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ORIGINAL PAPER

Health hazards implication for household solid waste collectors of north city corporation in Dhaka: a post-COVID study

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Abstract

Solid waste management has been one of the challenging tasks for the waste collectors at Dhaka North City corporations, especially during the post-COVID-19 period, since this task exposes several acute and chronic illnesses. The perilous implications of waste collection on the health condition of the waste collectors at the Dhaka North City Corporation (DNCC) have often been ignored, and they have to work without adequate protective measures. Though different research has already been done regarding the occupational health hazards of waste collectors, the novelty of this study is that it considers the post-COVID period and focuses on the solid waste picker of DNCC. This study aimed to evaluate the current health hazards faced by DNCC household waste collectors and suggest remedial actions. A questionnaire-based survey ($n=415$) assessed work environment, socio-economic status, and post-COVID-19 health hazard awareness through convenience sampling. Descriptive statistics, Pearson's chi-square tests, and binary logistic regression were adopted to analyze the data. Descriptive statistics portray that 81.8% of waste pickers are not satisfied with their work environment. Additionally, 66% of solid waste collectors face health issues, and 58% of waste collectors are unaware of the risk of COVID-19. Pearson's chi-square tests reveal that the health hazards of waste pickers are significantly associated with job type, working hours, Awareness of solid waste effect on health and severe suffering history. Additionally, the binary logistic regression model exposed job type, Awareness of solid waste effect on health, frequently suffered diseases, and severe suffering history has significant (p-value < 0.05) impact on the health hazard of a waste picker of DNCC. Regarding the policy implication, Dhaka North City Corporation must take immediate action that will significantly reduce the hazardous impacts of solid waste collection on the health of the waste collectors by supplying them with adequate protective measures.

Keywords Household Solid Waste · Waste Collection Workers · Health Hazards · COVID-19 · Dhaka North City Corporation (DNCC) · Bangladesh

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Introduction

Rapid industrialization and urbanization development have been producing mammoth amounts of waste day in and day out in the capital city of Bangladesh. This humongous amount of industrial and household waste has become the biggest challenge for waste management authorities like the North and South city corporations of Dhaka. In the northern part of Dhaka city, the residential areas, along with the number of populations, are growing exponentially. Consequently, every day, this part of Dhaka city produces tons of waste, leading the waste collectors of north city corporation to accomplish an impossible job of managing the waste now and then. Moreover, households producing solid waste also pose huge occupational health risks for their collectors, especially after the COVID-19 pandemic. Hence, it is high time to evaluate the exposure of household waste collectors to occupational health hazards, especially in the northern part of Dhaka city. Not only a mega city like Dhaka, but waste management has also become a significant global challenge in the twenty-first century, and almost every country is fighting to manage solid waste in a sustainable manner all over the world. (Ahmed et al., 2022). The pace of production of municipal solid waste (MSW) in emerging nations has increased significantly due to factors including population growth, fast urbanization, a thriving economy, and rising standards of living (Zahoori and Ghani, 2017; Ali et al. 2014; Minghua et al. 2009). The issues related to the management of MSW have grown alarmingly severe in developing countries over the past few decades (A. Ahsan et al. 2014).

In comparison to the growth of urbanization, waste production is still growing (Islam 2016). The swift rise in MSW has emerged as a significant global challenge in maintaining a pollution-free planet amidst the ongoing trend of urbanization. Globally, 2.01 billion metric tons of municipal solid waste are produced yearly. By 2030, 2.59 billion tons of MSW will be generated annually, and by 2050, 3.40 billion tons (Kaza et al. 2018). Also, MSW generation in Asia is predicted to increase from the current rate of 1 million tons per day to 1.8 million tons per day by 2025 (Hoornweg and Bhada-Tata 2012). Nearly 30% of the waste produced worldwide, according to Waste Atlas, needs to be appropriately collected (Jerin et al. 2022). Disease transmission, fire dangers, foul odour, air and water pollution, annoyance with the aesthetics, and financial losses are the most frequent issues connected to improper solid waste management systems (Shum et al. 2020; Rahman et al. 2008). Maghrebi et. al, (2022) reported that the number of days with a good Air Quality Index (AQI) has significantly decreased during the pandemic, despite the positive trend in the global AQI. However, Solid waste management must minimize dangers to the environment and human health, which affects how it is stored, collected, and disposed of (Kassim and Ali 2006).

The existing studies have revealed that the global challenges of solid waste management, as discussed above, is a pretty similar case for Bangladesh that simultaneously poses significant risks to both human and environmental health (Ahmed et al., 2022). This concerning issue has always been given less priority over the years (Abedin and Jahiruddin 2015). However, the statistical figures attest to why this solid waste production and its management must be given much priority for the sake of environmental and human health. For instance, in 2013, the amount of municipal solid waste (MSW) generated in urban areas of Bangladesh was 52,00,919 tons per year by 3,69,86,768 people, which is equivalent to the rate of 0.35 kg per capita per day (Shams et al. 2017; Islam 2017). However, it is expected that by 2025, waste production in Bangladesh's municipal regions will increase by 0.6 kg/cap/day (Bhuiyan 2010) where the total produced waste volume will be 57,718 tons/day (Hoornweg and Perinaz, 2012).

However, Dhaka is the capital city of Bangladesh and the most densely populated metropolitan with 22 million inhabitants. It is separated into two city corporations: Dhaka South City Corporation (DSCC) and Dhaka north city corporation (DNCC). City corporations are responsible for collecting and disposing of MSW. Around 6,000 tons of solid garbage are produced daily by these two city corporations; however, approximately 40–50% of this waste is collected for final disposal (Ahmed et al., 2022). Nevertheless, it is worth mentioning that household waste collection is not only a challenging task, but it also has a severe economic and health impact on the lives of these waste collectors in Dhaka city. It is also one of the riskiest jobs in the first place.

To be very specific, a recent study reveals that workers are exposed to physical, biological, and chemical risks and occupational morbidities (Melaku and Tiruneh 2020). Collecting residential waste requires a vehicle that travels through traffic all year round. It also requires repeated heavy physical activities, such as the manual collecting, lifting and handling of left garbage and heavy bins (Patil and Kamble 2017; Ray et al. 2005). Consequently, MSW collection workers experience several occupational health issues like muscle and ligament sprains, cuts and lacerations, and different allergies (Joy and Chitra 2018; Shuvai 2017). MSW collectors have to work for long hours and often encounter

many workplace accidents due to handling hazardous chemicals, pollutant materials, and sordid substances that potentially lead to physical and mental health risks (Joy and Chitra 2018; Cointreau 2006) as it is evident that COVID-19 caused an enormous number of mortality of people globally. At the same time, it also exposed the limitations of the health sector. It became a great lesson for humanity and to what extent people should be sincere about the risk of viruses. However, the post-COVID period should be considered seriously with much preparation to protect people's lives from any virus that can potentially cause health hazards.

Nevertheless, the absence of adequate protective equipment and its application during working hours is one of the causes of occupational health issues for MSW collectors in city corporations (Melaku and Tiruneh 2020). In addition, solid waste workers (MSWWs) of the city corporations are also exposed to various pathogens such as bacteria, fungi, viruses, parasites, and cysts. Besides, some of the toxic substances like endotoxins and beta-glucans, as well as chemicals originating from both the waste and its decomposition process, have a lethal impact on their health condition. Eventually, MSWWs are exposed to vehicle exhaust emissions, noise, extreme temperatures, and ultraviolet radiation (Athanasiou et al. 2010; Lavoie et al. 2006; Poulsen et al. 1995). Nevertheless, waste collectors always remain in danger of underlying chronic diseases like hypertension, heart disease, diabetes, respiratory illnesses, asthma, kidney disease, and liver (Sharior et al. 2023). Hence, this study aims to measure the health hazards posed by household solid waste collectors in Dhaka North City Corporation (DNCC) during the post-COVID period.

Literature review

The city planning process undertaken by the city corporation often ignored the proper waste management system compared to a couple of other sectors like water and energy over the years (Ahmed et al., 2022; Song et al. 2015). The world bank reveals that in South Asia and Sub-Saharan Africa, only 44% of waste is collected. Moreover, 93% of the waste collected in low-income countries is dumped in open places (Kaza et al. 2018). In addition, MSW is responsible for increasing the greenhouse gases (GHG) in the atmosphere, and it also creates an adverse impact on climate. Organic solid waste degradation produces greenhouse gas (GHG) emissions, a significant environmental concern (Gautam, and Agrawal 2021; Maria et al. 2020). Gautam, and Agrawal, (2021) further informed that more than 50% of the collected garbage is not managed appropriately and is instead burned outdoors or disposed of in landfills in many developing countries. Additionally, between 10 and 40 percent are processed by composting and recycling. About 5% of all greenhouse gas emissions into the atmosphere are attributable to waste management alone (GHG, CO2, N2O, and CH4). Shams et al. (2017) estimate that nearly 49,000 million tons of CO2 are produced annually by uncontrolled waste, or it also contributes to 3.5% of all anthropogenic GHG emissions globally. Besides, one-tenth of the methane emissions globally as biogas is accounted for by MSW landfills, which are the third greatest anthropogenic source of methane after agricultural and enteric fermentation. By 2020, it was anticipated that these landfill emissions would increase to 816 MtCO (Maria et al. 2020).

By 2050, solid waste-related emissions will rise to 2.6 billion tons of CO_2 equivalent if the industry does not adapt to changes (Kaza et al. 2018). Several cities in various countries, such as China, India, Malaysia, Thailand, and Bangladesh, are grappling with serious waste management issues due to the swift population growth, industrialization, and urbanization they are experiencing (Riaz et al. 2023; Zohoori, and Ghani, 2023; Zohoori, and Ghani 2017). However, many recent literatures exposed occupational health hazards among the waste collectors working in the municipality in different parts of the world (Intauno, and Poshai 2023; Melaku, and Tiruneh 2020; Elsayed Farid Amr, and Abdel Malek Hussein, 2021; and Thakur et al. 2018).

Occupational health related issues are evident in the article published by Patil and Kamble (2017), where the authors revealed that solid waste collectors were exposed to 100% musculoskeletal diseases, 90% respiratory difficulties and headaches issues, 25% dermatological problems, 15% gastrointestinal problems respectively. In addition, the duo also found that waste collectors experienced 100% allergies, 50% stomachache, 45% asthma and bronchitis in their lungs, 25% cough and cold, 25% vomiting, 20% hearing impairment, 15% fever, 10% typhoid, and 5% malaria etc. respectively, among some other conditions. However, Thakur et al. (2018) explained that waste collectors are also exposed to external injuries due to absence of protective equipment and their ignorance to use these during their work. Hence, many pathogens (bacteria, fungi, viruses, parasites, and cysts), toxic substances (endotoxins and beta-glucans), chemicals etc. are frequently derived from the waste and its breakdown, vehicle exhaust fumes, noise, extremely high and low temperatures, and ultraviolet radiation etc. severely pose risks to waste collectors.

Furthermore, the results of this study indicated that employees lack enough protection against these kinds of occupational health risks and that new laws and regulations

are required to ensure their safety. The study conducted by Majumdar and Srivastava (2012) has also found that municipal solid waste workers face a variety of occupational risks, including exposure to toxic materials from chemical and solvent residues, disease-carrying flies and pests, other microbiological contaminants, emissions from the degradation of the organic fraction, and musculoskeletal issues from handling heavy loads of generated household solid waste. Similarly, Velasco Garrido et al. (2015) have reported that musculoskeletal complaints, of which back pain accounted for 67.2% and other musculoskeletal complaints for 15.4%, were the most prevalent health issues. Besides, 15% of the workers reported having asthma or chronic obstructive pulmonary disease (COPD). Every individual who disclosed receiving a diagnosis of COPD or asthma had previously smoked or was currently smoking. They have also found that the occupational group under investigation has a lower HRQoL.

According to Ahmed (2019), Bangladesh's metropolitan regions generate about 25,000 tons of solid waste per day, or 170 kg per person annually. There are authorized locations for the disposal of municipal solid trash in nine out of twelve city corporations in Bangladesh. On the other hand, Razzak (2020) noted a number of issues with landfill administration. Landfills function as open-air, unsanitary crude disposal sites because city corporations and municipalities lack the necessary landfill operation and management units. However, currently, Dhaka alone manages about 500 tons of waste each day, and by 2032, that number is expected to rise to 8500 tons (Islam 2021). In metropolitan areas, the collection efficiency varies from 37 to 77%, meaning that an average of 55% of solid waste goes uncollected (Ahmed 2019). Uncollected waste, and especially plastic and polyethylene items, clog drains and contaminate soil, groundwater, air, and drainage systems. It also ends up in water bodies and water systems (Islam 2021).

DSCC comprises five zones and 57 wards, while DNCC comprises five and 36 wards. Approximately 100,000 waste pickers are employed at Dhaka city alone, as reported by the Bangladesh Labor Foundation (BLF). DNCC's jurisdiction, covering 82.4 square kilometres, has only 199 garbage containers of various sizes, whereas DSCC has 321 containers (Hasan and Islam, 2018). Dhaka city MSW system follows a conventional approach, like the waste collectors at Dhaka city move around door-to-door to collect waste. The waste collectors collect the MSW directly from the origin point using a small van, open truck, and a small bin to carry the waste from one place to another. During the collection of waste, the solid waste directly contaminates them because they do not wear proper clothing, face masks, hand gloves, or gumboots, and they are unskilled workers (Ahmed et al., 2022). The issue of health hazard of the waste collectors in DNCC is hardly documented with empirical evidence. However, a recently published qualitative study conducted by Urme et al., (2021) revealed the hazardous state of the waste collectors in the following FGD verbatim by one of the respondents, *"I cannot eat properly, I lost my appetite after starting to live here [mentioned the landfill] […]."* Further, Urme et al., (2021) also summarized that People who work close to landfills frequently sustain injuries, and rashes usually appear on their feet from walking in contaminated fields or waterways. Moreover, a major stakeholder brought attention to the risks to the occupational health of landfill workers from the absence of protective equipment and the possibility of contracting hepatitis B and jaundice. Overall, the results showed that people who live or work close to landfills suffer from poor waste management (Urme et al. 2021). Another study conducted by Uddin et al., (2021) has also presented evidence of musculoskeletal disorders among the solid waste collectors working at the selected areas of Dhaka city. The authors further noted that almost 85.3% of the workers are exposed to musculoskeletal disorders due to duration of employment, lifting, pulling, pushing/carrying loads (> 20/kg) and walking for long periods of time (Uddin et al. 2021). However, the study conducted by Kabir (2015) has identified that street sweepers are frequently exposed to a range of risk factors as a result of their manual handling work, including dust particles, hazardous materials, loud noises, and exhaust fumes. Due to a lack of basic safety equipment, frequent infections and injuries have been recorded frequently while working. There were many low perceived health hazards. Robust religious justifications have been discovered to justify potential health risks. The study conducted by Rifat et al. (2018) revealed that waste collectors are more exposed to microbiological risks than the general public.

During the COVID-19 outbreaks, household waste collectors were in a hazardous situation, and they did not get any PPE or other protective equipment. At the beginning of COVID-19, the waste collectors and their family members experienced COVID-19 symptoms and did not have handwashing facilities (Sharior et al. 2023; Hoque 2020). Waste collectors' occupational health hazards and safety issues are overlooked in Bangladesh by the concerned authorities. However, the pandemic has changed the dynamics of waste generation, which is problematic for legislators and sanitation personnel (Mallapur 2020). During an outbreak, a more significant amount of non-infected products of the same type, as well as a variety of medical and hazardous waste, are produced, including contaminated masks, gloves, and other protective equipment (UNEP 2020). There may be

a risk of transmission if the virus is contaminated in ordinary solid waste from the municipality due to improper collection procedures. An efficient emergency response, therefore, must include the safe processing and ultimate disposal of the waste. Appropriate identification, collection, separation, storage, transportation, treatment, and disposal of biomedical and healthcare waste are all necessary for its effective management, along with vital supporting components, including worker safety, training, and disinfection (UNEP 2020). To reduce potential downstream effects on health and the environment, governments have suggested treating the management of medical, domestic, and other hazardous materials waste as an urgent and crucial public service (UNEP 2020).

The health risks faced by household solid garbage collectors in North City Corporation, Dhaka, are alarmingly severe. These risks include respiratory conditions such as breathing difficulties, coughing, and chest discomfort; skin conditions such as rashes and itching; musculoskeletal conditions such as back and joint pain; gastrointestinal difficulties such as acidity and diarrhea; and headaches and vision impairments (Khan et al. 2016). Furthermore, people working in waste disposal landfills have been shown to exhibit oxidative stress, elevated levels of lead, protein damage, and an imbalance in pro-oxidant and antioxidant equilibrium as a result of solid waste exposure (Alam et al. 2021). In addition to experiencing health issues including fever, exhaustion, dizziness, and vomiting, children who work in rubbish collecting often face financial difficulties (Biswas et al. 2020). Undernutrition results from poor eating habits among garbage collectors, and being underweight is significantly increased by insufficient food consumption, which increases health risks. The majority of garbage workers in Bangladesh who are assigned to sweep the streets are women, and they frequently lack the amenities necessary to maintain menstrual hygiene at work. Conversely, personal protection equipment (PPE) is insufficient and poorly suited to various body shapes (Alam et al., 2022).

Materials and methods

This research primarily focused on investigating the health hazards faced by waste in Dhaka, specifically within the Dhaka North City Corporation (DNCC). The study aimed to understand the impact of their work on their health and well-being. The convenience sampling method has been adopted here for the sampling procedure. Due to the unavailability of a sampling frame and budget constraints, this study used convenience sampling to collect data. Though bias is one of the drawbacks of convenience sampling, this study tries to reduce the biases by increasing the sample to 415 here, where the standard sample size is 385

$$\begin{aligned}&\left[\textit{considering sample size determination formula},\right.\\&n = \frac{Z^2pq}{d^2};p = \textit{proportion of success} = 0.5,\\&q = \textit{proportion of failure} = 05,\\&\textit{standard normal variate value},\\&z = 1.96\,\textit{at}\,5\%\,\textit{level os significance and}\\&d = \textit{margin of error} = 0.05\left.\right]\end{aligned} \tag{1}$$

(Cochran 1963).

For this purpose, interviews were conducted with approximately 415 waste pickers who operated at five waste dump points within the DNCC. These waste dump points were selected to ensure a relatively representative sample of waste pickers from different areas within the city.

A well-structured interview was conducted with the waste pickers using a carefully designed questionnaire that specifically addressed the health-related concerns of this community. The questionnaire covered aspects such as occupational health risks, exposure to the virus, adherence to preventive measures, access to healthcare services, and the impact of the pandemic on their livelihoods. The interviews were conducted in person, adhering to necessary safety protocols to ensure accurate data collection and to allow for clarifications or additional information, if necessary. This study takes the information based on a well-structured three-segmented questionnaire. The 1st section contains the demographical info of a waste worker, and the second section questions were asked to measure the respondents' knowledge about solid waste and health hazards. The third section contains information regarding their opinion about solid waste risk. Among these 415 responses, there are 402 complete responses, which are processed to analyze the health risk of waste pickers of DNCC. Initially, we have presented the demographic analysis of our study. Then, to determine the health hazard of waste collectors (HHWC), we try to identify the associated potential factors by adopting the chi-square test. Finally, a binary logistic regression is adopted here to identify the HHWC of DNCC by considering potential exposure variables. IBM SPSS version 20 has been employed to identify patterns and underlying factors within the data. The most popular method for assessing reliability in a questionnaire is Cronbach's alpha test (Cronbach 1951). This study found Cronbach's alpha coefficient value for this proposed questionnaire to be 0.609, which implies that the questionnaire is acceptable. However, Fig. 1 illustrates the study area for this particular research (Fig. 2).

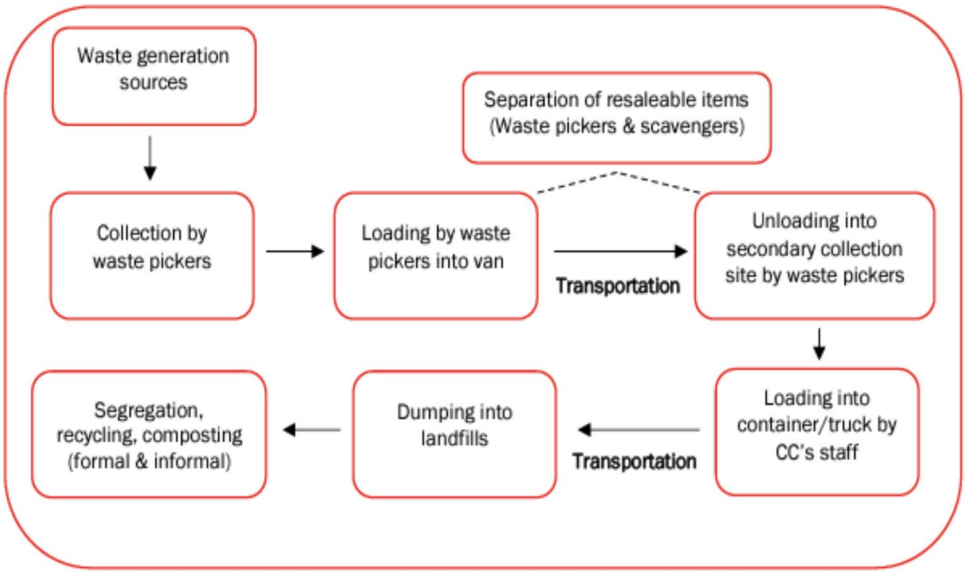

Fig. 1 Solid waste management process in Dhaka city (Islam 2021)

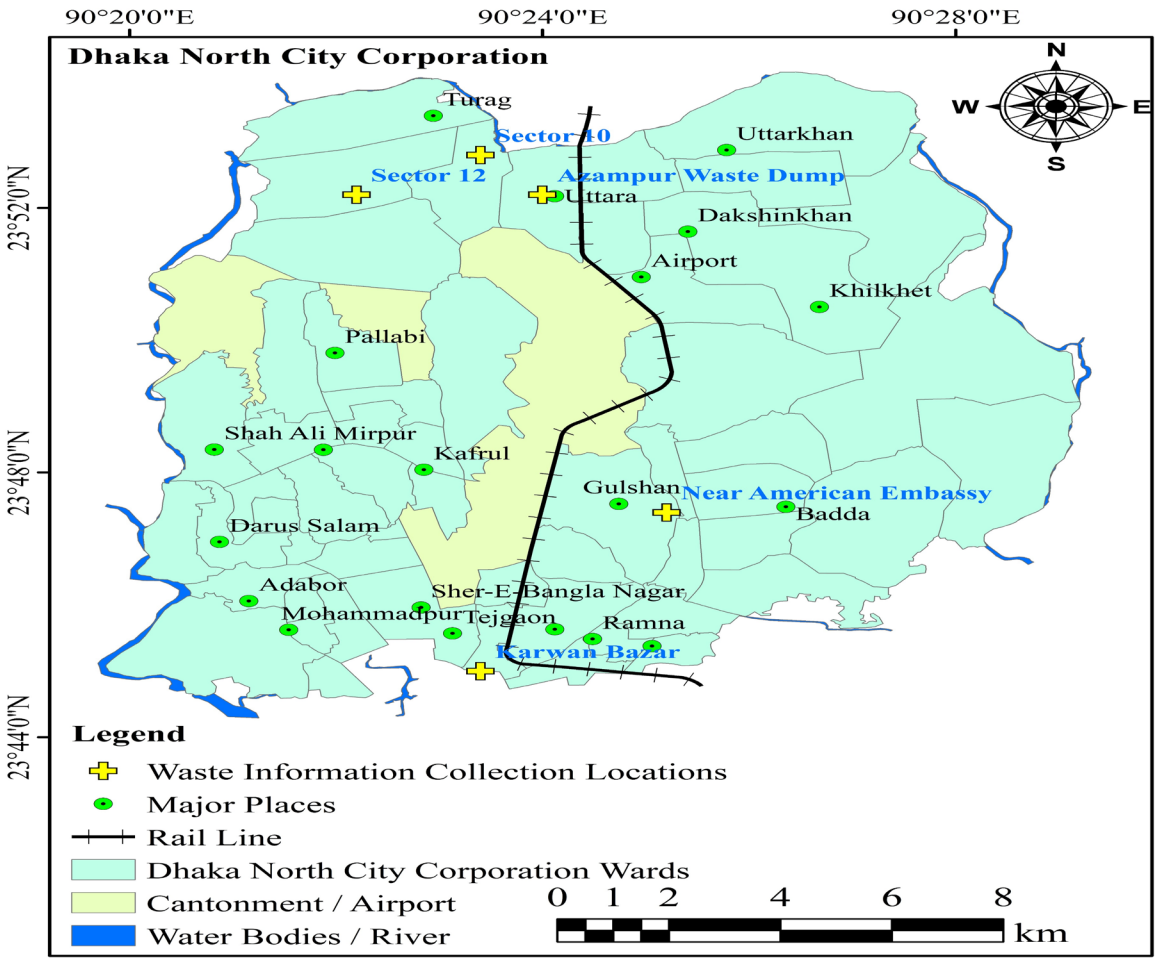

Fig. 2 Data collection from temporary dumping sites in DNCC

The research outcomes contributed to raising awareness about the health hazards faced by waste pickers during the COVID-19 pandemic and informed policy recommendations aimed at improving their working conditions, providing necessary protections, enhancing access to healthcare services, and supporting their overall well-being during those challenging times.

Model

The Pearson's chi-square test is a statistical technique used to analyze categorical data. This statistical test is employed to ascertain the level of significance in the disparity between observed data and the anticipated values. The application of this nonparametric test is necessary in order to assess a hypothesis associated with the distribution of a categorical variable. The Chi-Square test of independence determines whether the two sets of variables are likely to be connected with each other or not.

As our questionnaire is concentrated on health status, socio-economic situation and awareness of solid waste pickers, it focuses on categorical variables, and the Chi-square technique is the best method to access the association between categorical variables (Cochran 1952). Here, Chi-square ($\chi 2$) tests were used to examine the association between prevalence of suffering from long term diseases and some selected variables in order to determine the factors contributing to the health hazard of waste collectors.

A binary logistic regression analysis has been carried out to estimate the likelihood that a subject belongs into any one of the two groups of a dichotomous dependent variable (suffering from long term disease or not suffering from long term disease) considering the independent variables (continuous or categorical). This model has been selected for the following reasons:

1. This model is extremely adaptable with this study objectives and
2. Provides significant interpretation in the factors affecting the health of waste collectors.

Let consider a sample of n distinct observations concerning the pair (xj, yj),j = 1,2, … … n. The probability distribution of the outcome variable is Binomial i.e. $y_j \sim Bin\ (n_j,\ \lambda(x_j))$ where, y_j denote the value of a dichotomous response variable, and x_i denotes the value of the independent variable for the jth subject.

Now Now $y_j = \begin{cases} 1, & \textit{Suffering from long term disease} \\ 0, & \textit{Not suffering form term disease} \end{cases}$

In logistic regression, let us consider the conditional mean, λ(x), which represents the expected value of y given the value of x:

$$\lambda(x) = \frac{e^{\beta_0+\beta_1 x}}{1 + e^{\beta_0+\beta_1 x}} \tag{1}$$

In order to apply the logistic regression model described in Eq. (1) to a given set of data, it is necessary to estimate the unknown parameters β_0 and β_1 and for dichotomous data, $0 \le \lambda(x) \le 1$. The aim of binary regression model is to estimate the logit, which represents the natural log of the odds of subjects to be suffering from disease or not suffering from disease with predictors such as health problem, sickness, job type, whether respondents identify waste collection is an issue for their health and daily working hour and can be defined as:

$$logit\lambda(x) = ln\left[\frac{\lambda(x)}{1-\lambda(x)}\right] = \beta_0 + \beta_1(x) \tag{2}$$

Here, the predicted probability of the event (suffering from long-term disease) is presented by $\lambda(x)$ and the predicted probability of the alternate event is presented by $1-\lambda(x)$ and x is considered as the explanatory variable. The logit value varies from -∞ to + ∞. The conditional probability P (Y = 1|x) is given by the expression for λ(x) in Eq. (1), and the conditional probability P(Y = 0|x) is given by the term 1-λ(x) for any unknown parameter β = β0 and β1, the vector parameters. Since it is assumed that the observations in a logistic regression are independent, the likelihood function can be found as follows:

$$l(\beta) = \prod_{j=1}^{n} \lambda(x_j)^{y_j}[1 - \lambda\left(x_j\right)^{1-y_j}] \tag{3}$$

For ease of mathematical calculations, log of Eq. (3), log likelihood, can be written as:

$$l(\beta) = \ln[l(\beta)] = \sum\nolimits_{j=1}^{n} \{y_j \ln\left[\lambda\left(x_j\right)\right] + \left(1 - y_j\right)\ln\left[1 - \lambda\left(x_j\right)\right]\} \tag{4}$$

So, this binary logistic regression explains the link between independent variables and binary dependent variables. It suits dichotomous dependent variables and categorical or continuous independent variables.

Outcome variable

As this study concentrate the health hazard of waste pickers of DNCC, the response of suffering in long term disease is

Table 1 Targeted variables of this study

Sl	Variable	Asked question	Categories of the variable
1	Working hour	How long (in hour) need to work a day?	a) 2–5 h b) 6–8 h c) More than 8 h
2	Awareness of solid waste affect to health	Do waste issues directly affect your health?	a) No b) Yes
3	Job type	Your job type?	a) Part-time b) Full-time
4	Frequently suffered diseases	What type of health problem you suffer from?	a) Bacillary dysentery/ amoebic dysentery/ Diarrhea b) Typhus/cholera/ plague c) None of these
5	Severe suffering history	What type of sever health problem you suffer from?	a) Skin disease/injury/ Pain (Joint/back) b) Cough/Cold/Asthma/ Anemia

considered as the outcome variable in here. In the questionnaire, we get 402 complete responses, which are used to analysis the total health risk. The responses taken from the question *"Are you suffering from any long-term diseases for this waste collection job?"* There is dichotomous response of this question as 1. No (0) and 2. Yes (1).

Table 2 Demographic distribution of waste collectors of DNCC

Variable	Categories	Frequency	Percentages
Gender	Male	402	100
	Female	0	0
Age	15–20	23	5.7
	21–25	134	33.3
	26–30	131	32.6
	31 or above	114	28.4
Level of education	No education	203	50.5
	Primary	191	47.5
	Secondary	8	2
Job type	Part-time	103	25.6
	Full-time	299	74.4
Satisfaction with Job environment	No	329	81.8
	Yes	73	18.2
Proper training before doing Job	No	396	98.5
	Yes	6	1.5
Type of the carrier used in collecting waste	Van with container	376	93.5
	Waste Basket	22	5.5
	Plastic bag or others	4	1
Types of reusable solid waste usually collected	Plastic Bottle	221	55
	Polyethene	107	26.6
	Metal	14	3.5
	Electronic waste	25	6.2
	Paper	35	8.7

Table 3 Association of socio-economic variable and knowledge of waster collector with the health hazard risk

Variables with category	"Are you suffering from any long-term diseases for this waste collection job?		Chi-square	*P*-value
	Yes (%)	No (%)		
Age			2.071	0.558
15–20	15 (3.7)	8 (2)		
21–25	94 (23.4)	40 (10)		
26–30	81 (20.1)	50 (12.4)		
31 or above	76 (18.9)	38 (9.5)		
Level of education			3.866	0.145
No education	143 (35.6)	60 (14.9)		
Primary	119 (29.6)	72 (17.9)		
Secondary	4 (1)	4 (1)		
Job type			3.877	0.049*
Part-time	60 (14.9)	43 (10.7)		
Full-time	206 (51.2)	93 (23.1)		
Satisfaction with Job environment			0.396	0.529
No	220 (54.7)	109 (27.1)		
Yes	46 (11.4)	27 (6.7)		
Working hour				
2–5 h	17 (4.2)	13 (3.2)	16.795	0.00*
6–8 h	209 (52)	81 (20.1)		
More than 8 h	40 (10)	42 (10.4)		
Type of the carrier used in collecting waste			0.60	0.741
Van with container	247 (61.4)	129 (32.1)		
Waste Basket	16 (4)	6 (1.5)		
Plastic bag or others	3 (.7)	1 (.2)		
Awareness of solid waste affect to health			6.365	0.012*
Yes	129 (32.1)	48 (11.9)		
No	137 (34.1)	88 (21.9)		
Frequently suffered diseases				
Bacillary dysentery/amoebic dysentery/Diarrhea	129 (48.9)	48 (36.1)		
Typhus/cholera/ plague	69 (26.1)	33 (24.8)		
None of these	66 (25)	52 (39.1)		
Sever suffering history			9.165	0.02*
Skin disease/injury/Pain (Joint/back)	169 (42)	65 (16.2)		
Cough/Cold/Asthma/Anemia	97 (24.1)	71 (17.7)		

Exposure variables

From the defined questionnaire this study has investigate the potential exposure variables that can explain the health hazard of the waste collector of DNCC. From chi-square test, this study has determined some potential exposures that have been used later in binary logistic model to explain the suffering of waste collector by any long-term diseases. The following table give the description of our selected independent variables, (Table 1)

Results and discussion

Demographic distribution

This questionnaire-based survey revealed that the household waste-collector Job in DNCC is dominated by male workers in all study areas. Table 3 states that the lowest age of these male workers is 15 years, where the maximum percentage has been dominated by the age group 21–30, which is 65.9%. Besides, 28.4% are more than 30 years old. The education level of the waste worker reveals that 50.5% of respondents have no education, and 47.5% have education up to the primary level. Only 2% of waste worker cross their primary

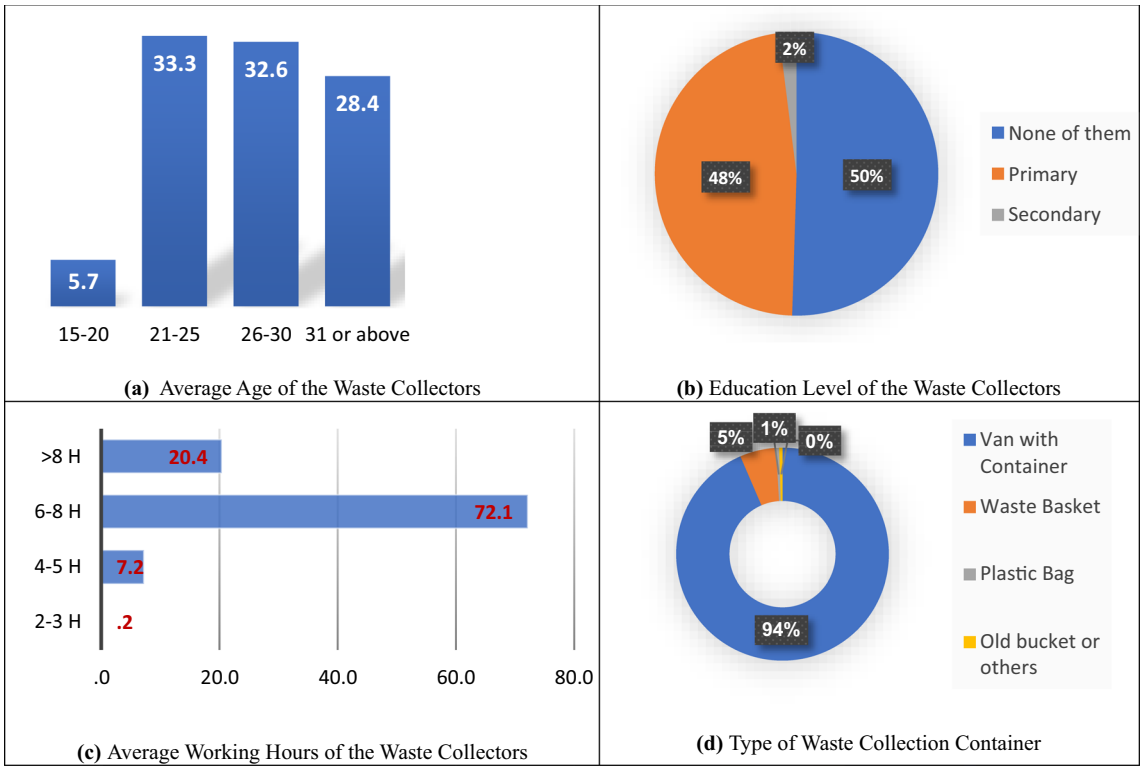

Fig. 3 Average age, education, working hours and type of waste collection containers of the waste collectors

education level. This statistic clearly shows the lack of literacy in this profession.

Additionally, 74.4% of workers are doing full-time jobs, whereas 25.6% are doing part-time jobs (Table 2). Among them, 58.2% of workers are doing permanent jobs under DNCC, and 98.5% need proper training before starting this job. Most workers use a van with a container to collect solid waste, which is 93.5%. The details of the socio-demographic statistics have been provided in Table 3.

Figure 3 (a) above demonstrates the age frequency of the respondents. It shows that 33.3% of the respondents are aged between 21 to 25 years. However, 32.6% and 28.4% of respondents are between the ages of 21, 30, and 31 years and above, respectively. Only 5.7% of respondents remain between 15 and 20 years. Conversely, Fig. 3 (b) represents the respondents' education level, showing that half of the respondents do not have any formal educational background. Of the rest of the respondents, 48% have primary-level education, and only 2% of the respondents have completed secondary-level education. Moreover, Fig. 3 (c) indicates that more than 70% of the respondents work between 6 and 8 h, whereas more than 20% work for more than 8 h. However, only a few respondents work between 2 to 5 h. Hence, this result reveals that more than 90% of the waste collectors have to work long hours, thus highly exposing them to waste-generated health hazards. On the other hand, Fig. 3 (d) displays that the maximum (94%) waste collection containers are vans, with containers usually pulled by the waste collectors daily. These van containers often remained open, and waste collectors remained closed to these vans for long hours, as shown in Fig. 3. Only 5% of the waste collection is done through a waste basket. Hence, the North City Corporation should take this issue seriously and provide more wastebaskets in prominent public places.

However, Fig. 4 (a) highlights that food waste and fiber bags dominate the standard municipal solid waste. Food waste is perishable waste that pollutes the environment quickly and simultaneously becomes hazardous to the health of its collectors. This figure also reveals that 40% of the waste is plastic, scrap paper and cartons. In addition, Fig. 4 (b) demonstrates that a maximum number of waste collectors must be aware of the consequences of COVID-19. During COVID-19 19, a considerable amount of waste was generated from personal protective equipment, which has vast adverse implications for the health of the waste collectors in the North City corporation. However, the finding of

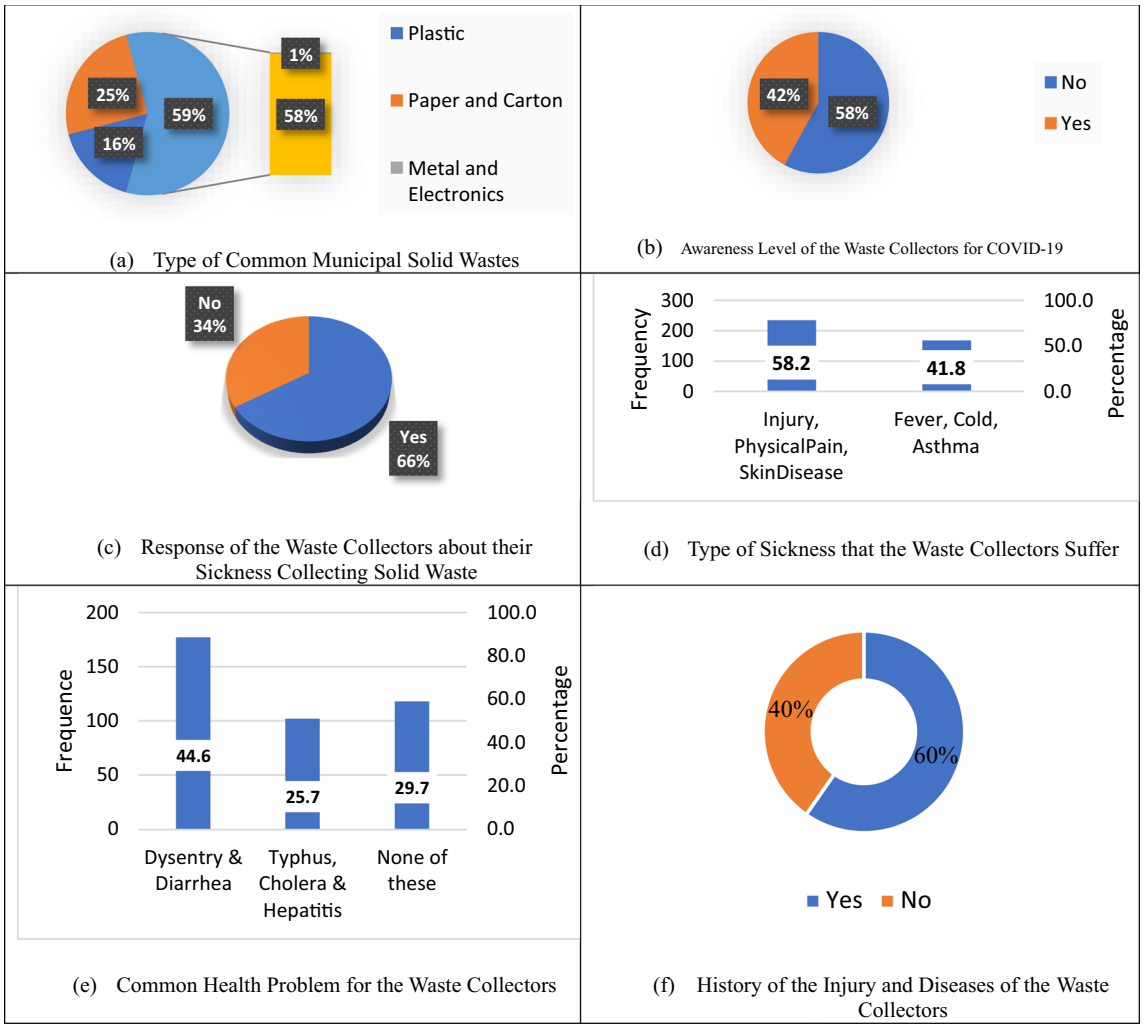

Fig. 4 Different heath hazards of the solid waste collectors

this study also shows that 20% of waste collectors are well aware of the COVID-19 implications on their health. On the contrary, Fig. 4 (c) reveals that 65% of the waste collectors at Dhaka North City Corporation have been suffering from long-term diseases. The solid waste collection procedure infects the waste collectors in many infectious long-term disorders. However, 34% of the respondents replied negatively regarding the long-term illnesses that may arise from their work. However, this study also finds that 58.2% of the waste collectors at Dhaka North City Corporation have frequently been suffering from physical injuries, pains, and skin diseases now and then (Fig. 4 d). Moreover, a significant number of people, precisely 41.8% of the waste collectors, also frequently suffer from fever, colds, and asthma. This study proves that waste collectors working at Dhaka North City corporations are exposed to diseases that significantly affect their health. Furthermore, Fig. 4 (e) has also identified the percentage of common health problems that waste collectors are frequently exposed to. For instance, dysentery and diarrhea significantly affect most waste collectors (44.6%). However, the study also finds that 25.7% of the waste collectors suffer from typhus, Cholera and Hepatitis diseases. However, interestingly, among the total respondents, 29.7% replied that they are exposed to any of these diseases, as shown in Fig. 3 (f). Additionally, Fig. 4 (f) of this study exposes the history of injury and disease due to waste collection. Here, it is evident that 60% of the waste collectors replied positively that they have an account of injury and several conditions due to waste collection during their working tenures. However, 40% of the employees do not have any record of any damage or illnesses because they are collecting solid waste.

Table 4 Outputs of binary logistic regression analysis

Variables with category	Estimated Parameter	Odds Ratio	Standard error	*p*-value
Job type				
Part-time	Reference group	––	––	––
Full-time	0.525	1.691	0.263	.046*
Working hour				
2–5 h	Reference group	––	––	––
6–8 h	0.469	1.599	0.408	.251
More than 8 h	−0.616	0.504	0.456	.176
Awareness of solid waste affect to health				
Yes	0.562	1.753	0.236	.018*
No	Reference group	––	––	––
Frequently suffered diseases				
Bacillary dysentery/amoebic dysentery/Diarrhea	0.653	1.921	0.270	.016*
Typhus/cholera/ plague	0.301	1.351	0.305	.323
None of these	Reference group	––	––	––
Sever suffering history				
Skin disease/injury/Pain (Joint/back)	0.704	2.023	0.228	.002*
Cough/Cold/Asthma/Anemia	Reference group	––	––	––

Note: '*' implies at 5% level of significance

Table 5 Output of model summary

	Chi-square	df	Sig
Hosmer and lemeshow Test	4.812	8	0.777
Nagelkerke R Square	0.339		

Outputs based on chi-square test and binary logistic model

The study has investigated the association between the health hazard of waste collectors (HHWC) and different socio-demographic variables, which are briefly provided in Table 4. Here, Table 4 revealed that age, level of education, type of waste carrier and satisfaction with the Job environment have an insignificant association with the health hazard of the waste collector (HHWC). In contrast, job types, working hours, and frequently suffered diseases have statistically significant associations with the HHWC—the details of the chi-square output are provided in Table 3.

Findings from the association investigation found that those who are performing full-time jobs have a percentage of being affected by long-term diseases compared to the part-time jobholders (Table 3). These findings indicate the lack of safety and hygiene product supply, which may occur in this situation to the full-time job holders. In addition, a lack of training to collect the waste may have an impact on the health hazards of the waste collector. Additionally, it provides the information that those who suffer frequently from dysentery or diarrhea may have more chance of suffering from long-term diseases. However, skin disease, injury and pain history support the same scenario.

The outputs of the binary logistic model in Table 4 identifies that those who are working as a full-time waste collector are 1.691 times more likely to suffer from long-term diseases compared to those working as part-timers. Even though their daily working hours show an insignificant impact on the condition, this may indicate that whether working shorter hours or longer hours, waste collectors are at risk of suffering from long-term illnesses. From the awareness aspect of waste collectors, those aware that waste collection is affecting their health are 1.733 times more likely to understand that their suffering from disease is due to waste collection. Additionally, those individuals who already suffer from any skin disease injury or pain are 2.023 times more likely to have long-term illness compared to those who have cold or asthma-related disease. Not only this, in frequently suffered disease Bacillary dysentery/amoebic dysentery/Diarrhea affected individuals have 1.921 times more risk of suffering long-term disease compared to the non-suffered individuals.

The Hosmer–Lemeshow test is a statistical technique performed to assess the goodness of fit of the logistic regression model. This test examines the null hypothesis, which states that the logistic model is appropriately specified, against the

alternative theory, which states that the logistic model is not adequately defined. This study has performed an HL test to validate the binary logistic model, which supports the Null hypothesis at a 5% significance level in Table 5. Additionally, the Nagelkerke R Square, which measures the goodness of fit of a logistic model provided here, has an estimated value of 0.339. This value has confirmed a moderate association between the predictor variables and outcome variables.

Conclusion

Like most developing countries, Bangladesh needs to pay more attention to the adverse health risks that waste pickers suffer—the hazards to waste pickers' occupational health need to be considered by pertinent parties. This study aimed to look into the health concerns associated with waste pickers' profession after the COVID-19 period. Supported by the findings from the study, Waste pickers are significantly at a higher risk of occupational health. Descriptive statistics help us to conclude that solid waste collection workers had a variety of acute and chronic illnesses, including typhus, cholera, hepatitis, and diarrhea; they also had physical injuries, pain, skin diseases, fever, cold, and asthma, among other conditions. Collecting waste involves repetitive heavy lifting, hauling, tugging, or pushing of bins and containers, all of which involve static muscle contraction and raise the risk of musculoskeletal issues. Additionally, from the chi-square findings, we have found that the health hazards of waste pickers are significantly associated with job type, working hours, Awareness of solid waste affecting health and severe suffering history. Mostly, those waste collectors spend 8–9 h a day in their work where they are facing intense road dust, traffic noise, uncovered dustbins in the cart, pathogenic microorganisms in solid waste, flies and mosquitoes, solid waste leachate, wet waste, offensive odors, inadequate personal protective equipment, lack of personal cleaning supplies like soap and water, and lack of restroom amenities. These factors may increase their health risk, though most are aware of COVID-19. Our proposed model found that those working as a full-time waste collector are more likely to suffer from long-term diseases than those working as part-timers. This study pointed out that working hours are essential in health hazards, which suggests revising their working hours. Frequently suffered diseases and severe suffering history have a significant impact on the health hazards of those waste pickers. That means an unhealthy work environment, less training and lack of proper equipment, leading to frequent suffering and also increasing the risk of health. The awareness aspect of waste collectors also plays a vital role in the evidence of the binary logistic model of this study, which presents that after COVID-19, those who were more aware of diseases had less health suffering history. In conclusion, the study summarizes a health issue that affects waste collection personnel for the Dhaka North City Corporation more frequently than it does the broader public. These results are linked to reductions in health-related quality of life, likely accounting for at least some of these deficiencies. To reduce occupational risk, the Dhaka North City Corporation might improve the process of transferring household waste into curbside bins by constructing ramps and platforms for pushcart emptying.

Policy recommendation

1. Since many waste collectors suffered during COVID-19 and suffered from different health issues nurturing solid waste, city corporation should ensure their occupational safety and health (OSH).
2. They must be provided with personal protective equipment (PPE). During the COVID period or normal times, they are not offered PPE, which is a severe health hazard for waste collectors.
3. They have to work long hours; therefore, their working hour can be shifted based on where their operating hour can be declined from morning to noon (6 am-12 pm & 12 pm–6 pm).
4. The waste collectors are not regular employees of the city corporation. They are working under the third party. Therefore, they do not have that many employee rights, and labor law is always ignored for them. Maybe the third party is getting more benefits from exploiting these waste collectors. In reality, their monthly salary is not even that much regular. At that time, waste collectors protested but not that strongly; they only did not collect waste on time, or they threw all the household garbage on the main roads or highways as their protest. Therefore, a serious issue should be looked after so that they get their salary on time and have career growth. Anyway, the authorities should try to maintain their labor laws and Humanitarian issues always.
5. Although the waste collectors work under a third party, the city corporation or municipality authority must recognize their responsibility towards the waste collectors, they work hard to clean up our surrounding environment.
6. The city corporation or musicality must consider their health hazards and provide personal protective equipment (PPE) to maintain their occupational safety and health. At the same time, they also need to consider their

salary and wedge for their better livelihood considering the recent scenario of the living standard.

7. There should be free health checkup facilities for waste collectors to reduce their health hazards by nurturing dirty waste materials. Since each of the wards has one of the clinics under the city corporation in Dhaka, it is possible to provide them with free health checkup cards. For sure, it will help to reduce their injury and other sickness caused by collecting waste.

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Declarations

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References

Abedin MA, Jahiruddin M (2015) Waste generation and management in Bangladesh: an overview. Asian J Med Biol Res 1(1):114–120

Ahmed N When the garbage piles up. the daily star. retrieved from https://www.thedailystar.net/opinion/environment/news/when-the-garbage-piles-1810375. 7 Oct 2019

Ahsan A, Alamgir M, El-Sergany MM, Shams S, Rowshon MK, Daud NN (2014) Assessment of municipal solid waste management system in a developing country. Chin J Eng 2014(1):561935

Alam MU (2022) Hygiene knowledge and practices and determinants of occupational safety among waste and sanitation workers in Bangladesh during the COVID-19 pandemic. Hyg Environ Health Adv 4:100022

Alam MM, Hossain MS, Islam N, Murad MW, Khan NA (2021) Impacts of health and economic costs on street children working as waste collectors in Dhaka city. Int J Environ Sustain Dev 20(1):29–50

Ali SM, Pervaiz A, Afzal B, Hamid N, Yasmin A (2014) Open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city. J King Saud Univ Sci 26(1):59–65

Amr EF (2021) Occupational health hazards and the use of safety protective measures among municipal solid waste collectors. Egypt J Health Care 12(2):830–853

Athanasiou M, Makrynos G, Dounias G (2010) Respiratory health of municipal solid waste workers. Occup Med 60(8):618–623

Bhuiyan SH (2010) A crisis in governance: Urban solid waste management in Bangladesh. Habitat Int 34(1):125–133

Biswas A, Rifat MA, Sufian HB, Zahid MK (2020) Dietary practices and nutritional status of the urban vulnerable: a cross-sectional study on waste collectors of Dhaka city in Bangladesh. World Nutrit 11(4):44–55

Cochran WG (1963) Sampling techniques. Wiley, New York

Cochran, W. G. (1952). The $\chi 2$ test of goodness of fit. The Annals of mathematical statistics, 315–345.

Cointreau S (2006) Occupational and environmental health issues of solid waste management: special emphasis on middle-and lower-income countries. Urban papers, 2

Cronbach LJ (1951) Coefficient alpha and the internal structure of tests. Psychometrika 16(3):297–334

Gautam M, Agrawal M (2021) Greenhouse gas emissions from municipal solid waste management: a review of global scenario. Carbon footprint case studies: municipal solid waste management, sustainable road transport and carbon sequestration, 123-160

Hasan MM, Rahman MH (2018) Assessment of healthcare waste management paradigms and its suitable treatment alternative: a case study. J Environ Pub Health 2018(1):6879751

Hoornweg, D Bhada-Tata P What a waste: a global review of solid waste management. URL: https://openknowledge.worldbank.org/entities/publication/1a464650-9d7a-58bb-b0ea-33ac4cd1f73c. (2012)

Hoque SN Hardship of waste workers in Bangladesh during coronavirus pandemic revealed. 2020 URL: https://practicalaction.org/news-media/2020/08/25/hardship-of-waste-workers-in-bangladesh-during-coronavirus-pandemic-revealed/

Intauno K, Poshai L (2023) Examining the occupational safety and health hazards encountered by municipal waste collectors in murewa rural district council, Zimbabwe. Int J Law Pub Pol (IJLAPP) 5(2):59–71

Islam KN (2016) Municipal solid waste to energy generation in Bangladesh: possible scenarios to generate renewable electricity in Dhaka and Chittagong city. J Renew Energy 2016(1):1712370

Islam KN (2017) Greenhouse gas footprint and the carbon flow associated with different solid waste management strategy for urban metabolism in Bangladesh. Sci Total Environ 580:755–769

Islam S (2021) Urban waste management in Bangladesh: an overview with a focus on Dhaka. Proceedings of the 23rd ASEF summer university ASEF education department, virtual, 20

Jerin DT, Sara HH, Radia MA et al (2022) An overview of progress towards implementation of solid waste management policies in Dhaka, Bangladesh. Heliyon 8(2):e08918. https://doi.org/10.1016/j.heliyon.2022.e08918

Joy P, Chitra AKJ (2018) A cross-sectional study to assess the health profile of street sweepers and sanitary workers in a zone of Greater Chennai Corporation, Tamil Nadu, India. Int J Community Med Public Heal 5(10):4357–4362

Kabir A, Farhana N, Akter F, Jesmin S, Ali A (2015) Sweeping practices, perceptions and knowledge about occupational safety and health hazards of street sweepers in Dhaka city, Bangladesh: a qualitative inquiry. Int J Commun Med Pub Health 2(3):237–243

Kassim SM, Ali M (2006) Solid waste collection by the private sector: households' perspectives findings from a study in Dar-es-Salaam city. Tanzania Habitat Int 30(4):769–780

Kaza S, Yao L, Bhada-Tata P, Van Woerden F (2018) What a waste 2.0: a global snapshot of solid waste management to 2050. World Bank Publications.

Khan MMR, Sultana F, Akter F (2016) Solid waste management scenario of some selected places in Dhaka City. As J Innovat Res Sci Eng Technol 1(8):1–6

Lavoie J, Dunkerley CJ, Kosatsky T, Dufresne A (2006) Exposure to aerosolized bacteria and fungi among collectors of commercial, mixed residential, recyclable and compostable waste. Sci Total Environ 370(1):23–28

Maghrebi M, Danandeh Mehr A, Karrabi SM, Sadegh M, Partani S, Ghiasi B, Nourani V (2022) Spatiotemporal variations of air pollution during the COVID-19 pandemic across Tehran, Iran: commonalities with and differences from global trends. Sustainability 14(23):16313

Mallapur C (2020) Sanitation workers at risk from discarded medical waste related to COVID-19. IndiaSpend. URL. Available online:https://www.indiaspend.com/sanitation-workersat-risk-from-discarded-medical-waste-related-tocovid-19/ Accessed on 26 April 2020

Maria C, Góis J, Leitão A (2020) Challenges and perspectives of greenhouse gases emissions from municipal solid waste management in Angola. Energy Rep 6:364–369

Melaku HS, Tiruneh MA (2020) Occupational health conditions and associated factors among municipal solid waste collectors in Addis Ababa Ethiopia. Risk Manag Health Pol 3:2415–2423

Minghua Z, Xiumin F, Rovetta A, Qichang H, Vicentini F, Bingkai L, Giusti A, Yi L (2009) Municipal solid waste management in Pudong new area. Chin Waste Manag 29(3):1227–1233

Patil PV, Kamble RK (2017) Occupational health hazards in municipal solid waste collecting workers of Chandrapur city. Cen India Int J Environ 6(1):46–57

Poulsen OM, Breum NO, Ebbehøj N, Hansen ÅM et al (1995) Collection of domestic waste review of occupational health problems and their possible causes. Sci Total Environ 170((1-2)):1–19

Rahman MM, Sultana KR, Hoque MA (2008) Suitable sites for urban solid waste disposal using GIS approach in Khulna city, Bangladesh. Proce Pak Acad Sci 45(1):11–22

Ray MR, Roychoudhury S, Mukherjee G, Roy S, Lahiri T (2005) Respiratory and general health impairments of workers employed in a municipal solid waste disposal at an open landfill site in Delhi. Int J Hyg Environ Health 208(4):255–262

Razzak MA Landfill management: are we doing it right? New Age. retrieved from https://www.newagebd.net/article/111187/are-we-ng-it-right. (15 July 2020a)

Riaz U, Iqbal S, Jamil M (eds) (2023) Waste problems and management in developing countries. CRC Press

Rifat MA, Biswas A, Sufian HB, Azad F, Zahid MD (2018) Socio-economic status, hygiene practices and microbial exposure of the waste collectors of Dhaka city inBangladesh. Glob J Health Sci 10(12):96

Shams S, Sahu JN, Rahman SS, Ahsan A (2017) Sustainable waste management policy in Bangladesh for reduction of greenhouse gases. Sustain Cities Soc 33:18–26

Sharior F, Alam MU, Zaqout M, Cawood S, Ferdous S, Shoaib DM, Tidwell JB, Hasan M, Hasan M, Rahman M, Farah M (2023) Occupational health and safety status of waste and sanitation workers: a qualitative exploration during the COVID-19 pandemic across Bangladesh. PLOS Water 2(1):e0000041

Shum PL, Kok HK, Maingard J, Schembri M, Bañez RM, Van Damme V, Barras C, Slater LA, Chong W, Chandra RV, Jhamb A (2020) Environmental sustainability in neurointerventional procedures: a waste audit. J Neurointerven Surg 12(11):1053–1057

Shuvai CHIKOMBE (2017) Occupational Safety and health hazards associated with solid waste management in Bindura, Zimbabwe (Doctoral dissertation, Masters Thesis (Unpublished))

Song Q, Li J, Zeng X (2015) Minimizing the increasing solid waste through zero waste strategy. J Clean Prod 104:199–210

Thakur P, Ganguly R, Dhulia A (2018) Occupational health hazard exposure among municipal solid waste workers in Himachal Pradesh, India. Waste Manage 78:483–489

Uddin J, Giasuddin ASM, Khalil MI, Kamrujjaman M (2021) Prevalence and associated factors of musculoskeletal disorders among municipal solid waste disposal male workers in a selected Area of Dhaka city. Work 8(18):19

UNEP. (2020). BASEL: waste management an essential public service in the fight to beat COVID-19. The United Nations Environment Programme (UNEP) and The Basel Convention. URL:http://www.basel.int/Implementation/PublicAwareness/PressReleases/WastemanagementandCOVID19 /tabid/8376/Default.aspx. (accessed 5.17.20)

Urme SA, Radia MA, Alam R, Chowdhury MU, Hasan S, Ahmed S, Sara HH, Islam MS, Jerin DT, Hema PS, Rahman M (2021) Dhaka landfill waste practices: addressing urban pollution and health hazards. Build Cit 2(1):700

Velasco Garrido M, Bittner C, Harth V, Preisser AM (2015) Health status and health-related quality of life of municipal waste collection workers–a cross-sectional survey. J Occup Med Toxicol 10(1):1–7

Zohoori M, Ghani A (2017) Municipal solid waste management challenges and problems for cities in low-income and developing countries. Int J Sci Eng Appl 6(2):39–48