

Knowledge, Attitudes, and Practices Regarding Hepatitis B and C Infection among Informal Waste Pickers in Aden, Yemen: A Cross-Sectional Study

Ali N. M. Gubran

a.Alyafei@aden.ust.edu

University of Science and Technology

Naif Taleb Ali

University of Science and Technology

Hanan A. A. Mohammed

University of Science and Technology

Enas Wafi Mohammed Al-hubaishi

University of Science and Technology

Sara Mohammed Ali Kolais

University of Science and Technology

Salsabeel Abdulaziz Mohammed Al-yafeai

Aden University

Safa'a Mohammed M. Darwiesh

Sana'a University

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Abstract

Background

Informal waste pickers constitute a marginalized occupational group in low-resource settings and may experience substantial occupational exposure to blood-borne pathogens, including hepatitis B virus (HBV) and hepatitis C virus (HCV). However, hepatitis-related knowledge, attitudes, and protective practices in this population remain poorly characterized. To our knowledge, this study is among the first in the Arab region to jointly assess HBV- and HCV-related knowledge, attitudes, and practices (KAP) specifically among informal waste pickers.

Methods

A community-based cross-sectional study was conducted among 177 informal waste pickers in Aden, Yemen, in 2025. Participants were recruited using non-probability snowball sampling across all eight administrative districts. Data were collected using a structured, pre-tested, interviewer-administered questionnaire covering sociodemographic characteristics, occupational history, and HBV/HCV-related KAP. Descriptive statistics and appropriate tests of association were used to examine participant characteristics and KAP outcomes. Pearson correlation was used to assess relationships between recorded KAP scores, and robust Poisson regression was used to examine factors associated with self-reported needle-stick injury.

Results

A total of 177 informal waste pickers participated (mean age, 29.6 ± 13.4 years; 74.0% male). The study identified substantial gaps in hepatitis-related knowledge and occupational protection. Only 11.9% correctly identified the etiology of hepatitis, 5.6% identified the main transmission modes, 7.9% recognized relevant symptoms, and 15.8% were aware of the HBV vaccine. Needle-stick injuries were reported by 87.0%, while 88.7% reported exposure to glass or other sharp objects. Routine use of protective equipment was uncommon: 1.1% reported using protective gloves, 1.1% eye protection, 0.6% face masks, and 4.0% safety boots. Only 4.5% had previously been screened for HBV/HCV, and 1.7% reported having received HBV vaccination. Knowledge score was positively correlated with attitude score ($r = 0.585$, $p < 0.001$). In the robust Poisson regression analysis, the associations between the recorded sociodemographic and occupational characteristics and needle-stick injury should be interpreted cautiously, as the estimates differed from those reported in the original analysis.

Conclusions

Informal waste pickers in Aden, Yemen, experience substantial occupational exposure to sharps and marked gaps in hepatitis-related knowledge and preventive protection. Strengthening occupational health interventions—including accessible health education, HBV vaccination, provision and promotion of appropriate personal protective equipment, hepatitis screening, and safer sharps-handling and disposal systems—should be prioritized for this underserved occupational population. Further studies using validated KAP instruments and representative sampling are warranted to confirm these findings and evaluate intervention effectiveness.

Key Message

What is already known on this topic:

Informal waste pickers are a marginalized occupational group who may experience substantial exposure to blood-borne pathogens, including hepatitis B virus (HBV) and hepatitis C virus (HCV). However, evidence on HBV- and HCV-related knowledge, attitudes, and protective practices among informal waste pickers remains limited, particularly in the Arab region.

What this study adds:

This study provides evidence on HBV- and HCV-related knowledge, attitudes, and occupational practices among informal waste pickers in Aden, Yemen. It identifies substantial gaps in hepatitis-related knowledge, very limited use of personal protective equipment, frequent exposure to glass and other sharp objects, and a high prevalence of self-reported needle-stick injuries (87.0%). Only 1.1% of participants

reported routine use of protective gloves, while 1.1% reported eye protection, 0.6% face-mask use, and 4.0% safety-boot use. Knowledge and attitude scores were positively correlated ($r = 0.585$, $p < 0.001$).

How this study might affect research, practice, or policy:

The findings provide a baseline for developing targeted health-education, hepatitis B vaccination, screening, and occupational-safety interventions for informal waste pickers in Yemen and similar low-resource settings. They highlight the need to recognize informal waste pickers within occupational-health and waste-management policies and to improve access to appropriate personal protective equipment, safer sharps-handling and disposal systems, vaccination, and hepatitis prevention services. Future research should use validated KAP instruments and representative sampling to confirm these findings and assess the effectiveness of targeted interventions.

1. Introduction

Hepatitis B virus (HBV) and hepatitis C virus (HCV) are major global public health challenges [1]. In 2022, an estimated 254 million people were living with chronic HBV infection (3.3% of the global population) and approximately 50 million with chronic HCV infection (0.7%), with an estimated 1.3 million deaths attributable to these infections [2]. Both viruses can cause serious chronic liver disease, including cirrhosis and hepatocellular carcinoma [3].

HBV and HCV are blood-borne pathogens transmitted primarily through exposure to infected blood and body fluids. HBV can also be transmitted sexually and perinatally from an infected mother to her newborn, whereas HCV transmission occurs predominantly through exposure to infected blood [4]. Occupational contact with contaminated sharps, needles, glass, and other materials that may be contaminated with blood can increase the risk of blood exposure, particularly among workers who manually collect and sort waste [5]. Informal waste pickers (IWPs) are individuals who manually collect, salvage, and sort recyclable or reusable materials—such as plastics, metals, and glass—from landfills, dumpsites, streets, and waste containers as a source of livelihood [5].

A recent global meta-analysis by Souza-Silva et al. reported substantial vulnerability to viral hepatitis among waste pickers, with pooled HBV seropositivity of 15% (95% CI: 10–20%) and HCV seropositivity of 8% (95% CI: 4–12%) [6]. The authors highlighted occupational hazards, poor working and living conditions, and limited health literacy as important concerns in this population and emphasized the importance of appropriate personal protective equipment and hepatitis B immunization [6]. Similarly, a systematic review and meta-analysis by Tolera et al. (2023) reported evidence of hepatitis viral infections among sanitary workers globally, with the highest prevalence observed among sewage workers [7]. Together, these findings indicate that occupational groups involved in waste collection and handling may face important risks related to blood-borne infections and occupational injuries.

In Yemen, previous research in Sana'a documented inadequate medical-waste handling, limited occupational training, and insufficient use of protective measures among hospital waste workers, but did not provide a combined assessment of HBV/HCV-related knowledge, attitudes, and practices among informal waste pickers [8]. In Aden, previous investigations have focused primarily on viral-hepatitis prevalence and occupational exposure among formal municipal waste collectors and informal waste workers [9–12]. Related research on occupational safety among scavengers has also been reported elsewhere in the Arab region [13]. However, evidence specifically addressing the combined HBV/HCV-related knowledge, attitudes, and practices of informal waste pickers in an Arab setting remains limited.

Therefore, this study aimed to assess HBV/HCV-related knowledge, attitudes, and practices among informal waste pickers in Aden, Yemen, and to examine demographic and occupational characteristics associated with reported occupational exposure and needle-stick injuries. By characterizing these knowledge gaps, attitudes, and occupational practices, the study seeks to provide locally relevant evidence to inform hepatitis prevention and occupational-safety interventions for this underserved population.

2. Subjects and Methods

2.1 Study Design and Setting

A community-based cross-sectional study was conducted among informal waste pickers in Aden Governorate, Yemen, from August to December 2025. Aden is a coastal governorate in southern Yemen comprising eight administrative districts: Al-Mansoura, Al-Mualla, Al-Tawahi, Crater, Dar Saad, Khormaksar, Sheikh Othman, and Al-Buraiqeh. Informal waste picking is practiced at various municipal landfills, street dumpsites, and recycling collection sites across the governorate.

2.2 Sample Size and Sampling Technique

Because informal waste pickers in Aden are an informal and unregistered occupational population, no comprehensive sampling frame was available, and the size of the target population could not be reliably enumerated. Consequently, probability-based sampling was not feasible. A non-probability convenience sampling approach, supplemented by snowball recruitment, was therefore used to identify and recruit eligible participants. This approach has been used in previous studies involving hard-to-reach and marginalized occupational populations, including informal waste pickers, where establishing a complete sampling frame is challenging [14, 15, 19].

The sample size was determined pragmatically according to the number of eligible participants who could be reached during the predefined data-collection period and who met the study eligibility criteria. A total of 177 informal waste pickers were recruited from all eight administrative districts of Aden Governorate. The sample size was broadly comparable with those reported in previous KAP studies among waste handlers or waste pickers in low-resource settings, including studies from Nigeria (n = 98) [14], Ethiopia (n = 120) [15], and Yemen (n = 120) [18]. Recruitment continued throughout the predefined study period, and participants were enrolled as eligible individuals were identified and agreed to participate.

Because convenience and snowball recruitment were used, the resulting sample was not intended to be statistically representative of all informal waste pickers in Aden. Accordingly, findings should be interpreted in light of the potential for selection bias and limited generalizability.

2.3 Study Population

The study population comprised informal waste pickers actively engaged in collecting, sorting, or handling discarded materials at municipal landfills, street dumpsites, and recycling collection sites across the eight administrative districts of Aden Governorate. Participants were recruited using convenience sampling supplemented by snowball recruitment because of the informal and unorganized nature of this occupational population.

Eligible participants were those who were actively engaged in informal waste picking for at least six months, were aged 15 years or older, and were willing to participate and provide informed consent in accordance with the study's ethical procedures. Formal waste collectors and formal municipal waste workers were excluded, as were informal waste pickers who declined to provide informed consent. A total of 177 eligible informal waste pickers were enrolled in the study.

2.4 Data Collection Instrument

Data were collected through face-to-face interviews using a structured, pre-tested, interviewer-administered questionnaire. The questionnaire was developed based on a review of relevant literature and included sections covering sociodemographic characteristics, occupational characteristics, knowledge of hepatitis B and C, attitudes toward hepatitis prevention and infection, and occupational exposures and protective practices.

Sociodemographic and occupational characteristics: Information was collected on age, sex, marital status, education level, economic status, residence district, living arrangement, daily working hours, and duration of informal waste-picking work.

Knowledge assessment: The questionnaire included items assessing knowledge of hepatitis B and C, including their causes, symptoms, modes of transmission, effects on the liver, potential association with cancer, curability/treatability, dietary precautions, herbal treatments, and awareness of HBV vaccination. Responses were recorded according to the predefined response options in the questionnaire. Item-level responses are presented descriptively as correct, incorrect, or "do not know." Knowledge scoring and categorization were based on the prespecified scoring key used during data analysis.

Attitudes assessment: Attitudes toward hepatitis B and C were assessed using items addressing perceived disease impact, perceived risk of infection, need for protection, willingness to receive HBV vaccination, and stigma-related beliefs, including views regarding isolation or social distancing of infected individuals. Responses considered favorable according to the questionnaire's scoring key were coded accordingly. Item-level attitude responses are reported descriptively.

Occupational exposures and protective practices: Participants were asked about occupational exposure to needle-stick injuries, glass or other sharp materials, blood or body-fluid splashes, and bloody materials. They were also asked about the routine use of personal protective measures, including protective gloves, eye protection, face protection, and safety boots, as well as previous HBV/HCV screening and HBV vaccination.

Because the available dataset contains differences between the variables recorded for scoring and the number of items described in the original manuscript, the final composite knowledge, attitude, and practice classifications were not defined solely from the item

descriptions above. The scoring structure was therefore reviewed against the original questionnaire and coding scheme before final inferential analyses and classification of participants into good/poor knowledge, positive/negative attitude, or good/poor practice categories.

2.5 Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics version 21.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were summarized using frequencies and percentages for categorical variables and means and standard deviations for continuous variables, as appropriate. Associations between categorical variables were assessed using Pearson's chi-square test. Where expected cell frequencies were small, the appropriate exact test was considered. For comparisons involving non-normally distributed continuous variables, non-parametric tests were used as appropriate.

Pearson's correlation coefficient was used to assess the linear relationships among the recorded knowledge, attitude, and practice scores. The direction and coding of each score were considered when interpreting the correlation coefficients, with higher scores defined according to the corresponding scoring scheme. Because the scoring structure of the composite KAP measures requires verification against the original questionnaire and coding scheme, composite-score analyses were interpreted cautiously and were not used to support classifications that could not be independently reproduced from the available dataset.

A robust Poisson regression model with a log link and robust variance estimation was used to estimate prevalence ratios (PRs) and adjusted prevalence ratios (aPRs), with corresponding 95% confidence intervals (CIs), for factors associated with reported needle-stick injury. This model was selected because prevalence ratios provide a directly interpretable measure of association for a common binary outcome. Variables with $p < 0.20$ in univariable analyses were considered for inclusion in the multivariable model. The final model included the prespecified candidate variables meeting this criterion.

All statistical tests were two-sided, and a p value < 0.05 was considered statistically significant. Effect estimates were reported with 95% CIs.

Because the available dataset did not permit independent reproduction of the structural equation model reported in the original manuscript, SEM-derived path coefficients, indirect effects, and mediation estimates were not considered sufficiently verifiable for the final analysis. Any path-analysis or mediation results will therefore be reported only after verification against the original AMOS model/output and the finalized KAP scoring algorithm.

3. Results

3.1 Sociodemographic and Occupational Characteristics

A total of 177 informal waste pickers participated in the study. The mean age of participants was 29.6 ± 13.4 years, with an age range of 15–70 years. Most participants were male (131, 74.0%), while 46 (26.0%) were female. Regarding marital status, 98 (55.4%) participants were unmarried and 79 (44.6%) were married.

Educational attainment was generally low. Sixty-five participants (36.7%) were illiterate, 86 (48.6%) had completed primary education, and only 26 (14.7%) had reached secondary education. All participants (177, 100.0%) reported a low economic status. With regard to accommodation, 114 (64.4%) lived with their families, whereas 63 (35.6%) lived alone.

Regarding occupational history, 103 (58.2%) participants had worked as informal waste pickers for less than 5 years, 47 (26.6%) for 5–10 years, and 27 (15.3%) for 10 years or more. Most participants reported working for 10 hours or more per day (114, 64.4%), while 46 (26.0%) worked 5–10 hours per day and 17 (9.6%) worked fewer than 5 hours per day (Table 1).

Table 1
Sociodemographic and occupational characteristics of informal waste pickers (N = 177)

Characteristic	Category	n (%)
Age (years)	< 19	39 (22.0)
	19–29	39 (22.0)
	30–39	45 (25.4)
	≥ 39	54 (30.5)
	Mean ± SD	29.6 ± 13.4
	Range	15–70
Sex	Male	131 (74.0)
	Female	46 (26.0)
Marital status	Unmarried	98 (55.4)
	Married	79 (44.6)
Education	Illiterate	65 (36.7)
	Primary	86 (48.6)
	Secondary	26 (14.7)
Economic status	Low	177 (100.0)
Accommodation	Alone	63 (35.6)
	With family	114 (64.4)
Work duration	< 5 years	103 (58.2)
	5–10 years	47 (26.6)
	≥ 10 years	27 (15.3)
Daily working hours	< 5	17 (9.6)
	5–10	46 (26.0)
	≥ 10	114 (64.4)

Note. SD, standard deviation. The age-group labels require correction/verification because the supplied categories overlap at age 39 and the raw aggroup coding should be checked before submission.

3.2 Knowledge regarding hepatitis B and C

Knowledge regarding HBV and HCV was generally limited. Only 21 (11.9%) participants correctly identified the etiology of viral hepatitis, whereas 10 (5.6%) provided an incorrect response and 146 (82.5%) reported that they did not know.

Knowledge of symptoms was particularly limited: only 14 (7.9%) participants correctly identified the symptoms of hepatitis, while 162 (91.5%) reported that they did not know. Similarly, only 10 (5.6%) participants correctly identified the modes of transmission, whereas 167 (94.4%) reported no knowledge of transmission routes.

Regarding disease consequences, 57 (32.2%) participants knew that hepatitis affects the liver, while 13 (7.3%) responded incorrectly and 107 (60.5%) were uncertain. Only 31 (17.5%) recognized the association between chronic hepatitis and liver cancer, whereas 66 (37.3%) denied this association and 80 (45.2%) were uncertain.

Knowledge concerning treatment and prevention was also limited. Thirty-three participants (18.6%) reported that hepatitis was curable, 31 (17.5%) recognized that HBV/HCV are treatable, and 32 (18.1%) demonstrated knowledge regarding dietary precautions. Sixty participants (33.9%) reported awareness of herbal treatments. Only 28 (15.8%) participants were aware of the HBV vaccine.

Overall, the findings indicate substantial gaps in participants' knowledge across the major domains of hepatitis prevention, transmission, clinical manifestations, and vaccination (Table 2).

Table 2
Knowledge items regarding hepatitis B and C (N = 177)

Knowledge item	Correct n (%)	Incorrect n (%)	Do not know n (%)
Causes of hepatitis	21 (11.9)	10 (5.6)	146 (82.5)
Symptoms	14 (7.9)	1 (0.6)	162 (91.5)
Modes of transmission	10 (5.6)	0 (0.0)	167 (94.4)
Affect the liver	57 (32.2)	13 (7.3)	107 (60.5)
Cause cancer	31 (17.5)	66 (37.3)	80 (45.2)
Curable	33 (18.6)	52 (29.4)	92 (52.0)
Treatable	31 (17.5)	56 (31.6)	90 (50.8)
Dietary precautions	32 (18.1)	23 (13.0)	122 (68.9)
Herbal treatments	60 (33.9)	20 (11.3)	97 (54.8)
Aware of HBV vaccine	28 (15.8)	27 (15.3)	122 (68.9)

3.3 Attitudes toward hepatitis B and C

Participants also demonstrated limited awareness and unfavorable responses across several attitude-related items. Forty participants (22.6%) believed that hepatitis has a major impact, while 35 (19.8%) did not and 102 (57.6%) reported that they did not know.

Thirty-nine participants (22.0%) reported worrying about hepatitis infection, whereas 29 (16.4%) did not and 109 (61.6%) were uncertain. Only 38 (21.5%) recognized that informal waste picking places them at risk of HBV/HCV infection; 17 (9.6%) did not recognize this risk and 122 (68.9%) were uncertain.

Thirty-four participants (19.2%) believed that they needed protection against HBV/HCV infection, while 19 (10.7%) did not and 124 (70.1%) were uncertain. Regarding stigma-related attitudes, 30 (16.9%) believed that patients with HBV/HCV should be isolated, 21 (11.9%) disagreed, and 126 (71.2%) were uncertain.

Regarding vaccination willingness, 39 (22.0%) participants reported willingness to receive an HBV vaccine, whereas 23 (13.0%) were unwilling and 115 (65.0%) were uncertain (Table 3).

Table 3
Attitudes toward hepatitis B and C (N = 177)

Attitude item	Yes n (%)	No n (%)	Do not know n (%)
Major impact	40 (22.6)	35 (19.8)	102 (57.6)
Worry about infection	39 (22.0)	29 (16.4)	109 (61.6)
Waste picking puts them at risk	38 (21.5)	17 (9.6)	122 (68.9)
Need protection	34 (19.2)	19 (10.7)	124 (70.1)
Patients should be isolated	30 (16.9)	21 (11.9)	126 (71.2)
Willing to receive HBV vaccine	39 (22.0)	23 (13.0)	115 (65.0)
<i>Note. The current raw dataset contains six attitude items contributing to the recorded attitude score; the manuscript's statement that seven items were used must be verified against the original questionnaire.</i>			

3.4 practices and exposure to hepatitis risk factors

Protective practices were markedly inadequate. Only 2 participants (1.1%) reported routine use of protective gloves, and the same proportion (2, 1.1%) reported routine use of eye protection. Only 1 participant (0.6%) reported routine use of a face mask, while 7 (4.0%) reported routine use of safety boots.

Occupational exposure to sharps was common. A history of needle-stick injury was reported by 154 participants (87.0%), while 23 (13.0%) reported no such exposure. Exposure to glass or other sharp objects was reported by 157 participants (88.7%). Exposure to body-fluid

splashes was reported by 9 participants (5.1%), while exposure to bloody materials was reported by 3 (1.7%).

Health-service-related preventive practices were also uncommon. Only 8 participants (4.5%) reported having been screened for HBV or HCV, and only 3 (1.7%) reported having received HBV vaccination (Table 4).

Table 4
Occupational practices and hepatitis B/C exposure
(N = 177)

Variable	Yes n (%)	No n (%)
Protective gloves	2 (1.1)	175 (98.9)
Eye protection	2 (1.1)	175 (98.9)
Face mask	1 (0.6)	176 (99.4)
Safety boots	7 (4.0)	170 (96.0)
Needle-stick injury	154 (87.0)	23 (13.0)
Glass/sharp exposure	157 (88.7)	20 (11.3)
Body-fluid splashes	9 (5.1)	168 (94.9)
Bloody materials	3 (1.7)	174 (98.3)
HBV/HCV screening	8 (4.5)	169 (95.5)
HBV vaccination	3 (1.7)	174 (98.3)

These findings demonstrate a substantial occupational exposure burden combined with very limited use of personal protective equipment and limited uptake of hepatitis-related preventive health services.

3.5 Association between participant characteristics and KAP measures

The distribution of the recorded categorical KAP classifications varied across several sociodemographic and occupational characteristics. In the original analysis, knowledge classification was reported to be associated with marital status, accommodation, and work duration, while attitude classification was reported to be associated with accommodation and practice classification with daily working hours.

However, because the underlying composite-score construction is not fully consistent with the scoring procedures described in the Methods section, these categorical association results should be interpreted cautiously and should be re-estimated after the KAP scoring algorithm has been definitively verified. In particular, the recorded knowledge, attitude, and practice classifications do not fully correspond to the item numbers and cut-offs specified in the Methods section (Table 5).

Table 5
Associations of selected characteristics with recorded KAP classifications (N = 177)

Characteristic	Category	Knowledge good	Knowledge poor	P	Attitude positive	Attitude negative	P	Practice good	Practice poor	P
Marital status	Unmarried	6 (6.1)	92 (93.9)	0.015	17 (17.3)	81 (82.7)	0.484	12 (12.2)	86 (87.8)	0.658
	Married	14 (17.7)	65 (82.3)		17 (21.5)	62 (78.5)		8 (10.1)	71 (89.9)	
Accommodation	Alone	3 (4.8)	60 (95.2)	0.041	7 (11.1)	56 (88.9)	0.042	7 (11.1)	56 (88.9)	0.953
	With family	17 (14.9)	97 (85.1)		27 (23.7)	87 (76.3)		13 (11.4)	101 (88.6)	
Work duration	< 5 y	7 (6.8)	96 (93.2)	0.019	16 (15.5)	87 (84.5)	0.216	13 (12.6)	90 (87.4)	0.761
	5–10 y	6 (12.8)	41 (87.2)		13 (27.7)	34 (72.3)		4 (8.5)	43 (91.5)	
	≥ 10 y	7 (25.9)	20 (74.1)		5 (18.5)	22 (81.5)		3 (11.1)	24 (88.9)	
Daily hours	< 5	3 (17.6)	14 (82.4)	0.568	6 (35.3)	11 (64.7)	0.208	4 (23.5)	13 (76.5)	0.102
	5–10	6 (13.0)	40 (87.0)		8 (17.4)	38 (82.6)		7 (15.2)	39 (84.8)	
	≥ 10	11 (9.6)	103 (90.4)		20 (17.5)	94 (82.5)		9 (7.9)	105 (92.1)	

Note. These P-values are based on the classifications currently stored in the CSV (knowledge ≥ 7 on the recorded score, attitude ≥ 4, practice ≥ 9) using Pearson χ^2 . They are NOT suitable as definitive publication results until the questionnaire scoring key is verified; the manuscript's stated scoring rules do not match the stored variables.

3.6 Correlations between knowledge, attitude, and practice scores

Pearson correlation analysis demonstrated a strong positive association between the recorded knowledge and attitude scores ($r = 0.585$, $p < 0.001$).

When the currently recorded composite scores in the dataset were directly examined, the correlation between knowledge and practice was negative and weak ($r = -0.180$, $p = 0.017$). Similarly, the correlation between attitude and practice was negative and weak and did not reach conventional statistical significance ($r = -0.134$, $p = 0.077$).

Thus, while the positive relationship between knowledge and attitude was robust, the relationships involving the practice score were weak and did not support the positive KAP pathway reported in the original manuscript. These findings also indicate the importance of verifying the direction and construction of the practice score before interpreting relationships among the three KAP domains (Table 6).

Table 6
Pearson correlations among recorded composite scores (N = 177)

Variable	Knowledge	Attitude	Practice
Knowledge	1.000	0.585 (< 0.001)	-0.180 (0.017)
Attitude	0.585 (< 0.001)	1.000	-0.134 (0.077)
Practice	-0.180 (0.017)	-0.134 (0.077)	1.000

Note. Values are Pearson r with two-tailed P-values in parentheses. These are reproducible from the current CSV.

3.7 Needle-stick injury and multivariable analysis

Needle-stick injury was highly prevalent in the study population, with 154 of 177 participants (87.0%) reporting a history of such exposure.

The original manuscript reported significant associations between needle-stick injury and work duration and knowledge score in modified Poisson regression. However, these regression estimates could not be reproduced from the currently available raw dataset using the

documented variables and outcome coding. Therefore, the previously reported prevalence ratios and adjusted prevalence ratios are not presented here as definitive findings (Table 7).

A final multivariable analysis should be reported only after verification of the outcome coding, predictor coding, KAP score construction, reference categories, and the exact dataset used to generate the original regression model.

Table 7
Robust Poisson regression for needle-stick injury (N = 177)

Predictor	Univariable PR	95% CI	P	Adjusted PR	95% CI	P
Age (per year)	1.001	0.996–1.005	0.711	1.001	0.996–1.006	0.708
Female vs male	1.103	0.993–1.226	0.068	1.205	1.064–1.364	0.003
Primary vs illiterate	1.064	0.930–1.216	0.366	1.063	0.953–1.265	0.196
Secondary vs illiterate	1.111	0.951–1.299	0.186	1.098	0.998–1.398	0.053
Work duration (per year)	1.005	0.998–1.011	0.162	1.005	0.997–1.014	0.192
Knowledge score (per point)	0.985	0.947–1.023	0.429	0.980	0.944–1.018	0.298
Daily hours (per hour)	1.009	0.994–1.023	0.239	1.012	0.996–1.027	0.135
<i>Note. Outcome: needle-stick injury (yes = 1). Robust Poisson regression with robust standard errors. Estimates were recalculated from the current CSV and therefore replace the manuscript's original regression numbers only if the authors confirm that this CSV is the final analysis dataset and the stated outcome/codings are intended.</i>						

3.8 Structural relationships among knowledge, attitude, and practice

The original manuscript reported a structural equation model indicating positive pathways from knowledge to attitude and from attitude to practice, together with partial mediation of the knowledge–practice relationship by attitude.

Although the reported SEM coefficients are internally arithmetically consistent, the complete model could not be independently reproduced from the currently recorded composite scores. In particular, direct analyses of the available knowledge, attitude, and practice scores did not reproduce the reported positive attitude–practice and knowledge–practice pathways.

Accordingly, the SEM findings should not be interpreted as definitive until the underlying scoring procedures, model specification, observed versus latent variables, and the exact analysis dataset are verified. Because the study used a cross-sectional design, any indirect association identified after verification should be interpreted as a statistical mediation/pathway rather than evidence of a causal mediation process (Table 8).

Table 8
Reproducible observed-score path analysis (exploratory; N = 177)

Path	Standardized β	SE	P-value	Interpretation
Knowledge → Attitude	0.585	0.061	< 0.001	Significant positive association
Knowledge → Practice	−0.155	0.092	0.094	Not statistically significant
Attitude → Practice	−0.043	0.092	0.641	Not statistically significant
Knowledge → Practice, total (zero-order r)	−0.180	—	0.017	Small negative association
Indirect effect via attitude	−0.025	—	—	Exploratory product of paths
<i>Note. This table is NOT a replacement for the original latent-variable SEM. The reported SEM coefficients/fit indices in the manuscript could not be reproduced from the current composite scores. Because the study is cross-sectional, no causal mediation should be claimed. A definitive SEM table requires the original AMOS/SPSS model, syntax/output, and verified scoring key.</i>				

3.9 Summary of the Main Findings

Overall, the study population demonstrated substantial gaps in knowledge regarding HBV and HCV, particularly concerning disease etiology, symptoms, transmission, complications, and vaccination. Awareness of HBV vaccination was low, and uptake of hepatitis screening and HBV vaccination was extremely limited.

Occupational exposure to sharps was very common, with 87.0% reporting needle-stick injuries and 88.7% reporting exposure to glass or other sharp objects. At the same time, routine use of protective equipment was extremely uncommon, with glove use reported by only 1.1% of participants, eye protection by 1.1%, face-mask use by 0.6%, and safety-boot use by 4.0%.

The strongest reproducible relationship among the recorded KAP scores was the positive correlation between knowledge and attitude ($r = 0.585$, $p < 0.001$). The currently recorded practice score did not show a significant positive relationship with either knowledge or attitude. These findings highlight substantial occupational and preventive-health vulnerabilities among informal waste pickers in Aden and underscore the need for improved hepatitis education, vaccination, screening, and occupational protection.

4. Discussion

To our knowledge, this study is among the first in the Arab region to jointly examine HBV- and HCV-related knowledge, attitudes, and practices among informal waste pickers. Previous research from the region has primarily focused on medical-waste management, occupational health and safety, or formal waste handlers, rather than providing an integrated HBV/HCV KAP assessment specifically among informal waste pickers [8, 13]. The present findings therefore contribute baseline evidence on an understudied occupational group that operates largely outside formal occupational health and safety systems and experiences substantial exposure to potentially hazardous, unsegregated waste.

4.1 Comparison with Global and Regional Studies

The present study identified substantial gaps in HBV- and HCV-related knowledge among informal waste pickers. A similar pattern of limited hepatitis-related knowledge has been reported among waste scavengers in Lagos, Nigeria, where 95.9% of participants were classified as having poor knowledge regarding HBV [14]. In contrast, a study among formal medical waste handlers in Ethiopia reported that 97.2% had heard about hepatitis [15]. These differences may partly reflect variation in occupational settings, access to formal training and institutional health education, and availability of occupational health services. However, differences in study populations, measurement instruments, and knowledge classification criteria should be considered when comparing these findings.

The vulnerability of waste pickers to hepatitis-related occupational hazards is also supported by global evidence. A global meta-analysis reported pooled seropositivity estimates of 15% for HBV and 8% for HCV among waste pickers and highlighted the occupational and social vulnerabilities affecting this population [6]. In the present study, the high frequency of reported needle-stick injuries and exposure to sharp objects further indicates substantial occupational exposure to potential blood-borne hazards. Although these findings do not establish hepatitis infection in the present sample in the absence of serological testing, they underscore the importance of preventive measures, including appropriate personal protective equipment, vaccination against HBV, and access to hepatitis screening and occupational health services.

Attitudes toward hepatitis prevention also appeared unfavorable in the present study. Similarly, Oladipo and Odeyemi reported a predominantly negative attitude toward HBV among waste scavengers in Lagos, Nigeria [14]. The similarity between these findings suggests that unfavorable perceptions and limited engagement with preventive measures may represent an important barrier in informal waste-picking populations. Nevertheless, differences in questionnaire structure and attitude classification criteria should be considered when interpreting cross-study comparisons.

Given the cross-sectional design, the relationships among knowledge, attitudes, and practices should be interpreted as statistical associations rather than causal pathways. Any indirect association identified between these domains should therefore be regarded as hypothesis-generating and should be confirmed in longitudinal or intervention studies.

4.2 Novel Findings

Several associations observed in the present study may provide useful hypotheses for further investigation among informal waste pickers. However, these findings should be interpreted cautiously because the cross-sectional design does not establish temporal or causal relationships, and the knowledge-score classification requires verification against the original questionnaire and scoring algorithm.

Marital status was associated with knowledge level in the present analysis. Although previous research among waste handlers has examined sociodemographic factors in relation to hepatitis-related outcomes, the specific relationship between marital status and HBV/HCV-related knowledge among informal waste pickers appears to be insufficiently characterized. One possible explanation is that household and social networks may influence access to health-related information; however, this mechanism was not directly assessed in the present study. Therefore, the finding should be considered hypothesis-generating rather than evidence that marital status itself

determines hepatitis-related knowledge. Further studies should examine whether household communication, social support, or access to health information explains this association.

Accommodation was also associated with knowledge level in the present study. This observation may reflect differences in social support, living circumstances, or access to health information between participants living alone and those living with family. However, these potential mechanisms were not measured directly and should therefore not be interpreted as established explanations. Previous studies from Aden have reported hepatitis B and C infection among municipal waste collectors [9, 10], providing relevant regional context, although these populations differ from the informal waste pickers investigated in the present study. Consequently, the findings should not be assumed to be directly comparable across occupational groups.

Work duration was another factor associated with knowledge level in the present analysis. This finding is potentially important because longer occupational experience may be accompanied by greater exposure to occupational hazards and health-related information. Nevertheless, the cross-sectional design prevents determining whether longer work duration leads to greater knowledge or whether other characteristics of workers with longer tenure account for the observed association. In addition, Ramatsoma et al. reported that each additional year of landfill work experience was associated with a small increase in the prevalence of self-reported workplace injury among informal waste pickers in Johannesburg [19]. Their findings provide occupational context for the importance of work duration, but they do not directly establish a relationship between work duration and hepatitis-related knowledge.

Taken together, these findings suggest that social and occupational characteristics may influence hepatitis-related knowledge among informal waste pickers. However, the observed associations should be confirmed using validated KAP scoring instruments and multivariable analyses in larger, preferably longitudinal, studies. Such research could also assess the mediating roles of household communication, access to health information, occupational training, and duration of exposure to waste-picking activities.

4.3 Comparison of Statistical Methods

The present study used complementary statistical approaches to examine the relationships among sociodemographic characteristics, occupational factors, and KAP-related outcomes. Modified Poisson regression with robust variance was selected to estimate prevalence ratios for the binary occupational outcome, given the cross-sectional design. However, the regression estimates should be interpreted cautiously and should be reported only after verification against the final dataset, outcome coding, and statistical model specification.

Previous research among informal waste pickers in Johannesburg reported that each additional year of landfill work experience was associated with a small increase in the prevalence of self-reported occupational injury [19]. This provides relevant occupational context for examining work duration in the present population. Nevertheless, differences in study populations, outcome definitions, and analytical specifications should be considered when comparing effect estimates across studies. In particular, an association between work duration and injury does not by itself establish a relationship between work duration and hepatitis-related knowledge.

The relationships among knowledge, attitudes, and practices were additionally examined using correlation and structural modeling. The observed positive association between knowledge and attitude suggests that participants with higher knowledge scores tended to report more favorable attitudes. However, the statistical model should not be interpreted as demonstrating causal influence because the data were collected at a single time point. Any indirect association among knowledge, attitude, and practice should therefore be considered exploratory and hypothesis-generating rather than evidence of causal mediation.

The finding that 68.9% of participants did not know whether their work placed them at risk is particularly important from a public-health perspective. Limited recognition of occupational risk may represent an important barrier to adoption of preventive measures, although the present study did not directly test whether risk perception caused subsequent changes in protective behavior. Future longitudinal and intervention studies should therefore evaluate whether improving risk perception, knowledge, and attitudes leads to measurable improvements in occupational safety practices.

4.4 Regional and Global Context

Regional evidence provides important context for the occupational and preventive challenges identified in the present study. Edrees et al. (2022), in a study of 120 medical waste handlers in Sana'a, Yemen, reported HBsAg prevalence of 9.17% and anti-HCV prevalence of 5.0% [18]. Their findings also indicated an association between HBV vaccination status and hepatitis test results. Although these findings support the importance of vaccination as part of occupational hepatitis prevention, the cross-sectional nature of that study does not establish a causal protective effect, and HBV vaccination should not be interpreted as protection against HCV infection. In the present study, only 1.7% of informal waste pickers reported having received HBV vaccination, indicating a substantial gap in access to or uptake

of an established preventive intervention and supporting the need to improve HBV vaccination coverage among this occupationally vulnerable population.

Previous studies among municipal waste collectors in Aden have also documented hepatitis B and C infection in this occupational setting [9, 10]. These findings provide relevant local evidence that waste-related occupational groups may experience exposure to blood-borne viral infections. However, the municipal waste collectors investigated in those studies differ from the informal waste pickers included in the present study, and differences in occupational organization, working conditions, healthcare access, and exposure patterns should be considered when comparing the populations.

At the global level, Tolera et al. (2023) reported substantial seroprevalence of viral hepatitis among sanitary workers, with particularly elevated rates among sewage workers and other occupational groups involved in sanitation and waste-related activities [7]. This evidence supports the broader concern that workers involved in waste and sanitation may experience increased occupational exposure to blood-borne hazards. The present study complements this epidemiological evidence by examining hepatitis-related knowledge, attitudes, preventive practices, and occupational exposures among informal waste pickers, a population that remains comparatively understudied. Nevertheless, because the present study did not include serological testing for HBV or HCV, the observed knowledge and behavioral findings should be interpreted as indicators of preventive gaps and occupational vulnerability rather than evidence of hepatitis infection or transmission within the study population.

4.5 Strengths and Limitations of the Study

A major strength of this study is its focus on an understudied occupational population. To our knowledge, it is among the first studies in the Arab region to jointly examine HBV- and HCV-related knowledge, attitudes, and practices among informal waste pickers. The study provides baseline evidence from an occupational group that operates largely outside formal occupational health and safety systems and may inform future research and the development of targeted preventive interventions. Recruitment across all eight administrative districts of Aden Governorate also provided geographical diversity within the study setting and allowed participants from different occupational and sociodemographic contexts to be included. In addition, the study assessed several dimensions of hepatitis-related knowledge, attitudes, preventive practices, and occupational exposures, providing a broader description of the challenges faced by informal waste pickers.

The study also has several important limitations. First, the cross-sectional design prevents determination of temporal relationships and causal inferences between KAP measures, sociodemographic or occupational characteristics, and occupational exposures. Associations identified in the study should therefore be interpreted as correlational rather than causal. Longitudinal studies would be required to determine whether changes in knowledge or attitudes precede changes in preventive practices or occupational outcomes.

Second, the absence of a sampling frame for the informal waste-picking population required the use of non-probability convenience sampling supplemented by snowball recruitment. Although participants were recruited across all eight administrative districts, this approach may have introduced selection bias, and the sample cannot be assumed to be representative of all informal waste pickers in Aden or Yemen. The findings should therefore be generalized cautiously beyond the study population.

Third, several variables were based on self-reported information collected through face-to-face interviews, including needle-stick injuries, exposure to sharps and blood splashes, personal protective equipment use, hepatitis screening, and vaccination history. These measures may be affected by recall bias, particularly for events occurring in the more distant past, as well as social desirability bias. Objective occupational observations or documentary verification of vaccination and screening status could reduce these sources of measurement error in future studies.

Fourth, the final sample consisted of 177 participants and was determined pragmatically according to the number of eligible participants who could be reached during the study period. The absence of a sampling frame and the non-probability recruitment strategy limit the interpretation of conventional precision-based sample-size calculations. Nevertheless, the sample size may have provided limited statistical power for detecting small associations, particularly in subgroup analyses. Future studies involving larger samples and probability-based recruitment, where feasible, would provide more precise estimates and allow more reliable assessment of potential determinants.

Fifth, the study did not include serological testing for HBV or HCV. Consequently, the findings cannot establish the prevalence of current or past infection among the participants or directly examine the relationship between KAP characteristics and biological infection status. The high frequency of occupational exposures observed in the study should therefore be interpreted as evidence of potential

occupational vulnerability rather than evidence of hepatitis transmission or infection. Future studies should combine behavioral and occupational assessments with HBV and HCV serological testing.

Sixth, the measurement and classification of the KAP domains require careful consideration. The interpretation of composite knowledge, attitude, and practice scores depends on the precise questionnaire items, coding scheme, and predefined classification thresholds. These scoring procedures should therefore be fully documented and verified against the original questionnaire and dataset before the reported proportions and inferential analyses are considered definitive. In particular, future studies should use validated instruments with clearly established scoring procedures and report their reliability and validity.

Finally, because the study was conducted exclusively among informal waste pickers in Aden Governorate, its findings may not be directly generalizable to informal waste pickers in other governorates of Yemen or to populations in other countries. Differences in waste-management systems, occupational organization, healthcare access, vaccination coverage, socioeconomic conditions, and sociocultural contexts may influence hepatitis-related knowledge, attitudes, practices, and occupational exposures. Replication in other Yemeni governorates and comparable settings would therefore be valuable.

5. Conclusions

This study identified substantial gaps in hepatitis-related knowledge, unfavorable attitudes, and inadequate preventive practices among informal waste pickers in Aden, Yemen. Overall, 88.7% of participants were classified as having poor knowledge, 80.8% had a negative attitude, and 88.7% had poor reported practices. Occupational exposures were common, with 87.0% reporting needle-stick injuries and 88.7% reporting exposure to glass or other sharp objects. In contrast, the reported use of protective equipment was very limited, with only 1.1% routinely using gloves, 1.1% using eye protection, 0.6% using face masks, and 4.0% using safety boots. Only 4.5% reported previous screening for HBV or HCV, and 1.7% reported receiving HBV vaccination.

Knowledge was positively associated with attitude, indicating that participants with higher knowledge scores tended to report more favorable attitudes. However, the relationship between knowledge and reported practice was weak and should be interpreted cautiously, particularly given the need to verify the scoring procedures and analytical results for the KAP domains. Because this was a cross-sectional study, the observed associations cannot establish that knowledge or attitude causes changes in occupational practices or injury risk.

These findings highlight important opportunities for public-health and occupational-health interventions among informal waste pickers. Priority measures should include accessible and culturally appropriate health-education programs addressing HBV/HCV transmission, prevention, occupational hazards, and HBV vaccination; improved access to free HBV vaccination and HBV/HCV screening; and provision of appropriate personal protective equipment accompanied by practical training on its correct and consistent use. Measures to reduce exposure to discarded sharps, including improved waste segregation and safer sharps-disposal practices at relevant collection and disposal sites, should also be considered where feasible.

Because informal waste pickers operate largely outside formal occupational health and safety systems, collaboration among public-health authorities, municipal authorities, waste-management services, and community organizations is important for developing sustainable preventive programs. Future studies should use validated and clearly documented KAP instruments, larger samples, longitudinal or intervention designs, and, where feasible, serological testing for HBV and HCV. Such research would help determine whether targeted improvements in knowledge, vaccination, access to protective equipment, and occupational safety translate into measurable reductions in occupational exposure and infection risk.

Overall, the findings indicate a need to recognize informal waste pickers as an occupationally vulnerable population and to integrate their preventive and healthcare needs into broader hepatitis-control and occupational-health strategies in Yemen.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Medical Research Ethics Committee (MREC), Faculty of Medicine & Health Sciences, University of Science and Technology, Aden, Yemen, No. (UST-ETH-2026-0066), Date: 1/8/2025. The study was performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from the parents or legal guardians of participants younger than 18 years before data and sample collection. Participants aged 18 years or older provided informed consent themselves before participation.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Author Contribution

ANMG conceptualized and designed the study, supervised data collection, performed statistical analysis, and drafted the manuscript. NTA contributed to study design, data interpretation, and critical revision of the manuscript. HAAM contributed to data collection, data entry, and literature review. EWMA, SAMA and SMAK contributed to data collection and questionnaire administration and quality control. SMMD contributed to data interpretation and critical revision of the manuscript. All authors read and approved the final manuscript.

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Data Availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

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