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Solid Waste Management and Health Risks: A Public Health Perspective

Dr. Amit Sachdeva[1*], Mr Nasim Ahmed[2], Mrs. Tamanna Rahman[3], Dr. Anju Sachdeva[4]

[1]Assistant Professor, Department of Community Medicine, Indira Gandhi Medical College, Shimla, Himachal Pradesh
[2]Independent Researcher, Guwahati Assam, India Email: nasim@iarcon.org
[3] MSc in Herbal Science and Technology , Anandaram Dhekial Phookan College under Guwahati University, Assam
[4]Physiotherapist, Shimla, Himachal Pradesh

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Abstract: Background: Rapid urbanization, population growth, changing consumption patterns and the expanding use of disposable materials have transformed solid waste into a major environmental and public health challenge. When waste is not prevented, segregated, collected, treated and disposed of safely, it contaminates air, water and soil; facilitates vector breeding; contributes to climate change; and exposes workers and neighbouring communities to biological, chemical, physical and psychosocial hazards. **Objective:** This narrative review critically examines the health risks associated with municipal solid waste and its management, evaluates current evidence, and discusses recent global and Indian developments, policy priorities and research needs. **Key findings:** Health effects occur throughout the waste chain, from household storage and collection to transport, sorting, recycling, treatment and final disposal. The clearest evidence concerns occupational injuries, respiratory and dermatological symptoms, musculoskeletal disorders, gastrointestinal illness and psychosocial adversity among waste workers. Communities near poorly controlled dumpsites may experience increased exposure to particulate matter, toxic combustion products, landfill gases, contaminated water and disease vectors. Associations with adverse reproductive outcomes and selected cancers have been reported, but causal interpretation remains limited by exposure misclassification, residual confounding and reliance on older facilities. Modern engineered treatment can reduce risk, but it cannot substitute for waste prevention, segregation and material recovery. **Conclusion:** Solid waste management should be treated as a preventive public health service rather than merely a municipal cleanliness function. Health-protective systems require waste reduction, universal collection, source segregation, safe organic-waste treatment, controlled disposal, elimination of open burning, occupational protection, inclusion of informal workers, environmental surveillance and transparent community engagement.

Keywords: Municipal solid waste; environmental health; waste workers; open dumping; waste burning; circular economy; India.

INTRODUCTION

Solid waste is the visible endpoint of patterns of production and consumption, but its health consequences are often displaced onto populations with the least political and economic power. Municipal solid waste comprises household refuse and similar waste generated by commercial establishments, institutions, markets and public spaces. It contains food and garden waste, paper, plastics, glass, metals, textiles and other materials; where segregation is poor, it may also be mixed with batteries, electronic components, chemicals, sharps and health-care waste.

The scale of the challenge is increasing. The United Nations Environment Programme estimated that global municipal solid waste generation could rise from approximately 2.1 billion tonnes in 2023 to 3.8 billion tonnes by 2050. Direct global waste-management costs were estimated at US$252 billion in 2020, increasing to US$361 billion when health, pollution and climate-related externalities were considered.[1]

The magnitude of these external costs demonstrates why inexpensive disposal practices, particularly uncontrolled dumping and burning, are not genuinely low-cost solutions.

Waste-related risk is distributed unequally. High-income settings generally achieve wider collection coverage and greater use of engineered treatment, although their per-capita waste generation is high. In many low- and middle-income countries, rapidly growing waste volumes exceed municipal collection, financing and treatment capacity. Uncollected refuse accumulates in streets, drains, vacant land and water bodies, while mixed waste is deposited at uncontrolled or inadequately engineered dumpsites. Informal workers recover valuable materials under hazardous conditions, providing an important environmental service without receiving commensurate occupational protection or social security.

This review examines the principal pathways through which solid waste affects health, critically appraises the epidemiological evidence, and identifies practical priorities for health-centred waste governance, with particular attention to India.

Waste Management as a Chain of Health Exposures

Waste-related health risks do not arise only at landfills. They occur across an interconnected chain beginning with waste generation. Poor household storage attracts flies, rodents and stray animals. Irregular collection prolongs community exposure and encourages roadside dumping or burning. Manual loading and transport expose workers to sharp objects, biological material, dust, traffic injuries and heavy physical workloads. Mixed-waste sorting increases contact with faecal matter, animal remains, chemicals, broken glass and contaminated medical items. Treatment and disposal may generate bioaerosols, leachate, smoke, ash, noise, odour and greenhouse gases.

The composition of waste and the management method determine the hazard profile. Organic-rich waste decomposes rapidly in warm climates, producing odour, leachate and methane. Plastics and chemically treated materials can release toxic substances when burned. Batteries, fluorescent lamps and electronic waste contribute heavy metals and persistent chemicals when mixed with municipal refuse. Construction debris generates dust and obstructs drainage, while discarded containers retain water and support mosquito breeding.

Exposure occurs through inhalation, ingestion, skin contact, injury and, indirectly, through contaminated food and water. The groups at greatest risk include waste collectors, street sweepers, sorters, landfill workers, informal waste pickers, children accompanying workers, residents near dumpsites, pregnant women, older adults and people with pre-existing respiratory or cardiovascular disease. Vulnerability is amplified by poverty, insecure housing, malnutrition, limited access to health care and weak enforcement of labour standards.

Health Risks from Inadequate Collection and Open Dumping

Uncollected or openly dumped waste creates conditions conducive to communicable disease transmission. Accumulated refuse offers food and shelter to rodents and flies, while discarded tyres, containers and plastic materials collect rainwater and support mosquito breeding. Waste can obstruct storm-water drains, worsening urban flooding and spreading faecally contaminated water. The relationship between waste accumulation and individual infectious diseases is nevertheless difficult to quantify because inadequate waste management commonly coexists with poor drainage, unsafe water, crowding and deficient sanitation.

Open dumpsites generate leachate containing dissolved organic matter, pathogens, metals and other contaminants. Where sites lack liners, drainage and leachate treatment, contaminants can enter surface water and groundwater. People may be exposed through drinking water, irrigation, bathing, consumption of locally grown food or direct contact. The toxicological plausibility of harm is clear, but epidemiological attribution is challenging because landfill composition changes over time and historical exposure data are rarely available.

Decomposing organic waste produces methane, carbon dioxide, hydrogen sulphide and volatile organic compounds. Odour itself can impair well-being, provoke headache and nausea, restrict outdoor activity and increase stress. Landfill instability, fires and explosions constitute additional risks. Methane also contributes to climate change, which indirectly affects health through heat, extreme weather, food insecurity and the changing distribution of infectious diseases.

A systematic review by Vinti and colleagues found reported associations between municipal waste-management facilities and mortality, adverse birth outcomes, respiratory illness, cancer, gastroenteritis and vector-borne disease.[2] However, findings were inconsistent across settings. Many studies used

residential distance as a surrogate for exposure, lacked individual-level information on mobility and occupation, or could not distinguish the effect of the facility from neighbourhood deprivation. Consequently, proximity should be interpreted as a screening indicator of potential exposure rather than proof of causation.

Open Waste Burning and Air Pollution

Open burning is among the most hazardous waste-management practices because combustion is incomplete, uncontrolled and performed without emission treatment. Smoke may contain fine and ultrafine particulate matter, carbon monoxide, nitrogen oxides, volatile organic compounds, polycyclic aromatic hydrocarbons, metals, acid gases, dioxins and furans. Emissions vary according to temperature, oxygen availability and the composition of the material burned.

Short-term exposure can cause eye and throat irritation, cough, wheeze, headache and exacerbation of asthma or chronic respiratory disease. Fine particulate matter can penetrate deep into the lungs and enter the circulation, providing a plausible pathway to cardiovascular morbidity. Repeated burning near homes, schools and worksites may create substantial cumulative exposure, especially for children and older people.

The distinction between open burning and regulated incineration is important. Modern incinerators use controlled combustion, continuous process monitoring and air-pollution-control systems. Nevertheless, concerns remain regarding stack emissions, ash disposal, cumulative exposure and the risk that large incineration capacity may discourage waste prevention and recycling. A systematic review of incineration studies reported associations with selected cancers, congenital anomalies, infant deaths and miscarriage, particularly around older facilities, but concluded that heterogeneity in technologies, pollutants and study methods prevented definitive causal conclusions.[3] Evidence from poorly controlled or outdated plants should not be applied uncritically to modern facilities; equally, absence of observed harm over short follow-up periods cannot establish long-term safety.

Waste-to-energy should therefore occupy a limited position within the waste hierarchy. It may be appropriate for carefully characterized, non-recyclable, high-calorific residual waste where stringent emission control, ash management and independent monitoring are feasible. Burning mixed, wet municipal waste is inefficient, produces problematic residues and may undermine composting and recycling.

Occupational Health of Waste Workers

Occupational risk is the most consistently documented health dimension of solid waste management. Workers experience cuts, puncture wounds, falls, vehicle injuries, animal bites, heat exposure, dust, bioaerosols, repetitive movement, manual lifting and contact with decomposing matter. Lack of washing facilities, irregular employment, inadequate protective equipment and delayed access to medical care compound these exposures.

A systematic review of 58 studies on informal waste pickers found frequent physical, social, biological, chemical, ergonomic and mechanical hazards. Reported health outcomes included skin disease, communicable illness, musculoskeletal and respiratory disorders, gastrointestinal symptoms, injuries and non-communicable conditions.[4] The review highlighted substantial heterogeneity and reliance on self-reported outcomes, but the consistency of occupational hazards across diverse settings is compelling.

Indian evidence reflects similar vulnerabilities. Ravindra and colleagues assessed street sweepers, waste collectors and informal waste pickers in Chandigarh and documented incomplete use of protective equipment, together with respiratory problems, injuries and allergic symptoms.[5] Although the study was cross-sectional and cannot determine causality, it illustrates the interaction between hazardous work, poverty, low literacy and weak occupational safeguards.

Personal protective equipment is necessary but insufficient. Gloves, footwear, masks, reflective clothing and eye protection must be suitable for local temperature, workload and waste type; otherwise sustained use is unlikely. Prevention should follow the hierarchy of controls: segregating hazardous material at source, mechanizing dangerous operations, designing safer collection vehicles and sorting lines, controlling dust, providing shade and hydration, limiting excessive loads, ensuring vaccination and instituting injury-reporting systems. Periodic health examinations should be linked to treatment and compensation rather than conducted as isolated screening exercises.

The informal sector presents both a policy challenge and an opportunity. Waste pickers recover plastics, paper, metals and glass that might otherwise be dumped or burned. Abrupt exclusion through privatization or mechanization can remove livelihoods without eliminating informal recovery. A just

transition requires registration, identity cards, cooperatives or worker enterprises, access to segregated materials, fair payment, social protection, occupational training and representation in municipal decision-making.

Psychosocial and Community Effects

Waste-related health extends beyond measurable toxic exposure. Persistent odour, smoke, flies, noise, truck movement and fear of contamination affect quality of life and may contribute to stress, sleep disturbance, anxiety and social conflict. Communities near disposal sites often experience stigma, declining property values and limited influence over land-use decisions. These burdens frequently fall on low-income settlements, migrant communities and socially marginalized groups, raising questions of environmental justice.

Risk communication is especially important where evidence is uncertain. Authorities sometimes dismiss community concerns because causal associations are not conclusive, while activists may attribute every local illness to a nearby waste facility. A more credible approach combines transparent environmental monitoring, accessible disclosure of results, independent health assessment and meaningful community participation. Uncertainty should be communicated openly rather than used either to deny plausible risk or to imply certainty unsupported by evidence.

Indian Policy and Implementation Context

India's waste-management framework has evolved from an emphasis on disposal towards segregation, resource recovery and scientific processing. The Solid Waste Management Rules, 2016 expanded responsibilities beyond municipal authorities to waste generators, institutions, resident associations, market bodies and event organizers. The rules require source segregation, door-to-door collection, separate handling of sanitary and domestic hazardous waste, processing of biodegradable material, recovery of recyclables and disposal of residual waste in sanitary landfills.[6] The notified Solid Waste Management Rules, 2026 further signal an effort to strengthen accountability and modernize regulation.[7]

Swachh Bharat Mission–Urban has increased political visibility and infrastructure investment. Government data released in June 2026 reported that urban India was processing 129,206 tonnes of the 159,109 tonnes of municipal waste generated daily, compared with processing rates below one-fifth at the beginning of the mission. The same source reported remediation of more than 1,100 legacy dumpsites.[8] These gains are important, but national percentages should be interpreted cautiously. "Processed" waste may include technologies of variable environmental performance, and aggregate reporting can obscure substantial differences between cities, wards and seasons.

India's central implementation gap remains poor segregation at source. When food waste is mixed with plastics, glass, sanitary waste and hazardous household material, compost quality deteriorates, recycling becomes unsafe, biomethanation becomes less reliable and the residual fraction becomes unsuitable for efficient energy recovery. Mixed collection therefore locks municipalities into costly downstream sorting and disposal.

Legacy dumpsite remediation through biomining has expanded rapidly. Remediation can reduce fire risk, recover land and separate combustible, recyclable and soil-like fractions. However, moving or screening old waste does not eliminate contaminants. Projects require site assessment, dust suppression, worker protection, leachate control, appropriate use or disposal of recovered fractions and post-remediation groundwater monitoring. Reclaimed land should not automatically be considered safe for unrestricted residential or institutional use.

Table 1. Major Waste-Management Practices, Health Risks and Priority Controls

Waste-management stage or practice	Principal hazards and exposure pathways	Main health concerns	Strength and limitations of evidence	Priority public health actions
Unsegregated household storage and irregular collection	Pathogens, flies, rodents, animal contact, retained water and drain blockage	Gastrointestinal disease, vector-borne disease, injuries and neighbourhood nuisance	Strong biological plausibility; disease-specific attribution confounded by sanitation, drainage and housing	Universal scheduled collection, covered storage, source segregation and drain maintenance

Manual collection, sweeping and sorting	Sharps, broken glass, bioaerosols, dust, heavy lifting, traffic and heat	Cuts, infections, respiratory symptoms, dermatitis, musculoskeletal disorders and heat illness	Consistent occupational evidence, but many studies are cross-sectional and use self-reported outcomes	Engineering controls, safe vehicles, suitable protective equipment, vaccination, hydration, health care and injury surveillance
Open dumping	Leachate, vectors, landfill gases, unstable slopes, fires and direct contact	Respiratory and gastrointestinal illness, injuries, stress and possible reproductive effects	Associations reported, but exposure measurement and control of confounding are frequently weak	Eliminate open dumps, control access, manage leachate and gas, remediate legacy waste and monitor nearby water
Open waste burning	$PM_{2.5}$, carbon monoxide, PAHs, dioxins, furans, metals and irritant gases	Acute respiratory symptoms, asthma exacerbation and potential cardiovascular, developmental and carcinogenic effects	Toxicological basis is strong; population exposure data remain limited in many low-resource settings	Prohibit and enforce against burning while ensuring affordable collection and treatment alternatives
Composting and biomethanation	Bioaerosols, odour, machinery and contaminated feedstock	Respiratory and skin symptoms, injuries and community nuisance	Generally lower risk when feedstock is segregated and facilities are well operated	Segregated organic waste, enclosure, ventilation, vector control, process monitoring and safe compost standards
Controlled incineration or waste-to-energy	Stack emissions, occupational heat, ash and residues	Potential respiratory, reproductive and carcinogenic effects depending on technology and control	Older plants show more adverse associations; evidence for modern plants is less conclusive and long-term follow-up is limited	Use only for suitable residual waste, apply stringent emission limits, continuous monitoring and safe ash disposal
Sanitary landfill	Residual leachate, methane, odour, vehicle emissions and long-term site contamination	Nuisance, respiratory symptoms, stress and potential chronic exposure	Lower risk than open dumping but not risk-free; outcomes depend heavily on engineering and operation	Liners, leachate treatment, gas capture, daily cover, buffer zones, closure plans and long-term monitoring
Informal recycling	Mixed hazardous exposure, child labour, unsafe dismantling and social insecurity	Injury, toxic exposure, infection, chronic respiratory disease and psychosocial harm	Consistent descriptions of multi-hazard exposure; limited longitudinal and biomonitoring evidence	Formal recognition, cooperatives, fair remuneration, safe workspaces, social security and exclusion of children

Public Health Significance

Effective waste management generates benefits across several public health domains. Reliable collection reduces vector habitat and neighbourhood contamination. Segregated organic-waste treatment can reduce methane emissions and produce compost or biogas. Recycling reduces demand for virgin materials and the pollution associated with extraction and manufacturing. Safer working conditions protect a large and often invisible labour force. Drain clearance improves flood resilience, while eliminating open burning contributes to cleaner air.

Waste management is therefore linked to communicable disease control, non-communicable disease prevention, occupational health, climate resilience, urban planning and health equity. Yet health departments are often peripheral to municipal waste decisions. Public health agencies should participate in facility siting, environmental impact assessment, worker-health programmes, outbreak investigation, risk communication and surveillance around major disposal sites.

Recent Advances

Recent practice increasingly emphasizes circularity, decentralized organic-waste treatment and data-driven management. Digital weighing systems, geographic information systems, vehicle tracking and sensor-enabled containers can improve route planning and identify service gaps. Satellite and drone imagery can detect illegal dumping and landfill expansion, although such systems require field validation and safeguards against surveillance misuse.

Mechanical sorting, optical recognition and automated material recovery may reduce worker contact with mixed waste, but technological performance declines when incoming material is wet and heavily contaminated. Decentralized composting and biomethanation can reduce transport burdens, provided facilities maintain odour, vector and digestate control. Extended producer responsibility is shifting part of the cost of managing packaging, plastics, tyres, batteries and electronic products from municipalities towards producers, although transparent auditing and prevention of fraudulent recycling claims remain essential.

The most important conceptual advance is the recognition that waste management alone cannot resolve continuously increasing material throughput. UNEP modelling suggests that a circular-economy pathway combining waste prevention with comprehensive management could produce substantial net economic benefits by 2050.[1] Waste prevention, durable product design, repair, reuse and reduced reliance on unnecessary single-use materials must therefore precede recycling and disposal.

Challenges and Limitations of the Evidence

The health literature is constrained by inconsistent definitions of waste facilities, inadequate measurement of pollutants and substantial heterogeneity in local conditions. Residential distance is frequently used as a proxy for exposure despite variation in wind direction, water pathways, time spent at home and individual behaviour. Long latency periods complicate cancer and reproductive studies, while facilities may change technology during follow-up.

Many occupational studies lack unexposed comparison groups, objective clinical measurements or longitudinal assessment. Informal workers are mobile and poorly represented in administrative data. Publication bias may favour studies reporting adverse associations, whereas industry-funded facility monitoring may emphasize regulatory compliance without assessing cumulative or community-level exposure.

Conversely, uncertainty should not be mistaken for absence of risk. Waiting for definitive causal evidence before controlling open burning, mixed-waste handling or unlined dumping would be inconsistent with preventive public health. Intervention priorities can be justified through the precautionary principle, exposure reduction and the availability of safer alternatives.

Future Directions

Future policy should establish health-centred performance indicators rather than relying primarily on tonnes collected or processed. Indicators should include open-burning events, worker injuries, protective-equipment availability, vaccination coverage, leachate quality, groundwater contamination, facility emissions, vector density, complaints and the proportion of genuinely segregated waste.

Research should prioritize prospective cohorts of workers and communities, personal exposure monitoring, biomonitoring where ethically justified, standardized outcome definitions and natural

experiments evaluating facility upgrades or dumpsite closure. Studies must distinguish between open dumps, sanitary landfills, composting units, biomethanation plants and different generations of incineration technology.

Indian cities require locally adapted approaches. Dense metropolitan areas may need regional processing and engineered residual disposal, whereas smaller towns and hill settlements may benefit from decentralized organic-waste systems, material-recovery centres and carefully planned transport of non-recyclable residuals. Climate, terrain, tourism, seasonal population change and market access for recovered materials should shape technology selection.

Health systems should recognize waste workers as a priority occupational group. Municipalities should provide baseline and periodic examinations, tetanus and hepatitis B vaccination according to exposure risk, injury care, respiratory assessment, heat protection, maternity safeguards and access to insurance. Informal-worker organizations should participate in programme design, monitoring and grievance redressal.

CONCLUSION

Solid waste becomes a health hazard not simply because it exists, but because products are designed for disposal, waste is mixed at source, collection is incomplete and treatment transfers risk to workers or disadvantaged communities. The most credible evidence demonstrates substantial occupational hazards and clear exposure pathways from open dumping and burning. Evidence concerning cancer, reproductive outcomes and long-term community effects is suggestive but remains methodologically heterogeneous.

A health-protective waste system begins with prevention and segregation, followed by reliable collection, recovery of materials, safe biological treatment of organic waste and engineered disposal of a minimized residual fraction. Incineration and biomining may have defined roles, but neither can compensate for uncontrolled waste generation or poor segregation. India has made measurable progress in collection, processing and legacy-waste remediation, yet consistent implementation, worker protection, environmental monitoring and data transparency remain decisive challenges.

Treating solid waste management as an essential public health service would shift attention from visible cleanliness to prevention of exposure, protection of workers, environmental justice and long-term population health. The objective should not merely be to move waste out of sight, but to reduce its generation and manage every remaining material without transferring harm across places, populations or generations.

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