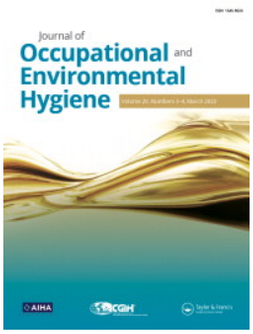

Taylor & Francis
Taylor & Francis Group

Journal of Occupational and Environmental Hygiene

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uoeh20

# Characterization of perceived biohazard exposures, personal protective equipment, and training resources among a sample of formal U.S. solid waste workers: A pilot study

**Aurora B. Le, Abas Shkembi, Anupon Tadee, Anna C. Sturgis, Shawn G. Gibbs & Richard L. Neitzel**

**To cite this article:** Aurora B. Le, Abas Shkembi, Anupon Tadee, Anna C. Sturgis, Shawn G. Gibbs & Richard L. Neitzel (2023) Characterization of perceived biohazard exposures, personal protective equipment, and training resources among a sample of formal U.S. solid waste workers: A pilot study, Journal of Occupational and Environmental Hygiene, 20:3-4, 129-135, DOI: 10.1080/15459624.2023.2179060

**To link to this article:** https://doi.org/10.1080/15459624.2023.2179060

JOURNAL OF OCCUPATIONAL AND ENVIRONMENTAL HYGIENE
2023, VOL. 20, NOS. 3–4, 129–135
https://doi.org/10.1080/15459624.2023.2179060

Taylor & Francis
Taylor & Francis Group

SHORT REPORT



# Characterization of perceived biohazard exposures, personal protective equipment, and training resources among a sample of formal U.S. solid waste workers: A pilot study

Aurora B. Le[a], Abas Shkembi[a], Anupon Tadee[a], Anna C. Sturgis[a], Shawn G. Gibbs[b], and Richard L. Neitzel[a]

[a]Department of Environmental Health Sciences, School of Public Health, University of Michigan, Ann Arbor, Michigan; [b]Department of Environmental and Occupational Health, School of Public Health, Texas A&M University, College Station, Texas

**ABSTRACT**

In the United States, the majority of waste workers work with solid waste. In solid waste operations, collection, sorting, and disposal can lead to elevated biohazard exposures (e.g., bioaerosols, bloodborne and other pathogens, human and animal excreta). This cross-sectional pilot study aimed to characterize solid waste worker perception of biohazard exposures, as well as worker preparedness and available resources (e.g., access to personal protective equipment, level of training) to address potential biohazard exposures. Three sites were surveyed: (1) a family-owned, small-scale waste disposal facility, (2) a county-level, recycling-only facility, and (3) an industrial-sized, large-scale facility that contains a hauling and landfill division. Survey items characterized occupational biohazards, resources to mitigate and manage those biohazards, and worker perceptions of biohazard exposures. Descriptive statistics were generated. The majority of workers did not report regularly coming into contact with blood, feces, and bodily fluids (79%). As such, less than one-fifth were extremely concerned about potential illness from biological exposures (19%). Yet, most workers surveyed (71%) reported an accidental laceration/cut that would potentially expose workers to biohazards. This study highlights the need for additional research on knowledge of exposure pathways and perceptions of the severity of exposure among this occupational group.

**KEYWORDS**

Biological exposures; occupational health; PPE; waste employees

## Introduction

In the United States (U.S.), nearly half a million workers are classified as "Waste Management and Remediation" workers by the Bureau of Labor Statistics. U.S. waste workers have higher injury and illness rates compared to workers across all private industries with total recordable case rates of 3.1 vs. 2.7 per 100 full-time workers, respectively (BOLS 2022a, 2022b). Workers managing solid waste that is generated from residential, commercial, and non-hazardous sources represent the majority of the solid waste worker population. Solid waste workers are exposed to several occupational hazards (e.g., extreme temperatures, poor ergonomics) but one of the chief concerns is biohazard exposure. Waste collection, sorting, and disposal can lead to elevated exposure to biohazards such as bioaerosols, bloodborne and other pathogens, fungi, and human and animal excreta (Dorevitch and Marder 2001; Rushton 2003; Athanasiou et al. 2010).

A previous assessment of medical waste workers following the 2014–2016 Ebola outbreak showed that these workers were underprepared and under-trained to manage highly infectious, Category A classified waste (Le et al. 2018). The COVID-19 pandemic has highlighted the stress associated with occupational biological exposure and how a worker's health, safety, and well-being are intrinsically coupled with their lives inside and outside of the workplace (Dennerlein et al. 2020; Krishnamoorthy et al. 2020). While SARS-CoV-2 has not been demonstrated to be transmitted through contact with solid waste, medical waste associated with COVID-19 patients is handled as regulated medical waste. However, the high number of COVID-19-positive individuals isolating at home inevitably leads to the disposal of SARS-CoV-2 contaminated

CONTACT Aurora B. Le aurorale@umich.edu Department of Environmental Health Sciences, School of Public Health, University of Michigan, Ann Arbor, MI 48109, USA.

Supplemental data for this article can be accessed online at https://doi.org/10.1080/15459624.2023.2179060. AIHA and ACGIH members may also access supplementary material at http://oeh.tandfonline.com.

waste within municipal solid waste (Vu et al. 2021). Additionally, the pandemic has underscored that all workers, especially essential workers such as solid waste workers, are vulnerable to more commonplace biological exposures given the nature of their work. Training and knowledge on prevention, mitigation, and management of biological exposures are of the utmost importance (Nghiem et al. 2020; Sharma et al. 2020).

To the best of the authors' knowledge, levels of worker training and preparedness to prevent, mitigate, and manage potential biohazard exposures, and worker perceptions of those exposures in the solid waste industry have not been assessed. Hence, this descriptive pilot study sought to characterize perceived biohazard exposures and exposure control resources among a sample of solid waste workers in the U.S.

## Materials and methods

The participants in this cross-sectional, pilot study consisted of adult waste workers recruited from solid waste sites in southeast Michigan during the fall of 2021. Thirty-nine waste sites were contacted through publicly available information by the research staff via telephone and email. Three waste site supervisors consented to participation and provided the research team access to onsite employees at pre-scheduled times. After informed consent was received, solid waste workers were surveyed on occupational biohazards, levels of work stress, and safety climate. Participants filled out hard-copy surveys at the beginning or end of their shifts. The survey took approximately 20 min to complete and did not collect any personal identifiers (e.g., name, birthdate, email). Participants received $40 upon survey completion. The focus of this Short Report is the first section of the survey – occupational biohazards. The three participating solid waste sites are characterized as: (1) a family-owned, small-scale waste disposal facility, (2) a county-level and recycling-only facility, and (3) an industrial-sized, large-scale facility that contains a hauling and landfill division.

Survey items for the occupational biohazards portion were developed by the authors in consultation with a solid waste subject matter expert to characterize occupational biohazards in the solid waste industry, resources to mitigate and manage those biohazards, and worker perceptions of individual biohazard exposures (see supplemental file). Questions regarding worker exposures and perception of exposures asked about the frequency of contact with sharps and blood, feces, or bodily fluids (0 = Never, 4 = Always). Workers were asked about their level of concern regarding exposures or illness due to contact with waste contaminated with biohazards and how prepared they felt to prevent exposure (0 = Not at all, 4 = Extremely). Workers were also asked if they ever had an accidental needlestick, laceration, and/or cut during work (yes/no). Workers that responded "yes" were asked if they reported the incident to a supervisor and about the level of stress experienced as a result of the work-related accidental needlestick, laceration, or cut.

Training and personal protective equipment (PPE) questions asked if workers had received infection control and prevention training in the last 12 months and/or training on donning and doffing PPE in the last 12 months (yes/no). Workers were also asked to select from an inventory list of PPE that their workplace has deemed mandatory/required for standard duties and what PPE is available to them that are not part of the mandatory/required list. Workers were asked if, in addition to routine work, the heightened use of masks or respiratory protection during the COVID-19 pandemic was required and included questions on respiratory protection programs and PPE maintenance (see supplemental file).

Workers were asked about practices contributing to their health such as hand hygiene behaviors. The questions distinguished between the use of hand sanitizer vs. hand washing with soap and water during key moments for potential cross-contamination (e.g., before and after meals, before leaving work) (0 = Never, 4 = Always). Lastly, workers were asked how they received up-to-date information on infectious diseases in relation to their work and if their workplace had procedures for health monitoring of employees after a suspected or confirmed exposure to biohazards (yes/no).

Data cleaning and all analyses were conducted in R studio using R v3.6.3 (Boston, MA). Counts and percentages were determined to provide descriptive statistics. The study was approved by the University of Michigan Institutional Review Board (Protocol ID HUM00202683).

## Results

### *Worker exposure*

The demographics of the study participants, which included 68 workers, are detailed elsewhere (Le et al. 2022). Just over one in five participants reported frequent contact with sharps (most of the time/always), and the majority (87%) reported coming into contact with sharps at least rarely (see Table 1). No workers

**Table 1.** Self-reported worker exposure and concern and preparedness about exposures and/or illnesses n (%).

| | All | Multi-site | | Single site |
|---|---|---|---|---|
| | N = 68 | Hauling (N = 36) | Landfill (N = 15) | County/small business (N = 17) |
| Contact with sharps | | | | |
| Never | 9 (13%) | 8 (22%) | 1 (7%) | 0 (0%) |
| Rarely/sometimes | 45 (66%) | 19 (53%) | 12 (80%) | 14 (82%) |
| Most of the time/always | 14 (21%) | 9 (25%) | 2 (13%) | 3 (18%) |
| Contact with blood, feces, and bodily fluids | | | | |
| Never | 9 (13%) | 5 (14%) | 4 (27%) | 0 (0%) |
| Rarely/sometimes | 45 (66%) | 24 (67%) | 9 (60%) | 12 (71%) |
| Most of the time/always | 14 (21%) | 7 (19%) | 2 (13%) | 5 (29%) |
| Concerned about exposures/illness | | | | |
| Not at all | 19 (28%) | 11 (31%) | 4 (27%) | 4 (24%) |
| Slightly/moderately | 36 (53%) | 13 (36%) | 10 (67%) | 13 (76%) |
| Very/extremely | 13 (19%) | 12 (33%) | 1 (6%) | 0 (0%) |
| Prepared to prevent exposures/illness | | | | |
| Not at all | 12 (18%) | 9 (25%) | 1 (6%) | 2 (12%) |
| Slightly/moderately | 37 (54%) | 18 (50%) | 10 (67%) | 9 (53%) |
| Very/extremely | 19 (28%) | 9 (25%) | 4 (27%) | 6 (35%) |

from the single-site facilities and only one worker from the landfill division reported never having come into contact with sharps. Participants reported similar levels of contact with blood, feces, and bodily fluids as those with sharps. Twenty-eight percent of participants reported never being concerned about work-related exposures and/or illnesses, with similar reported levels across sites. On the other hand, very high/extreme concerns were discordant across sites (19% overall). While 33% of hauling workers reported high/extreme levels of concern, only 6% of landfill and no single-site workers reported being highly/extremely concerned about work-related exposures and/or illnesses. More participants felt very/extremely prepared to prevent exposures and/or illnesses (28% overall).

### Training and administrative controls

Nine percent of participants reported the presence of an RPP at work, and none reported knowledge of an RPP from single-site facilities (see Table 2). Reporting on whether training on infection prevention and donning/doffing PPE was conducted within the last year was relatively low (28% and 40%, respectively), with the landfill division reporting the highest training prevalence (47% and 67%, respectively). Similarly, reported training on selecting proper PPE depending on the risk of contact with biohazards was low (24% overall), although reported training on determining whether PPE was effective was high (71% overall; 93% among landfill workers). Training on the maximum working times allowed in disposable PPE was the lowest (16% overall), with hauling workers reporting the highest prevalence of having received training on PPE (22%) and landfill the lowest (7%).

### PPE and monitoring devices

Overall, the majority of workers were required to wear safety vests/reflective clothing (90%) and steel-toe boots (82%) while performing standard duties (see Figure 1). While safety vests/reflective clothing were made available nearly ubiquitously across job sites, only 59% of workers at single-site facilities reported steel-toe boots being made available by the employer. Just over half of workers reported hard hats and single-use gloves being required on the job overall, although hard hats and single-use gloves were frequently made available for landfill workers (100% and 93%, respectively). Similarly, although eye protection and puncture-resistant gloves were mandatory for 43% of workers, only 87% of landfill workers reported that these PPE were made available for employee use by their employer.

The use of surgical/procedure masks, boot/shoe covers, N95 respirators (employer-provided/employee-chosen), face shields, and coveralls were all rarely reported as mandatory (<10%). However, surgical/-procedure masks were made available for over a third of noncommercial employees due to the COVID-19 pandemic. Similarly, face shields (27%), and coveralls (27%) were made available more regularly for landfill workers. Gas monitors were predominantly made available for landfill workers (27%).

### Worker health

The majority of workers reported good/excellent physical health (59%), with similar levels reported across sites except for the physical health among landfill workers (33%). Overall, 15% of participants reported an accidental needlestick injury and no landfill

**Table 2.** Self-reported worker training levels, n (%).

| | All | Multi-site | | Single site |
|---|---|---|---|---|
| | N = 68 | Hauling (N = 36) | Landfill (N = 15) | County/small business (N = 17) |
| Respiratory protection program (yes) | 6 (9%) | 2 (6%) | 4 (27%) | 0 (0%) |
| Infection prevention in last year | 19 (28%) | 9 (25%) | 7 (47%) | 3 (18%) |
| Donning and doffing PPE in the last year | 27 (40%) | 14 (39%) | 10 (67%) | 3 (18%) |
| Selecting proper PPE | 16 (24%) | 6 (17%) | 7 (47%) | 3 (18%) |
| Determining if PPE is effective | 48 (71%) | 24 (67%) | 14 (93%) | 10 (60%) |
| Maximum time allowed in disposable PPE | 11 (16%) | 8 (22%) | 1 (7%) | 2 (12%) |

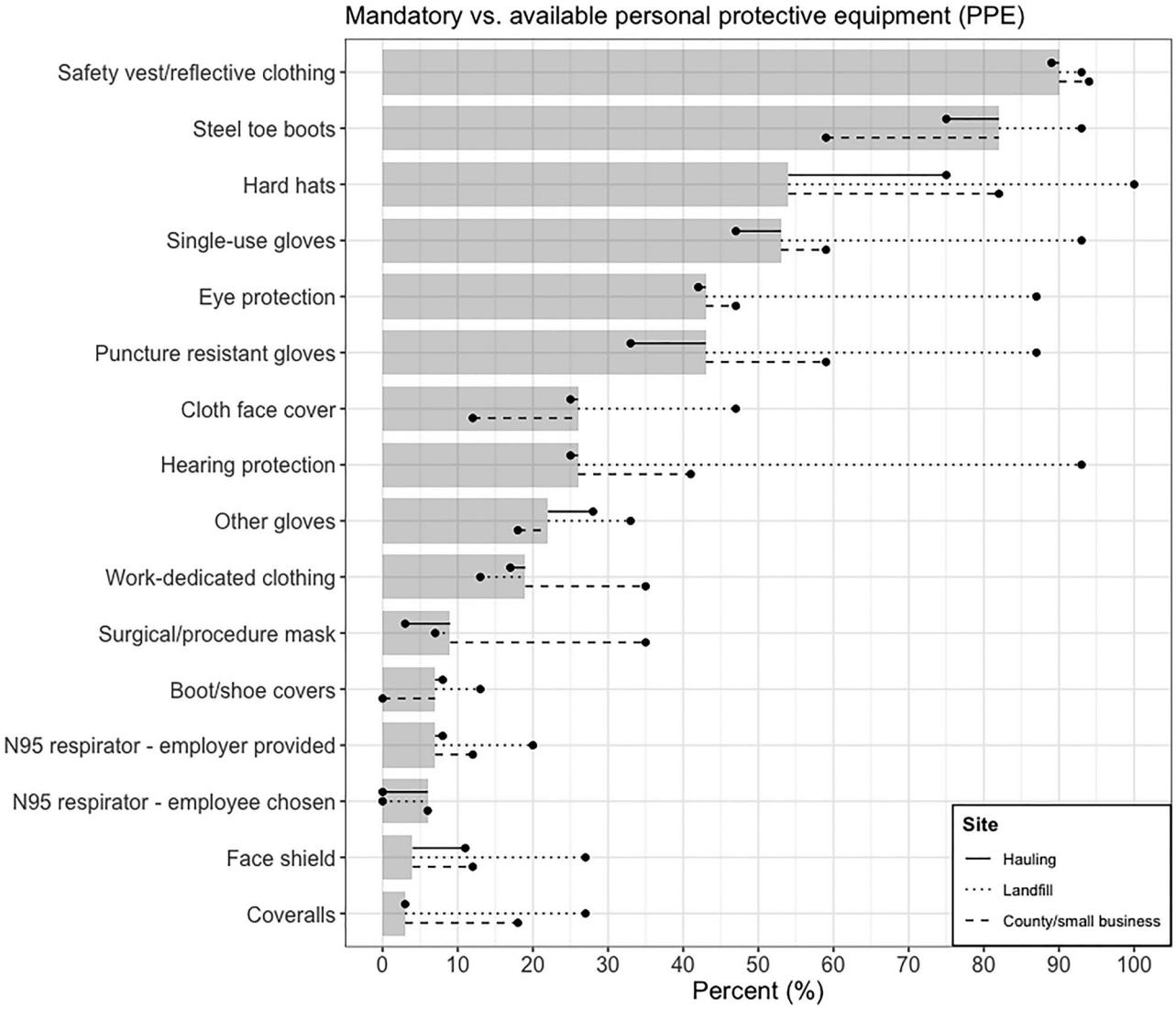


**Figure 1.** Percent (%) of respondents who reported that personal protective equipment (PPE) is mandatory while performing standard duties (grey bar) compared to the percent who reported PPE is made available to them by their employer by work site (Hauling division – solid line; Landfill division – dotted line; County/small business – dashed line).

workers reported such an injury. Overall, 71% reported an accidental laceration/cut and nearly all single-site facility workers (94%) reported such an injury. The majority of workers reported an accidental needlestick (60%) or laceration/cut (69%) to their supervisors. All workers with a needlestick injury reported experiencing stress from the incident. While 64% of those injured from lacerations/cuts experienced stress from reporting the injury to a supervisor, all those at the landfill site experienced stress. Such stress at the noncommercial sites was relatively low (36%). Only 26% of workers reported the workplace having a health monitoring program, with similar levels across sites. Surprisingly, 40% of workers did not

**Table 3.** Self-reported worker health, accidental exposure, follow-up with supervisor, and self-reported stress n (%).

| | All | Multi-site | | Single site |
|---|---|---|---|---|
| | N = 68 | Hauling (N = 36) | Landfill (N = 15) | County/small business (N = 17) |
| Physical health | | | | |
| Poor | 4 (6%) | 2 (6%) | 2 (13%) | 0 (0%) |
| Fair | 25 (37%) | 12 (33%) | 8 (54%) | 5 (29%) |
| Good | 29 (42%) | 18 (50%) | 3 (20%) | 8 (47%) |
| Excellent | 10 (15%) | 4 (11%) | 2 (13%) | 4 (24%) |
| Mental health | | | | |
| Poor | 6 (9%) | 2 (6%) | 2 (13%) | 2 (12%) |
| Fair | 22 (32%) | 12 (33%) | 5 (33%) | 5 (29%) |
| Good | 29 (43%) | 14 (39%) | 7 (47%) | 8 (47%) |
| Excellent | 11 (16%) | 8 (22%) | 1 (7%) | 2 (12%) |
| Accidental needlestick injury (yes) | 10 (15%) | 8 (22%) | 0 (0%) | 2 (12%) |
| Reported to supervisor (yes) | 6 (60%) | 5 (63%) | – | 1 (50%) |
| Stress from reporting | 6 (100%) | 5 (100%) | – | 1 (100%) |
| Accidental laceration/cut (yes) | 48 (71%) | 23 (64%) | 9 (60%) | 16 (94%) |
| Reported to supervisor (yes) | 33 (69%) | 17 (74%) | 5 (56%) | 11 (69%) |
| Stress from reporting | 21 (64%) | 12 (70%) | 5 (100%) | 4 (36%) |
| Workplace health monitoring | | | | |
| Yes | 18 (26%) | 11 (31%) | 3 (20%) | 4 (24%) |
| I don't know | 27 (40%) | 11 (31%) | 9 (60%) | 7 (41%) |
| No | 23 (34%) | 14 (38%) | 3 (20%) | 6 (35%) |

know if they have a workplace health monitoring program with the highest percentage amongst landfill workers (60%) (see Table 3).

## Discussion

This descriptive, cross-sectional pilot study characterized biohazard exposures, perceptions of those exposures, and resources (e.g., PPE and training) among a sample of formal solid U.S. waste workers at three sites in Michigan. At the time of survey administration, COVID-19 had been declared a global pandemic for nearly 18 months (CDC 2021); yet approximately one-third of workers reported not receiving infection prevention training or training on PPE donning and doffing in the last year. Since some solid waste workers perform outdoor duties (e.g., landfill operations) or have limited contact with colleagues and the general public (e.g., driving garbage or recycling truck), employers may perceive employee risk of contracting COVID-19 and other infections as low and may not have required additional or refresher training(s). However, in a study assessing COVID-19 mortality among working-age Californians, by industry and occupation, those in transportation and logistics, and facilities, such as waste management and remediation services, had higher per-capita COVID-19 mortality compared to non-essential workers (Chen et al. 2022). This highlights that waste workers could benefit from additional, in-depth training on mitigating and managing biohazards—whether this is internal (e.g., from supervisors and management) or in partnership with occupational and environmental health and safety (OEHS) professionals—and periodic refresher trainings.

Regarding PPE and monitoring devices, most employees, regardless of site type, wore safety vests/reflective clothing and steel-toed boots. Notably, landfill workers consistently had PPE readily available more than other sites for nearly all types of PPE. Hand protection (e.g., single-use gloves, puncture-use gloves) was used less than half the time when performing standard duties despite exposed hands being high risk for cuts, abrasions, and surface- and cross-contamination. The use of gas monitors occurred predominantly at the industrial landfill site to monitor toxic gases generated by the landfill (Young and Parker 1983). The use of respiratory protection was limited, and less than 10% of workers reported enrollment in a site respiratory protection program (Occupational Safety and Health Administration (OSHA) regulation Respiratory Protection (29 CFR 1910.134)). However, recent consensus frameworks by the National Academies of Sciences, Engineering, and Medicine have published methods to protect workers from inhalation hazards that are not part of an RPP. The COVID-19 pandemic exposed the risk of airborne exposure to biological materials and the usefulness of respiratory protection to the public. As employers observed a rise in the voluntary use of respiratory protection at work, even when the employer was not required to provide such PPE workers, worker education on best practices for respiratory protection, selection, use, maintenance care, and limitations is recommended (NASEM 2022).

Due to potential exposure to blood and other potentially infectious materials, many waste workers require mandatory bloodborne pathogen (BBP) training as required by OSHA regulation 29 CFR 1910.1030 Bloodborne Pathogens. Despite occasional contact with sharps (e.g., needles), feces, and bodily fluids, approximately 28% of participants were not concerned about exposures or the potential for illness, and 53% were only slightly or moderately concerned. This may be attributed to a lack of knowledge retention on BBP training, perceptions of occupational risk that decrease as job tenure increases (Nichol et al. 2008), or complacency and/or lack of incentive to maintain job skills and knowledge. Yet nearly three-quarters of workers reported experiencing an accidental laceration or cut and almost two-thirds of those affected reported feeling stress due to the cut/laceration. Solid waste workers may perceive the laceration or cut as a physical exposure rather than biological exposure and therefore the worker may be less concerned. Nearly three-quarters of workers stated they did not know whether a workplace post-exposure health monitoring program existed. This may indicate that workers do not fully understand the direct application of training to job duties and that training outcomes may need to be evaluated (e.g., using the Kirkpatrick Model of Learning Evaluation) by workplace leadership to determine if the training is eliciting a reaction or opinion (e.g., useful, boring), which is considered the lowest level of learning, or leading to best practice learning, behavioral changes, and positive organizational changes, which is the highest level of learning (Smidt et al. 2009). Furthermore, workplace leadership and OEHS staff, if there are any onsite or within the respective organizations, may consider training modalities more suited for adult learning (e.g., mobile, friendly online training modules, hands-on exercises) rather than lecture or verbal information conveyed via daily huddles or toolbox talks (Smidt et al. 2009).

### *Limitations*

This study has several limitations. First, this study was cross-sectional and therefore causation cannot be inferred. Second, the sample size analyzed was relatively small from a statistical perspective, and less than 10% of the sites contacted agreed to participate. Additionally, because site supervisors provided permission for the researchers to collect worker data, there is a potential for selection bias. There was also the potential for recall bias since workers were asked time-specific questions. Lastly, the study sites only included three waste sites from southeast Michigan, with one of each type, so generalizability to other waste industry sectors (e.g., medical) and regions may be limited.

Future research is needed to effectively address solid waste worker health and well-being. A larger and more geographically distributed sample size is needed, as well as sampling from multiple sites with the same characteristics (e.g., large industrial sites). Due to the potential for recall bias, a prospective longitudinal study is warranted to further investigate the effects of occupational biohazard exposures. Furthermore, to better understand the efficacy, the long-term effectiveness of training programs needs to be analyzed (e.g., assessment of training modalities, knowledge retention within this population, incorporation of linguistically appropriate training materials for diverse solid waste worker worksites).

## Conclusion

This study is the first, to the knowledge of the authors, to characterize worker perceptions of biohazard exposures and levels of training and resources among a sample of U.S. waste workers. For the occupational and environmental health and safety practitioner, this study demonstrates that this is an industry, with both small- and large-scale industrial worksites such as construction and manufacturing, which may be underserved from an OEHS perspective. For the researcher and the solid waste industry, this study highlights the need for additional research on knowledge of exposure pathways and perceptions of the severity of exposure among this occupational group. By understanding solid waste worker perceptions of biohazard exposures, employers, practitioners, and researchers can determine the next steps needed to improve workplace safety and health and enhance the knowledge, skills, and training of solid waste workers to assist them in understanding the potential severity of biological exposures and how to prevent, mitigate, and manage such exposures.

## Acknowledgments

We thank the site supervisors and workers at solid waste facilities in southeast Michigan for collaborating with us on this research. We thank Anne Germain at the National Waste & Recycling Association for providing her subject matter expertise and helping us refine the measures for the portion of the survey presented in this study. We thank Jason Golec for his assistance with site recruitment.

## Disclosure statememt

The authors declare no conflicts of interest.

## Funding

This publication was supported by the Grant or Cooperative Agreement Number, T42 OH008455, funded by the Centers for Disease Control and Prevention. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention or the Department of Health and Human Services.

## ORCID

Aurora B. Le http://orcid.org/0000-0002-6866-6779
Abas Shkembi http://orcid.org/0000-0002-5398-861X
Anupon Tadee http://orcid.org/0000-0002-8294-8211
Shawn G. Gibbs http://orcid.org/0000-0002-6041-5166
Richard L. Neitzel http://orcid.org/0000-0001-5500-2589

## Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## References

Athanasiou M, Makrynos G, Dounias G. 2010. Respiratory health of municipal solid waste workers. Occup Med (Lond). 60(8):618–623. DOI: 10.1093/occmed/kqq127.

Bureau of Labor Statistics (BOLS). 2022a. Industries at a glance: waste management and remediation services: NAICS 562; [accessed 2023 Jan 25]. https://www.bls.gov/iag/tgs/iag562.htm.

Bureau of Labor Statistics (BOLS). 2022b. Employer-related workplace injuries and illnesses, 2021; [accessed 2023 Jan 25]. https://www.bls.gov/news.release/osh.nr0.htm.

Centers for Disease Control and Prevention (CDC). 2021. CDC museum COVID-19 timeline; [accessed 2021 Oct 12]. https://www.cdc.gov/museum/timeline/covid19.html.

Chen YH, Riley AR, Duchowny KA, Aschmann HE, Chen R, Kiang MV, Mooney AC, Stokes AC, Glymour MM, Bibbins-Domingo K. 2022. COVID-19 mortality and excess mortality among working-age residents in California, USA, by occupational sector: a longitudinal cohort analysis of mortality surveillance data. Lancet Public Health. 7(9):e744–e753. DOI: 10.1016/S2468-2667(22)00191-8.

Dennerlein JT, Burke L, Sabbath EL, Williams JA, Peters SE, Wallace L, Karapanos M, Sorensen G. 2020. An integrative total worker health framework for keeping workers safe and healthy during the COVID-19 pandemic. Hum Factors. 62(5):689–696. DOI: 10.1177/0018720820932699.

Dorevitch S, Marder D. 2001. Occupational hazards of municipal solid waste workers. Occup Med. 16(1):125–133.

Krishnamoorthy Y, Nagarajan R, Saya GK, Menon V. 2020. Prevalence of psychological morbidities among general population, healthcare workers and COVID-19 patients amidst the COVID-19 pandemic: a systematic review and meta-analysis. Psychiatry Res. 293:113382. DOI: 10.1016/j.psychres.2020.113382.

Le AB, Hoboy S, Germain A, Miller H, Thompson R, Herstein JJ, Jelden KC, Beam EL, Gibbs SG, Lowe JJ. 2018. A pilot survey of the US medical waste industry to determine training needs for safely handling highly infectious waste. Am J Infect Control. 46(2):133–138. DOI: 10.1016/j.ajic.2017.08.017.

Le AB, Shkembi A, Sturgis AC, Tadee A, Gibbs SG, Neitzel RL. 2022. Effort–reward imbalance among a sample of formal US solid waste workers. Int J Environ Res Public Health. 19(11):6791. DOI: 10.3390/ijerph19116791.

National Academies of Sciences, Engineering, and Medicine (NASEM). 2022. Frameworks for protecting workers and the public from inhalation hazards; [accessed 2022 Mar 1]. https://nap.nationalacademies.org/download/26372.

Nghiem LD, Morgan B, Donner E, Short MD. 2020. The COVID-19 pandemic: considerations for the waste and wastewater services sector. Case Stud Chem Environ Eng. 1:100006. DOI: 10.1016/j.cscee.2020.100006.

Nichol K, Bigelow P, O'Brien-Pallas L, McGeer A, Manno M, Holness DL. 2008. The individual, environmental, and organizational factors that influence nurses' use of facial protection to prevent occupational transmission of communicable respiratory illness in acute care hospitals. Am J Infect Control. 36(7):481–487. DOI: 10.1016/j.ajic.2007.12.004.

Rushton L. 2003. Health hazards and waste management. Br Med Bull. 68(1):183–197. DOI: 10.1093/bmb/ldg034.

Sharma HB, Vanapalli KR, Cheela VS, Ranjan VP, Jaglan AK, Dubey B, Goel S, Bhattacharya J. 2020. Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. Resour Conserv Recycl. 162:105052. DOI: 10.1016/j.resconrec.2020.105052.

Smidt A, Balandin S, Sigafoos J, Reed VA. 2009. The Kirkpatrick model: a useful tool for evaluating training outcomes. J Intellect Dev Disabil. 34(3):266–274. DOI: 10.1080/13668250903093125.

Vu HL, Ng KT, Richter A, Karimi N, Kabir G. 2021. Modeling of municipal waste disposal rates during COVID-19 using separated waste fraction models. Sci Total Environ. 789:148024. DOI: 10.1016/j.scitotenv.2021.148024.

Young P, Parker A. 1983. Vapors, odors, and toxic gases from landfills. In: Hazardous and Industrial Waste Management and Testing, Proceedings of the Third Symposium. Philadelphia (PA): ASTM-Philadelphia; p. 24–41.