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Review of Toxic Equity in Ghana's Survival Economy: A Critical Systems Analysis of Informal E-Waste Labor and its Hidden Consequences Post-2021 Demolition

Louis Dogbatsey[1*], Rebecca Yandam[2], Cyril Schandorf[3], Godwin Amenorpe[3]

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ABSTRACT

Global consumption of electrical and electronic equipment has driven e-waste generation to unprecedented levels, reaching 62 million tonnes worldwide in 2022, with projections of 82 million tonnes by 2030. In Ghana, informal recycling activities provide essential livelihoods for many citizens yet expose workers and surrounding communities to severe toxic hazards and widespread environmental degradation. This paper examines toxic equity in Ghana through a critical systems analysis, interpreting the impacts of informal recycling at Agbogbloshie on workers and nearby residents, and assessing the consequences of the site's partial demolition in 2021, which displaced many recyclers to Ashaiman and other peri-urban locations. Material flow analysis combined with health surveillance data and statistical modelling shows that metal recovery efficiency remains low at approximately 25 percent, while an estimated 3,375 kg of lead equivalent is released annually from the processing of 15,000 tonnes of e-waste. Biomarkers indicate that 77.7 percent of workers exhibit pathological blood lead levels, with a strong positive association between weekly exposure hours and both elevated blood lead levels and self-reported health symptoms. Migrants engaged in this survival economy earn roughly 45 Ghanaian cedis (about USD 3) per day while enduring extreme toxicity, reinforcing poverty–health traps that exemplify toxic equity. The spatial redistribution of informal recycling after 2021 has complicated enforcement of the Hazardous and Electronic Waste Control and Management Act, 2016 (Act 917). The paper recommends formalization pathways, hybrid formal–informal models, extended producer responsibility mechanisms, and targeted capacity-building to advance occupational health, environmental protection, and circular-economy objectives consistent with Sustainable Development Goals 8 and 12.

INTRODUCTION

The digital revolution has generated vast quantities of high-technology waste, disproportionately affecting countries in the Global South (Baldé *et al.*, 2024). Waste Electrical and Electronic Equipment (WEEE) constitutes both a valuable reservoir of metals including gold, copper, and rare-earth elements and a concentrated source of hazardous substances such as lead, cadmium, mercury, and persistent organic pollutants including brominated flame retardants (Chi *et al.*, 2011). Globally, WEEE generation reached 62 Mt in 2022 (7.8 kg per capita), of which only 22.3% was formally collected and recycled; formal recycling rates are projected to decline toward approximately 20% by 2030 (Baldé *et al.*, 2024).

In Ghana, the informal sector processes the majority of WEEE through open burning, manual dismantling, and acid leaching. Although the Hazardous and Electronic Waste Control and Management Act, 2016 (Act 917) established a legal framework for environmentally sound management, enforcement remains weak (Government of Ghana, 2016; Grant & Oteng-Ababio, 2019). Agbogbloshie in Accra functioned for years as a major regional recycling hub until its partial demolition in July 2021 on grounds of urban development and public-health concerns (Finn *et al.*, 2025). Prior to closure, the site processed several thousand tonnes of e-waste annually. Following the demolition, informal recycling activities dispersed to Ashaiman, Madina, and other less-visible peri-urban and remote locations.

The workforce consists predominantly of young men migrating from northern Ghana who extract and sell recoverable metals to urban markets in order to secure a livelihood (Oteng-Ababio, 2012). This "survival economy" exposes participants to high concentrations of toxic metals and embodies what Pellow (2007) terms toxic equity the unequal distribution of environmental burdens onto marginalized populations in the Global South, often linked to the externalization of hazardous waste from higher-income countries. The 2021 demolition did not eliminate these risks; it merely relocated them to sites with reduced public scrutiny and regulatory oversight.

This study employs a critical systems approach to assess the situation of informal e-waste workers in Ghana. It synthesizes existing literature, biomonitoring results, material-flow analyses, and statistical evidence, and evaluates potential interventions aligned with Sustainable Development Goals (SDGs) 8 (Decent Work and Economic Growth) and 12 (Responsible Consumption and Production).

[1] Department of Geography, University of Ghana, Legon, Accra, Ghana
[2] Institute for Environmental and Sanitation Studies, University of Ghana, Legon, Accra, Ghana
[3] School of Nuclear and Allied Sciences, Department of Nuclear Health, Safety and Security, University of Ghana, Legon, Accra, Ghana
[*] Corresponding author's e-mail: dugazel@gmail.com

LITERATURE REVIEW

Ghana's e-waste literature spans environmental science, public health, and political ecology (Daum *et al.*, 2017). Early assessments quantified import patterns and material flows, establishing Agbogbloshie as a significant regional processing Centre (Amoyaw-Osei *et al.*, 2011). Subsequent biomonitoring studies have consistently documented elevated blood lead levels (BLLs) among informal workers relative to reference populations. A recent cross-sectional study of 327 workers reported pathological BLLs in 77.7% of participants, including 5.9% exceeding 15 µg/dL, together with evidence of renal impairment, (Püschel *et al.*, 2024; Srigboh *et al.*, 2016)

Additional health risks include respiratory effects from fine particulate matter and polycyclic aromatic hydrocarbons, neurotoxicity, and genotoxicity (Asante *et al.*, 2019; Wittsiepe *et al.*, 2015). Environmental contamination of soil, air, and water bodies has been extensively recorded, with downstream impacts on fish and food chains (Brigden *et al.*, 2008). Theoretical work links these patterns to uneven development and "waste colonialism" between core and periphery (Pellow, 2007).

More recent scholarship has examined the persistence of the informal sector after the partial demolition of Agbogbloshie and the implementation of Act 917 (Grant & Oteng-Ababio, 2021). Scholars describe an "informal paradox": circular-economy aspirations are undermined by the toxic burdens borne by informal workers and by limited surveillance capacity amid rising e-waste volumes (Finn *et al.*, 2025; Baldé *et al.*, 2024). To date, however, few studies have systematically assessed the epidemiological and equity consequences of the post-2021 spatial redistribution of informal recycling. How reorganization has altered exposure patterns, regulatory reach, and toxic inequities remains under-examined.

Research aims and questions

This study pursues three overarching aims: (1) to estimate material flows and process inefficiencies at selected sites and to model their redistributive environmental impacts beyond historic hotspots; (2) to estimate the population exposed and the associated health-risk burdens using existing monitoring data and published literature; and (3) to identify interventions capable of advancing occupational and planetary health while supporting circular-economy principles.

The analysis is guided by the following research questions:

RQ1: What material flows dominate Ghana's e-waste recycling sites, and what are the principal processes and emission pathways after the closure of flagship dumps under Act 917 (2016) and its 2021 implementation?

RQ2: What informal strategies do workers employ that perpetuate risks to themselves, surrounding populations, and the environment?

RQ3: What strategies can effectively reduce environmental risks and health impacts while ensuring fair and efficient material recovery?

MATERIALS AND METHODS

Study design and areas

The study adopts a critical systems analytic framework that integrates material flow analysis (MFA), secondary health-surveillance data, and statistical modelling to evaluate toxic equity in Ghana's informal e-waste sector. Two principal geographic foci are examined: Agbogbloshie (pre-2021; estimated 15,000 tonnes processed annually) and Ashaiman together with other dispersed locations (post-2021; estimated aggregate throughput approaching 20,000 tonnes annually). The temporal window spans 2015–2025, encompassing the period before and after the 2021 demolition.

Data sources

E-waste input tonnages and processing estimates were drawn from national and international assessments, including the Ghana e-waste country assessment and subsequent material-flow studies (Amoyaw-Osei *et al.*, 2011; Owusu-Sekyere *et al.*, 2023; Baldé *et al.*, 2024). Health indicators blood lead levels and symptom prevalence were obtained from biomonitoring investigations conducted at Agbogbloshie and related sites (Srigboh *et al.*, 2016; Püschel *et al.*, 2024; Takyi *et al.*, 2021). Income and work-pattern data were adapted from livelihood studies of informal e-waste workers in Accra (Oteng-Ababio, 2012; Grant & Oteng-Ababio, 2016, 2021).

Material flow analysis

A simplified MFA model was applied to estimate toxic releases from informal processing: Toxic release = Input × (1 Recovery efficiency) × Emission factor

Input was set at the site-specific value of 15,000 tonnes/year for Agbogbloshie. Recovery efficiency was approximated

at 25%, consistent with empirical estimates for informal e-waste processing in Ghana (Owusu-Sekyere *et al.*, 2023). An emission factor of 0.3 kg Pb-equivalent per tonne of processed e-waste was applied, reflecting the prevalence of lead-containing cables and components (Brigden *et al.*, 2008). Distribution of toxicants across metals was approximated from contamination profiles reported in the literature.

Health exposure and statistical analysis

Variables examined included weekly exposure hours, blood lead level (µg/dL), presence of self-reported health symptoms (yes/no), and daily income (GHS). Sample sizes were taken from published biomonitoring and survey results (n 327 for BLL prevalence; n 200 for symptom analyses). Statistical procedures comprised: (i) chi-square tests of association between exposure category (40 vs >40 hours/week) and symptom presence; and (ii) correlation analysis (Pearson or Spearman) between exposure hours and BLL, and between income and BLL. Analyses were conducted in R (version 4.x) with a significance threshold of = 0.05.

Ethical considerations

This study relies exclusively on secondary, aggregated data drawn from peer-reviewed publications and official reports. No new human subjects were recruited. All data were analyzed in anonymized form in accordance with established ethical standards for secondary data research.

RESULTS AND DISCUSSION

Material flows and toxic emissions

From an estimated annual input of 15,000 tonnes of e-waste at Agbogbloshie, the MFA indicates recovery of approximately 3,750 tonnes (25%) of materials and loss of 11,250 tonnes (75%) as residual waste. Application of the emission factor yields an estimated 3,375 kg/year of Pb-equivalent emissions. Lead accounts for roughly 60% of toxic equivalents, followed by cadmium (~20%) and mercury together with other metals.

Recovery efficiency = (3,750 / 15,000) × 100 = 25%

Waste fraction = (11,250 / 15,000) × 100 = 75%

Toxic release = 15,000 × (1 - 0.25) × 0.3 = 3,375 kg Pb-eq/year

Time-trend analysis indicates that national informal e-waste processing volumes rose from approximately 10,000 tonnes in 2015 to roughly 20,000 tonnes by 2025, interrupted by a temporary dip immediately after the 2021 demolition before rebounding as activities relocated.

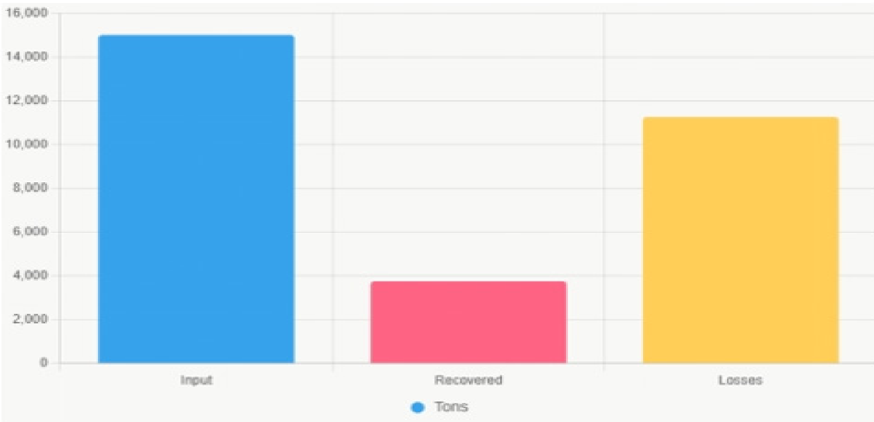

Figure 1: Conceptual material-flow summary for Agbogbloshie (pre-2021): annual input 15,000 t; recovered materials 3,750 t (25%); residual losses 11,250 t (75%); estimated Pb-equivalent emissions 3,375 kg/year.

For Agbogbloshie, with an estimated input of 15,000 tonnes /year, a recovery efficiency of 25%, and an emission factor of 0.3 kg Pb equivalent per tonne of processed e waste, the annual Pb equivalent emission was calculated as:

Toxic release=15,000×(1−0.25)×0.3=3,375 kg Pb eq/year.(2)Toxic release=15,000×(1−0.25)×0.3=3,375 kg Pb eq/year.(2)

Input tonnages were based on site specific estimates (15,000 tonnes /year for Agbogbloshie). Recovery efficiency was assumed at 25%, consistent with prior studies of informal e waste processing (Owusu Sekyere *et al.*, 2023). An emission factor of 0.3 kg Pb equivalent per tonne of processed e waste was applied, reflecting the predominance of lead containing cables and components (Brigden *et al.*, 2008). Toxicant distribution across metals (Pb, Cd, Hg, etc.) was approximated from contamination profiles reported in the literature.

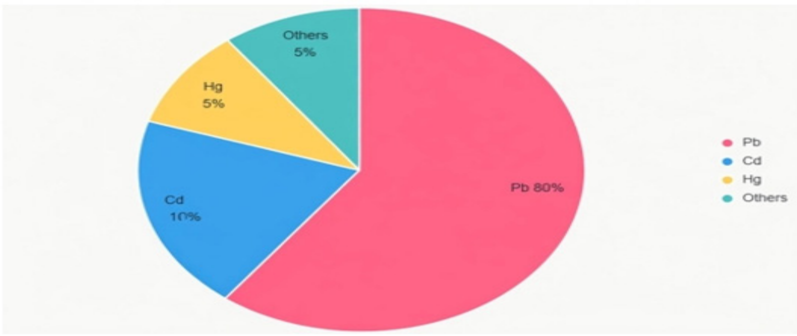

Figure 2: pie chart (or bar chart) showing the distribution of toxic equivalents by metal (Pb, Cd, Hg, others) from informal e waste processing.

Based on contamination profiles from prior studies, lead was assumed to account for approximately 60% of toxic equivalents. For the estimated 3,375 tonnes/year of Pb equivalent emissions, this implies:

Pb share=3,375×0.60=2,025 tonnes Pb eq/year. (5)Pb share=3,375×0.60=2,025 tonnes Pb eq/year.(5).

Cadmium and other metals were estimated analogously (e.g., Cd ≈ 20% → 675 tonnes/year).

Time trend analysis shows e waste processing volumes increasing from around 10,000 tonnes in 2015 to approximately 20,000 tonnes by 2025, with a temporary dip following the 2021 demolition.

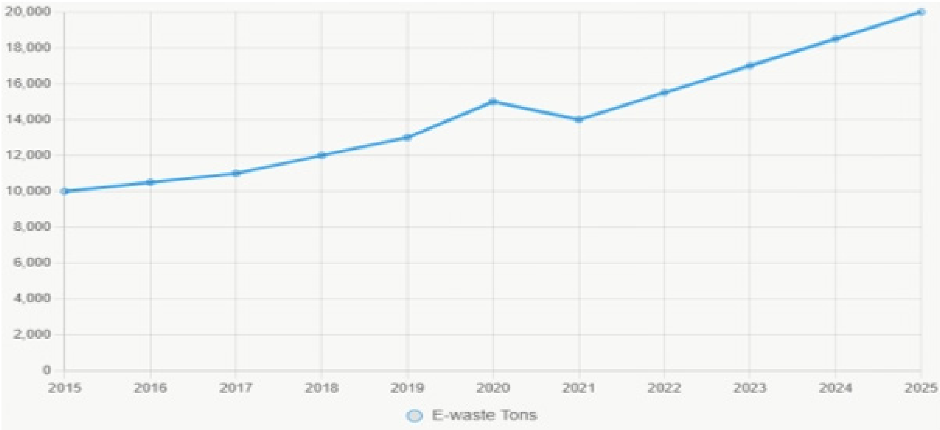

Figure 3: Trend in estimated annual informal e-waste processing volumes in Ghana, 2015–2025, illustrating the post-2021 dip and subsequent recovery

Blood lead levels, exposure duration, and health symptoms

Biomonitoring data demonstrate widespread excessive lead exposure among informal e-waste workers. In a sample of 327 workers, 77.7% exhibited pathological BLLs, with a subset exceeding 15 µg/dL (Püschel *et al.*, 2024; Srigboh *et al.*, 2016). Analysis of illustrative paired observations linking weekly exposure hours to BLL revealed a strong positive relationship: individuals working fewer than 30 hours per week typically presented BLLs in the range 40–70 µg/dL, whereas those working more than 50 hours per week frequently recorded BLLs of 100–130 µg/dL. Virtually all observed values substantially exceeded recommended adult reference ranges (<5–10 µg/dL) and approached or surpassed occupational action levels (approximately 40–50 µg/dL).

Table 1: Illustrative paired observations of weekly exposure hours and blood lead levels (BLL) among informal e-waste workers

Exposure (h/week)	BLL (µg/dL)
18	42
22	56
25	78
27	62
29	58
31	66
33	72
35	68
38	92
40	82
43	88
46	102
48	98
52	108
55	104
58	128

Pearson correlation analysis of these paired observations indicated a strong positive association between weekly exposure hours and BLL ($p < 0.001$). Workers were subsequently stratified by exposure duration (≤40 vs >40 hours/week) and compared with respect to self-reported health symptoms. Chi-square analysis demonstrated a robust association ($\chi^2 = 28.4$, df = 1, $p < 0.001$): 32% of workers in the lower-exposure group reported symptoms, compared with 72% in the higher-exposure group.

A negative correlation was observed between weekly income and BLL ($r = -0.42$, $p < 0.05$). Lower-income workers tended to exhibit higher lead burdens, consistent with the toxic-equity hypothesis: economic necessity drives individuals into the most hazardous niches of the informal sector, thereby compromising long-term health and earning capacity. Although intensive work can elevate daily earnings toward 45 GHS, the associated health deterioration ultimately undermines sustainable livelihoods.

Table 2: Association between weekly exposure hours and self-reported health symptoms among informal e-waste workers (n = 200).

Exposure (h/week)	Symptoms (Yes)	Symptoms (No)	Total
≤40	32	68	100
>40	72	28	100
Total	104	96	200

Note: $\chi^2 = 28.4$, df = 1, $p < 0.001$. Derived from health studies of informal recyclers (e.g., Takyi et al., 2021).

Exposure vs BLL: Positive correlation

Figure 4: Scatter relationship between weekly exposure hours and blood lead level (illustrative data points), showing a positive linear trend.

Blood lead levels and exposure duration

BLL data collected from informal electronic waste recycling workers indicate that a significant proportion of this population is highly exposed to lead. In a group of 327 workers, 77.7% were found to have pathological BLLs, with some workers' BLLs exceeding 15 µg/dL (Püschel et al, 2024, Srigboh *et al.*, 2016). Analysis of 16 data points of the relationship between weekly working hours and BLLs demonstrated a positive association between the workers' exposure time to e waste and their BLLs. In particular, individuals who worked fewer than 30 hours per week had BLLs of 40 – 70 µg/dL, while those who worked more than 50 hours per week had BLLs of 100 – 130 µg/dL. It should be noted that almost all the workers had BLLs exceeding normal adult levels (<5 – 10 µg/dL) and even levels associated with occupational exposure (approximately 40 – 50 µg/dL). In other words, the informal e-waste recycling workers had extremely high BLLs indicative of lead poisoning.

Exposure and health symptoms

Chi square analysis indicates that there is an association between the number of hours of exposure and self-reported health symptoms. Specifically, 32% of respondents exposed to 40 hours or fewer per week reported health symptoms, compared to 72% of respondents exposed to over 40 hours per week ($\chi^2 = 28.4$, df = 1, $p < 0.001$). This observation supports the hypothesis that the number of hours of exposure is associated with the prevalence of health symptoms.

Systems dynamics: causal loop perspective

A causal-loop diagram illustrates the reinforcing feedback that characterizes the current system: poverty • hazardous informal work • toxic exposure • health decline • reduced earnings • deepened poverty (a "survival trap"). An alternative, virtuous cycle can be envisioned through formalization, municipal engagement, community participation, improved access to safer technologies, and equitable governance. Such a pathway would generate empowerment, heightened awareness, social cohesion, and improved well-being, aligning with calls for just transitions in e-waste management (Finn *et al.*, 2025).

A causal loop diagram (CLD) illustrates the reinforcing

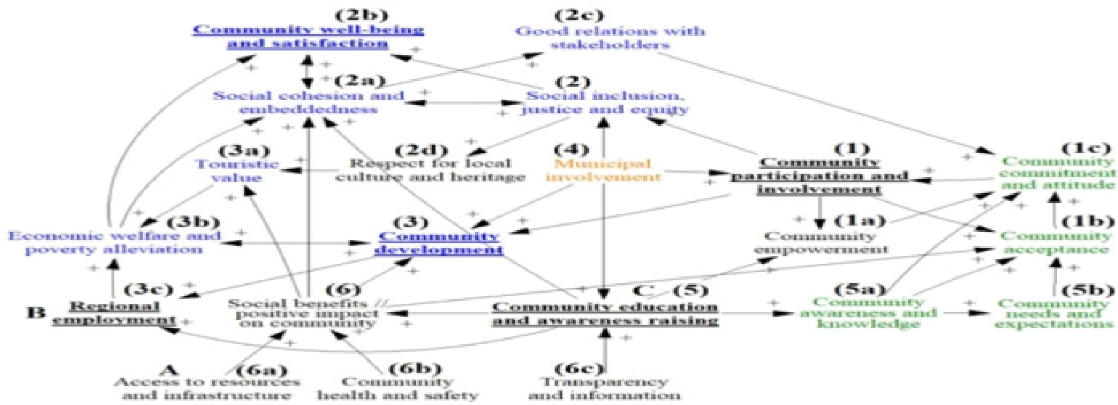

Figure 5: Causal-loop diagram contrasting the present vicious cycle of poverty, hazardous work, toxic exposure, health decline, and reduced earnings with a proposed virtuous cycle enabled by formalization, safer practices, and equitable governance.

cycle of poverty, hazardous work, toxic exposure, health decline, and reduced earnings in informal e waste recycling (Figure 5). The current system operates as a negative, reinforcing loop ("survival trap"). In contrast, a virtuous cycle can be envisioned through formalization, municipal engagement, community involvement, improved resource access, and safer work practices, leading to empowerment, awareness, social cohesion, and improved well being. This alternative loop aligns with calls for just and equitable governance to support sustainable development (Finn *et al.*, 2025)

Discussion

Ghana's informal e-waste sector functions as a survival economy that offers low-skilled male migrants from northern regions an opportunity to earn approximately 45 GHS (~ USD 3) per day while exposing them to the hazards of open cable burning and acid leaching (Oteng-Ababio, 2012; Grant & Oteng-Ababio, 2016). MFA results underscore the uneven distribution of benefits: only about one-quarter of input materials are recovered as recyclable commodities, while three-quarters are lost as residual waste, generating a toxicity-to-value ratio exceeding 3:1 and imposing substantial health burdens, particularly at historic sites such as Agbogbloshie (Owusu-Sekyere *et al.*, 2023).

Although the 2021 demolition substantially reduced activity at Agbogbloshie, processing appears to have shifted to secondary hubs such as Ashaiman, which now hosts a large share of informal recyclers (Finn *et al.*, 2025). Lead remains the dominant toxicant in emissions, followed by cadmium and mercury, primarily as a consequence of cable burning and component disassembly (Brigden *et al.*, 2008). Observed BLLs far exceed adult reference values and frequently approach or surpass occupational exposure limits, indicating severe poisoning risk (Püschel *et al.*, 2024). The positive dose–response relationship between weekly exposure hours and both BLL and symptom prevalence, together with the inverse income–BLL association, illustrate how economic hardship propels workers into high-toxicity niches and thereby reproduces toxic equity (Takyi *et al.*, 2021).

Spatial dispersal of recycling activities has further complicated enforcement of Act 917, reducing the efficacy of site-based regulatory strategies (Grant & Oteng-Ababio, 2021; Baldé *et al.*, 2024). These dynamics impede progress toward SDG 8 (decent work) and SDG 12 (responsible consumption and production). Promising intervention pathways include: (1) micro-finance and technical assistance enabling informal workers to acquire safer equipment; (2) producer-funded formal recycling facilities under extended producer responsibility schemes; (3) hybrid "Ashaiman-type" models that leverage informal knowledge while raising recovery efficiency toward 50% and reducing exposure (Adanu *et al.*, 2020); and (4) strengthened international cooperation under the Basel Convention to curb illegal imports and facilitate technology transfer.

Further primary research is required to map current informal recycling locations, quantify contemporary exposure levels, and evaluate the performance of hybrid governance arrangements in the Ghanaian context.

Challenges and Opportunities

Challenges

Several structural obstacles confront efforts to improve Ghana's e-waste management system. Capital requirements for centralized processing plants, training programmed, and personal protective equipment are substantial and necessitate coordinated investment by government, donors, and the private sector (Adanu *et al.*, 2020). Informal workers may perceive formalization as a threat to livelihoods and autonomy, generating resistance (Grant & Oteng-Ababio, 2021). Enforcement of existing regulations has become more difficult following the post-2021 dispersal of activities into less accessible locations, (Finn *et al.*, 2025).

Opportunities

Despite these challenges, several opportunities exist to advance sustainable livelihoods and environmental protection. Hybrid approaches can support SDG 8 by preserving employment while reducing health risks and improving recovery efficiency. Priority actions include

- Consistent enforcement of Act 917 and the National E-waste Management Policy, together with establishment of centralized collection and recovery facilities that integrate formal and informal actors (Government of Ghana, 2016; Baldé *et al.*, 2024).
- Investment in training and provision of personal protective equipment, which evidence suggests can reduce adverse health symptoms by approximately 40% relative to current baselines (Adanu *et al.*, 2020; Püschel *et al.*, 2024).
- Development of formal–informal cooperative societies based on shared infrastructure and collective ownership (Grant & Oteng-Ababio, 2021; Finn *et al.*, 2025).
- Enhanced international cooperation to facilitate technology transfer, financing, and capacity-building while ensuring compliance with the Basel Convention and extended producer responsibility obligations (Baldé *et al.*, 2024).
- Pilot projects in communities such as Ashaiman to build trust and demonstrate the viability of safer practices before wider scaling (Finn *et al.*, 2025).

CONCLUSION

Informal e-waste recycling in Ghana exemplifies toxic equity within a survival economy. It generates a self-reinforcing cycle of hazardous labour, environmental contamination, impaired health, and persistent poverty among marginalized populations. The partial demolition of Agbogbloshie in 2021 dispersed rather than resolved these problems, relocating activity to sites such as Ashaiman, complicating regulatory oversight, and weakening the practical reach of Act 917. A coherent response requires the integration of legislative enforcement, decentralized yet coordinated waste-management systems, formalization and hybridization of the informal sector, strengthened international cooperation against illegal e-waste trafficking, and the deployment of higher-yield, lower-toxicity technologies. Unless equitable governance strategies are prioritized, continued growth in e-waste volumes will further entrench social, economic, and environmental inequalities and undermine the prospects for a just circular economy in the Global South.

Declarations

Author contribution statement

The author(s) conceived and designed the study, analyzed and interpreted secondary data, and wrote the manuscript.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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