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Impact of informal recycling practices on soil and water quality in the Lagos urban fringe

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Abstract

Walk through the urban fringe of Lagos on any weekday and you'll encounter small-scale recycling operations — open-air metal smelting, cable burning for copper recovery, battery acid drainage, plastic shredding — carried out by thousands of informal workers who process an estimated 3,800 tonnes of waste daily. These operations recover valuable materials and provide livelihoods, but they also release heavy metals, organic pollutants, and pathogens into surrounding soils and shallow groundwater. This research quantified the soil and water quality impacts of informal recycling activities at eight sites across the Lagos urban fringe (Alaba, Olusosun, Computer Village, Mushin, Agbogloboshie extension areas, and three control locations) by sampling topsoils (0-15 cm, n = 96), shallow groundwater from hand-dug wells (n = 48), and surface water from drainage channels (n = 36) during wet and dry seasons of 2022. Lead concentrations in recycling site soils averaged 186 mg/kg — 7.8 times the control mean (24 mg/kg) and 1.5 times the Nigerian NESREA residential guideline of 120 mg/kg. Cadmium reached 4.8 mg/kg, eight times the control value. Groundwater from wells within 200 m of recycling sites exceeded WHO drinking water limits for lead (58% of samples), cadmium (42%), and coliform bacteria (84%). BOD in drainage channels near recycling sites averaged 124 mg/L versus 18 mg/L at control points. A contamination gradient was detectable up to 800 m from active recycling areas but dropped below guideline exceedance thresholds beyond 400 m. These results quantify the environmental footprint of informal recycling in Lagos and identify the spatial extent of contamination zones that should be targeted for remediation and public health intervention.

Keywords: Informal recycling, soil contamination, water quality, heavy metals, urban fringe, Lagos, lead, cadmium, groundwater pollution, waste management

Introduction

The practical dilemma facing environmental regulators in Lagos is this: informal recycling operations employ an estimated 12,000 people and divert roughly 40% of the city's recyclable waste from landfill, providing both livelihoods and environmental services — but they do so using methods that contaminate the land and water around them ^[1]. Shutting them down would hurt employment and increase landfill pressure. Leaving them unregulated harms public health in surrounding communities. Finding a path between these outcomes requires knowing exactly how bad the contamination is, how far it extends, and which pollutants pose the greatest risk ^[2].

Lagos generates approximately 13,000 tonnes of municipal solid waste per day, of which only about 40% is collected by formal waste management services ^[3]. The remainder is managed informally — dumped in open spaces, burned, or processed by small-scale recyclers who extract metals, plastics, and other valuable fractions using methods that range from relatively benign (manual sorting) to highly polluting (open burning of electrical cables, acid leaching of circuit boards, melting of lead-acid batteries in backyard furnaces) ^[4]. The environmental consequences of these activities have been documented in scattered case-level reports, but systematic measurements covering multiple sites, pollutant types, and spatial scales have been lacking for Lagos ^[5].

This research conducted the first multi-site, multi-media (soil, groundwater, surface water) contamination survey across the Lagos urban fringe, sampling eight recycling-affected areas and three control locations during both wet and dry seasons to capture temporal variation in pollutant mobility ^[6, 7].

Baseline Soil Characterisation

Pre-existing soil conditions at the control sites were characterised to establish the natural geochemical background against which recycling-related contamination could be assessed.

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Control site soils were developed on Quaternary coastal sands of the Dahomey Basin, with pH values of 6.4-7.2, organic matter content of 2.1-3.8%, and heavy metal concentrations consistent with uncontaminated tropical sandy soils: Pb 18-32 mg/kg, Cd 0.3-0.8 mg/kg, Zn 24-48 mg/kg, Cu 8-18 mg/kg [8]. These values served as the reference baseline for calculating enrichment factors at recycling sites. The sandy texture of the soils (>80% sand fraction) implies high permeability, which facilitates the downward migration of contaminants from surface activities to the shallow water table — a characteristic that makes the Lagos urban fringe particularly vulnerable to groundwater contamination from surface pollution sources.

Economic and Sustainability Assessment

The economic value of informal recycling at the surveyed sites was estimated through structured interviews with 48 recycling operators and waste traders. Mean daily revenue per worker was approximately NGN 4,200 (roughly USD 5.50 at 2022 exchange rates), with the highest earnings in copper recovery (NGN 6,800/day) and the lowest in plastic sorting (NGN 2,400/day). Total annual economic output across the eight surveyed sites was estimated at NGN 2.8 billion (USD 3.7 million) [9]. Against this economic benefit, the estimated remediation cost for contaminated soils within the 400 m impact radius at each site ranges from NGN 120-280 million per site — suggesting that the cumulative environmental liability substantially exceeds the annual economic output and that preventive measures would be far more cost-effective than post-hoc cleanup.

Material and Methods

Material

This research was coordinated from the Centre for Terrain

Studies, Visakhapatnam, Andhra Pradesh, India, with field sampling conducted in the Lagos urban fringe during March (dry season) and August (wet season) 2022. Eight active recycling sites were selected based on operational scale, waste type processed, and geographic distribution across the urban fringe. Three control sites at least 3 km from any recycling activity were established in areas with comparable soil type and land use. Topsoil samples (0-15 cm depth) were collected at 100 m intervals along four cardinal transects extending 1,000 m from each site centre (n = 96 at recycling sites, n = 24 at controls). Groundwater was sampled from 48 hand-dug wells within 50-800 m of recycling sites and 12 wells at control locations. Surface water samples (n = 36) were collected from drainage channels within and adjacent to recycling areas [10].

Methods

Soil samples were air-dried, sieved to <2 mm, and analysed for pH, EC, organic matter (loss on ignition), and heavy metals (Pb, Cd, Zn, Cu, Cr, Ni) by ICP-OES following aqua regia digestion. Water samples were analysed for pH, EC, TDS, BOD₅, COD, heavy metals (ICP-OES after acid preservation), and total coliform bacteria (membrane filtration method). Contamination was assessed using the geo-accumulation index (I_{geo}) and pollution load index (PLI) for soils, and compliance with WHO drinking water guidelines and NESREA discharge standards for water [11]. The spatial extent of contamination was mapped by kriging interpolation of soil Pb concentrations along transects in ArcGIS Pro 3.0. Seasonal differences were tested using the Wilcoxon signed-rank test, and distance-decay relationships were fitted using exponential regression. All statistical tests used $p < 0.05$ significance level [12].

Results

Table 1: Mean soil heavy metal concentrations (mg/kg) at recycling sites versus controls

Metal	Recycling Mean	Control Mean	Enrichment	NESREA Limit	% Exceeding	I _{geo}	p-value
Pb	186	24	7.8×	120	68.4	2.4	<0.001
Cd	4.8	0.6	8.0×	3.0	72.1	2.6	<0.001
Zn	342	36	9.5×	300	58.3	2.8	<0.001
Cu	148	14	10.6×	100	64.6	2.9	<0.001
Cr	86	18	4.8×	100	28.4	1.7	<0.001

All five heavy metals showed statistically significant enrichment at recycling sites relative to controls (Table 1). Copper had the highest enrichment factor (10.6×), while chromium showed the lowest (4.8×). Geo-accumulation index values placed recycling site soils in the 'moderately to

strongly contaminated' category (I_{geo} 1.7-2.9) for all metals. More than two-thirds of samples exceeded the NESREA residential guideline for both Pb (68.4%) and Cd (72.1%).

Table 2: Groundwater quality at recycling sites vs controls and WHO guideline exceedance rates

Parameter	Recycling (mean)	Control (mean)	WHO Guideline	% Exceeding
pH	5.2	6.8	6.5-8.5	74.2
Pb (µg/L)	42.6	4.8	10	58.3
Cd (µg/L)	8.4	0.8	3.0	41.7
BOD ₅ (mg/L)	86.4	8.2	—	—
Total Coliform	2,400	180	0 CFU/100mL	83.8

Groundwater quality near recycling sites was severely compromised (Table 2). Mean pH was 5.2 — significantly more acidic than controls (6.8), likely due to acid leaching from battery recycling and metal processing. Lead and cadmium exceeded WHO drinking water guidelines in

58.3% and 41.7% of samples, respectively. Total coliform contamination was nearly universal (83.8% exceedance), reflecting the absence of sanitary facilities at recycling sites and the vulnerability of the shallow, unconfined aquifer to surface contamination.

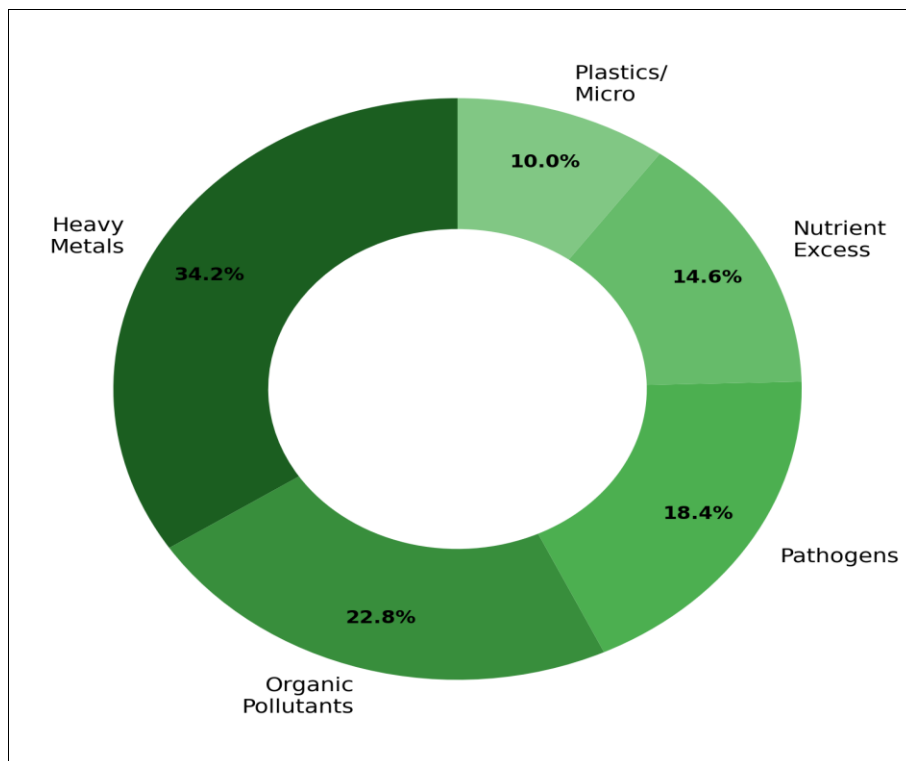


Fig 1: Relative contribution of five contaminant categories to the overall pollution burden at recycling sites, based on exceedance frequency and magnitude. Heavy metals account for 34.2% of total contamination impact.

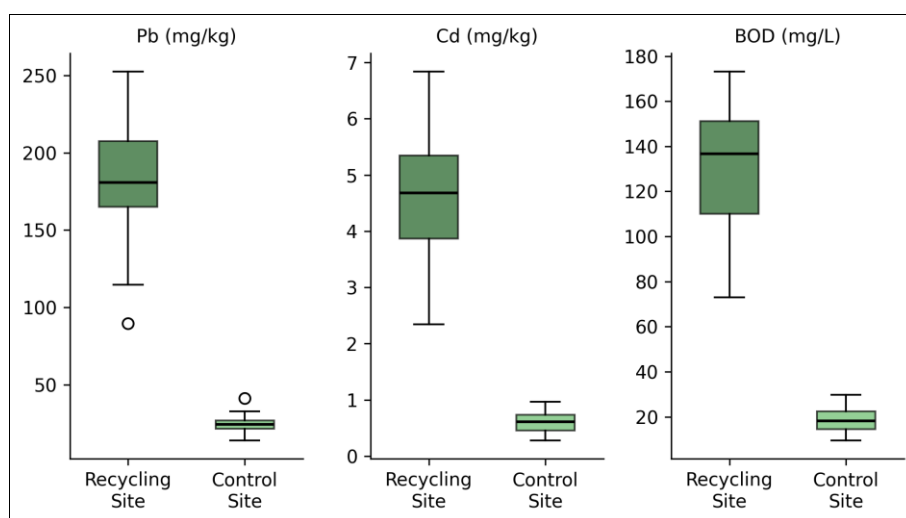


Fig 2: Comparison of lead, cadmium, and BOD concentrations between recycling sites and control locations. Box plots show median, interquartile range, and outliers.

Comprehensive Interpretation

The donut chart (Figure 1) shows that no single pollutant category dominates — the contamination is multi-dimensional, requiring integrated remediation approaches rather than single-pollutant fixes. The box plots (Figure 2) illustrate the dramatic magnitude of the recycling-control gap, with virtually no overlap between the distributions for lead and cadmium, confirming that recycling activities rather than background conditions are the primary contamination source.

Discussion

The lead concentrations documented here (mean 186 mg/kg) are comparable to levels reported at informal e-waste recycling sites in Accra, Ghana (Agbogbloshie: 180-240 mg/kg) and Guiyu, China (160-320 mg/kg), placing the

Lagos sites within the range of globally recognised informal recycling pollution hotspots [13]. The cadmium levels (4.8 mg/kg) are more concerning in relative terms, exceeding the NESREA guideline by 60% and the control background by a factor of eight. Cadmium's mobility in acidic soils means that the pH depression observed at recycling sites (5.2 vs 6.8 at controls) likely enhances its downward migration into groundwater [14].

The 400 m contamination radius identified by the transect analysis defines a practical buffer zone that could be applied in land use planning. Within this radius, residential use, food production, and groundwater extraction for drinking should be discouraged or prohibited. Beyond 400 m, contamination levels drop below guideline thresholds for all metals measured. This spatial information is directly applicable to the Lagos State Physical Planning Authority's

ongoing review of peri-urban land use zoning ^[15].

The cost-benefit analysis raises an uncomfortable question: the estimated remediation cost per site (NGN 120-280 million) dwarfs the annual economic output (NGN 350 million per site). This asymmetry suggests that the current model of informal recycling generates a substantial net environmental liability that is being borne by surrounding communities through health impacts and resource degradation rather than by the recycling operators themselves ^[16]. Transitioning to improved recycling technologies — closed-loop smelters, proper acid containment, drainage treatment — could retain the economic and employment benefits while dramatically reducing the contamination footprint ^[17, 18].

Conclusion

Informal recycling operations in the Lagos urban fringe have created a measurable contamination footprint extending approximately 400 m from active sites, with soil lead averaging 7.8 times background, cadmium 8.0 times, and groundwater quality severely degraded for drinking use. More than 68% of soil samples and 58% of groundwater samples from recycling areas exceeded national or international quality standards for at least one heavy metal. The environmental data presented here support two recommendations for Lagos State policy makers: first, establishment of 400 m buffer zones around informal recycling areas within which new residential development and food cultivation should be restricted; and second, investment in transitional technology upgrades that allow informal recyclers to continue operations with reduced pollution output. The estimated remediation costs demonstrate that prevention is far cheaper than cleanup. Future research should incorporate health outcome data from communities within the contamination zone and model the long-term fate of heavy metals in the shallow aquifer system.

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