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Reducing agate dust exposure in Khambhat, India: Protective practices, barriers, and opportunities

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Abstract

Aims: Agate workers in Khambhat, India and their community members are exposed to high levels of silica dust and related diseases. Use of effective prevention practices remains low, prompting the need for effective interventions which increase the uptake of and investment in prevention practices. We sought: (a) to describe knowledge, self-efficacy, and practices among a population of workers, their family members, and neighbors involved in or located close to agate processing; and (b) to explore which factors are related to use of prevention practices and willingness to invest in new dust control technologies.

Methods: A community survey was conducted to measure demographics, occupation and financial factors, knowledge, prevention practices, barriers, risk perceptions, and efficacy beliefs. Descriptive statistics were used and, among agate workers, hierarchical logistic regression explored predictors of prevention practice use and willingness to invest.

Results: Among 1120 respondents, approximately 44%, 35%, and 8% of workers, family members, and neighbors used prevention practices, respectively. Knowledge and risk perceptions were generally high, where efficacy beliefs were low. Workers who had high levels of education, worked at home, and had high efficacy beliefs were more likely to report using prevention practices and being willing to invest. Barriers to prevention practice use included financial barriers, and beliefs that prevention is ineffective and health is not at risk.

Conclusions: Interventions and future research should be designed to engage the community to improve preventive behavior, and implement affordable and effective dust control interventions in the agate industry.

KEYWORDS
informal sector, livelihood, quantitative survey, risk perception, silica, willingness to pay

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1 | INTRODUCTION

Over a decade ago the World Health Organization (WHO) and International Labour Organization (ILO) established the Global Programme for the Elimination of Silicosis, with the goal of eliminating silicosis by 2030.[1] Dust inhalation contributes to several other diseases including bronchitis, lung cancer, and autoimmune disorders.[1] Silicosis is incurable and often complicated by bacterial infections, such as tuberculosis,[2] or fungal infection, such as aspergillosis.[3] Yet adoption of control programs by specific countries is often lacking, partly because of the lack of funding available. The fibronodular lung disease due to inhalation of silica dust, silicosis, remains a persistent occupational disease in the developing world, so silica dust control is an important international priority.[1,2,4,5]

In India, an estimated 3 million workers are exposed to silica dust,[2,3,6,7] including an estimated 15 000-50 000 estimated workers in the agate industry.[8] Agate is a semi-precious stone used to make jewellery and other decorative items, which are primarily exported to the United States, Hong Kong, Thailand, and the European Union.[8] The grinding, polishing, and slicing of agate produces large amounts of fine silica particles (2-5 μm) that can be inhaled deep into the lungs. Consequently, silicosis and tuberculosis endemics are ongoing in and around Khambhat, Gujarat, where the 2500-year-old industry is located.[8] Agate workers, their families, and the surrounding communities are disproportionately affected. In 2002, a study by the Indian National Institute of Occupational Health found an extremely high silicosis prevalence among past-agate grinders (38.1%) and current agate grinders (29.2%) compared to undetectable prevalence (0%) in controls. Respirable dust levels ranged from 2.20-3.13 mg/m^3 near horizontal grinding machines, and 3.24-7.95 mg/m^3 near vertical grinding machines. These levels far exceed the permissible respirable dust level of 0.28 mg/m^3 in India, and even lower limits used in many other jurisdictions. Silicosis prevalence among the workers' family members (11%), and other community members (6.8%),[2] further highlighted the danger of the fine layer of silica dust, which is said to blanket the region.[8] (see figure A.1 in Supplementary Material Data S1).

High-efficacy dust control technologies, such as ventilation systems, can reduce the amount of respirable agate dust particles by 90%.[9] Cost-benefit analyses, conducted from a societal perspective, have indicated the overall benefit associated with their installation.[9] However, workers often lack access to these technologies, likely due to various financial, occupational, and knowledge barriers.[8,9] Previous studies have examined the use of prevention practices among workers in Khambhat and found the use associated with educational level.[10,11] However, neither the use of prevention practices among workers' family members and neighbous nor the barriers to prevention practices have been explicitly studied. Increasing the use of prevention practices remains an important strategy for reducing agate exposure in Khambhat.[4,9,11]

Several theoretical models have been used to conceptualize self-protective behavior and to inform intervention approaches.[12] Such models combine personal beliefs and expectancies, and organizational safety climate measures. Due to the home-based nature of the agate industry, it is expected that personal beliefs and expectancies are key determinants of prevention practice use. The Risk Perception Attitude (RPA) framework[13] proposes that one's perception of risk and one's efficacy beliefs (confidence in one's ability to prevent hazards) determine self-protective behavior. The RPA framework has been used to explain variation in risk perceptions and behaviors, to inform communication strategies, and to describe prevention practices in both developing countries and occupational contexts.[13-15]

2 | STUDY OBJECTIVES

Given the persistence of silica dust exposure and disease in agate-processing communities, we sought to identify barriers to the use of prevention practices, and opportunities for future interventions. Specifically, our objectives were: (a) to describe a population of workers, their family members, and neighbors involved in or located close to agate processing; and (b) to explore which factors (demographic, occupational, financial, perceptions and beliefs) are related to the use of prevention practices and willingness to invest in new dust control technologies.

3 | METHODS

We developed and used surveys to examine the demographics, knowledge, practices and beliefs of agate workers and community members in Khambhat, India in close collaboration with members of the People's Training and Research Centre (PTRC), of which JP is a member. PTRC was established as a not-for-profit, nongovernmental organization in 1992 to further workers' rights in occupational safety and health. It engages in participatory research projects, generates awareness through exhibitions, produces educational material, organizes training events, facilitates medical assessments and diagnosis of occupational diseases, provides legal counseling and support for those seeking compensation, and works with others for prevention of occupational accidents and disease.

3.1 | Sampling and recruitment

A referral-based sampling strategy was employed to maximize the efficiency. The peri-urban areas of Khambhat, where agate-processing is concentrated, were geographically

divided and sampling was conducted by peer researchers from the community. Three subpopulations in Khambhat were targeted, namely: agate workers, workers' family members, and workers' neighbors. To be included in the survey, agate workers had to be currently involved in agate work, family members had to be residing in a household where agate processing was done, and neighbors had to live within 15 meters of agate processing. Upon consent, consistent with University of Toronto Health Sciences Research Ethics Board approval, peer researchers administered surveys orally in Gujarati and data were translated to English. Recruitment began in late July 2015 and was completed by late August 2015.

3.2 | Survey tools

Surveys were developed in an iterative process between researchers at the University of Toronto, People's Training Resource Centre, and Workplace Health without Borders. Two surveys were utilized, one for workers, and one for family members and neighbors. (See Interview Guides A1 and A2 in Supplementary Material Data S1). Although the primary purpose of the surveys was data collection, in addition they were designed as educational tools. During the surveys, the interviewers communicated three awareness messages to participants regarding the danger of fine agate dust inhalation and the importance of preventative measures and proper dust disposal. Messages were placed after related questions to ensure they did not influence participants' answers.

Both surveys included questions regarding (a) demographics, (b) knowledge, (c) prevention practices and barriers, and (d) risk perceptions and efficacy beliefs. Demographic questions included sex, age, and level of education. Knowledge questions included questions related to familiarity with types of agate dust, health implications of agate inhalation, preventative methods, and knowledge sources. Prevention practice and barrier questions related to the use of and type of prevention practices used, and the barriers to using them. Risk perceptions and efficacy beliefs explored whether individuals thought they were at risk and if prevention practices were effective. We characterized risk perceptions and efficacy beliefs as "high" or "low" in line with previous research on the risk perception attitude (RPA) framework. In addition, the survey administered to workers included occupation- and workplace-specific questions including: characteristics of the respondent's work, including type of agate work, the location and daily duration of work and the number of years in the industry, as well as financial questions pertaining to willingness to pay for a new preventative intervention (exhaust system for dust control) and current financial situation as determined by debt. The latter was deemed particularly important in the context of small family business contract work.

3.3 | Data analysis

We calculated descriptive statistics of demographic, knowledge base, prevention, perception and belief variables among workers, family members, and neighbors. In addition, descriptive statistics on worker-specific variables were calculated. We assessed subgroup differences in knowledge, risk perception, efficacy belief, and prevention practices using chi-squared tests.

Among workers only, we explored which factors predicted current use of prevention practices. A hierarchical approach[16] guided multivariable logistic regression analysis based on a conceptual framework (see Figure 1).The conceptual framework was developed based on knowledge of the agate industry in Khambhat, the RPA framework, the desire to compare results with previous literature,[11] and available data. Factors were arranged based on their proximity to the outcome.

At the first stage, all conceptually proposed variables in the most distal level were included in a logistic regression model.[17] Likelihood ratio tests at $P < 0.2$ were used to determine if variables should remain in the model. This was done four times to establish the final model. At each stage, the model was assessed for fit (pseudo R^2) and for model contribution compared to previous stages (likelihood ratio test). Due

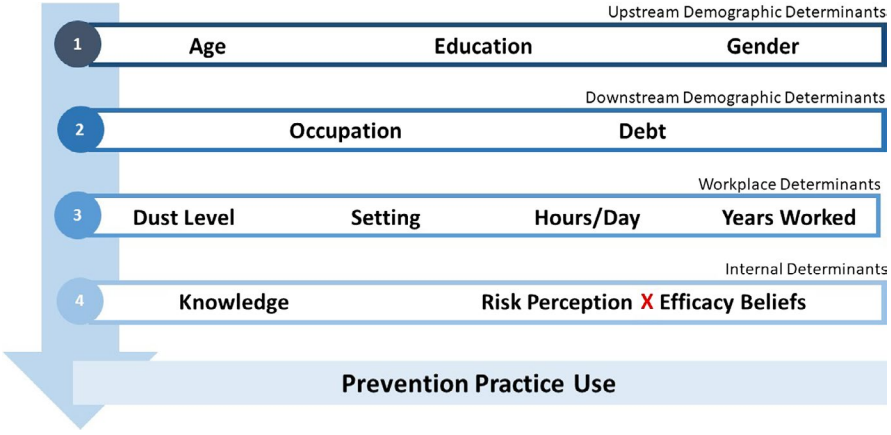

FIGURE 1 Hierarchical conceptual framework for prevention practice use among agate workers in Khambhat, India

to sample size limitations, the only interaction term included was the prespecified interaction between risk perceptions and efficacy beliefs. Variance inflation factors, DFBETAs, and goodness of fit were assessed for the models at each stage. All statistical analyses were performed in R (version 3.2.5).

The methods proposed by Victora and colleagues[16] were used to interpret results. Odds ratios and confidence intervals were calculated based on the model in which variables were first added. This method removes some power dampening, due to potential mediating effects, while adjusting for higher level confounders. Using a similar approach, we explored which variables predicted a worker's willingness to invest in a new preventative intervention. The conceptual framework was similar to the previous model, but included prevention practice use as another potential predictor (Figure A.2, Supplementary Material Data S1). In addition, due to a small number of outcomes, variables were only kept in the model if their $P < 0.1$, and no interaction term was included.

4 | RESULTS

4.1 | Demographics and knowledge

Basic demographics of the participating agate workers (n = 743), family members (n = 277), and neighbors (n = 100) are presented in Table 1. The majority of worker respondents were male (61.8%), in the 20-60 age range (93.2%), and had a standard level (1 to 8 years) of education (57.9%). (see Table A.1 in Supplementary Material Data S1.)

The majority of individuals surveyed (87.8%) knew that agate dust was harmful to health (see Table 1). This did not vary across subgroups ($\chi^2 = 0.057$, $P = 0.972$). Most individuals reported learning this from friends or family members (45.7%), health-care workers (26.9%), or the PTRC (26.6%). Employers or traders were reported as a knowledge source 1.2% of the time by all individuals, and 0.3% of the time by workers. Additionally, the majority of all individuals (69.6%)

TABLE 1 Knowledge of agate-related health consequences and prevention methods among agate workers, family members, and neighbors in Khambhat, India

	Worker		Family		Neighbor		Total[a]	
	n	%	n	%	n	%	n	%
Agate dust harmful to health?								
Yes	653	87.9	242	87.4	88	88.0	983	87.8
No	90	12.1	35	12.6	12	12.0	137	12.2
Total	743		277		100		1120	
Which type of dust is harmful?								
Dust that is very fine/not visible	471	72.4	153	63.5	58	63.0	682	69.6
Visible dust	115	17.7	74	30.7	22	25.0	211	21.5
Don't know	56	8.6	14	5.8	8	8.7	78	8.0
Other	9	1.4	0	0.0	0	0.0	9	0.9
Total	651		241		88		980	
What health effects does it cause?								
Hard to breathe/cough	316	48.5	101	42.1	66	75.9	483	49.3
Silicosis	212	32.5	74	30.8	32	36.8	318	32.5
Tuberculosis	223	34.2	107	44.6	30	34.5	360	36.8
Early death	3	0.5	0	0.0	2	2.3	5	0.5
Other	41	6.3	6	2.5	3	3.4	50	5.1
At least 1 selected	652		240		87		979	
What are prevention methods?								
Enclose process, move process, or more family	22	4.1	15	8.7	7	14.9	44	5.8
Exhaust ventilation duct	26	4.8	9	5.2	5	10.6	40	5.2
Dust mask, scarf, cloth	326	60.0	107	61.8	21	44.7	454	59.5
Wet handling	179	33.0	42	24.3	15	31.9	236	30.9
Other	28	5.2	6	3.5	4	8.5	38	5.0
At least 1 selected	543		173		47		763	

[a]N's vary by question due to missing responses.

knew that very fine dust was the type most dangerous to health. The most commonly known health consequence of inhalation, across subgroups, was difficulty in breathing or coughing. Approximately one-third of individuals knew agate dust could cause silicosis or tuberculosis, but very few individuals reported early death as a consequence.

Knowledge of several different prevention practices was apparent, most commonly use of: a dust mask, cloth, or scarf (roughly 60% of all individuals); wet handling (roughly 30% of all individuals); and enclosing or moving the process away from family members. Ventilation methods were only identified by approximately 5% of individuals. Most commonly individuals reported learning about types of prevention from friends and family members (41.8%), health-care workers (26.9%), and the PTRC (26.6%).

Actual use was lower, with a range of barriers to use (see Table 2), which varied across subpopulation. Most commonly individuals used wet handling methods, a dust mask, scarf or cloth to prevent dust inhalation. (See Figure A.3 in Supplementary Material Data S1) Barriers to prevention practice use included uncertainty regarding the effectiveness of interventions, not believing health was at risk, and cost.

4.2 | Occupation and workplace factors

Workers engaged in several types of agate processing (see Table A.2 in Supplementary Material Data S1). The most common type of processing reported was diamond wheel work, followed by agate drilling, agate cutting, and "other" work. The majority of workers reported being in the industry for more than 8 years, and worked 6 to 8 hours per day. Most workers (68.1%) reported some level of dust at work. Agate dust was most commonly disposed of by sweeping or shoveling dust, or using wet disposal or wash down methods.

4.3 | Financial factors

Although some workers reported prevention was too expensive (20.3% in Table 2), approximately 23% of workers were willing to invest in an exhaust system for dust control (see Table A.3 in Supplementary Material Data S1). Among them, 72.6% reported that they could invest 5000 Rupees or less. In addition, most workers reported being able to invest only after 6 months to a year. Approximately half of all workers reported owing debt. The majority owed to financial institutions, employers and traders, with fewer to friends or family members.

4.4 | Risk perceptions, efficacy beliefs, and barriers around prevention practice use

Reported risk perceptions, efficacy beliefs, and prevention practice use is presented by subgroup in Table 3. The majority of individuals (68.2%) had high risk perception, believing that they inhaled enough agate dust to be harmful to their health. This varied significantly across

TABLE 2 Agate inhalation prevention practices and barriers to their use, among agate workers, family members, and neighbors in Khambhat, India[a]

	Worker		Family		Neighbor	
	n	%	n	%	n	%
Prevention practices utilized						
Enclose process, move process or move family	3	1.1	6	9.5	2	33.3
Exhaust ventilation duct	29	11.1	1	1.6	0	0.0
Dust Mask, Scarf, Cloth	86	33.0	60	95.2	6	100.0
Wet Handling	145	55.6	9	14.3	1	16.7
Other	4	1.5	2	3.2	0	0.0
At least 1 selected	261		63		6	
Barriers to prevention						
Don't think dust is unhealthy	27	5.6	3	1.4	2	2.1
Don't think family's health is at risk	55	11.4	34	15.9	15	16.0
Don't think prevention makes a difference	125	25.9	65	30.4	30	31.9
Too expensive	98	20.3	10	4.7	11	11.7
Too time consuming/productivity loss	72	14.9	8	3.7	5	5.3
I don't know/Other	120	24.9	95	44.4	33	35.1
At least 1 selected	482		214		94	

[a]N's vary by question due to subsetting of questions and missing responses.

TABLE 3 Agate-related risk perceptions, efficacy beliefs, and prevention practices among agate workers, family members, and neighbors in Khambhat, India

	Worker		Family		Neighbor		Total		Pearson's Chi-squared test
	n	%	n	%	n	%	n	%	
Risk perception (Do you breathe enough dust to be harmful to your health?)									
High (Yes)	544	73.2	172	62.1	47	47.0	763	68.2	X2 = 41.046, $df = 4$, $P < 0.0001$
Low (No or don't know)	198	26.7	53	53.0	105	37.9	356	31.8	
Total	742		277		100		1119		
Efficacy beliefs (Do you believe dust inhalation can be prevented?)									
High (Yes)	305	41.0	54	19.5	20	20.0	379	33.8	X2 = 34.43, $df = 2$, $P < 0.0001$
Low (No or don't know)	438	59.0	80	80.0	223	80.5	741	66.2	
Total	743		277		100		1120		
Do you use prevention practices?									
Yes	328	44.1	96	34.7	8	8.0	432	38.6	X2 = 51.268, $df = 2$, $P < 0.0001$
No	415	55.9	181	65.3	92	92.0	688	61.4	
Total	743		277		100		1120		

subgroups, with workers reporting high-risk perception most frequently, followed by family members and neighbors. Efficacy beliefs also varied significantly between subgroups. However, only 33.8% of individuals reported high efficacy beliefs. The majority, consequently, did not believe or were unsure if agate dust inhalation could be prevented, consistent with findings in Table 3. Perhaps unsurprisingly therefore, the majority of individuals (61.4%) did not use prevention practices. Workers used prevention practices most frequently (44.1%), followed by family members (34.7%) and neighbors (8.0%). Variation across subgroups was significant.

4.5 | Factors associated with agate workers' use of prevention practices

Multivariable logistic regression of important factors for prevention practice use among workers is presented in Table 4. The final model included 12 outcomes per beta coefficient, meeting suggested guidelines.[17] Collinearity was low (VIFs <1.9), and no influential outliers were present as assessed by DFBETAs. Only one observation was missing, thus unlikely to influence estimates. Finally, a nonsignificant le Cessie-van Houwelingen test ($P = 0.128$) suggests a satisfactory fit.

Several demographic factors were significantly related to prevention practice use. Older individuals, males, and those with higher levels of education were more likely to report use of prevention practices. In addition, individuals who reported their work involved the vertical wheel, drum, diamond wheel, and emery wheel for agate processing had the highest odds of using prevention practices, relative to all workers. Having debt was not significantly associated with the use of prevention practices; thus this determinant was not retained in the model.

Controlling for demographic determinants, both dust level at work, and work location were the two occupational determinants that were associated with prevention practice use. Those self-reporting higher dust levels were more likely to report use of prevention practices. In addition, those who worked for an employer or in a factory were less likely to report use of prevention practices relative to those working in their own home. The number of years worked or number of hours worked per day was not associated with prevention practice use.

After controlling for demographic and occupational determinants, the interaction between risk perceptions and efficacy beliefs did not significantly contribute to the model predicted use of prevention practices ($P = 0.71$). In addition, neither risk perception alone nor knowledge that agate

TABLE 4 Results from hierarchical multivariable regression model predicting use of prevention practices (yes or no) among agate workers in Khambhat, India

	Variables	Ref	OR (95% CI)	*P*-value
Level 1[a]: Upstream Demographic Determinants	Age	Interval (5 levels)	1.40 (1.17-1.68)	<0.001
	Gender	REF: Female		
		Male	1.37 (1.00-1.86)	0.049
	Education	REF: Illiterate		
		1-8 y	1.43 (1.02-2.01)	0.041
		>8 y	2.65 (1.52- 4.70)	0.001
Level 2[b]: Downstream Demographic Determinants	Occupation	Chipper	0.32 (0.09-0.92)	0.050
		Cutter	2.56 (1.31-5.16)	0.007
		Diamond	7.38 (4.14-13.79)	<0.001
		Driller	2.02 (1.01-4.16)	0.050
		Drum	12.85 (6.02-28.97)	<0.001
		Emery	4.30 (1.94-9.77)	<0.001
		Vertical	15.26 (7.00-35.34)	<0.001
Level 3[c]: Workplace Determinants	Dust Level	REF: No dust		
		Some dust	2.89 (1.58-5.58)	0.001
		A lot of dust	4.80 (1.89-12.59)	0.001
	Work Location	REF: Home		
		Employer	0.50 (0.31-0.81)	0.005
		Factory	0.82 (0.46-1.45)	0.496
Level 4[d]: Internal Determinants	Efficacy Beliefs[e]	REF: Low		
		High	1.62 (1.12-2.33)	0.024

[a]Model 1: Age + Gender + Education (n = 743, pseudo $R^2 = 0.044$)
[b]Model 2: Model 1 + Chipper + Cutter + Diamond + Driller + Drum + Emery + Vertical (n = 743, pseudo $R^2 = 0.286$), debt ($P = 0.68$) removed from model.
[c]Model 3: Model 2 + Dust Level + Work Location (n = 742, pseudo $R^2 = 0.317$), workday length ($P = 0.91$), and years working ($P = 0.99$) removed from model.
[d]Model 4: Model 3 + Efficacy Beliefs (n = 742, pseudo $R^2 = 0.330$), knowledge agate is harmful ($P = 0.70$), risk perception ($P = 0.40$), and the interaction between risk perceptions and efficacy beliefs ($P = 0.72$) removed from model.
[e]Efficacy beliefs (Do you believe dust inhalation is preventable?) assessed as low (No or don't know) or high (Yes)

is harmful to health predicted use of prevention practices. However, agate workers who reported high efficacy beliefs, believing that dust inhalation is preventable, were more likely to report prevention practices relative to individuals with low efficacy beliefs.

4.6 | Factors associated with agate workers' willingness to invest

Multivariable logistic regression of factors associated with workers' willingness to invest in prevention practices are presented in Table 5. The final model included 20 outcomes per beta coefficient, meeting suggested guidelines.[14] Collinearity was low to moderate (VIFs <3.2), and no influential outliers were present as assessed by DFBETAs. Only one observation was missing, thus unlikely to influence estimates. Finally, a nonsignificant le Cessie-van Houwelingen test ($P = 0.547$) suggests a satisfactory fit.

Age and education, as upstream demographic determinants, predicted individuals' willingness to invest. Older individuals and those with higher levels of education were more likely to report being willing to invest. After controlling for age and education, workers involved in chipping, diamond wheel, drilling, drum, emery wheel and vertical wheel agate processing reported being willing to invest *less* often than all workers. Similar to the prevention practice model, debt was not significantly related to willingness to invest, and thus was removed from the model.

Controlling for demographic determinants, current prevention practice use and work location were workplace determinants that were associated with prevention practice use. Workers currently using prevention practices were more willing to invest than workers who did not use prevention practices. Perhaps understandably, individuals who worked for an employer or in a factory were less likely to report a willingness to invest relative to those working at home. Surprisingly, dust levels at work, number of years worked, or number of hours worked per day were not associated with the willingness to invest.

Similar to the previous model, after controlling for demographic and occupational determinants, risk perception and

TABLE 5 Results from hierarchical multivariable regression model predicting willingness to invest (yes or no) among agate workers in Khambhat, India

	Variables	Ref	OR (95% CI)	*P*-value
Level 1[a]: Upstream Demographic Determinants	Age	Interval (5 levels)	1.34 (1.09-1.67)	0.007
	Education	REF: Illiterate		
		1-8 y	2.90 (1.85-4.66)	<0.001
		>8 y	6.00 (3.18-11.47)	<0.001
Level 2[b]: Downstream Demographic Determinants	Occupation	Chipper	0.07 (0.02-0.22)	<0.001
		Diamond	0.38 (0.24-0.60)	<0.001
		Driller	0.19 (0.10-0.36)	<0.001
		Drum	0.15 (0.06-0.34)	<0.001
		Emery	0.17 (0.07-0.34)	<0.001
		Vertical	0.11 (0.04-0.34)	<0.001
Level 3[c] Workplace Determinants	Prevention Practices	REF: Don't use		
		Use	1.95 (1.24-3.10)	0.004
	Workday Length	Interval (4 levels)	0.71 (0.50-1.01)	0.057
	Work Location	REF: Home		
		Employer	0.09 (0.04-0.20)	<0.001
		Factory	0.16 (0.07-0.34)	<0.001
Level 4[d] Internal Determinants	Efficacy Beliefs[e]	REF: Low		
		High	4.66 (2.99-7.40)	<0.001

[a]Model 1: Age + Education (n = 743, pseudo $R^2 = 0.072$), sex ($P = 0.59$) removed from the model.
[b]Model 2: Model 1 + Chipper + Diamond + Driller + Drum + Emery + Vertical (n = 743, pseudo $R^2 = 0.205$), debt ($P = 0.29$) and cutter ($P = 0.45$) removed from model.
[c]Model 3: Model 2 + Prevention Practices + Workday Length + Work Location (n = 742, pseudo $R^2 = 0.338$), dust level ($P = 0.12$), years worked ($P = 0.12$) removed from model.
[d]Model 4: Model 3 + Efficacy Beliefs (n = 742, pseudo $R^2 = 0.415$), knowledge agate is harmful ($P = 0.86$), risk perception ($P = 0.56$) removed from model.
[e]Efficacy beliefs (Do you believe dust inhalation is preventable?) assessed as low (No or don't know) or high (Yes).

knowledge that agate is harmful to health did not predict willingness to invest. However, individuals who reported high efficacy beliefs, believing that dust inhalation is preventable, were more likely to report prevention practices relative to individuals with low efficacy beliefs.

5 | DISCUSSION

Previous research has highlighted the challenges in enhancing the occupational safety of workers in low- and middle-income countries, particularly in informal sectors.[18] In these sectors, including mining, welding, printing, textile manufacturing, and other small industries, substantial gaps exist in prevention practice use and preventative behavior.[19-23] Our findings are consistent with these studies, showing that just under half of the surveyed agate workers in Khambhat used prevention practices. This is, however, higher than previous research in Khambhat[10,11] that found 15%-22% of workers engaged in prevention practices. The difference could reflect true increases in prevalence of preventative behavior in Khambhat as a result of prior campaigns or be due to different demographics and agate occupations captured by different surveys. We also demonstrated for the first time that use of prevention practices is low among workers' family members (33%) and very low among neighbors (8%) who live in close proximity to agate processing. As silicosis is prevalent not only in workers, but in their family members and neighbors,[8] further promotion of preventative behaviors is needed throughout entire agate-processing communities.

5.1 | Limitations

Our study faced several limitations. The sampling in this study, driven by convenience, knowledge, and social connectedness of peer researchers, likely incurred selection biases, with segments of the population systematically missed. Additionally, due to the voluntary nature of the survey, participation bias could occur, as those with lower income, poorer health, and less disposable time would be underrepresented. Although selection bias should not be overlooked, using peer researchers was an appropriate

strategic choice.[24] The large sample size obtained allowed for the characterization of a significant proportion of the target population in Khambhat. Full data translation for agate workers was not available, which primarily limited analyses of the "other" categories. Observations were dropped if nontranslated data represented <1% of observations; otherwise data were retained and categorized as "other" for analyses. Additionally, in the survey, indicated skip patterns were not always observed. In analyses, these questions were considered independent. Due to small sample cell sizes among family members and neighbors, we did not conduct regression analyses in these subgroups. Although we collapsed categories to increase the number of observations in each cell, some still remained low, warranting caution in interpretation. Although several of the survey items were used to represent various constructs (risk perception, efficacy beliefs, and socioeconomic status), they were not explicitly designed to do so. Furthermore, we did not ask about health status, although a National Institute of Occupational Health colleague assessing agate worker x-rays during our field visits was diagnosing roughly one-third as silicotuberculosis. Hence we cannot link risk perceptions and practices with health status. Our ability to make causal inferences is limited by the cross-sectional nature of the data, particularly for complex risk perception and practice models. Despite these limitations, our study illuminates why individuals in agate-processing communities use or do not use preventative practices, and can inform the design of future interventions.

5.2 | Gaps in knowledge

While knowledge was generally high in workers, family members, and neighbors, gaps existed for targeting in future educational interventions. While all harmful effects of silica reported were accurate, the most common health consequences reported were symptoms alone (ie, cough, shortness of breath). Fewer individuals knew of the specific disease conditions (ie, silicosis, tuberculosis) caused by dust inhalation and very few reported early death as a consequence. When asked to name prevention practices, the majority of the participants reported knowledge of a cloth, mask, scarf, or wet handling methods. Unsurprisingly, these were the most commonly used prevention practice in all groups, despite their limited efficacy for reduction in silica inhalation, particularly dry cloths. Therefore, stressing the severe effects of agate exposure (silicosis and early death) and the use of prevention methods with demonstrated effectiveness (eg, ventilation systems) remains important.

The sources of knowledge and strategies for dissemination should be carefully considered in educational interventions. Friends and family members were most commonly reported as knowledge sources, followed by health-care workers and the PTRC. Involving these groups, particularly friends and family, in future educational interventions may increase knowledge dissemination. Incorporating education and community partners within a research project was a helpful approach. Community-based participatory research among informal sectors in occupational health is most likely to lead to action.[24]

5.3 | Efficacy of prevention practices

We explored the risk perceptions and efficacy beliefs of individuals in agate-processing communities. About 70% of individuals reported that they breathed enough dust to be harmful to their health, indicating generally high perception of risk. Awareness efforts, such as the messaging included at the end of our survey and other knowledge campaigns in the region,[25] may contribute to the high perception of risk in the community. Previous research highlights that other factors, such as previous experiences, the perceived ability to control risk, benefits (eg, economic) from risk-taking behaviors and a lack of incentives to use preventative practices may also impact risk perception.[26,27] While risk perceptions were generally high, there is still opportunity (eg, through continued awareness campaigns, incentivizing safety practices) to improve the perception of risk, especially among family members and neighbors. Fewer individuals believed that dust inhalation could be prevented, indicating a gap in efficacy beliefs. Similar to previous hypotheses and research on the RPA framework,[12-15] our regression analyses indicated that, controlling for demographic and occupational factors, workers with high efficacy beliefs were more likely to use prevention practices. Although more individuals using prevention practices had a high perception of risk, associations did not reach significance, similar to a previous study examining the RPA framework in HIV/AIDS prevention in Malawi.[14] Use of validated tools and longitudinal approaches may more easily detect associations.

Consistent with the regression results, the most common reported barrier to using prevention practices was the belief that they were ineffective. In addition, many respondents cited knowledge and use of prevention practices with unknown and potentially low efficacy (eg, masks, cloths, scarves, and wet handling). Use of these practices, if ineffective, could perpetuate low efficacy beliefs and may impact the adoption of more effective technologies. Increasing efficacy beliefs for effective prevention practices should be a key objective of future interventions. Previous research shows efficacy messages (ie, through a newspaper article) and supportive peer communication (ie, via SMS texts) can enhance self-protective behavior.[28] These types of interventions could be efficient and low-cost methods to increase the efficacy beliefs in agate-processing communities.

5.4 | Financial feasibility of prevention

Promoting knowledge of effective interventions will only improve health if individuals can obtain access to these technologies. Only 30% of workers reported being willing to invest in new technologies. Among these individuals, approximately half were only willing to invest <R2,000. Thus, ensuring that available interventions are low cost, or that subsidies are available (as suggested by Bhagia et al[9]) will be crucial to success. Interestingly having debt was not associated with the willingness to invest, suggesting that factors beyond cost could limit prevention practices currently or in the future.

5.5 | Employer-employee dynamics in agate processing

Several occupational factors were related to the use of prevention practices including work type, dust level, and work setting. The odds of using prevention practices were two times higher among those working at home compared to those working for an employer. In addition, despite over 40% of workers working for an employer, less than 3% reported employers as knowledge sources. While this could be related to knowledge gaps among employers, these factors are likely related to the informal work structure in the Khambhat agate industry, which has led to a lack of employee-employer contracts and implementation of workplace health regulations.[8] Education campaigns should also be aimed at employers to increase employer education, employee education, and prevention practices.

Patel and Robbins[8] suggest several other strategies including formalizing or reorganizing work structures, updating policies around home workers, and engaging with government to negotiate higher wages for agate work. Further research should include qualitative or pre-post intervention studies to evaluate interventions and improve the quality of evidence available on effective intervention strategies.

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DISCLOSURE

Approval of the research protocol: Research protocol approved by University of Toronto Health Sciences REB; *Informed consent*: provided as noted in methods section; *Registry and the registration no. of the study/trial*: N/A; *Animal studies*: N/A; *Conflict of interest*: As stated in affiliations. Note that the PTRC (JP) received sub-grant funding through the University of Toronto (from grant as noted above) for volunteer recruitment and payment, field data collection activities, and other aspects of participation in this research. As no ongoing work with agate workers, publication of this paper should not affect PTRC current operations or funding.

AUTHOR CONTRIBUTIONS

ML, PB, OM, JP, and DCC conceived the study; MS, LC, PB, ML, JP, DCC designed the data collection instruments; JP and team collected the data and translated material; LF, DCC, PB led data analysis and interpretation; LF wrote initial drafts; all authors critically commented on the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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