

Commentary

Urban Waste Management, Air Quality, and Public Health: Assessing the Health Burden of Rapid Urbanization in Sub-Saharan Africa

Chukwuemeka John^{1,†}

ABSTRACT

Rapid urbanization in sub-Saharan Africa (SSA) is placing increasing pressure on waste management systems and urban air quality, with significant health implications. This study integrates cross-city analysis of waste systems, air quality, and health burdens in rapidly urbanizing SSA. It examines the links between waste practices, pollution, and health outcomes in fast-growing SSA cities using international and national data sources. Inadequate collection, open dumping and burning, and poorly regulated landfills elevate pollutant concentrations, particularly PM_{2.5}, frequently exceeding World Health Organization guidelines. Resulting exposures are associated with respiratory and cardiovascular diseases, childhood infections, and premature mortality, disproportionately affecting low-income settlements. These inequities reflect deficits in governance and infrastructure. The study highlights the cumulative health burden of urbanization and calls for strengthened waste systems, reduced open burning, improved monitoring, and integration of health considerations into urban planning to support sustainable African cities. A comparative analysis of waste management, air quality, and related health impacts is conducted across four rapidly urbanizing SSA cities.

Rapid urbanization in Sub-Saharan Africa (SSA) is advancing without the institutional, infrastructural, and regulatory capacity required for effective management. Urban populations are projected to double by 2050, with cities such as Lagos, Nairobi, and Kinshasa expanding rapidly and intensifying pressures on governance, infrastructure, and socio-spatial equity (1–3). Limited financing and weak institutions contribute to the growth of informal settlements characterized by overcrowding, inadequate services,

and heightened environmental and health risks (4–6). Increasing consumption and waste generation further reveal the inadequacy of prevailing urban development models (2–3,5). Waste management systems remain under-resourced, relying heavily on open dumping and poorly managed landfills, while modern treatment and recycling options remain limited (7–11). Informal waste pickers contribute significantly to recycling yet remain marginalized, and community or public–private initiatives have limited impact without integrated regulatory and behavioral strategies (12–13). Air quality is deteriorating due to emissions from vehicles, industry, open waste burning, and biomass fuel use, often exceeding World Health Organization (WHO) guidelines and resulting in substantial health impacts (14–17). Weak monitoring capacity creates persistent data gaps that undermine accountability and obscure the full economic and health costs (15,18). Vulnerable groups (including children, older adults, and low-income communities) experience disproportionate exposure (14,19). Poor waste management and air pollution jointly intensify public health risks, contributing to infectious, respiratory, and chronic diseases. Mismanaged waste contributes to outbreaks such as cholera and malaria, while air pollution increases the incidence of asthma, lung cancer, and cardiovascular disease (20–21). Urban health systems, particularly in informal settlements, struggle to respond effectively (11,22–23). These interconnected challenges increase healthcare costs, reduce productivity, and constrain national development. This study proposes an integrated, justice-focused framework to align environmental and health policies and strengthen equitable, resilient urban health systems (Figure 1). Rapid urbanization in SSA has intensified air pollution through open waste burning, traffic emissions, industrial activity, and biomass fuel use. In many cities, PM_{2.5} concentrations exceed international guidelines, increasing the risk of respiratory and cardiovascular diseases and premature

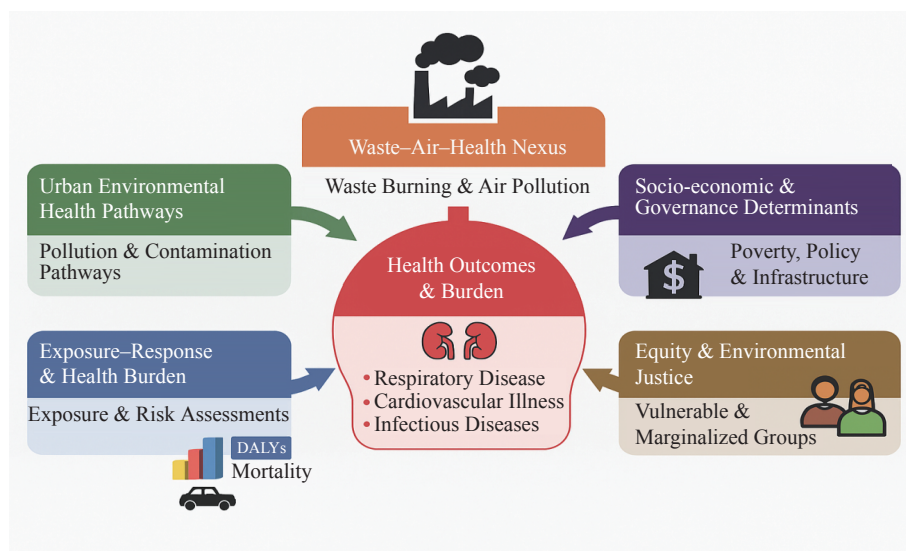


FIGURE 1. Linking urban waste management, air quality, and public health (19,21–22).

mortality. Weak regulation, inadequate waste management, and rising population density further compound this public health challenge.

Urban environmental health in rapidly growing SSA cities is further compromised by inadequate waste management, poor sanitation, and weak infrastructure, generating overlapping risks such as dumpsites, blocked drainage systems, and polluted air. Mismanaged waste emits methane, particulate matter, and pollutants from open burning, thereby worsening air quality and contributing to respiratory and cardiovascular diseases (Figure 2). Exposure–response evidence and health-burden frameworks help estimate cumulative risks and guide intervention priorities. These problems are intensified by poverty, informal housing, limited healthcare access, and governance weaknesses, including insufficient regulation and enforcement. Marginalized populations (particularly residents of informal settlements, children, and waste workers) face the greatest exposure, underscoring the need for equity-focused and environmentally just policies. Addressing these challenges requires integrated strategies that strengthen institutions, enhance accountability, and embed environmental health considerations within urban planning. This study uses a mixed-methods approach to examine health impacts across Addis Ababa, Lagos, Nairobi, and Accra. These cities were selected because they are among the fastest-growing urban centers in SSA and face substantial challenges related to air quality, waste management, and public health. Their geographic diversity and the availability of urban environmental data support comparative assessment within the region. Although



FIGURE 2. Conceptual and theoretical framework for urban waste management, air quality, and public health.

these four cities do not capture all regional variation, they provide a representative cross-section of urbanization patterns and environmental health challenges in SSA, enabling meaningful comparison while ensuring methodological feasibility. Data were drawn from municipal and national reports, peer-reviewed studies, satellite sources, WHO databases, and demographic surveys to capture pollutant indicators ($PM_{2.5}$, PM_{10} , NO_x , SO_2) and health outcomes, including respiratory disease, waterborne infections, and mortality. Spatial modeling was used to estimate exposure, and the WHO Environmental Burden of Disease framework was applied to quantify mortality and disability-adjusted life years (DALYs). Descriptive statistics, regression analysis, and

geographic information system techniques were employed, with ethical protocols and data triangulation used to address limitations such as data gaps and reliance on secondary sources. South Asia was included as a comparison region due to similar patterns of rapid urban growth, waste management pressures, and severe air-quality challenges. This comparison highlights shared vulnerabilities while illustrating differences in policy maturity and data availability that contextualize findings from the four African cities.

Method

A structured analytical framework was adopted, integrating secondary datasets on air quality, waste management, demographics, and health obtained from national statistics offices, environmental agencies, and international databases. Data were screened using predefined inclusion criteria and cross-validated across multiple sources to ensure consistency. Standardized data cleaning, harmonization, and verification procedures were applied to maintain data quality and analytical reliability. A comparative cross-city analytical approach was employed rather than a formal meta-analysis. Data were systematically compiled, harmonized, and evaluated across the four cities to assess associations among waste systems, air quality, and health outcomes.

Air Quality Impacts of Urbanization

Urban air pollution and related health burdens in SSA cities arise from interacting sources, including transport, household fuels, industry, mineral dust, and waste burning, shaped by meteorological conditions and governance contexts. PM_{2.5} concentrations frequently exceed WHO guidelines due to combined natural and anthropogenic emissions, including episodic biomass and waste burning (24–26). Rapid urbanization has increased municipal solid waste (MSW) generation at a pace exceeding management capacity, with collection coverage often limited to approximately 40%–50%, reinforcing open dumping and burning practices (7,27–29). Disposal outcomes are strongly influenced by governance factors, including financing, coordination, cost recovery, and enforcement (9,30). Fused satellite–sensor analyses indicate that peri-urban PM_{2.5} concentrations often exceed city-center levels due to open burning, biomass fuel use, and small-scale industries (Table 1), with Lagos and Nairobi recording the highest averages (31–32). Despite incremental improvements,

collection coverage remains constrained (approximately 65%–67%), while MSW generation is projected to reach about 269 million tons by 2030, widening service gaps in the absence of system expansion (28). Open waste burning emits fine particulates, black carbon, dioxins, and polycyclic aromatic hydrocarbons, with emissions influenced by waste composition and moisture content (7,28,33–34). Satellite-based source apportionment consistently identifies open burning as a significant contributor to PM_{2.5} concentrations (29–30).

Public Health Burden, Disease Patterns, and Comparative Analysis of the Four Cities

Modeling studies attribute approximately 168,000 annual PM_{2.5}-related deaths in Africa to solid fuel use, disproportionately affecting infants, children, and low-income populations where transitions to cleaner fuels remain limited (31–39). Waste pickers and nearby residents experience elevated PM_{2.5} exposure and increased cardiopulmonary risks, shaped by healthcare gaps and occupational hazards, including gender- and child-related vulnerabilities (28,40–44). Waste-related risk indicators remain independently associated with higher PM_{2.5} concentrations and greater health burdens, indicating that waste-sector reforms alone are insufficient (37,40–41,45–46). Evidence from Accra, Lagos, Nairobi, and Addis Ababa demonstrates policy dependent outcomes (Figure 3), with governance constraints sustaining pollution hotspots (30,47–51). Spatial gradients near burning sites and peri urban zones of approximately 30–35 µg/m³ correspond with findings from East Africa showing higher suburban pollution levels (Table 2) (31,52–54). Transitioning MSW management toward Integrated Solid Waste Management (ISWM), incorporating informal recyclers, eliminating open burning, and coordinating with clean cooking transitions can yield substantial health and climate benefits (30,34,38–39,55–56). Low-cost sensors, open data systems, governance reforms grounded in ISWM principles, and participatory planning approaches are essential for sustained and equitable improvements (14, 32,48,57–59). Policy recommendations were refined to reflect the specific urban and environmental conditions of Accra, Lagos, Nairobi, and Addis Ababa. City-specific strategies account for differences in waste management systems, air quality pressures, and governance capacity, thereby supporting more targeted

TABLE 1. Comparative assessment of air quality, waste, and health indicators across four cities, regional SSA evidence, and global benchmark.

Dimension/ indicator	This study (4 cities)	Regional SSA evidence	Global benchmarks/ evidence	Alignment/gap	Policy/practice implication
Ambient PM _{2.5} vs. WHO guideline	City averages exceed the WHO's annual 5 µg/m ³ ; highest in Lagos and Nairobi; exceedances common across urban and peri urban areas.	Most SSA cities record annual PM _{2.5} above 20–35 µg/m ³ ; widespread exceedance documented by WHO and regional low-cost networks.	WHO AQG tightened annual PM _{2.5} to 5 µg/m ³ ; adverse effects observed even at low concentrations.	Aligned with continental and global assessments.	Set interim air-quality targets; adopt "every reduction helps" strategies with phased reductions.
Spatial pattern of PM _{2.5}	Suburban and peri urban hotspots sometimes worse than CBDs (notably Nairobi), linked to combustion and open burning.	Satellite–sensor maps show lower PM _{2.5} in city centers and higher levels in suburbs in Kampala, Nairobi, Dar es Salaam; peri urban combustion implicated.	Global studies show heterogeneous urban patterns tied to land use and combustion sources.	Aligned with emerging East African evidence.	Extend monitoring beyond city cores; target peri urban combustion sources.
Role of open waste burning	Major contributor to local PM and toxic emissions, especially near low-service settlements and dumpsites.	Widespread across SSA with significant health and climate impacts; experiments confirm high emissions from mixed household waste.	Linked to black carbon and methane; prioritized in global SLCP mitigation agendas.	Fully aligned; highlights tractable short term reduction target.	Introduce no-burn ordinances, provide service alternatives, enforce compliance.
MSW collection coverage	Uneven coverage; service gaps common in low-income and peri urban areas; open dumping and burning persist.	SSA average collection around 65%–67%, with large gaps in low-income communities.	ISWM comparisons show LMICs lag HICs due to financing and governance constraints.	Aligned with SSA averages and global patterns.	Expand coverage through performance-based contracting, improved financing, and controlled disposal sites.
Waste generation trajectory/ composition	Waste growth outpaces capacity; organics dominant (e.g., about 60% in Addis); strong diversion potential.	SSA MSW projected to reach about 269 Mt by 2030; organics significant in most cities.	Global projections tie waste growth to income and urbanization; organics key for methane mitigation.	Aligned; highlights mitigation potential.	Scale source separation, composting and digestion supported by markets and standards.
Health burden (DALYs and mortality)	High burden consistent with elevated PM _{2.5} ; infants and children more affected.	Air pollution is the second leading risk factor for death and DALYs in SSA; about 1.1 million deaths recorded in 2019.	Large global burden from both ambient and household pollution; health benefits accrue with reductions at all levels.	Strong quantitative and qualitative alignment.	Pair ambient air-quality actions with clean cooking transitions.
Source specific mortality attribution	Findings align with modelling: trash burning, residential biofuel and open biomass are major drivers.	Continental modelling estimates ~167,700 PM _{2.5} -related deaths annually from these sources; strong regional variation.	Confirms importance of solid-fuel sources in urban intervention portfolios.	Aligned.	Target trash burning bans, biofuel replacement and controls on seasonal biomass burning.
Monitoring and data openness	Dependent on satellite and low-cost sensors; regulatory monitors sparse; QA/QC needed.	Only about 33% of SSA countries monitor regularly; just 8% share fully open data; satellite validation shows seasonal bias.	WHO database growing but still limited in SSA; open data becoming standard globally.	Aligned; exposes critical data gap.	Build open low-cost monitoring networks with calibration and public data portals.
Informal sector role	Integrating informal recyclers increases recovery if worker safety and fair pay are ensured.	Evidence shows inclusive models improve recovery; exclusion reduces system performance.	Global ISWM literature stresses context-specific governance and inclusive models.	Aligned.	Formalize informal roles, provide PPE and fair pay, co design facilities with waste-picker groups.
Economic case/co benefits	Air-quality and waste reforms provide substantial health and productivity benefits.	Six-city SSA analysis projects US\$138 billion avoided losses by 2040 with clean-air actions.	WHO and C40 highlight economic and health co benefits from incremental reductions.	Aligned; supports investment justification.	Use cost–benefit framing to attract climate and health financing for waste and air-quality improvements.

Abbreviation: QA=quality assurance; QC=quality control; DALY=disability-adjusted life year; AQ=air quality; AQG=air quality guidelines.

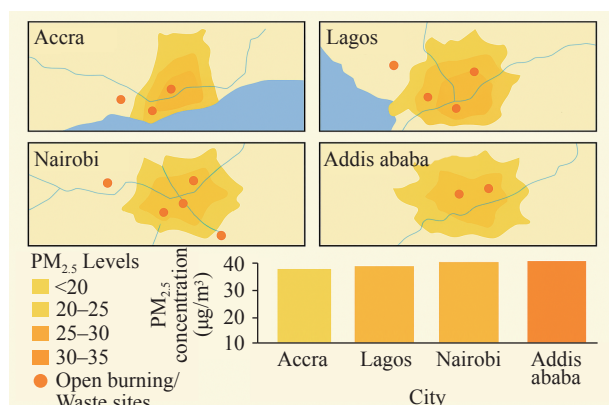


FIGURE 3. Spatial distribution and average PM_{2.5} concentrations and open waste burning hotspots in Accra, Lagos, Nairobi, and Addis Ababa (31–32).

and feasible actions.

Waste emissions, particularly from open burning and biomass use, are closely associated with elevated PM_{2.5} concentrations and related health risks across the four cities. Strengthened analysis indicates that inadequate waste management contributes to air-quality deterioration and increases the burden of respiratory and cardiovascular diseases. These findings are consistent with regional evidence identifying air pollution as a major environmental health risk in Africa, contributing to approximately 1.1 million deaths in 2019. Similar patterns of elevated PM_{2.5} exposure and associated health impacts have been documented in multiple African cities, although variations in monitoring coverage, source composition, and methodological approaches account for differences across studies. Differences in traffic emissions, industrial activity, dust, and open waste burning further explain variation among Accra, Lagos, Nairobi, and Addis Ababa, consistent with broader regional assessments. Seasonal increases in pollution, particularly during dry periods, align with trends reported in recent urban research. Open waste burning remains a significant contributor to PM_{2.5} concentrations, reinforcing WHO guidance that reducing particulate levels can generate meaningful health benefits. Variations from earlier findings largely reflect differences in data availability, sensor types, and local urban growth patterns. Overall, these comparisons underscore the need for city-specific measures targeting traffic emissions, industrial sources, and open waste burning (28,32,60).

The study's key strength is its integrated assessment of waste systems, air quality, and health using triangulated exposure estimates derived from satellite

observations, low-cost sensors, and established datasets (14), consistent with fused monitoring approaches in data-limited contexts (52,57). Limitations include monitoring gaps; potential satellite bias, such as winter overestimation in South Africa requiring calibration (53–54); and reliance on Global Burden of Disease exposure-response functions that may not fully capture local toxicity profiles or dumpsite-specific exposures (28,55). MSW analysis is additionally constrained by inconsistent indicators and limited documentation of informal activities (28,60–61). ISWM approaches can simultaneously address waste management, air pollution, and health through sanitary landfills, improved siting of transfer stations, and formalization of informal recyclers (30,32). Source separation supports composting and anaerobic digestion, while no-burn regulations require alternative disposal options such as drop-off sites and community-based monitoring (39,62). Expansion of air quality monitoring networks integrating satellite data, calibrated sensors, and reference-grade monitors is needed across SSA (14,59). Sustainable financing mechanisms can support organics diversion, landfill-gas capture, and clean cooking initiatives (21,55). Future research should prioritize high-resolution exposure mapping, longitudinal evaluation of integrated interventions, and comparative assessment of inclusive ISWM models using decision-support tools aligned with WHO 2021 guidelines (21,30–31,53,60,63).

Urban solid waste generation in SSA averages 0.78 kilograms per person per day, while collection rates ranging from 44% to 67% leave a substantial proportion of waste mismanaged, contributing to open dumping and inadequate landfill capacity. Addis Ababa reports annual PM_{2.5} concentrations of 20–60 µg/m³ arising from transport, biomass fuel use, construction dust, and open burning, with comparable pollution pressures observed in Accra, Lagos, and Nairobi despite inconsistent monitoring coverage. These conditions contribute to major health burdens, as particulate pollution was associated with 6.7 million global deaths in 2019 and high disability-adjusted life-year rates in rapidly expanding African cities (38–39).

Urban growth in Accra, Lagos, Nairobi, and Addis Ababa continues to exceed service capacity, resulting in MSW collection rates of approximately 65%–67% and PM_{2.5} concentrations substantially above the WHO guideline of 5 µg/m³. Widespread exceedances, including peri-urban hotspots linked to combustion and open waste burning, illustrate how inadequate

TABLE 2. Alignment of urban environmental health indicators with regional SSA and global evidence.

Dimension	This study's key finding (Accra, Lagos, Nairobi, Addis Ababa)	Regional SSA evidence	Global evidence	Alignment/gap	Practical implication
Urbanization trajectory and service strain	Rapid urban growth outpaces infrastructure; waste and air quality deficits increase exposure.	SSA urban population grew more than tenfold between 1960 and 2020; service expansion lags.	Urban growth strains services globally, with the largest deficits in LMICs.	Aligned; city cases reflect continent-wide trends.	Integrate environmental health into urban expansion plans; link densification to mandatory service upgrades.
MSW collection coverage	Persistent service gaps; greatest shortfalls in low-income areas.	Collection coverage averages around 65–67%, with large deficits in low-income communities.	Global surveys show wide variation; LMICs consistently below HIC performance.	Aligned with SSA averages.	Prioritize coverage in underserved wards; apply performance-based contracts and secure dedicated financing.
Open waste burning relevance	Frequent burning in peri urban belts; major contributor to PM and toxic exposure.	Widespread across SSA with significant health and climate impacts.	Emission studies confirm high PM, black carbon, and toxic gases from waste burning.	Aligned; hotspot patterns match SSA trends.	Enforce no-burn ordinances; provide community drop-off points and rapid collection with viable alternatives.
PM _{2.5} levels vs. WHO guideline (5 µg/m ³ annual)	All cities exceed guideline; Lagos and Nairobi show highest levels.	SSA urban PM _{2.5} commonly above guideline values; frequent exceedances reported across multi-country networks.	WHO (2021) tightened guideline to 5 µg/m ³ ; health effects observed even at lower concentrations.	Aligned with regional and global assessments.	Adopt "every reduction helps" strategies; set interim targets with year-on-year reductions.
Spatial pattern of exposure	Suburban belts exceed city cores in Nairobi and parts of Lagos due to peripheral combustion.	East African studies show cleaner city centers and more polluted suburbs (2019–2023).	Mixed global evidence; land use and source mix shape intra-urban patterns.	Aligned with East African findings; adds finer city-scale detail.	Expand monitoring beyond CBDs; target peri urban combustion sources (waste burning, kilns, biomass use).
Attributable health burden	Elevated morbidity and mortality linked to PM _{2.5} ; infants and children most affected.	Air pollution is the second leading risk factor in SSA; about 1.1 million deaths in Africa.	Global Burden of Disease studies attribute large DALYs to ambient and household pollution.	Strong alignment in magnitude and pattern.	Pair ambient air quality measures with clean cooking initiatives to maximize health gains.
Role of household energy	Solid fuel use increases the urban health burden even where ambient controls improve.	Household air pollution remains dominant in many SSA contexts.	Strong global evidence linking domestic solid fuels to cardiopulmonary outcomes.	Aligned.	Integrate clean cooking efforts into urban health and climate policies.
Monitoring and data openness	Sparse regulatory monitoring; requires satellite–sensor fusion and open data systems.	Only about one-third of SSA countries monitor regularly; about 8% provide fully open data.	Global norms increasingly mandate open, machine-readable air quality datasets.	Aligned; highlights severe regional data gaps.	Build calibrated low-cost sensor networks; mandate public open access to air quality data.
Informal recycling sector	High recovery achievable when informal recyclers are supported and integrated.	Inclusive models in SSA cities demonstrate high recovery; exclusion harms system performance.	Global ISWM literature supports flexible, context-specific, inclusive systems.	Aligned.	Formalizes roles; ensure PPE, fair pay; co-design MRFs with waste picker cooperatives.
Economic case and co-benefits	Air quality and waste reforms yield major health and productivity gains.	Six city SSA analysis estimates US\$138 billion avoided losses by 2040 with timely action.	WHO and C40 show measurable economic and health returns from incremental reductions.	Aligned; strengthens investment case.	Use cost-benefit framing to mobilize climate-health finance for organics diversion, sanitary landfills, and air quality controls.

Abbreviation: CBDs=central business districts; SLCPs=short-lived climate pollutants.

waste systems contribute to declining air quality. Organic waste constitutes a large share of the waste stream, driving methane emissions, open dumping,

and projected regional waste volumes of 269 million tons by 2030. These pressures translate into considerable public health burdens, with air pollution

in Africa associated with an estimated 1.1 million deaths in 2019 and approximately 168,000 PM_{2.5}-related deaths attributable to biomass, biofuel, and waste burning.

Strengthening waste management systems, including eliminating open burning, expanding collection coverage, and diverting organic waste to composting or anaerobic digestion, can contribute to reductions in PM_{2.5} and short-lived climate pollutants. Complementary measures, such as transitions to clean cooking, can further enhance health gains. Economic assessments indicate that coordinated clean air interventions could avert financial losses of about 138 billion US dollars by 2040, underscoring their cross-sectoral relevance. City-specific actions remain necessary, including expanded collection services in Accra, reduced open burning in Lagos, strengthened monitoring and cleaner transport in Addis Ababa, and improved recycling and landfill management in Nairobi. At the regional level, expansion of integrated waste management systems, strengthened regulatory frameworks, and enhanced air quality monitoring will be critical for managing rapid urban growth and safeguarding public health. The experiences of these rapidly developing cities demonstrate that improvements in waste management, air quality governance, and health-oriented urban planning must operate in a coordinated manner to support sustainable and climate-resilient urban development across SSA.

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Corresponding author: Chukwuemeka John, chuks.john@highlands.ac.uk

¹ Highlands College - Construction and Civil Engineering, University College Jersey, UK.

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