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Prevalence of Self-Reported Pulmonary Symptoms in a Community Residing Near a Cement Factory in Chilanga, Zambia: A Cross Sectional Study

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Abstract

There is a paucity of information on whether exposure to emissions from a cement factory has pulmonary ill effects on the residents of communities residing close to these factories. We aimed at determining the prevalence of pulmonary symptoms in a community residing near a cement factory.

Methods

Using residence in a community bordering a cement factory, as proxy measure of exposure to cement dust emissions, we conducted a cross sectional study in Freedom Compound, Chilanga, Zambia. Prevalence of self-reported pulmonary symptoms was captured using a modified American Thoracic Society questionnaire administered to respondents aged 15-59 years. The prevalence of pulmonary symptoms in this community was then compared to that of a control community, Bauleni, located 18 km from the cement plant.

Results

Residents of Freedom were 6.00 (95% CI 3.67 – 9.79); 3.30 (95% CI 2.04-5.34), 1.74 (95% CI 1.08-2.84); 5.71 (95% CI 2.02-16.20); and 5.16 (95% CI 1.41-18.94) times more likely to suffer from cough, phlegm, wheeze, asthma and pneumonia, respectively compared to residents in Bauleni.

Conclusion

The study shows that the prevalence of pulmonary symptoms was higher in residents in a community near a cement factory compared to the control. Furthermore, residents of the exposed community were several times more likely to report pulmonary adverse health effect compared to the control. Characterization of air pollutant levels and source apportionment studies in the exposed community are required to determine whether the observed excessive respiratory symptoms are due to emissions from the cement plant.

Keywords: Cement production; Emissions; Air pollution; Respiratory symptoms; Community; Zambia

Introduction

The cement industry is a potential anthropogenic source of ambient air pollution. Emissions include carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), sulphur dioxide (SO_2) and particulate matter (PM) of aerodynamic diameter size ranging from PM1.0 to PM10 which are known to have various adverse health effects on humans [1,2]. Communities near cement factories are thus at increased risk of exposure to these emissions. The respiratory system and the skin, being the most exposed body surfaces, are the most affected and repeated exposures could potentially lead to breakdown of defense mechanisms especially of the respiratory system. Although studies have shown contrasting findings, some of them [3-6] both in developing and developed countries have demonstrated a relationship between exposure to cement dust pollution and respiratory symptoms such as cough, wheeze, increased phlegm production, bronchitis and asthma. Most of the existing evidence of the deleterious effects of exposure to cement dust on human health is based on studies conducted in occupational setting [3-7] while very few have investigated the effect of cement dust exposure on the respiratory health of communities residing near cement factories [1,8,9].

The demand for improved living conditions such as improved built environments, dams and bridges has resulted in increased cement production with implicit increased environmental pollution and deleterious health effects on human populations. Globally, the production of cement increased from 3,310 million metric in 2005 to 4,180 million metric tonnes in 2014 [10,11]. Similarly, Zambia has experienced a steady increase in the production of cement in the last four years; from 9, 80,000 tons in 2010 to 2.2 million metric tons in 2014 [12]. Of this amount 61% is produced by Lafarge Chilanga cement plant which is located in the study area [12]. Chilanga district similar to the countrywide health reports show that respiratory illnesses are the second commonest cause of consultations with a health worker [13,14]. However, the incidence in Chilanga is above the national average. For instance, the national average for pneumonia in children aged less

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than five years (Under 5s) was 81 per 1000 while Chilanga reported 136/1000 in 2013 [15]. The observed difference in the incidence of respiratory illnesses in Chilanga could potentially be associated with ambient dust pollution in Chilanga district. The objective of this study was to determine the prevalence of self-reported pulmonary symptoms in Freedom Compound, a community residing near a cement factory in Chilanga.

Material and Methods

Study design

This was a cross sectional study conducted in two communities; the exposed community (Freedom compound) and a control (Bauleni). The study was conducted in November and December 2013; a period characterized by wet and warm climate.

Study area

Freedom compound is situated in one of the most densely populated areas in Chilanga. It is located on the leeward side at the edge and to the north-west of the cement factory. It is bounded on the western side by a major intercity tarred road. Access gravel roads coming off this major road cross the breadth and width of the settlement. Traffic on the major road includes heavy trucks, buses, vans and cars. Heavy trucks rarely traverse the inner parts of the settlement. Wind across the settlement is predominantly south-westerly resulting in most traffic emissions from the main road being blown away from the settlement. The control community, Bauleni, is located about 18 km from the cement factory outside the windward cement dispersion area. It is bounded by major tarred roads on three sides and has minor gravel standard roads in the inside of the settlement. Traffic on the major roads and minor roads is similar to that seen in Chilanga except there are fewer heavy trucks moving on the main roads. The major economic activity is informal trade in furniture, second-hand clothes and vegetables. There are no factories within or near to the Bauleni settlement.

Sample size

The prevalence of symptoms of interest in the two communities was unknown. However, evidence from studies from other parts of Africa suggest that the prevalence of respiratory symptoms such as cough and wheeze is around 30% for cement factory workers; while the prevalence in the control groups were found to be about 10% [3,16]. To calculate our sample size for this study, the prevalence of respiratory symptoms for the exposed and the control communities was assumed to be equal to that found in these studies. To detect a 20% difference at 95% confidence level and power of 80% we required a minimum sample size of 170 participants per community after adjusting for design effect of two (DE=2) and a non-response of 30%. In this study, we targeted to recruit 220 participants from each community.

Sampling of participants

A multi-stage random sampling method was used to select participants. The study communities were each divided into geographical clusters each containing a number of households. The households in each cluster were then enumerated and geocoded. Thus, the first tier sampling frame consisted of 25 and 42 clusters of household from Freedom and Bauleni, respectively. A subset of 10 clusters was randomly selected from each sampling frame using random number generator in excel. The second tier sampling comprised all households in the selected clusters. Twenty households were selected from each cluster. Lastly one individual from each selected household was randomly chosen for enrolment into the study. Inclusion criteria included the following: individuals aged 15-59 years and respondents must have resided in either of the study areas for at least 4 months prior to the survey. Participants employed in cement factory, construction industry, quarrying and mining were excluded. A detailed description of participant recruitment is given elsewhere [17].

Data collection

Data were collected using a modified American Thoracic Society (ATS) questionnaire which was administered to the selected participants by trained community health workers drawn from the health facilities serving the respective study communities. The data collected included participants' demographic and socioeconomic characteristics, the occurrence of respiratory symptoms and exposure to tobacco smoke.

Variables and measurements

Exposure variable: Residence in Freedom community was used as proxy measure of exposure to emissions from cement factory.

Outcome variable: The primary outcome was prevalence of pulmonary symptoms measured as cough, phlegm, wheeze, pneumonia, asthma and chronic bronchitis (Table 1).

Pneumonia, chronic bronchitis, asthma and phlegm were all self-reported and not confirmed with clinical records.

Smoking status was categorized into current, ex-smoker and secondary smoker. "Ex-smoker" was defined as cessation of smoking at least 12 months prior to the survey. Current smoker was defined as a person who smoked at least one cigarette in the last 11 months prior to the day of the survey. For all categories, it was established whether the cigarette was manufactured or locally rolled tobacco (or both), how many cigarettes were smoked per day, and for how long. "Secondary smoking" was if a participant was exposed to any household member that smoked in the house.

Data management and statistical analysis

Data were double entered independently, by two trained assistants, into a customized Microsoft Access database, with inbuilt validation capability. The two sets were compared, using Compare It program (Grig Software 2009, Vancouver, Canada) to identify discrepancies in entries. Any discrepancies identified were checked against the paper based data. Cleaning and coding was done in Microsoft Excel.

Analysis was performed using STATA version 12 (Stata Corp L 2011, College Station, Texas, USA). The unit of analysis was the individual respondent. To account for multistage cluster sampling and obtain correct estimates, STATA was set to svy mode, setting the primary sampling unit as the cluster of households.

Descriptive analysis within and between the exposed and control communities are reported; proportions, median and inter-quartile range (IQR) and 95% confidence intervals (CI). The Pearson's Chi-square test was used to compare differences in proportions of respiratory symptoms/conditions between the communities, while the Wilcoxon rank sum test was used to compare differences in the median. All statistical tests were two-sided and a P-value < 0.05 was considered as statistically significant while P-value ≥ 0.05 and ≤ 0.1 were considered marginally statistically significant.

To examine associations between area of residence and each of the outcomes, bivariate and multivariable logistic regression was used to obtain crude and adjusted odds ratios (ORs), P-values, and their

Cough	Phlegm	Wheeze
Cough on first going out-of-doors. Excluding clearing of throat	Bring up phlegm when going out of doors but not with mucoid discharge from the nose	Whistling sound on inspiration at least occasionally
Cough at all on getting up, or first thing in the morning	Bring up phlegm on getting up, or first thing in the morning	Feel out of breath due to attack of wheezing
Cough at all or during the rest of the day OR at night	Bring up phlegm during the rest of the day or at night	Required medication for wheezing attack
Cough as much as 4 times to 6 times a day, 4 or more days out of the week	Bringing up phlegm at least 2 times a day, 4 or more days out of the week	
*Any of the above	*Any of the above	*Any of other above

*Composite dichotomous variable if any of the respective symptoms was present. This was used in logistic regressions.

Table 1: Definition of outcome variables (pulmonary symptoms).

respective 95% CI. The following factors were assessed for possible confounding effect: age, gender, marital status, education, occupation, current smoking status (and number of pack years smoked), source of energy for cooking and lighting, whether cooking area was located within the main house or sleeping area; and ventilation of the dwelling house and whether respondent spent time home or away from home. For categorical factors, dummy variables were used in the model selection procedure. Furthermore, statistical interactions between community and other factors were investigated.

A model was built for each outcome. To obtain adjusted ORs for the "effect of residence" on the outcomes, all significant determinants (i.e., factors with a p value <0.05 in the Bivariate analysis) where placed in an initial regression model. This was followed by the addition, in stepwise manner, of factors that were marginally significant in bivariate analyses. Each time a new factor was added to the model, the ORs of the factors already in the model were checked. If the addition of a new factor changed the OR of any already included variable by more than 10%, the additional variable was retained in the model otherwise the variable was removed and another variable was added. Area of residence was considered the main explanatory variable and therefore was included in all models for each outcome of interest regardless of whether it was statistically significant in bivariate analyses.

Ethical considerations

The study protocol was reviewed and approved by a local research ethics committee in Zambia- ERES Converge IRB (00005948) and from IRBs of the Universities of Pretoria (0000 2535 IORG 0001662) and Michigan (00070842).

Results

Description of respondent's demographic and socioeconomic characteristics

The majority of the respondents in Bauleni were younger than 25 years (40%) compared to Freedom where the majority of respondents were between 25 and 39 years old (46%) (Table 2). Furthermore, there were more female respondents in Freedom than in Bauleni (84.1 vs. 73.2). The median number of years lived and the distribution of marital status were not significantly different between the communities. Although more respondents in Freedom than Bauleni had attained primary and tertiary education, a higher proportion in Freedom was unemployed compared to Bauleni (p value=0.001).

Smoking habits in the two communities was not different. Tobacco use was rarely reported. Only 23 respondents in the two communities reported having ever smoked: 17 and 6 were current smokers and ex-smokers respectively. The pack years for those who ever smoked ranged from 5 to 35 years. There was no significant difference in environmental secondary smoking between the two communities.

Socio economic characteristics of the communities: A higher proportion of respondents in Bauleni (53.9%) than in Freedom (44.4%) owned the houses they inhabited. A significantly higher proportion of houses in Bauleni than in Freedom were made of concrete material and roofed with metal sheets (p=0.020) (Table 3). However, Freedom had a higher proportional of houses that were plastered (58.8%), compared to Bauleni (38.8%). Most houses in both communities had one or two rooms and one to three windows per structure with no significant difference.

The major source of energy for lighting in both communities was electricity. However, the source of energy for cooking was different; charcoal was commonly used in Freedom (64.7%) than in Bauleni (%). Additionally, a significantly higher proportion of households in Freedom than in Bauleni had cooking areas located within the dwelling house.

Prevalence of respiratory symptoms

Generally, the prevalence of respiratory symptoms was higher in Freedom than in Bauleni (Table 4). Proportions of participants reporting cough, regardless of the time of the day, was higher in Freedom than in Bauleni: "cough morning" (37.6 vs. 23.5%, p value=0.003); "cough night" (48.1 vs. 14.6, p value <0.001); and "increased cough with phlegm" (55.9 vs. 13.9%; p value <0.001). Similarly, proportions of participants reporting phlegm production were significantly higher in Freedom compared to Bauleni (37.9 vs. 19.1, p value=0.003).

A higher proportion of respondents from Freedom reported suffering from wheeze compared to the control community (45.0 vs. 30.6%, p value=0.002) and a similarly higher proportion required medication for the wheeze in the exposed than in the control community (84.4 vs. 31.3 p value<0001).

While there was no significant difference in reported proportions of chronic bronchitis between the two communities, the prevalence of reported pneumonia, asthma, and the common cold were significantly different between the sites. About 20% of respondents from Freedom reported suffering from pneumonia compared to 3.5% from Bauleni (p value<0.001). Among those who reported suffering from pneumonia, on average 37% and 17.3% from Freedom and Bauleni respectively, knew the age of first attack. About ten times more respondents from

Factor	Total	Freedom	Bauleni	
		(Exposed)	(Control)	
	N=423	N=225	N=198	*p-value*
	n (%)	n (%)	n (%)	
Age in years:				
<25	158 (37.3)	77 (33.5)	81 (39.5)	
25 – 39	166 (37.0)	101 (46.2)	65 (31.7)	0.005
40+	99 (25.7)	47 (20.4)	52 (28.8)	
Gender				
Female	333 (78.2)	187 (84.1)	146 (73.2)	0.021
Male	90 (22.8)	38 (15.9)	52 (26.8)	
Marital status				
Single	138 (34.2)	71 (36.6)	67 (32.8)	
Married	245 (57.5)	135 (57.9)	110 (57.2)	0.099
Widow/divorced	40 (8.3)	19 (5.5)	21 (10.0)	
Years lived in community[a]		10 (4 – 22)	5 (14 - 23)	0.08
median (IQR)				
Gender				
Female	333 (77.2)	187 (84.1)	146 (73.2)	0.021
Male	90 (22.8)	38 (15.9)	52 (26.8)	
Education				
None	28 (6.5)	4 (1.1)	28 (6.5)	
Primary	241 (54.9)	147 (63.9)	94 (49.7)	
Secondary	145 (36.8)	66 (30.8)	79 (40.3)	<0.001
Tertiary	9 (1.8)	8 (4.2)	1 (0.4)	
Employment status[b]				
Unemployment	270 (66.4)	153 (75.5)	117 (61.6)	0.003
Employed	133 (33.6)	56 (24.5)	77 (38.4)	
Smoking status[c]				
Never smoker	397 (95.8)	209 (94.5)	188 (96.6)	
Ex-smoker	6 (1.2)	5 (2.0)	1 (0.6)	0.381
Current	17 (3.0)	10 (3.5)	6(2.8)	
Secondary smoke				
No	399 (94.0)	216 (96.9)	183 (92.4)	
Yes	24 (6.0)	9 (3.1)	15 (7.6)	0.057

[a]missing values 8 and 8 for Freedom and Bauleni respectively.
[b]missing values 16 and 4 for Freedom and Bauleni respectively.
[c]missing values 1 and 3 for Freedom and Bauleni respectively.

Table 2: Description of study participants by demographic characteristics stratified by community.

Freedom reported having asthma compared to Bauleni (p value<0.001). Furthermore, a much higher proportion of respondents from Freedom (46.5%) reported suffering from common cold compared to 8.2% from Bauleni (p value<0.001).

Characteristics	Total	Freedom (Exposed)	Bauleni control	
	N=423	N=225	N=198	*p-value*
	n (%)	n (%)	n (%)	
House ownership				
Owned	180 (46.5)	85 (44.4)	95 (53.9)	
Rented	224 (50.4)	124 (49.4)	100 (44.8)	0.021
Other	19 (3.1)	16 (6.2)	3 (1.3)	
How old house (Years)[a]				
1-20	70 (19.1)	33 (16.9)	37 (20.4)	
21-40	23(7.4)	6 (3.9)	17 (9.5)	0.08
Unknown	322 (73.5)	184 (79.3)	138 (70.1)	
House material[b]				
Mud	49 (12.3)	36 (16.5)	13 (6.6)	0.02
Concrete	351 (87.5)	171 (76.5)	180 (90.9)	
Roof material[c]				
Metal	191 (45.9)	55 (24.1)	136 (71.5)	<0.001
Asbestos	225 (54.1)	167 (75.9)	58 (28.5)	
House plastered				
Yes	205 (48.5)	130 (58.8)	75 (38.5)	0.01
No	213 (50.4)	90 (48.0)	123 (61.5)	
No. of rooms[d]				
1-2	240 (58.4)	123 (50.8)	117 (53.5)	0.53
3+	117 (41.6)	92 (49.2)	79 (46.5)	
No. of windows				
None	25 (5.9)	10 (4.4)	15 (6.8)	
1-3	280 (60.7)	148 (58.8)	132 (61.8)	0.31
4+	118 (33.4)	67 (36.8)	51(31.4)	
Carpet in house				
No	228 (55.9)	103 (44.0)	91 (44.2)	0.002
Yes	194 (44.1)	121 (56.0)	107 (55.8)	
Kitchen location				
Outside	225 (58.0)	102 (46.5)	123 (64.6)	0.004
Inside				
Inside	198 (42.0)	123 (53.5)	75 (35.4)	
Source energy cook				
Electricity	199 (50.4)	82 (35.3)	117 (59.0)	0.001
Charcoal	224 (49.6)	143 (64.7)	81 (41.0)	
Source energy light[f]				
Electricity	288 (73.1)	149 (72.3)	139 (73.4)	0.834
Candle	104 (26.9)	51 (27.7)	53 (26.6)	

[a]2 and 6 values missing for Freedom and Bauleni respectively.
[b]18 and 5 missing values for Freedom and Bauleni respectively.
[c]3 and 4 missing values for Freedom and Bauleni respectively.
[d]10 and 2 values missing for Freedom and Bauleni respectively.
[e]3 and 2 missing values for Freedom and Bauleni respectively.
[f]25 and 6 missing values for Freedom and Bauleni respectively.

Table 3: Description of respondents by social economic status stratified by community.

Predictors of respiratory symptoms

However, the ORs fro residence, through remaining significant,

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		Community		
		Freedom	**Bauleni**	
	Total	N=225	N=198	*p-value*
	N=423	n=%	N=%	
Cough[a]				
Cough morning	127 (28.7)	81 (37.6)	46 (23.5)	*0.003*
Cough night	133 (26.8)	108 (48.1)	25 (14.6)	*<0.001*
Increased cough with phlegm	135 (27.8)	112 (55.9)	23 (13.9)	*<0.001*
Any cough	164 (32.4)	133 (58.7)	31 (17.4)	*<0.001*
Phlegm[b]				
Increased phlegm	135 (27.8)	112 (55.9)	23 (13.9)	*<0.001*
Phlegm from chest	96 (20.4)	77 (31.1)	19 (12.3)	*<0.001*
Phlegm morning	92 (22.0)	60 (28.2)	32 (18.5)	*<0.023*
Phlegm night	88 (19.1)	69 (31.1)	19 (12.3)	*<0.001*
Any phlegm	116 (25.9)	83 (37.9)	33 (19.1)	*0.003*
Wheeze[d]				
Wheeze	157 (35.9)	94 (45.0)	63 (30.6)	*0.002*
Wheeze requiring medication[e]	101 (55.9)	77 (84.4)	24 (31.4)	*<0.001*
Chronic bronchitis[f]				
Reported	9 (1.5)	7 (2.3)	2 (0.8)	*0.09*
*Confirmed**	6 (57.2)	6 (85.5)	0 (0)	*0.032*
Age (yrs) at 1st attack median (Q_1, Q_3)	14 (5 - 20)	14 (3 - 20)	17 (13 – 21)	*0.378*
Pneumonia				
Reported	55 (9.5)	48 (20.1)	7 (3.5)	*<0.001*
*Confirmed**	24 (32.7)	22 (37.2)	2 (17.2)	*0.339*
Age (yrs) at 1st attack: median (Q_1, Q_3)	17 (7.5 -20)	20 (7 - 20)	20 (20)	*0.239*
Asthma				
Reported	27 (4.3)	24 (9.7)	3 (1.1)	*<0.001*
Confirmed	22 (84.5)	19 (67.7)	3 (16.8)	*0.204*
Age at 1st attack median (Q_1, Q_3)	18 (10 - 20)	16.5 (10 - 20)	20 (5 - 20)	0.761
Common cold**[f] **(Yes)	124 (22.2)	105 (46.5)	19 (8.2)	*<0.001*

[*]Diagnosis confirmed by health worker.
[a]one missing value from Freedom.
[b]2 missing values; none from Bauleni and 2 from Freedom
[c]4 missing values for Bauleni and 1 missing values for Freedom
[d]2 missing values for Bauleni and 1 missing values for Freedom
[e]denominator only those that reported wheeze
[f]1 missing value for Bauleni

Table 4: Prevalence of respiratory symptoms.

reduced from 7.03 (95% CI 2.43 – 20.34) to 5.16 (95% CI 1.41 018.94) after adjusting for confounders.

Residence, marital status, education, occupation, smoking status, presence of floor carpet and type of energy used for cooking were significant predictors of phlegm production in bivariate analysis. However, in multivariate analysis only residence, smoking status and presence of floor carpet were statistically significant; and the OR of residence reduced from 4 .06 (95% CI 2.53-6.51) to 3.30 (95% CI 2.04-5.34) after adjusting for potential confounders.

Independent determinants of wheeze included residence, age, occupation, smoking status and where the respondents spent most of the time. However, in multivariate analysis only residence retained significance. Respondents from Freedom community were 1.74 (95% CI 1.08-2.84) times more likely to report episodes of wheezing compared to those from Bauleni community after adjusting for other predictors. Residence was not significantly associated with chronic bronchitis (p=0.169). However, residence was strongly associated with asthma; respondents from Freedom were 5.71 (95% CI 2.02-16.20) times more likely to report asthma compared to those from Bauleni, after controlling for other factors.

Residence, education, occupation, time where respondents spent most of the time, type of energy used for cooking and location of the kitchen were independent predictors of pneumonia. However, the ORs for residence, though remaining significant, reduced from 7.03 (95% CI 2.43-20.34) to 5.316 (95% CI 1.41-18.94) after adjusting for confounders.

Discussion

This study has revealed that the prevalence of the various pulmonary symptoms of interest was two to four times higher in Freedom, the exposed community, compared to Bauleni, and that residing in Freedom was a significant determinant for the occurrence of the pulmonary symptoms.

In dust-polluted ambient environments, the main route of exposure to the dust is the respiratory tract. The resultant irritation sets off a physiological response to clear the airways culminating in enhanced cough and phlegm production [18]. In this study the prevalence of self-reported cough and phlegm production was higher among respondents from the exposed community compared to their counterparts from the control community. Irrespective of the time of the day, the prevalence of cough was significantly higher in the exposed than control communities, suggesting a persistent irritant in the ambient environment. Moreover, compared to those from the control community, respondents from the exposed community were 6.00 times more likely to report cough after adjusting for confounders. These findings could be linked to a basic reaction of irritations of the respiratory tract due to a dusty environment; possibly due to cement dust emanating from the cement plant. Similar findings, though reporting lower prevalence, have been reported by Sana [8] and Oyinloye [9]. However, earlier studies did not demonstrate such relationship [19,20]. The disparity could be attributed to the differences in the study settings. The studies that did not find association included only factory workers; a selection criterion that could have introduced bias related to the “healthy worker” effect. This bias could have masked the effects of cement dust on respiratory tract since sick workers were unlikely to be included in the studies as they stayed home. Our study drew participants from the community, thereby increasing the probability of including individuals with compromised respiratory health status and eliminating any selection bias.

The prevalence of phlegm production from the chest was significantly higher in the exposed than control community; 55.9% against 13.9%. The difference was evident even after adjusting for

Symptom/ Condition	Independent factors	Crude ORs	*(95% CI)*	p-value	Adjusted ORs	*(95% CI)*	p-value
Cough[a]	Community						
	Bauleni	1			1		
	Freedom	6.78	4.79– 9.59	<0.001	**6**	**3.67 – 9.79**	**<0.001**
	Age						
	<25	1			1		
	25-39	0.9	0.57– 1.42	0.652	0.69	0.36 – 1.33	0.255
	40+	0.55	0.32– 0.97	0.041	0.51	0.24 – 1.05	0.067
	Gender						
	male	1			1		
	Female	1.19	0.59 -2.36	0.309	1.79	0.90 – 2.31	0.119
	Energy for cooking						
	Electricity	1			1		
	Charcoal	2.09	1.41 - 3.12	0.001	1.44	0.90 – 2.31	0.019
Phlegm[b]	Community						
	Bauleni	1			1		
	Freedom	4.06	2.53 - 6.51	<0.001	**3.3**	**2.04 – 5.34**	**<0.001**
	Age						
	<25	1			**1**		
	25-39	0.77	0.40- 1.49	0.417	**0.68**	**0.34 – 1.37**	**0.263**
	40+	0.6	0.32 – 1.14	0.114	**0.69**	**0.30 – 1.59**	**0.362**
	Gender						
	Male	1			**1**		
	Female	1.34	0.64 – 2.79	0.411	**1.83**	**0.76 – 4.39**	**0.165**
	Smoke status						
	Never	1			**1**		
	Ex-smoker	11.78	3.05– 46.06	0.001	**6.66**	**1.06 – 42.01**	**0.044**
	Current smoker	0.62	0.18 – 2.18	0.441	0.36	0.10 – 1.36	0.124
	Carpet						
	No	1			**1**		
	Yes	0.37	0.21 – 0.65	0.002	**0.38**	**0.22 – 0.68**	**0.002**
	Cook energy						
	Electricity	1			1		
	Charcoal	1.6	0.93 – 2.74	0.08	1.01	0.54 – 1.78	0.95
Wheezing[c]	Community						
	Bauleni	1			**1**		
	Freedom	1.86	1.28 – 2.68	0.002	**1.74**	**1.08 – 2.84**	**0.026**
	Age						
	<25	1			**1**		
	25 -39	1.23	0.70 -2.16	0.46	1.22	0.68 – 2.181	0.472
	40+	0.47	0.24 – 0.91	0.027	**0.41**	**0.23 – 0.73**	**0.005**
	Gender						
	Male	1			1		
	Female	0.99	0.69 – 1.43	0.98	1.03	0.66 – 1.60	0.888
	Smoke status						
	Never	1			1		
	Ex-smoker	1.58	0.54 – 4.56	0.38	5.09	0.82 – 31.28	0.076
	Current smoker	4.49	1.00- 20.17	0.05	2.42	0.69 – 8.51	0.158
Chronic[d]	Community						
bronchitis	*Bauleni*	1			1		
	Freedom	3.6	0.73– 17.78	0.11	3.25	0.58 – 18.39	0.169
	Age						
	<25	1			1		
	25-39	2.7	030 – 27.99	0.385	141	0.09 – 21.64	0.792
	40+	2.16	0.31– 15.17	0.417	1.67	0.16 – 17.71	0.651

	Gender						
	Male	1			1		
	Female	0.33	0.05 – 2.03	0.217	0.47	0.09 – 2.55	0.36
	Community						
Asthma[e]	*Bauleni*	**1**			**1**		
	Freedom	**9.42**	**3.30 – 26.9**	**<0.001**	**5.71**	**2.02 – 16.20**	**0.002**
	Age						
	<25	1			1		
	25-29	1.51	0.71 – 3.23	0.26	1.62	0.45 – 3.64	0.62
	40+	1.35	0.46 – 3.96	0.564	1.31	0.51 – 7.09	0.314
	Gender						
	Male	**1**			**1**		
	Female	**0.27**	**0.09 – 0.81**	**0.022**	**0.33**	**0.11 – 0.96**	**0.043**
	Time where						
	Home	**1**			1		
	Away	**14.1**	**2.62 – 76.2**	**0.004**	6.54	0.92 – 46.49	0.059
	Floor carpet						
	No	**1**			1		
	Yes	**0.36**	**0.14 – 0.97**	**0.043**	37	0.11 – 1.14	0.08
	Kitchen location						
	Outside	**1**			1		
	Inside	**2.1**	**0.01 – 4.33**	**0.046**	1.91	0.96 – 3.77	0.06
	Energy for lighting						
	Electricity	**1**			1		
	Charcoal	**2.1**	**0.01 – 4.33**	**0.003**	2.69	0.85 – 8.43	0.085
	Energy for Cooking						
	Electricity	**1**			1		
	Charcoal	**2.06**	**1.21 -3.349**	**0.01**	0.91	0.21 – 3.76	0.887
	Community						
Pneumonia[f]	*Bauleni*	**1**			**1**		
	Freedom	**7.03**	**2.43-20.34**	**0.001**	**5.16**	**1.41 – 18.94**	**0.016**
	Age						
	<25	**1**			1		
	25 - 39	**0.35**	**0.16 - 078**	**0.014**	0.24	0.89 – 0.62	0.006
	40+	**0.69**	**0.27 – 1.77**	**0.419**	0.77	0.29 – 2.02	0.578
	Gender						
	Male	**1**					
	Female	**0.68**	**0.31 – 1.48**	**0.309**	**0.99**	**0.39 – 2.52**	**0.991**
	Energy for cooking						
	Electricity	1			1		
	Charcoal	1.85	0.89 – 3.86	0.092	1.58	0.74 – 2.61	0.289
	Kitchen location						
	Outside	**1**			1		
	Inside	**1.85**	**0.96 – 3.61**	**0.066**	1.39	0.74 – 3.37	0.218

[a]adjusted for age, gender, marital status, educational attainment, occupation, smoking status, presence of floor carpet and energy for cooking.
[b]adjusted for age, gender, marital status, educational attainment, occupation, smoking status, presence of carpet and energy for cooking.
[c]adjusted for age, gender, occupation, smoke status, and time where respondent spent most of the day.
[d]adjusted for age, gender, marital status and time where respondent spent most of the day.
[e]adjusted for age, gender, presence of floor carpet, time where respondent spent most of the day, source of energy for cooking and lighting and location of kitchen.
[f]adjusted for age, gender, education attainment, time where respondent spent most of the day, source of energy for cooking and location of kitchen.

Table 5: Significant factors associated with outcomes in Bivariate and Multivariate- analyses.

smoking and presence of floor carpet in the household; the two most commonly reported determinants of phlegm production [21,22]. This suggested a positive association of exposure to polluted ambient environment and increased phlegm from the chest as has been observed elsewhere [5,23,24].

The prevalence of wheeze was observed in 45% of respondents from the exposed community compared to about 31% from the control community. These results are consistent with findings from other studies [5,6,25,26]. Although, these studies used different sets of participants; production line workers as exposed and blue collar workers as control, they revealed that prevalence of wheeze was consistently higher among the production line workers compared to the blue collar workers. The underlying assumption of these studies was that production line workers were more exposed to emission of cement production. Mwaisalage et al, Mengasha et al and Ahmed Hafiz omer et al have demonstrated that the concentration of PM2.5, PM10 and other pollutants exceeded the exposure limits around the production line compared to other factory plant areas within same premises [3,23,27]. Wheezing is a sign of constriction of the airways resulting from irritants including dust [28]. Therefore, the observed 60% increase in odds of reporting a wheeze among the respondents from Freedom is suggestive of a deleterious health effect of cement dust on the respiratory tract. Although several other factors can lead to wheeze, the results show that there were no significant demographic and socio-economic characteristic differences between the two communities.

The prevalence of chronic bronchitis was similar between the exposed and control communities. Chronic bronchitis is less commonly reported at health facilities in developing nations [29-31] and thus subject to under reporting or misdiagnosis. Our study could have failed to show significant association due to insufficient numbers to attain the necessary power.

Respondents from the exposed community, compared to the control, were five times more likely to report asthma. Asthma is a respiratory disorder characterized by hyper-responsive airways to irritants including dust, pollen and other allergens in susceptible individuals [32]. Our findings are similar to those of Kyu Tae Cha et al. [33] who showed that the prevalence of asthmatic symptoms was higher among individuals exposed to cement dust. Additionally, results from our study reveal that gender and kitchen location are independent determinants of asthma after adjusting for other confounders. This is congruent with medical literature which shows that the prevalence and severity of asthma is higher in women compared to men in post puberty years [34,35]. Furthermore, this study shows that spending time in or around home, after adjusting for residence, floor carpet, and energy source for cooking increases the risk of asthma and these findings are consistent with results from other studies [21,36]. However, it is possible that factors of domestic micro-environment that were not considered in this study contributed to these finding.

In this study, the infectious disease of pneumonia was highly associated with residence. Evidence from elsewhere suggest that dust in the ambient environment is associated with increased respiratory tract infections ranging from the common cold [37], pneumonia [38] to tuberculosis [39]. Additionally, a recent study showed that construction workers aged 20-64 years who were exposed to inorganic dust were 1.87 times more likely to die from pneumonia [38]. This observation has been related to the compromised non-specific defense mechanism of mucociliary self-clearance, due to repeated exposure of the airways to dusty ambient environment [40,41].

Some factors, such as energy for cooking and lighting had unexpected effects in this study. While literature shows that using “dirty fuels” (biomass and fossil fuels) resulted in higher rates of respiratory disorders, both source of lighting and cooking did not achieve statistical significance after adjusting for potential confounders. The effect of “dirty fuels” as source of lighting could not have been significant as the proportion using these fuels in the two communities was similar. This could be due to the small number of respondents with disease conditions such as asthma, pneumonia, and chronic bronchitis [42,43].

Interpretations of this study’s findings should take into consideration its limitations. The major limitation is that the reported illnesses were not ascertained with medical records. This could potentially have introduced misclassification bias. Related to this was the ability to accurately report the number of times respondents experienced respiratory symptoms resulting in either over- or under-reporting. More importantly, there has been a lot of media attention on the effect of cement dust pollution on the environment in and around Chilanga. This could potentially have lead to over-reporting among respondents from Freedom. Moreover, the number of respondents with pneumonia, asthma and bronchitis was small leading to unreliable estimates of effect size.

Conclusion

The prevalence of respiratory symptoms was several times higher in the exposed community compared to the control. This could be related to ambient air pollution due to emissions from the nearby cement production plant. However, firmer evidence would require further studies involving chemical characterization of the exposure and source apportionment to determine whether the observed excessive pulmonary symptoms are due to emission from the cement plant.

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Author Contributions

Emmy Nkhama, Kuku Voyi, Seter Siziya and J. Timothy Dvonch conceived and designed the study; Emmy Nkhama, Micky Ndhlovu, Kuku Voyi acquired the data. Emmy Nkhama, Micky Ndhlovu and Seter Siziya analysed and interpreted the data; Emmy Nkhama and Micky Ndhlovu drafted the article; Emmy Nkhama, Micky Ndhlovu, J. Timothy Dvonch, Seter Siziya and Kuku Voyi critically revised the intellectual content of the article.

Conflicts of Interest

The authors declare no conflict of interest.

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