (64.3% in Rumuodara to 80.0% in Diobu), whereas disposal frequency in the control community was more varied. Disposal methods practiced differs acrossed the sampling communities. Open burning was the main method in Egbelu (77.1%), with a further 10.0% disposing into drainage channels or water bodies and 5.7% dumping openly. Private waste collectors were most used in Rumuodara (65.7%), Diobu (75.7%) and Borokiri (52.9%). In the control community municipal collection was the main method (69.1%), and no

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respondent reported burning, open dumping or disposal into drains.

Table 1: Socio-demographic characteristics of respondents, n (%)

Variable	Location or Community				
	Egbelu (n = 70)	**Rumuodara (n = 70)**	**Diobu (n = 70)**	**Borokiri (n = 70)**	**Control (n = 68)**
Age (years)					
18–25	9 (12.9)	19 (27.1)	12 (17.1)	11 (15.7)	9 (13.2)
26–35	13 (18.6)	7 (10.0)	7 (10.0)	16 (22.9)	18 (26.5)
36–45	12 (17.1)	14 (20.0)	21 (30.0)	13 (18.6)	21 (30.9)
46–55	16 (22.9)	18 (25.7)	16 (22.9)	16 (22.9)	11 (16.2)
56 and above	20 (28.6)	12 (17.1)	14 (20.0)	14 (20.0)	9 (13.2)
Gender					
Male	27 (38.6)	27 (38.6)	33 (47.1)	30 (42.9)	30 (44.1)
Female	43 (61.4)	43 (61.4)	37 (52.9)	40 (57.1)	38 (55.9)
Education					
No formal	11 (15.7)	10 (14.3)	15 (21.4)	14 (20.0)	6 (8.8)
Primary	23 (32.9)	23 (32.9)	20 (28.6)	26 (37.1)	6 (8.8)
Secondary	21 (30.0)	24 (34.3)	20 (28.6)	15 (21.4)	28 (41.2)
Tertiary	15 (21.4)	13 (18.6)	15 (21.4)	15 (21.4)	28 (41.2)
Occupation					
Civil servant	25 (35.7)	40 (57.1)	7 (10.0)	26 (37.1)	31 (45.6)
Self-employed	29 (41.4)	21 (30.0)	43 (61.4)	28 (40.0)	29 (42.6)
Student	8 (11.4)	8 (11.4)	19 (27.1)	5 (7.1)	4 (5.9)
Unemployed	8 (11.4)	1 (1.4)	1 (1.4)	11 (15.7)	4 (5.9)

Table 2: Waste types, disposal frequency and disposal methods, n (%)

Variable	Location or Community				
	Egbelu	**Rumuodara**	**Diobu**	**Borokiri**	**Control**
Main waste type					
Food/organic	4 (5.7)	19 (27.1)	12 (17.1)	25 (35.7)	23 (33.8)
Plastics	51 (72.9)	11 (15.7)	7 (10.0)	29 (41.4)	16 (23.5)
Paper/carton	7 (10.0)	13 (18.6)	13 (18.6)	9 (12.9)	4 (5.9)
Glass/metal	3 (4.3)	7 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)
Mixed waste	5 (7.1)	20 (28.6)	38 (54.3)	7 (10.0)	25 (36.8)
Disposal frequency					
Daily	54 (77.1)	45 (64.3)	56 (80.0)	52 (74.3)	25 (36.8)
Twice a week	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	20 (29.4)
Weekly	16 (22.9)	14 (20.0)	14 (20.0)	18 (25.7)	11 (16.2)
Occasionally	0 (0.0)	11 (15.7)	0 (0.0)	0 (0.0)	12 (17.6)
Disposal method					
Municipal collection	5 (7.1)	24 (34.3)	17 (24.3)	26 (37.1)	47 (69.1)
Private collector	0 (0.0)	46 (65.7)	53 (75.7)	37 (52.9)	21 (30.9)
Open burning	54 (77.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Open dumping	4 (5.7)	0 (0.0)	0 (0.0)	7 (10.0)	0 (0.0)
Drain/water body	7 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

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Results on Segregation, proximity to dumpsites and awareness of health risks revealed that, segregation before disposal was generally poor (Table 3). Only 7.1% of respondents in Diobu, 15.7% in Borokiri, 17.1% in Egbelu and 22.9% in Rumuodara separated their waste, compared with 39.7% in the control community, which still left 60.3% not segregating. Segregation differed significantly across the five locations ($\chi^2 = 24.85$, df = 4, $p < 0.001$) and was lower in the four study communities combined (44/280, 15.7%) than in the control (27/68, 39.7%; $\chi^2 = 19.39$, $p < 0.001$). Overall, 20.4% of all respondents (71/348) separated waste. The proportion reporting a dumpsite close to their residence ranged from 8.8% in the control community to 42.9% in Borokiri ($\chi^2 = 32.43$, df = 4, $p < 0.001$).

Among those reporting a nearby dumpsite, most placed it within 50 m of the home, particularly in Egbelu and Borokiri.

Awareness was high. All respondents in Egbelu, Rumuodara, Borokiri and the control community, and 88.6% in Diobu, agreed that waste disposal affects community health.

All respondents in the four study communities were aware of the health risks of improper disposal, compared with 73.5% (50/68) in the control community (Fisher's exact test, $p < 0.001$); overall, 94.8% (330/348) of respondents were aware of such risks.

Table 3: Segregation, proximity to dumpsites and awareness of health risks, n (%) answering "Yes"

Response of Yes to Question	Location or Community				
	Egbelu	**Rumuodara**	**Diobu**	**Borokiri**	**Control**
Separate waste before disposal	12 (17.1)	16 (22.9)	5 (7.1)	11 (15.7)	27 (39.7)
Dumpsite close to residence	10 (14.3)	9 (12.9)	13 (18.6)	30 (42.9)	6 (8.8)
Waste disposal affects community health	70 (100.0)	70 (100.0)	62 (88.6)	70 (100.0)	68 (100.0)
Aware of health risks of improper disposal	70 (100.0)	70 (100.0)	70 (100.0)	70 (100.0)	50 (73.5)

Environmental conditions and adequacy of waste collection as to Perceived cleanliness and reported nuisances differed markedly between the study communities and the control (Table 4). Egbelu was rated worst, with 64.3% describing it as very dirty and 32.9% as dirty. Rumuodara and Diobu were also predominantly rated dirty (72.9% and 54.3%), whereas 52.9% of Borokiri respondents rated their surroundings moderately clean. In the control community, 25.7% described the area as very clean and 57.1% as moderately clean, and none described it as very dirty.

Nuisance profiles varied: foul odour was reported most in Egbelu (42.9%), flies and rodents in Borokiri (37.1%), blocked drainage in Diobu (31.4%) and smoke from burning waste in Rumuodara (17.1%). In the control community, 82.9% reported none of the listed nuisances. Waste-collection services were judged inadequate or very inadequate by 92.9% of respondents in Egbelu (80.0% inadequate, 12.9% very inadequate), whereas 94.3% in the control community rated services adequate or very adequate (70.0% very adequate). The other three communities fell between these extremes.

Table 4: Observed nuisances and perceived cleanliness, % of respondents

Indicator	Egbelu	Rumuodara	Diobu	Borokiri	Control
Nuisance observed					
Foul odour	42.9	34.3	28.6	22.9	0.0
Flies/rodents	18.6	22.9	25.7	37.1	0.0
Blocked drainage	28.6	25.7	31.4	25.7	17.1
Smoke from burning waste	11.4	17.1	14.3	14.3	0.0
None of these	0.0	0.0	0.0	0.0	82.9
Perceived cleanliness					
Very dirty	64.3	20.0	32.9	14.3	0.0
Dirty	32.9	72.9	54.3	32.9	14.3
Moderately clean or very clean	2.9	7.1	12.9	52.9	82.9

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The airborne microbial quality showed that, mean airborne counts are shown in Table 5. THBC was highest in Egbelu (727.20 CFU/m³), followed by Rumuodara (530.66), Diobu (400.94) and Borokiri (334.12), and lowest in the control community (98.27); the study-community means were 3.4 to 7.4 times the control value. Fungal counts followed a similar pattern: Egbelu 157.29, Rumuodara 137.58, Diobu 78.61 and Borokiri 39.31 CFU/m³, against 15.72 CFU/m³ in the control (2.5 to 10 times lower). *Staphylococcus* counts were highest in Egbelu (290.09 CFU/m³), followed by Rumuodara (169.03), Borokiri (125.79) and Diobu (117.92), and lowest in the control (78.61).

Table 5: Mean airborne microbial counts (CFU/m³) by community

Community	Total HB	Total fungi	*Staphylococcus* sp
Egbelu	727.20	157.29	290.09
Rumuodara	530.66	137.58	169.03
Diobu	400.94	78.61	117.92
Borokiri	334.12	39.31	125.79
Control	98.27	15.72	78.61

The bacterial isolates were *Staphylococcus* spp. (32%), *Bacillus* spp. (25%), *Escherichia coli* (16%), *Streptococcus* spp. (10%), *Pseudomonas* spp. (10%) and *Micrococcus* spp. (7%). Fungal isolates were *Aspergillus* (32%), *Penicillium* (30%), *Fusarium* (16%), *Mucor* (15%) and *Rhizopus* (7%). Percentages are of isolates pooled across the study communities.

Discussion

Waste-handling routes differed across the study communities, but a common feature was weak reliance on the municipal system: municipal collection was the main method only in the control community (69.1%), while private collectors carried most waste in Rumuodara, Diobu and Borokiri and open burning predominated in Egbelu. Where formal collection is unreliable, households turn to private operators, burning, dumping or drains, and the city's long-recognised collection and disposal problems (Ayotamuno & Gobo, 2004; Ogbonna et al., 2007) appear to persist.

Open burning of plastic-dominated waste, as in Egbelu, is of particular concern because uncontrolled burning is a recognised source of air pollution and a feature of waste management in low-income settings (Kaza et al., 2018; Giusti, 2009).

Segregation was low everywhere, including the control community, where six in ten respondents still did not separate waste. Source separation depends on more than willingness: it needs separate containers, a collection system that keeps the streams apart and a market or facility for recovered materials. None of these was assessed directly here, so the explanation that poor segregation reflects missing infrastructure is an interpretation, but it is consistent with the higher segregation and better service ratings in the control community.

Nearly all respondents (94.8%) knew that improper disposal poses health risks, yet only 20.4% separated waste and a substantial share burned, dumped or discharged waste into drains. The control community is instructive: it had the lowest awareness of health risks (73.5%) but the best practices and the most favourable service ratings. This pattern suggests that access to reliable services, rather than awareness alone, shaped behaviour. The control community also had higher educational attainment, so socio-economic advantage may contribute as well. Earlier work in Port Harcourt recommended pairing continuous public enlightenment with adequate technical services (Ogbonna et al., 2007), and the present data support that combination. Self-reported awareness may also be inflated by social desirability, and awareness of risk in general is not the same as knowing what to do differently.

The checklist and questionnaire findings point the same way. Egbelu combined the highest proportion of respondents rating the area dirty or very dirty (97.1%), the poorest rating of collection services (92.9% inadequate or very inadequate), widespread open burning and the most plastic waste. Reported nuisances reflected local conditions: foul odour in Egbelu, flies and rodents in Borokiri, where 42.9% of respondents also reported a dumpsite close to home, and blocked drainage in Diobu. Across the four study communities, 22.1% of respondents (62/280) reported a nearby dumpsite versus 8.8% (6/68) in the control (chi-square p = 0.013).

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Flies, rodents and blocked drains are the means by which waste affects health beyond the dumpsite itself, through vector-borne and water-related disease and flooding (Boadi & Kuitunen, 2005; Giusti, 2009).

Airborne bacteria, fungi and *Staphylococcus* were higher in all four study communities than in the control community, and Egbelu had the highest values for all three indicators. The ranking of communities by microbial load broadly mirrored their ranking by perceived dirtiness and poor collection, which strengthens the case that waste conditions contribute to airborne microbial burden. This is an ecological comparison across five sites, however, and cannot establish that waste caused the differences. The control site, in a GRA, differs from the study communities in land use, population density, traffic and socio-economic status, and other sources such as human activity, soil and dust resuspension, drains and vegetation also contribute airborne microorganisms.

The isolates are those expected from decomposing refuse and disturbed environmental media. *Staphylococcus*, *Pseudomonas*, *Streptococcus* and *E. coli* include opportunistic or pathogenic species, *Bacillus* is a common spore-former, and *Aspergillus*, *Penicillium*, *Fusarium*, *Mucor* and *Rhizopus* include allergenic and opportunistic fungi. Bioaerosols of this kind are associated with respiratory, allergic and infectious effects (Douwes et al., 2003). At Olusosun dumpsite in Lagos, exposure to bioaerosols was linked to dumpsite activities and may contribute to chronic respiratory symptoms among workers (Akpeimeh et al., 2019), and dumpsite soils in Port Harcourt show altered microbial activity relative to reference soils (Amadi et al., 2023). The presence of *E. coli* in air may reflect faecal contamination of dust or drains but was identified here only to genus or species level by routine methods, so its source cannot be inferred. Identification to genus level also does not establish that isolates were pathogenic strains.

Residents of the study communities, and particularly children, older adults, people with asthma or other chronic respiratory disease, and anyone working with waste, are plausibly exposed to higher bioaerosol loads than residents of cleaner areas. Health outcomes were not measured, so the findings indicate exposure potential rather than disease burden.

They nevertheless provide baseline evidence for environmental-health surveillance and justify follow-up studies linking exposure to respiratory and gastrointestinal outcomes. The study combined resident-reported practices, direct observation and measured airborne counts in the same communities with a comparison site, which allowed practices and environmental conditions to be read together. Limitations should be noted. The design was cross-sectional, and the sample (348) was below the calculated minimum of 384. Practices, awareness and nuisances were self-reported. Passive settle-plate sampling is semi-quantitative, depends on particle size and settling behaviour, and gives a snapshot rather than long-term exposure (Pasquarella et al., 2000). Microbial results are community means without formal statistical comparison, there was a single control community, and sampling was not stratified by season or weather. Species-level identification, antimicrobial susceptibility and particle-size distribution were not assessed. Finally, the questionnaire could not separate the effects of proximity to dumpsites from those of community-wide sanitation conditions. Studies with repeated, volumetric and size-fractionated sampling, several control sites and health outcome data would strengthen causal interpretation.

Conclusion

Waste generation and disposal in the study communities of Port Harcourt are associated with poor segregation, unreliable collection, open burning and dumping, poorer perceived sanitation and higher airborne bacterial, fungal and *Staphylococcus* loads than in a cleaner control community. Residents are largely aware of the health risks, so the central problem is the gap between awareness and the services, infrastructure and enforcement that make safe practice possible.

Recommendations: On this evidence we recommend: Waste-management authorities should provide regular, reliable collection and strategically located collection points, prioritising the communities with the poorest service ratings and those next to dumpsites. Open burning of waste, especially plastics, and disposal into drains should be discouraged and enforced against, alongside regulation of unauthorised dumping and the siting of disposal facilities.

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