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INFORMAL URBAN LIVELIHOODS AND ENVIRONMENTAL INEQUALITY: OCCUPATIONAL HEALTH RISKS AMONG WASTE PICKERS IN GHAZIABAD, INDIA

Usha RANI [1], Kvetoslava MATLOVICOVA[2], Bindhy Wasini PANDEY [3], Hemendra Kumar VAISHNAV [4], Rajpal SAINI [5], Sanjay Kumar DEY[*6], Maria GOZNER [7], Zoltán BUJDOSO [8], Prabuddh Kumar MISHRA[1]

[1] University of Delhi, Department of Geography, Shivaji College, Delhi, India; usharani@shivaji.du.ac.in (U.R.); prabuddh@shivaji.du.ac.in (P.K.M.)
[2] University of Economics in Bratislava, Faculty of Commerce, Department of Tourism, Bratislava, Bratislava, Slovakia; kvetoslava.matlovicova@euba.sk (K.M.)
[3] University of Delhi, Department of Geography, School of Economics, Delhi, India; bwpandey@geography.du.ac.in (B.W.P.)
[4] Indian Institute of Management Jammu, Jagti, Jammu, India; hemendra24@hotmail.com (H.K.V.)
[5] Mohanlal Sukhadia University, Department of Statistics, Faculty of Mathematical Sciences, University of Delhi, New Delhi, India; Udaipur, Rajasthan, India; rajpal.saini.stats@gmail.com (R.S.)
[6] University of Delhi, Laboratory for Structural Biology of Membrane Proteins, Dr. B.R. Ambedkar Center for Biomedical Research, Delhi, India; sdey@acbr.du.ac.in (S.K.D.)
[7] University of Oradea, Faculty of Geography, Tourism and Sport, Department of Geography, Tourism and Territorial Planning, Oradea, Romania; mariagozner@yahoo.com (M.G.)
[8] Hungarian University of Agriculture and Life Sciences, Institute of Regional Economics and Rural Development, Gyongyos, Hungary; bujdoso.zoltan@uni-mate.hu (Z.B.)

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Abstract: The present study seeks to examine the effects of hazardous working conditions at urban landfills on the health status of waste pickers in Ghaziabad, India. The study identifies the factors of resilience and health concerns experienced by scavengers at work. It also aims to understand the specific difficulties and health consequences they experience. Finally, the impact of selected socio-economic factors on the subjective well-being of the respondents is indirectly explored, as this can be considered an indication of their socio-economic status and perceived quality of life. Data were obtained via four primary surveys carried out in 2023. To determine the immediate health impact of waste pickers' occupations, the following biometric tests were conducted: BMI, oximeter readings, blood pressure, pulse rate, chronometer readings, body temperature and general well-being. Data were collected in several phases using standardised questionnaires and biometric tests. A series of in-depth interviews and group discussions were also conducted to gain insight into the daily rituals, working practices, and challenges faced by waste pickers. We also observed them directly at work in landfills to understand the factors enabling them to perform this health-risking work in the long term. In the statistical analysis, descriptive statistics, the chi-square test, and the two-proportion z-test were employed to assess the relationship between waste pickers and selected health indicators. Another level of statistical testing was also performed to determine whether the proportion of waste pickers is significantly higher than that of the control group (non-waste pickers) in terms of well-being, i.e. health and socio-economic indicators. The results revealed that the health status of the waste pickers was statistically significantly worse than that of the control group. This included a higher prevalence of skin, respiratory and musculoskeletal problems, as well as poorer dietary habits and higher alcohol and tobacco consumption. Key risk factors identified were low levels of education, low income and inadequate protective equipment at work. Our findings demonstrated a pronounced adverse effect of working and living conditions on the health of waste pickers. This highlights the need to introduce preventive measures, improve access to healthcare, and strengthen social protection for this marginalised group. These findings also could contribute to the planning of urban development in Indian cities, with the aim of improving living conditions by applying environmental justice principles.

Keywords: waste, landfills, waste pickers, environmental justice, informal urban livelihoods

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INTRODUCTION

In recent decades, the production of municipal solid waste (MSW) has grown at an unprecedented rate around the world, making it one of the most pressing global environmental issues. While its volume was 2.01 billion tonnes per year in 2016 (Kaza et al., 2018; Rajaeifar et al., 2017), the World Bank (UNEP, 2024) estimates that, at the current rate of production, the total volume will almost double to 3.4–3.8 billion tonnes per year by 2050. The negative environmental impacts of disproportionate waste production are closely intertwined with the dynamic processes of urbanisation and population growth, driven by industrial and commercial development (Chenn et al., 2019). In many parts of the world,

[*] Corresponding author

particularly in the Global South, urbanisation processes have often been poorly managed and occurred rapidly, failing to match the needs of urban population growth. Consequently, large urban areas have emerged where a significant proportion of the population resides in slums and informal settlements lacking access to basic infrastructure (Kaza et al., 2018; Slevin et al., 2020; Uhunamure et al., 2021). However, the accumulation of mixed municipal waste in landfills poses both an opportunity and a threat to poor urban communities. The opportunity lies in the recyclable components that can be monetised to provide essential livelihoods for entire families. The challenge is that waste pickers are exposed to health risks when collecting and separating recyclable materials from toxic and hazardous substances without adequate protective equipment (Anand, 2010; Hoornweg & Bhada-Tata, 2012; Chenn et al., 2019).

The collection of recyclable waste in landfills thus represents a health-threatening livelihood for numerous groups of poor slum dwellers, which they (un) voluntarily undertake despite the obvious health risks because they have no other alternative. Despite the fact that the manual waste separation they carry out is a significant contribution to the circular economy (recycling), in most cases it remains without formal recognition and often without at least minimal material support, in the form of the provision of the necessary protective work equipment for this hazardous work in terms of its impact on their health. However, health risks are also faced by other residents (Noje et al., 2025; Meng, 2025) who inhabit areas located near landfills (especially illegal ones) or waste incinerators, or otherwise health-risk territories (dependent on contaminated water sources or soil, or areas with high concentrations of health-damaging air emissions).

As the above considerations suggest, environmental problems cannot be addressed in isolation; they must be considered alongside the wide range of social factors that contribute to them (Susilo et al., 2021; Klimovský et al., 2016). Indeed, deepening social disparities contribute to increased pressure on natural resources. Rising poverty and marginalisation rates force the poor to exploit natural resources directly and intensively, ensuring their survival in the short term but leading to ecosystem degradation and the depletion of non-renewable resources in the long term. Conversely, the disproportionate growth in wealth and the consumerist lifestyle promoted by the neoliberal economic model also contribute to the systematic depletion of non-renewable resources needed to continually stimulate growth in demand for products and services. Furthermore, social inequalities are disproportionately distributed, with vulnerable communities bearing the brunt of negative environmental impacts such as pollution, climate change and land degradation (Matlovič & Matlovičová, 2024).

These communities have the fewest resources for adaptation. The urban environment provides limited livelihood opportunities for marginalised communities. In this case, waste picking as part of the informal sector is often one of the few livelihood options available to large groups of people living in poverty in urban areas. Despite the health risks associated with this work, it is socially embedded. The risky livelihood strategy of urban communities dependent on waste picking contributes to their marginalisation due to their lack of access to education and information resources, and their minimal participation in decision-making processes (Demkova et al., 2022; Brunn et al., 2018; Matlovičova et al., 2022; 2016).

Without transforming social structures and systemic relationships, achieving sustainable solutions to current social and environmental challenges in cities seems unlikely for the time being.

Concept of Environmental Justice: A brief outline of the framework

The concept of environmental justice emerged as a critique of the tendency for environmental burdens, such as pollution, landfills and industrial zones, to be located near communities of low socioeconomic status and frequently ethnic or otherwise marginalised groups (Bullard, 1993; Schlosberg, 2007). In other words, environmental risks and their subsequent impacts on communities inhabiting such areas are not evenly distributed, but are systematically transferred to socially vulnerable groups. A specific example is the location of large landfills near slums, which are inhabited by poor communities for whom waste collection is often the only livelihood option. The essence of environmental injustice is that, while waste pickers contribute to sustainable waste management, they are exposed to unnecessarily high health risks due to a lack of access to adequate occupational protection and healthcare.

Environmental burdens, such as landfills, pollution and poor sanitation, are often located in areas inhabited by socially and economically disadvantaged groups (Bullard, 1993; Schlosberg, 2007). Thus, waste pickers face environmental injustice: on the one hand, they contribute to waste reduction by collecting and separating recyclable materials from mixed municipal waste landfills; on the other hand, they (un)voluntarily inhabit and work in environments that pose a risk to their health. Furthermore, they are unnecessarily exposed to a high level of risk, as they work without adequate protection, recognition or compensation. In this context, Schlosberg (2007) proposes a pluralistic environmental justice framework which, unlike traditional economic indicators, evaluates justice based on individuals' actual ability to live a dignified life (the *capabilities approach*). He argues that addressing only the distribution of environmental *'goods'* (e.g. clean air, access to a park) and *'burdens'* (e.g. landfills, pollution) is not enough, and that we also need to respect the multiple kinds of relationships people have with places, reflecting these in policy and environmental decisions. In this case, the emphasis is on *'capabilities'*, or the real choices of lifestyle that an individual values, and *'functionings'*, or the specific aspects of life that a person chooses and is able to do or be, reflecting their state of being and activities (e.g. being healthy, being educated, living in a safe environment, participating in social life or having simple freedom of movement; Schlosberg, 2007).

This opens up the debate on environmental justice, where not only human health is at stake, but also the health of natural ecosystems. It stresses that justice must include not only an equitable distribution of environmental benefits and burdens, but also inclusive decision-making and respect for different forms of place consciousness, both *natural*, i.e. the way individuals and communities are aware of their connection to the natural environment, and *social*, i.e. the way people are aware of the significance of place within their identities, histories and social relations. Such a capability-based approach is a normative approach to human well-being (Matlovič & Matlovičova, 2020; 2025) focuses on individuals' actual ability to achieve a valued life, rather than merely having the right or freedom to do so. The *capabilities approach* emerged in the 1980s as an alternative to welfare economics. However, early work by Sen (1999; 1985) and Nussbaum (2000; 2006) considered it to be an approach aimed at creating conditions that enable people to live fulfilling lives, including maintaining meaningful connections with the natural and social environments.

Rakodi (2002: 2–22) builds on the considerations outlined above by *adopting an urban livelihoods approach*, which describes survival strategies in urban environments, emphasising the informal sector, access to assets, and adaptive capacity. The work of waste pickers is an example of an informal livelihood determined by economic marginalisation, a lack of alternative income, and limited access to basic assets such as healthcare, education and occupational safety. This activity takes place in an *„urban risk environment"*. The social vulnerability of waste pickers, when considered within the concept of *vulnerability* concept (Wisner et al., 2004; Turner, 2003), is determined by a combination of systemic inequalities and the individual capacity to cope with shocks and stresses. Waste pickers are vulnerable to environmental hazards, and their lack of access to healthcare, education, and financial resources makes them even more so. Resilience mechanisms such as religious beliefs, community cohesion are poor substitutes for inadequate institutional support.

Recent papers (Gemmiti et al., 2025; Chakraborty et al., 2025) also discuss the uneven distribution of environmental burdens among different social groups. For example, Gemmiti et al. (2025: 1-3) examine the spatial and socio-demographic dimensions of environmental injustice in Italy, specifically in the context of so-called *Sites of National Interest* (SNIs), i.e. sites identified by the Italian government as zones with severe environmental burdens due to high levels of soil, water and air contamination from industrial activities. The authors point out that residents living in SNIs are significantly more likely to experience socioeconomic disadvantage. Specifically, they describe lower household incomes, higher unemployment rates and lower levels of education, which limit awareness of environmental risks. They also note a higher proportion of elderly people, who are more vulnerable to the health impacts of contamination. In the context of the *capabilities approach* mentioned above, these findings demonstrate that living in a contaminated environment limits individuals' right to live with dignity and to enjoy good health without fear of physical or environmental threats. Other notable works include those of Chakraborty et al. (2025), who explored the concept of environmental justice in a broader context using selected Canadian metropolitan areas as case studies, specifically Ottawa-Gatineau and Montreal, where communities inhabiting seismically active zones were examined. Based on their research findings, the authors argue that environmental justice should be understood not only as the equitable distribution of environmental benefits and risks, but also as a means of exposing and mitigating the vulnerability of historically or systemically marginalised populations. They highlight that ethnic minorities, seniors and low-income households are more likely to reside in areas with higher risk levels (Chakraborty et al., 2025; Matlovič et al., 2020). By doing so, Chakraborty et al. (2025) extend the scope of environmental justice beyond toxic pollution to encompass natural hazards, which, despite their natural origin, have highly socially contingent impacts. In other words, the environmental risks we face are not the same for everyone: those who are least prepared for them are the most affected (Wisner et al., 2004: 4–5). These contexts allow us to define the essence of the principle of *environmental justice* as the pursuit of equality of access to natural resources and equality in bearing the burden of environmental risks.

The urban risk environment in Indian slums

The rapid pace of urbanisation and population growth are two of the major demographic challenges facing contemporary India. This trend accelerated significantly after the economic reforms of the 1990s, which generated growth but did not benefit everyone equally (Chen et al., 2019; Kaza et al., 2018). This has resulted in growing regional disparities and widening socioeconomic inequalities (Kostilnikova et al., 2022; Sumarmi, 2021). The current population of 1.46 billion people (estimated by Worldometer for 2025) has additionally resulted in substantial rural-to-urban migration, particularly toward major metropolitan centres such as Mumbai, Delhi and Kolkata. However, this migratory movement, fuelled by hopes of a better life and job opportunities, often runs up against the limits of urban infrastructure and the availability of housing, jobs and basic social services (Slevin et al., 2020). The result is the expansion of slums — informal, illegal settlements lacking adequate amenities such as electricity, water, sanitation and safety standards — in which approximately 40–50% of the urban population lives (Kaza et al., 2018; Uhunamure et al., 2021).

The emergence of slums in India cannot be understood as a consequence of poverty alone; rather, it is the result of a complex interplay of multiple factors. Important push factors that force rural populations to leave the countryside and seek livelihoods in cities include the climate crisis, among others. Climate change has led to a decline in rainfall, resulting in reduced agricultural yields due to drought, flooding or land depletion. This forces millions of people to leave the countryside. However, there are also cultural factors, such as caste and ethnic marginalisation. Indeed, India's slums are often inhabited by the poorest sections of society, such as Dalit members of the lowest caste or migrants from minority ethnic groups. Lastly, the lack of affordable housing forces migrants to settle on unused land or land with unclear or disputed ownership. In many cases, their proliferation is fostered by city governments' politically and economically motivated reluctance to legalise or integrate slums into urban plans. In some cases, this is exacerbated by corruption, clientelism and inadequate control mechanisms for public resources earmarked for social housing. Finally, structural unemployment also fuels their growth, as many urban newcomers are unable to find formal employment and consequently end up in the informal economy, whose activities are linked to the slums. These factors, alongside others, therefore drive the urban processes that enable slum formation in India, while simultaneously hindering their elimination or integration into formal urban spaces. Consequently, slums are becoming an increasingly common feature of the Indian urban environment, providing a space for the increased concentration of poor and socially excluded communities who depend on risky urban livelihoods.

The scarcity of formal income-generating opportunities and limited access to educational resources compels many slum residents to sustain their livelihoods through the collection, sorting, and recycling of waste, frequently undertaken directly at urban dumpsites or on city streets (Nuhu, 2016). Globally, it is estimated that over 15 million individuals are engaged in such activities as their primary source of livelihood (De Salvo et al., 2008). As this figure is from 2008, it is likely that the number is now several times higher. In India alone, it is estimated that between 1.5 and 4 million people make a living from waste collection, over 500,000 of whom are based in the capital city of Delhi (Noda, 2022).

The collection of recyclables and other items at municipal solid waste (MSW) landfills is usually carried out by people without adequate protective equipment. This can lead to both acute and chronic health problems, such as respiratory illnesses, infections and abnormal blood test results caused by prolonged exposure to toxic substances.

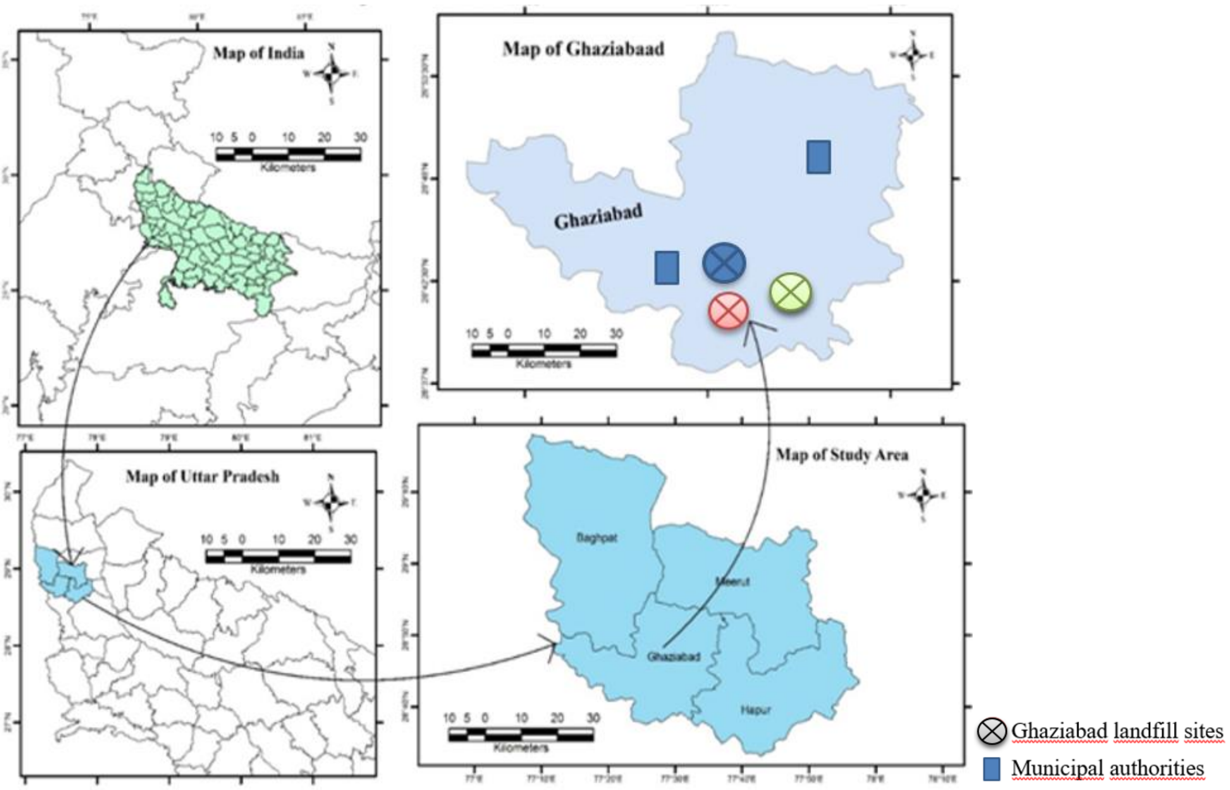
Several studies have investigated the effects of this work on the health of employees. For instance, Salve et al. (2017, 2020) examined the health of more than 300 waste pickers in Mumbai, India. They identified the presence of respiratory, eye, skin or nail diseases (or a combination of these) in almost half of them. Kumari & Kiran (2022) found high rates of accidents, falls, musculoskeletal problems and waterborne infections of nearly 40% in a similarly focused study in Ayodhya, Uttar Pradesh, India. Other studies (e.g. Van de Klundert & Lardinois, 1995; Hoozemans et al., 2004; Chokhandre et al., 2017; Akuressage & Dissanayake, 2017; Salve, 2020,) have confirmed that waste pickers experience a significantly higher prevalence of injuries, respiratory diseases, eye infections, and stomach problems. This is due not only to direct contact with toxic or noxious substances, but also to poor hygiene (a proximate cause of infectious diseases), improper waste management, and the use of toxic materials found in waste as fuel. Many other factors have also been identified as increasing health risks. Moreno-Sanchez et al. (2004) describe the overpopulation of disease-carrying insects as a consequence of poor sanitation in the cities of Hyderabad and Mysore. Improper waste management practices, inadequate drainage systems and the accumulation of solid waste, sewage and effluents also pose a direct threat to the health of India's slum-dwellers (Palakurthy & Kesari, 2021). The increased morbidity of waste pickers is thus a direct consequence of multiple deprivations, including a lack of basic necessities and unsuitable working and living conditions, in slums where proper sanitation facilities, clean drinking water and electricity are lacking (Slack et al., 2009; Water, 2019; Slack, 2009).

The studies underscore the pressing necessity to mitigate the environmental, social, and health consequences of waste management, enhance occupational conditions while safeguarding workers' health, and ensure systematic regulation alongside intervention by the competent local authorities. The studies also point to the need to raise awareness among waste pickers of health risks, and to promote inter-sectoral cooperation in order to protect their health rights and encourage the adoption of preventive measures. The National Urban Sanitation Policy (NUSP, 2020) was adopted by the Indian government in November 2008 in response to the inadequate sanitation conditions in Indian cities. By addressing urban sanitation problems holistically, the strategy seeks to improve both the environment and human health while lowering health risks that disproportionately impact underprivileged groups. The Indian Ministry of Urban Development's main objective under the NUSP is to fully sanitise cities and towns. To achieve this ambitious goal, a series of partial objectives and targets have been established. Specifically, there is a need to develop integrated, city-wide sanitation plans. These plans should include measures to strengthen institutional provision and raise awareness, particularly among poor communities, of the negative impact of environmental stresses and poor hygiene habits on human health. The aim is to encourage behavioural change and promote the implementation of low-cost or cost-effective technologies for the well disposal of waste, especially sewage and other noxious liquid waste (NUSP, 2020). A total of 120 cities were involved in preparing urban sanitation plans. The financial costs were covered by a government grant from the Indian Ministry of Urban Development, which allocated Rs. 13 million for this purpose, as well as by external funding from various agencies and NGOs (NUSP, 2020). In addition to financial support, the Government of India regularly monitors cities and awards the national 'Nirmal Shahar Puraskar' prize to those that achieve the best results in promoting urban sanitation and encouraging households to participate in improving urban living spaces and ensuring the safe collection, treatment and disposal of waste (NUSP, 2020).

Ghaziabad Case Study (Uttar Pradesh, India)

As mentioned above, the Government of India has captured many measures to improve the environment of urban communities by supporting various initiatives and investing in upgrading water infrastructure, public services, housing and education, as well as sanitation facilities. In this context, several initiatives have been put into action, including the 1954-launched India Sanitation Program. The Nirmal Bharat Abhiyan, the Central Rural Sanitation Programme (1986), and the Total Sanitation Campaign (1999). (2012), and the subsequent versions of the *Swachh Bharat Abhiyan* (SBA) (2014, 2019, 2020–21, 2024–25). Many other supporting initiatives have also been implemented (Sinha & Sinha, 2017; Novotný et al., 2018; Bhandare, 2014; Sengupta, 2020; Basumatary et al., 2022). However, rapid population growth in Indian cities poses a huge challenge, with population concentrations exceeding current infrastructure capacity. Although the situation is gradually improving thanks to the proactive approach of the Indian government, it is estimated that, by 2023, around 162 million people (mostly from communities with a low socioeconomic status) will still not have sanitation facilities in their homes (Jain et al., 2025). 71% of these people live in just six Indian states: *Bihar, Jharkhand Rajasthan, Madhya Pradesh, Uttar Pradesh, and Uttarakhand.* More than ten million people in each of these states lack a toilet (Jain et al., 2025). Ensuring acceptable hygiene conditions is particularly challenging in urban areas, where several million households lack sanitation facilities and over 30% of faeces produced are not adequately treated (NUSP, 2020).

In evaluations of Indian cities conducted under the National Urban Sanitation Policy (NUSP, 2020), the state of Uttar Pradesh has long been among the worst performers in terms of implementing measures to improve living conditions for slum communities in urban areas. This is why we focused on it when looking for a suitable area in which to conduct our research. Specifically, we focused on *Ghaziabad*, a city in the state of Uttar Pradesh with a population of 1.6 million and a population density of 4,060 persons per km² (according to data from the 2011[1] Census of India). Situated in close proximity to the capital, Delhi, and between the Ganga and Yamuna rivers, it is an important rail hub for northern India. The city has a tropical to temperate climate, with summer highs of 43°C and winter lows of 3°C. These locational factors help to promote its growth. Today, *Ghaziabad* is one of the world's fastest-growing cities, having experienced a population growth rate of around 41% between 2001 and 2011 (Census of India, 2011). There are three large landfills of mixed municipal waste in the city (Figure 1). Approximately 10,000 to 12,000 people make their living from waste collection at these sites (Dev, 2020). Although waste pickers constitute a significant component of the city’s waste management system, the health implications of their hazardous living and working conditions have thus far not been examined to a sufficient extent.



Fugure 1. Location of Ghaziabad in India

The city generates 1,400 tons of municipal solid waste per day on average (AM IST, 2023 estimate), but has the capacity to process only around 600 tons of this, converting it to compost. The categories of recyclables, inorganic or inert waste, biodegradable waste, and infectious waste were considered in this case. Ghaziabad Nagar Nigam (GNN), also known as Ghaziabad Municipal Corporation, has started construction of the Galand Waste to Energy Plant, which is planned to have the capacity to process 2,500 tonnes of waste and generate energy from it. The plant will be built on an area about four times larger than the current one. It was scheduled for commissioning in 2018 (Khandelwal, 2021). However, construction was suspended for four years following protests by local residents, after which the Ghaziabad Municipal Corporation abandoned the project. The corporation is currently looking for other plots of the same size so that it can process the city's collected waste into compost, at least temporarily. There are two landfills in the district of Ghaziabad. The National Green Tribunal is monitoring the sites and has directed agencies in Ghaziabad to clear all remaining waste from the site adjacent to residential areas. Around 1,200 metric tonnes of fresh solid waste has piled up at the Shakti Khand landfill (marked blue in Figure 1) in Indirapuram (marked red in Figure 1). The Galand site (35 acres) manages the areas administered by the GDA and the Ghaziabad Municipal Corporation's Pratap Vihar, Kavinagar and Vasundhara zones (Times of India, 2018). The Mohammadpur Amad Baghpat site (21 acres) covers Muradnagar, Modinagar and Mohan Nagar, addressing waste issues and curbing environmental contamination (Times of India, 2018). Residents are experiencing deteriorating living conditions due to decomposing waste and toxic smoke from fires polluting the air they breathe (Figure 2). Ghaziabad produces 1,200 to 1,400 tonnes of solid waste daily. Due to dumping close to urban areas, the city is at risk of environmental and health issues (Times of India, 2023). A planned landfill site will handle 30% of the non-recyclable waste, which is a significant portion of the city's daily waste production of 1,400 tonnes (data collected from

1 The latest official census data is from 2011. The census originally planned for 2021 has been postponed indefinitely due to the complicated conditions of the ongoing pandemic. According to media reports, Prime Minister Narendra Modi's government plans to begin collecting population data across the country in March 2027.

a Hindustan Times Report, 2023). Previously, the city managed 150,000 tonnes of waste in Indirapuram and 491,000 tonnes in Pratap Vihar (shown in green on Figure 1). Currently, there are 122 places where waste is still not being managed properly.

In order to address waste issues, the Ghaziabad Municipal Corporation is seeking bioremediation for 287,000 tonnes of waste, particularly in the Bhikhanpur area. The Ghaziabad Development Authority (GDA) has identified Galand (35 acres) and Mohammadpur Amad in Baghpat (21 acres) as potential landfill sites with waste-to-energy plants, which would support the daily collection of 1,200 tonnes of waste (data collected from a Hindustan Times report,2023).

Figure 2. Waste pickers in Ghaziabad (Source: Authors fieldwork)

Research objectives and methodology

One of the main motivations behind the research was the National Urban Sanitation Policy (NUSP, 2020), which placed *Ghaziabad* city in the worst 'black' category in the 2009–10 sanitation assessment. The measures taken over the next ten years brought about some improvement. According to Times of India reports, Ghaziabad performed well in the 2022 Swachh Survekshan (an annual survey conducted by the Government of India to assess cleanliness and sanitation in urban and rural areas), placing first in Uttar Pradesh and 12th in India among large cities with populations of 10–40 lakh, up from 18th in 2021. Despite this improvement, many critical health issues were reported among waste pickers in this district, which require a comprehensive research study concerning the health risks. Such studies provide valuable data and information needed to design and optimise measures to improve the health and overall quality of life of poor urban communities who make a living from collecting waste from local dumpsites. In the context of the current challenges in achieving the global Sustainable Development Goals, their importance is growing. They contribute to solving the problem of reducing the growing volume of municipal waste by separating it for subsequent recycling, which indirectly improves the quality of life of poor urban communities that rely on waste collection for their livelihoods. In order to improve their health and socio-economic status, it is important to examine the hazardous working conditions that waste pickers face and their impact on both their health and their perceived quality of life.

This study aims to investigate the impact of the hazardous working conditions at urban landfills on the health of waste pickers in Ghaziabad, India. The study will identify the factors of resilience and health concerns experienced by scavengers at work. The study aims to understand the specific difficulties and health consequences they experience. The impact of selected socio-economic factors on the subjective well-being of the respondents is also indirectly explored, as this can be considered a reflection of their socio-economic status and perceived quality of life. In other words, the paper aims to assess the extent to which hazards in the working environment impact the health and well-being of waste pickers in Ghaziabad, and to explore the strategies they use to cope with challenges at work. Methodologically, descriptive statistics, including percentages and statistically significant studies, were used to analyse the data. The analysis was carried out using a statistical package for the social sciences, SPSP 15.0 version. The Chi-Square test (Magnello, 2005; Pearson, 1900) and two proportion Z - Test (Montgomery & Runger, 2020) were used in the statistical analysis. First, to find the association between attributes *i.e.*, waste-pickers and health indicators, we defined null and alternative hypotheses as follows:

H_0: There is no statistically significant correlation between an individual's well-being and their health indicators

H_1: There is a statistically significant correlation between an individual's well-being and their health indicators (1)

Secondly, we defined another hypothesis to check the following association:

H_0: There is no statistically significant correlation between an individual's well-being and their socio-economic conditions

H_1: There is a statistically significant correlation between an individual's well-being and their socio-economic conditions. (2)

Test statistic is defined as:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \quad (3)$$

Break down the chi-square (χ^2) formula is as follows: χ^2 -Chi-square statistic); O_i -Observed frequency for category *I;* E_i (Expected frequency for category *i*);

$(O_i - E_i)^2$: The squared difference between observed and expected; Units: (counts)².

$(O_i - E_i)^2 / E_i$: Normalized squared deviation for each category; Since numerator has units (counts²) and denominator has units (counts), the result has units of counts; But in practice, because frequencies are counts, the ratio is treated as dimensionless (statistical measure, not physical units).

∑ (Summation); Adds up the contributions of all categories (from *i = 1* to *n*). Final χ^2 is dimensionless.

Decision Rule: If corresponding $p - value < \alpha(0.05)$ for the test statistic then H_0 is rejected else fails to reject the null hypothesis (H_0). Following are the hypotheses which are being tested and their conclusions.

Next, another level of statistical test was performed to find whether waste-pickers' proportion is significantly high or not when the comparison is made with control group (non-waste-pickers) on their wellbeing *i.e.*, health, socio-economic indicators etc. $Z - test$ for two proportions was performed to test the following hypothesis:

H_0: $P_{waste\text{-}picker} = P_{control\ group}$ - There is **no significant difference** in proportions between waste-picker's well-being and non-waste picker's well-being.

H_1: $P_{waste\text{-}pickers} < P_{control\ group}$ – The proportion of individuals in non-waste pickers group demonstrate a statistically higher well-being than waste pickers group* (4)

*waste picker's well-being is low as compared to control group for proportion supposed to be high.

Test Statistic is defined as:

$$Z = \frac{\hat{p}_{waste-pickers} - \hat{p}_{control\ group}}{\sqrt{p(1-p)\left(\frac{1}{n_{waste-pickers}} + \frac{1}{n_{control\ group}}\right)}}$$

where,

$\hat{p}_{waste-pickers}$ = Sample proportion from the waste-pickers group; $\hat{p}_{control\ group}$ = Sample proportion from the control group

$n_{waste-pickers}$ = Sample size of the waste − pickers group; $n_{control\ group}$ = Sample size of the control group

$$p = \frac{x_{waste-pickers} + x_{control\ group}}{n_{waste-piscker} + n_{control\ group}} \quad (5)\ \&\ (6)$$

Decision Rule: If corresponding $p - value < \alpha(0.05)$ for the test statistic, H_0 is rejected it fails to reject the null; hypothesis (H_0). Following are the hypotheses which are being tested and their conclusions.

Research design and primary data collection

This study adopts a cross-sectional research design and focuses on a highly socially vulnerable area: the largest garbage dump in Ghaziabad, a city in the Indian state of Uttar Pradesh (Figure 1). We adopted a multidimensional research protocol divided into four distinct phases to explore the conditions and health of the individuals examined in this context comprehensively. The first phase of the research aimed to identify and explore the feasibility of data gathering strategies. To ensure clarity and effectiveness in measuring health indicators, this phase included selecting participants from both waste-pickers and control group (non-waste-pickers), field-testing different questionnaires, and organising biometric assessment tests. Three critical actions were taken by the study team in the first phase:

(1) identification of subjects – the subjects of the study were selected from waste pickers at the landfill and communities not involved in waste picking activities;

(2) field testing – as a pilot test, 20 questionnaires were used to assess their usefulness and ensure question clarity;

(3) scheduling biometric assessment tests - biometric assessment tests, including measures linked to health indicators, were arranged for the selected participants.

The primary goal of the Survey Announcement phase was to inform participants about the upcoming study and encourage their engagement. This phase included notifying key members of the waste-picker and non-waste-picker communities (control group) about the survey, explaining the study's significance, establishing reception points for gathering participants in each community, and providing individual explanations to ensure clear understanding of the study's objectives. The phase consisted of two parts, the first of which aimed to inform participants about the study, while the second aimed to collect data from them: (1) announcement and (2) data collection.

(1) The study team informed both waste pickers and other community members about the upcoming poll, explaining its purpose and nature. Specifically, notices describing the study and its objectives were sent to prominent figures in both communities. Designated areas were set up in each community where respondents could gather to take part in the survey. People from the communities were then invited to participate in the survey, and researchers personally explained the study to each respondent to ensure they understood its objectives.

(2) The study was carried out with a sample size of 304 respondents. Of these, 203 were waste pickers and 101 were non-waste pickers in the control group (Table 1).

Data were obtained via four primary surveys, which were carried out in 2023. The primary purpose of the data collection phase was to gather as much information about the respondents as possible. Structured questionnaires were used to collect socio-demographic data, information on job habits, and perceptions of health conditions.

Table 1. Sample structure

	Variables	Waste-pickers respondents (%)	Control group(%)	Σ
Age groups (years)	20-29	39.41	19.80	100%
	30-39	35.47	41.58	
	40-49	22.17	25.74	
	50+	2.96	12.87	
Sex	Male	53.69	49.50	100%
	Female	46.31	50.50	
Levels of Education	Primary school	12.98	17.82	100%
	High school	5.29	21.78	
	University	3.37	8.91	
	Illiterate	77.83	51.49	
Medical history	chronic disease	45.32	20.79	100%
	Hypertension	23.65	7.92	
	Diabetes	2.96	11.88	
	Heart disease	7.88	2.97	
	No major problems		56.44	
Family history of CVD	No	40	64.36	100%
	Yes	60	35.64	
Income (INR per month)	(1) Below 2000	10.84	3.96	100%
	(2) 3000-5000	34.48	38.61	
	(3) 6000-8000	38.42	17.83	
	(3) 9000-11,000	11.82	29.70	
	(4) 12,000-15000	4.43	6.93	
	(6) 16000-20,000	0	1.98	
	(7) Above 20,000	0	0.99	

To determine the immediate health impact of waste pickers' occupations, the following biometric tests were conducted: BMI, oximeter readings, blood pressure, pulse rate, chronometer readings, body temperature, and general well-being. Participants were also provided with meals during this period. Data were collected using standardised questionnaires (Table 2) and biometric tests. Data collection actually took place in several phases.

Table 2. Survey content

Research areas	Variables
Occupation	Nature of work, waste-picking status, workplace, work duration, time of day, method of waste collection, tasks performed, what type of material collection, weight of waste collected per day/week in kg, money earned per kg of waste per day/week, type of transport used for reaching the site of work, distance travelled to reach the site of work in km,
Working Condition	Drinking water at the workplace, toilets at the worksite, special place for eating at the workplace, bathing status and frequency after work, and use of disinfectants in washing clothes, and hands. Availability and use of personal protective equipment (PPE), Covid-19 awareness etc.
Health Exposure	Physical, chemical and biological exposure
Occupational Health Hazards	Occupational injuries, accidents, animal bites, encounters with rotting waste, accidents reporting
Harassment and Abuse	Harassment by caretakers of the dumping site, by the public, police, exploitation by kabari, and physical, mental, and sexual abuse.
Ergonomics Hazards including Musculoskeletal Problems (physical health)	Prevalence of ergonomic exposures, pain, areas of pain, pain counts
General Health Problems	Chronic disease
Intestinal Health	Intestinal worms, leptospirosis, diarrhoea, dengue fever, Zika virus or chikungunya, hepatitis A, B, C?
Skin Problems	Infections, rashes
Eye Problems	Infections, redness
Cardiovascular diseases	Heart attack
Respiratory Diseases	Upper respiratory symptoms, lower respiratory symptoms (LRS), bronchitis, asthma, lung problems, tuberculosis problems, pneumonia
Sexually Transmitted Diseases	Hepatitis, Phyllis
Cancer	Various type of body cancer like skin, lungs, breast, prostate etc.
Use of Medicines	For what purpose like blood pressure, temperature, severity of disease

Healthcare Services	Vaccination, work training, health check-up camp, treatment facility,
Aspirations	
Mental Health	Anxiety, depression, work, other mental disorders, such as schizophrenia, bipolar disorder, psychosis, or obsessive-compulsive disorder (OCD)
Depression	Depression
BMI	Weight, height, BMI, lean body mass, protein, bone mass, water, BMT, fat, muscle, vs fat, and body age
Brontometer	Level-1, level 2, level 3 readings
Oximeter	Oxygen, pulse rate
Overall feelings of health	
Household Amenities and Assets	Address, origin state, house ownership, type and material of housing, number of dwelling rooms, household family size, household expenditure every month, source of drinking water, sewer system, access of household to latrine, and bathroom facility,
Eating Habits of Individuals	Meals/day, food preference, frequency of eating green vegetable/week, frequency of eating pulses/week, frequency of eating fruits/week
Lifestyle Habits	Tobacco/gutka chewing, betel nuts, smoking status, alcohol consumption, drugs consumption, drug addiction, status of physical activity
Socio-economic Profile of Individuals	Monthly income, education level
Identification questions	Name, place of residence, districts, locality, age, category/caste, sex, marital status

In order to gain insight into the daily rituals, working practices and challenges faced by waste pickers, as well as the factors enabling them to perform this health-risking work long term, we observed them directly at work in landfills. We also conducted a series of in-depth interviews to gain a more thorough understanding of their socioeconomic status and other relevant factors. Finally, group discussions were organised for those who did not wish to participate in the survey, to encourage their participation and also to gain information about the situation of the less open-minded waste pickers.

RESULTS AND DISCUSSION

Our survey results showed that the food habits, tobacco intake and alcohol consumption of waste pickers were significantly poorer than those of non-waste pickers in the control group. The relationship between engagement in waste picking and unfavourable dietary practices, along with elevated consumption of tobacco and alcohol, was subjected to statistical verification, as presented in Tables 3 and 4. The chi-square test and the two-sample test of proportions demonstrate a significant statistical association between waste picking and health-compromising behaviours, including suboptimal dietary intake (fewer than three meals per day: 78% of waste pickers versus 42% of non-waste pickers, $p = 0.002$), elevated tobacco use (51% versus 37%, $p = 0.024$), and increased alcohol consumption (67% versus 39%, $p = 0.004$). Results of Chi-Square test for food, tobacco intake, and regular drinking (alcohol consumption) habits of non-waste-pickers versus waste-pickers found a significantly low food intake and higher alcohol as well as tobacco in taking habits in the latter indicating a probable reason for their worse health issues (Table 3).

Table 3. Chi-Square test for food, tobacco intake, and drinking habits

	Selection	Waste-pickers (%)	Control group (%)	p-value	Decision
Food	3 or more meals/day	22%	58%	0.002	H_0 rejection
	<3 meals/day	78%	42%		
Tobacco	Yes	51%	37%	0.024	H_0 rejection
	No	49%	63%		
Alcohol consumption	Yes	67%	39%	0.004	H_0 rejection
	No	33%	61%		

Table 4. Z-test for food, tobacco intake, and drinking habits

	Selection	Waste-pickers (%)	Control group (%)	P-value	Decision
Food	3 or more meals/day	22%	58%	0.002	H_0 rejection
	<3 meals/day	78%	42%		
Tobacco	Yes	51%	37%	0.014	H_0 rejection
	No	49%	63%		
Drink (alcohol consumption)	Yes	67%	39%	0.012	H_0 rejection
	No	33%	61%		

Table 5. Chi-Square test for communicable and skin diseases

	Selection	Waste-pickers (%)	Control group (%)	p-value	Decision
Itching	Yes	37%	9%	0.004	SH_0 rejection
	No	63%	91%		
Allergies	Yes	37%	9%	0.004	H_0 rejection
	No	63%	91%		
Upper respiratory symptoms (URS)	Yes	76%	61%	0.014	H_0 rejection
	No	24%	39%		
Eye Infection	Yes	26%	7%	0.021	H_0 rejection
	No	73.9%	93%		

The results of the proportional Z-test comparing the food, tobacco and alcohol consumption habits of non-waste pickers and waste pickers revealed that the latter had significantly lower food intake and higher alcohol and tobacco consumption, indicating a probable cause of their poorer health (Table 4).

The results of the chi-square test for communicable and skin diseases in non-waste pickers versus waste pickers revealed a significantly higher incidence in the latter, indicating a probable occupational risk of waste picking (Table 5).

Specifically, work-related morbidities encompassing dermatological and respiratory conditions—such as allergic reactions, pruritus, upper respiratory tract symptoms, and ocular infections—were analysed statistically, as presented in Tables 5 and 6. The chi-square test and the two-sample test of proportions demonstrate a significant association between waste picking and each of these morbidities: pruritus (37% of waste pickers versus 9% of non-waste pickers, p = 0.004), allergic manifestations (37% versus 9%, p = 0.004), upper respiratory tract syndrome (76% versus 61%, p = 0.014), and ocular infections (26% versus 7%, p = 0.021).

Table 6. Z-test for communicable and skin diseases

	Selection	Waste-pickers (%)	Control goup (%)	p-value	Decision
Itching	Yes	37%	9%	0.003	H_0 rejection
	No	63%	91%		
Allergies	Yes	37%	9	0.003	H_0 rejection
	No	63%	91%		
Upper respiratory symptoms (URS)	Yes	76%	61%	0.014	H_0 rejection
	No	24%	39%		
Eye Infection	Yes	26%	7%	0.021	H_0 rejection
	No	79%	93%		

Table 7. Chi-Square test for non-communicable diseases

	Selection	Waste-pickers (%)	Control goup (%)	p-value	Decision
Hypertension	Yes	24%	8%	0.005	H_0 rejection
	No	76%	92%		
Musculo skeletal issues	Yes	80%	66%	0.010	H_0 rejection
	No	20%	34%		
Fatigue in the last 3 months	Yes	57%	34%	0.001	H_0 rejection
	No	43%	66%		

Table 8. Proportional Z-test for non-communicable diseases

	Selection	Waste-pickers (%)	Control goup (%)	p-value	Decision
Hypertension	Yes	24%	8%	0.005	H_0 rejection
	No	76%	92%		
Musculoskeletal issues	Yes	80%	66%	0.011	H_0 rejection
	No	20%	34%		
Fatigue in the last 3 months	Yes	57%	34%	0.001	H_0 rejection
	No	43%	66%		

The results of the chi-square and proportional Z-tests indicate a significant relationship between waste pickers and certain non-communicable disorders, such as hypertension (affecting 24% of waste pickers versus 8% of non-waste pickers, p-value 0.005), musculoskeletal issues (80% of waste pickers versus 66% of non-waste pickers, p-value 0.010) and fatigue in the last three months (57% of waste pickers versus 34% of non-waste pickers, p-value 0.001), as shown in Tables 7 and 8. Thus, our research confirmed that non-communicable diseases (NCDs) occur at significantly higher rates among waste pickers than among non-waste pickers.The chi-square and proportional Z-tests' results indicate a significant relationship between waste-pickers and physical injuries (82% of waste-pickers versus 19% of non-waste-pickers, p-value 0.001), and physical discomfort in the last year (91% of waste pickers versus 81% of non-waste pickers, p-value 0.010).

However, non-waste pickers worked more than eight hours a day (39% of non-waste pickers versus 26% of waste pickers, p-value 0.020). The results of the chi-square and proportional Z-tests for the other parameters (injuries at work, physical discomfort in the last year, and longer working hours) showed a significantly higher occurrence among waste-pickers than non-waste-pickers, indicating a probable occupational risk of waste-picking (Tables 9 and 10).

Table 9. Chi-Square test for other parameters

	Selection	Waste-pickers (%)	Control group (%)	p-value	Decision
Injured while working	Yes	82%	19%	0.001	H_0 rejection
	No	18%	81%		
Physical Discomfort in 1 last year	Yes	91%	81%	0.010	H_0 rejection
	No	9%	19%		
Working hours	8 or <8 Hours/Day	74%	61%	0.020	H_0 rejection
	>8 Hours/Day	26%	39%		

Table 10. Proportional Z-test for other parameters

	Selection	Waste-pickers (%)	Control group (%)	p-value	Decision
Injured while working	Yes	82%	19%	0.001	H_0 rejection
	No	18%	81%		
Physical Discomfort in 1 last year	Yes	91%	81%	0.010	H_0 rejection
	No	9%	19%		
Musculoskeletal issues	Yes	80%	66%	0.010	H_0 rejection
	No	20%	34%		
Fatigue in last 3 months	Yes	57%	34%	0.001	H_0 rejection
	No	43%	66%		
Worm on the workplace	Yes	47%	37%	0.04	H_0 rejection
	No	53%	63%		

The application of chi-square and proportional Z-tests yielded evidence of a statistically significant association between engagement in waste picking and limited literacy attainment. Within the analytical framework of this study, literacy was operationalized as the demonstrated ability to read, write, and comprehend, whereas illiteracy denoted the absence of formal schooling or educational enrolment. Empirical results indicate that 78% of waste pickers across the three landfill sites were classified as illiterate, compared with 22% identified as literate.

By contrast, the distribution among non-waste pickers reflected 52% illiterate and 48% literate respondents. These disparities were statistically significant ($p < 0.005$; see Tables 11 and 12). Moreover, proportional Z-test outcomes revealed a significant association between waste picking and low-income status ($p = 0.003$), underscoring the role of economic marginality as a structural driver of participation in this occupation. Income stratification data further demonstrated that 44.5% of waste pickers earned between Rs. 501 and 1,000 per month, 36% between Rs. 1,001 and 1,500, 15% between Rs. 1,501 and 2,000 (below the poverty line), while only 4.43% exceeded Rs. 2,500 (above the poverty line). Patterns of labor force participation revealed that 46.5% of respondents had engaged in waste picking for one to three years, 24.6% for four to five years, and 28.9% for six years or longer. Work intensity was also substantial, with 36% engaged in daily labour, 34.2% reporting six days per week, 26.3% five days per week, 1.8% four days per week, and 0.9% two days per week; an additional 0.9% did not specify their working frequency. The results of the proportional Z-tests indicate a significant relationship between waste pickers and an unhealthy BMI (body mass index), with a p-value of 0.010. However, this relationship was not observed among non-waste pickers, as shown in Table 13.

Table 11. Chi-Square test for education

	Selection	Waste-pickers (%)	Control group (%)	p-value	Decision
Education	Illiterate	78%	51.5%	0.003	H_0 rejection
	Literate	22%	48.5%		

Table 12. Results of proportional Z-test for education

	Selection	Waste-pickers (%)	Control group (%)	p-value	Decision
Education	Illiterate	78%	51.5%	0.003	H_0 rejection
	Literate	22%	48.5%		
Income	BPL (Below poverty line)	95.55%	90%	0.030	H_0 rejection
	APL (Above poverty line)	4.43%	10%		

Table 13. Proportional Z-test for BMI

	Selection	Waste-pickers (%)	Control group (%)	p-value	Decision
BMI	Healthy	40%	42%	0.010	H_0 rejection
	Unhealthy	60%	58%		

CONCLUSIONS

The adverse health consequences faced by waste pickers in India have received limited scholarly and policy attention, a trend consistent with broader patterns observed across many low- and middle-income countries (Schenck et al., 2019). It is imperative that relevant stakeholders acknowledge and address the occupational hazards inherent to waste picking. This study, employing a triangulated approach that combined symptomatology, self-reported questionnaires, and records of clinical and hospital consultations, investigated the environmental and occupational health risks associated with waste picking in the Ghaziabad region of India. The findings indicate a markedly elevated likelihood of occupational morbidity among waste pickers. These results align with community health surveys that have documented diverse health problems arising from environmental exposure to landfill sites (de Araújo & Sato, 2018).

Empirical evidence links waste picking and landfill exposure to heightened prevalence of adverse health outcomes, including increased rates of self-reported morbidity, diminished self-rated health, and more frequent clinical consultations (Made et al., 2020). The present research corroborates associations between waste picking and both communicable and non-communicable disease burdens. Specific health impairments identified include musculoskeletal disorders, gastrointestinal and dermatological conditions, as well as ocular and auditory complications (Aminuddin &

Rahman, 2015). Furthermore, the study documented that approximately 50% of respondents across the three landfill sites reported tobacco use. Given well-established epidemiological evidence, such high prevalence of smoking represents an additional compounding risk factor, particularly for respiratory morbidity.

Tobacco use constitutes a major determinant of respiratory morbidity, with extensive epidemiological evidence substantiating its role in amplifying the prevalence of respiratory pathologies (Liu et al., 2015).

Its distribution is socioeconomically patterned, disproportionately concentrated among socially marginalized and economically precarious populations, including waste pickers (Burney et al., 2013). As highlighted by Hiscock et al. (2012), smoking often emerges as a maladaptive coping mechanism for the alleviation of psychosocial stressors and emotional distress. The present study further corroborates this association, demonstrating that individuals with a prior history of smoking displayed an elevated probability of experiencing respiratory complications. Importantly, tobacco consumption operates as a critical confounding variable in the nexus between occupational exposure to landfill environments and the manifestation of respiratory symptomatology (Liu et al., 2015).

Ethnographic observations across the three landfill sites revealed considerable heterogeneity in operational conditions, yet a pervasive absence of adequate occupational safeguards. While respondents generally expressed awareness of the necessity of personal protective equipment (PPE), its actual availability and utilization were grossly insufficient. Standardized protective devices—such as N95 respirators, dust masks, and protective eyewear—were conspicuously absent, thereby exacerbating inhalation risks associated with airborne particulates. In many cases, waste pickers substituted discarded clothing and footwear retrieved from landfill sites as improvised PPE (Made et al., 2020). Such practices, however, fall significantly short of occupational health standards and contribute to cumulative health vulnerabilities (Nyathi et al., 2018). Unsurprisingly, the majority of participants reported chronic respiratory complaints, findings that resonate with prior research attributing elevated rates of respiratory morbidity among waste pickers to sustained exposure to landfill-derived pollutants (Nyathi et al., 2018).

Airborne particulate matter, particularly visible dust generated during landfill operations—most prominently during the unloading of refuse from garbage trucks—represents a critical occupational hazard for waste pickers. The excavation and sorting of materials such as bricks, cardboard, cans, and wood inherently exacerbate particulate concentrations, thereby intensifying exposure risks to the respiratory tract and mucosal membranes (de Araújo & Sato, 2018). The absence of consistent use of appropriate personal protective equipment (PPE) substantially magnifies these vulnerabilities. Findings from this study underscore significant associations between waste picking and the manifestation of allergic and dermatological conditions. These observations are consistent with cross-sectional epidemiological evidence from Kota Bharu, Malaysia, where 65.5% of surveyed waste pickers reported gastrointestinal disorders and 70.3% reported dermatological symptoms (Aminuddin & Rahman, 2015).

Musculoskeletal morbidity also emerged as a salient occupational health concern. Statistical analyses revealed a significant correlation between waste picking and the prevalence of bodily pain across the three landfill sites. The task structure of waste picking—frequent kneeling during sorting and repetitive manual handling of waste materials—creates biomechanical stressors particularly affecting the lower extremities. Moreover, excessive lifting is associated with a spectrum of musculoskeletal disorders, including lumbar disc prolapse, tendon pathologies, overexertion-related pulmonary strain, and chronic shoulder and back pain (Da Silva et al., 2006). These results, while consistent in direction, differ in magnitude from those of Aminuddin and Rahman (2015), who reported musculoskeletal complaints among 94% of waste pickers in Kota Bharu. Ocular morbidity represents another domain of elevated occupational risk. The use of protective eyewear is recognized as an effective intervention to mitigate risks of lacerations and ocular trauma from sharp debris (e.g., broken glass), as well as exposure to infectious agents present in waste streams (Kuijer et al., 2010). However, field observations revealed that none of the waste pickers at the studied landfill sites utilized protective goggles. The lack of access to, and inconsistent use of, PPE such as eye protection reflects structural deficits in occupational health safeguards (Gutberlet et al., 2013). Consequently, waste pickers, regardless of prior history of infectious disease, remain persistently exposed to preventable occupational health hazards (Made et al., 2020)

A longitudinal cohort study conducted in India demonstrated that waste pickers who self-rated their health as poor exhibited a threefold increased risk of contracting infectious diseases. As Gutberlet et al. (2013) and Godfrey et al. (2017) note, waste pickers are routinely exposed to hazardous substances embedded in landfill waste streams. Such exposures encompass biological pathogens, toxic chemicals, and heavy metals, cumulatively generating a high-risk occupational milieu. The absence or inappropriate use of adequate personal protective equipment (PPE) further amplifies this vulnerability, intensifying both acute and chronic health risks (Made et al., 2020).

Findings from chi-square and proportional Z-tests provided empirical evidence of a statistically robust association between waste picking and infectious disease prevalence. After adjusting for potential confounders, individuals with a history of chronic illnesses were found to be twice as likely to report poor self-rated health compared to their counterparts without chronic conditions. This finding aligns with prior research establishing a strong linkage between chronic morbidity and diminished self-perceived health status (Uhunamure et al., 2021). Similarly, epidemiological evidence from Malaysia (Norsa'adah et al., 2020) underscores the health consequences of landfill exposure, revealing robust associations with non-communicable conditions such as diabetes mellitus and hypertension. Collectively, these findings highlight the intersection of occupational exposure, environmental toxicity, and the compounded burden of infectious and chronic diseases among waste pickers. By foregrounding both the adaptive resilience and the occupational health vulnerabilities of waste pickers in Ghaziabad, this study seeks to address a critical knowledge deficit and to contribute to evidence-based advocacy for this marginalized yet indispensable labor force.

Beyond documenting lived experiences, the research provides epidemiological validation of the multifaceted risks to which waste pickers are exposed within landfill environments, thereby establishing a reference framework for subsequent investigations into the health and social consequences of waste management practices in Ghaziabad.

Statistical analyses employing chi-square and proportional Z-tests revealed significant associations between waste picking and multiple markers of social and behavioral disadvantage. Specifically, waste pickers exhibited higher prevalence of suboptimal dietary intake ($p = 0.002$), household income deprivation ($p = 0.003$), and limited literacy ($p < 0.005$), when compared with non-waste pickers (Tables 3, 4, 11, and 12). The analysis further identified elevated burden of allergic and infection-related morbidities among waste pickers, including ocular infections ($p = 0.021$), upper respiratory tract illness ($p = 0.014$), general allergies ($p = 0.004$), and dermatological manifestations such as pruritus ($p = 0.004$) (Tables 5 and 6). In addition, the chi-square and proportional Z-tests underscored the disproportionate prevalence of non-communicable and chronic conditions within the waste picker cohort. These included occupational injuries ($p = 0.001$), musculoskeletal disorders ($p = 0.010$), fatigue within the preceding three months ($p = 0.001$), and hypertension ($p = 0.005$).

Comparative analysis also demonstrated that non-waste pickers were statistically more likely to report extended workdays exceeding eight hours ($p = 0.020$) (Tables 7–10). Taken together, these findings highlight the syndemic interaction of occupational exposure, socioeconomic deprivation, and health vulnerability, underscoring the structural risks inherent in waste picking as practiced at landfill sites in Ghaziabad. This study is intended to serve as a catalyst for provincial health authorities, district and municipal administrations, and other relevant stakeholders to strengthen public health responses targeted at the occupationally vulnerable population of waste pickers. Future large-scale, multi-site investigations encompassing landfill settings across additional provinces are strongly recommended. Longitudinal cohort studies, in particular, would provide a rigorous epidemiological framework for systematically tracking morbidity trajectories and elucidating the causal pathways through which landfill exposure contributes to adverse health outcomes. Parallel to this, environmental surveillance and risk assessment mechanisms are essential for generating robust empirical baselines that can be used to quantify the cumulative health burden attributable to landfill-related exposures.

The empirical evidence from this study underscores that occupational engagement in landfill environments exerts a profound impact on health status, with statistically significant associations identified between landfill exposure and heightened susceptibility to communicable and non-communicable diseases, alongside increased prevalence of mental health disorders. The findings further highlight the urgency of directing the attention of policymakers and institutional actors to the health risks faced by waste pickers. Given their structural vulnerability, continuous monitoring of both the socioeconomic and health profiles of waste pickers is required at local, regional, and national levels. Such monitoring should be accompanied by the design and implementation of evidence-based risk prevention strategies, informed by reliable epidemiological data and context-specific baseline indicators. Targeted health promotion and preventive measures are likewise imperative. Enhanced awareness campaigns could empower waste pickers to recognize early warning signs of illness, while structured training initiatives are needed to improve their capacity to safely handle hazardous materials encountered in landfill environments. Reducing infectious disease transmission requires both the provision of adequate and standardized personal protective equipment (PPE) and the promotion of hygienic practices.

The deployment of mobile health clinics proximal to landfill sites could provide a vital first point of care for this underserved population. At a structural level, however, the most sustainable intervention remains the implementation of effective, multi-tiered waste management systems across all levels of governance.

By foregrounding the occupational health vulnerabilities of waste pickers in Ghaziabad, this study makes a significant contribution to regional public health discourse. Through comprehensive health assessment and the identification of resilience factors, the research offers actionable insights for policymakers and institutional stakeholders seeking to develop targeted interventions, protective infrastructures, and support systems for this marginalized workforce (Brunn et al., 2018; Demková et al., 2022; Herman et al., 2022; Boros & Korcsmáros, 2024). Moreover, these findings hold relevance for broader waste governance agendas, with the potential to inform integrated policies that simultaneously advance waste pickers’ well-being and promote sustainable, socially equitable waste management practices.

Research limitations

This study provides a preliminary appraisal of the occupational health risks to which waste disposal workers in Ghaziabad, India, are subjected. The evidence generated offers an enhanced understanding of the extent and specificity of waste pickers’ exposure to occupational and environmental hazards. From an epidemiological standpoint, however, the robustness and generalizability of such findings necessitate a substantially larger sample frame - on the order of at least 1,000 respondents - to ensure adequate statistical power and external validity. It is important to perform biochemical analyses of physiological parameters, which will be carried out in the next phase of the study. Additionally, the cross-sectional study used a convenient sampling method, which did not allow for an accurate assessment of the entire waste picker community.

It must also be acknowledged that the validity of self-reported data may have been compromised by response bias. Waste pickers demonstrated hesitancy in addressing certain survey items, likely attributable to apprehensions regarding potential repercussions from landfill authorities, thereby raising the possibility of deliberate misreporting. Moreover, the reliance on self-assessed health histories introduces susceptibility to social desirability bias, wherein respondents may have systematically overstated their health status in order to project an appearance of physical well-being to data collectors. Such dynamics underscore the limitations inherent to self-report methodologies in marginalized populations, particularly in contexts characterized by heightened vulnerability, surveillance, and power asymmetries.

Ethical clearance: The Department of Research Ethics Committee at the Delhi School of Public Health and Institute of Eminence, University of Delhi with reference to IoE2022/037/257 approved this study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional committee.

Author Contributions: Conceptualization, K.M.; methodology, S.K.D, R.Y., K.M. and H.K.V.; validation, P.K.M., M.G.; primary data collection, U.R.; statistical analysis S.K.D., B.W.P. and H.K.V.; writing - original draft preparation, U.R. and K.M; writing - review and editing, R.S., K.M., Z.B. and P.K.M.

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