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Original Research Article

Particulate pollution, house location, gravel road, and associated respiratory health effects among the residents of Rehoboth metropolis, Namibia

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Elsewhere, the risk of poor respiratory health outcomes due to particulate pollution among urban dwellers has been well documented. However, there is limited evidence to link urban air quality to population health among residents of Rehoboth metropolis, Namibians where the dominance of gravel roads in residential areas threaten dust pollution on daily basis. The study was conducted to establish the association between particulate pollution, house location and presence of gravel roads and the prevalence of self-reported respiratory ailments among residents of Rehoboth metropolis, Namibia. Data on residents' self-reported respiratory ailments, house location and environmental exposure were collected using structured questionnaires, while particulate dust levels were monitored using the ASTM D1739 reference method. The study found high particulate concentration and high self-reported respiratory ailments (> 66%) in Rehoboth metropolis. While respondents' location was associated with respiratory symptoms that include usual cough (p-value=0.009) and usual phlegm (p-value=0.04); distance of respondents' houses to gravel road location were not significantly associated with the self-reported respiratory ailments. However, high vehicle traffics on the gravel roads near homes was significantly associated with episode of cough, phlegm, and breathlessness (p-value=0.01). This study revealed that self-reported respiratory ailments, namely cough, phlegm and breathlessness are associated with high vehicle traffics on the gravel roads near homes. This may be due to increased dust pollution emanating from the high vehicle traffics on the gravel roads and suggests residents' allergic reactions to dust. Thus, it is recommended that as a short term mitigation measure, the town council should frequently sprinkle water on the gravel road to suppress dust emissions from vehicle traffics flow while long term control measure should include asphalting the road.

Key words: particulate, pollution, self-report, respiratory health, Rehoboth

INTRODUCTION

The increasing severity of dispersion and fallout of fugitive dusts in urban areas has shown spontaneous linkage with higher degree of health disorders especially, bronchial ailments (Chow et al., 2012). The potential adverse health effects following both acute and chronic exposures to air pollution in both living and working environment have prompted local and international focus on both regulation and control of dusts pollution from the point of generation (Falcon-Rodriguez et al., 2016; Pope, 2000; Pope and Dockery, 2006; Sacks et al., 2011). Airborne dust comprises of fine and coarse particles. The fine particles, especially $PM_{2.5}$ have been associated with respirable health problems due to ability to deposit and block the lower airways and gas exchanging portions of lung (Sacks et al., 2 011;

Pope,2000; Pope and Dockery, 2006; Davidson et al., 2005).

Dust particles, especially those emanating from traffic emissions has the ability to penetrate deep into the human lungs and causing scaring of alveolar tissues including both chronic and acute cardiopulmonary effects and related mortalities (Simoni et al., 2002; Pope, 2000). Consequently, the monitoring of dust particles related pollution in urban centres has been set as a priority to ascertain the associated risk in order to evaluate the health implications of dust inhalation and ingestion by human population (pope 2000; Chow et al., 2012; Meng et al., 2013).

The current Namibian industrialisation agenda including increased construction projects such as roads and houses coupled with other anthropogenic activities have resulted in high emissions of particulates in the urban environment. The risk of poor respiratory health outcomes in relation to urban air quality has been well documented in the developed countries (Davidson et al., 2005; Pope, 2000; Sacks et al., 2011; Meng et al., 2013). Dust particle size, chemical compositions and the frequency of exposure to particulate matters determine the significant impact of dust on population health, specifically cardiopulmonary related morbidity and mortality (Davidson et al., 2005). However, there is limited evidence to link urban air quality to population health among many developing countries such as Namibia, which could be attributed to lack of effective monitoring programmes. The absence of data on particulate pollution suggests the need for developing countries to generate baseline data to inform the formulation of policies regarding public health and future references.

Some studies on fall-out dust in Namibia showed deterioration of site (Kgabi et al., 2013).However, such studies did not relate fallout dust to respiratory health diseases. The major impacts of air quality in our world today are judged by doctor visits, school day lost hospital admissions, mortality and morbidity rates, of which literature linking particulate pollution and health is limited for most developing nation. This study therefore, seeks to find if there is any link between urban air qualities to population respiratory health outcomes among Namibian population. Consequently, the monitoring of dust fallout in Rehoboth metropolis becomes necessary.

MATERIALS AND METHODS

Study area

The study focused on Rehoboth metropolis. The town of Rehoboth is located on latitude 23°19'S and longitude 17°05'E based on the Global positioning system (GPS) geographical information recorded at the site on 09 September 2015. The town has an estimated landmass of 639 Sq.Km (Maps of the world, 2015). According to Namibia 2011 population and housing census preliminary result, Rehoboth has a population of 28,843 and density 44.4/Sq.Km. The average daily traffic volume on the roads in Rehoboth town is about 560 vehicles. While the average vehicular speed in the town is about 70 Km/h. In terms of road infrastructure, commercial and industrial activities, Rehoboth metropolis has only two tarred road and several network unpaved (gravel) roads. The town has an upcoming industrial layout which currently constitutes mainly brick making, carpentry and mechanical garages with low level activities. Thus, the major possible contributors to particulate pollution in Rehoboth metropolis may be attributed to vehicular activities, incineration of waste materials, vehicular wears and tear as well as the use of biomass fuel for cooking purposes.

Study population

Study respondents were selected based on their availability, willingness to participate and should have lived in the town for more than 2 years. One adult, 18 years and above per household were approached and if agreed interviewed. A total of 121 respondent participated in the study and informed consent was obtained from all participants.

Particulate pollution monitoring

A total of 20 ambient dust samplers were mounted at various points within different blocks of Rehoboth metropolis over 30 days from January 2014 to October 2014, at two months interval, covering both dry and wet season. Gravimetric analyses were conducted at the Namibian University of Science and Technology, Environmental Health Sciences' pollution laboratory, using the ASTM D1739 reference method for both extraction and calculation of the fallout dust. During each sample collection, a pre-cleaned plastic bucket was filled with 5 litre of distilled water, and 10 ml of biocide added to prevent algae growth. Then, the bucket was placed on a pole, 2m above the ground level in an open place free from any sort of obstruction and left to stand for 30 days period to collect dust depositions.

Thereafter, the buckets were removed and the remaining solution in each bucket filtered gravimetric using a Buchner funnel apparatus, in the pollution Laboratory of the Environmental Health Science Programme, at the Namibia University Science and technology. Filter papers used in the gravimetric analysis of the collected dust were weighed before and after filtration using a weighing scale with 6 digits. The final particulate matter (PM) concentration was calculated using the following formula:

Fall-out rate ($mg/m^2/day$) = (collected mass x 1)/(0.043 X days) (Malakootian et al., 2013).

Monthly average of PM Levels were calculated and allocated to individuals living within one km of a particular sampling station.

Respondents' data

Structured questionnaires were used to collect data on respondents' demographic information, history of occupational exposure to dust over a period of 1 year, family health history and respiratory diseases/symptoms. Furthermore, information on the type of energy used for cooking and distance of respondents' houses from the busy gravel roads were collected.

Statistical analysis

Data obtained from questionnaires were coded, entered and analysed using SPSS statistical software version 22, and checked for conformity to normality assumptions (Fransman et al., 2003). Descriptive statistics were used to analyse the frequencies of respiratory diseases/symptoms .Bivariate chi-square tests were used to test for associations between demographic factors and respiratory diseases/symptoms. Multiple logistic regression analysis were used to estimate the overall effect of exposure variables on respiratory outcomes, adjusted for confounders such as TB, sex, age; and smoking (Ehrlich et al., 2011).

RESULTS

Respondents' information

Among the participants, the age group20 to 30 years had the highest representation with males having 20 (36.4%) and females 28 (42.4%). The majority of males (55.6%) indicated that they had never smoked cigarette, while 37% of them indicated they were current smokers compared to the females of whom only 13.8% indicated they are current smokers while 83.1% indicated that they had never smoked cigarettes (Table.1). The majority of respondents in both males (93%) and females (86.4%) indicated that the road passing by their houses were unpaved roads. On the history of occupational exposure to dust for more than a year, 34% among males indicated that they had been exposed for more than a year while only 3% of the females were exposed for more than a year (Table 1).

In addition, the majority of respondents (females 84.9% and male 78.2%) indicated using electricity as source of energy for cooking while 12.1% of the females' respondents indicated that they use solid fuels for cooking. The male's respondents indicated using a variety of energy sources including electricity (78.2%), solid fuel (16.4%), gas (3.6%) and paraffin (1.8%) for cooking. Most of the respondents indicated that they experience frequent vehicle movement near their homes and have dust particles on indoor surfaces (Table.1).

Fall-out concentrations

Block B had the lowest fallout concentration for both wet and dry season. Block E and F recorded the highest fallout concentration for both seasons while Block D only recorded high fallout dust levels for the dry season (Table 2).

Prevalence of respiratory diseases/symptoms

The prevalence of any respiratory symptoms is above average, 66% in Rehoboth town for the sample that participated in this study. There was a 17.4% prevalence of usual cough, 25.6% of usual phlegm, and 25.6% of episodes of cough and phlegm, 16.5% of breathlessness, 20% of wheezing, 12.4% of bronchitis, 4.5% of emphysema, 8.3% of asthma, 7.4% of TB and 4% of chest illness (Table 3).

Bivariate analysis between the respiratory health outcomes and the different risk factors was conducted and the results are highlighted in Table 4. The results obtained showed that age category was not associated with any respiratory symptoms, which suggests that age category of respondents was not a significant risk factor for any respiratory symptoms. The block that a respondent resided was associated with self-reported respiratory symptoms such as usual cough (p-value=0.009) and usual phlegm (p-value=0.04).

Residential block was also associated with self-reported respiratory diseases such as asthma (p-value=0.05), TB (p-value=0.04) and chest illness (p-value=0.01). The residential block was also associated with any of the respiratory symptoms (p-value=0.001) and any respiratory diseases (p-value=0.02). Distance from the road to resident location was not significantly associated with any of the respiratory symptoms and diseases. Smoking status was associated with breathlessness (p-value=0.03), wheezing (p-value=0.05) and emphysema (p-value=0.005). Gender was associated with overall respiratory symptoms (p-value=0.05) and overall respiratory diseases (p-value=0.02).

A history of occupational exposure to dust exposure was a significant risk factor for any respiratory symptoms (p-value=0.03), while indoor dust was a significant risk factor for episode of cough and phlegm (p-value=0.004), wheezing (p-value=0.04) and any respiratory symptoms (p-value=0.003). Period at current residence was significantly associated with bronchitis (p-value=0.02) and emphysema (p-value=0.006). Vehicle traffics near home was significantly associated with episode of cough and phlegm (p-value=0.02) and breathlessness (p-value=0.01).

The significant risk factors on bivariate chi-square tests with p-value <= 0.05 were included in the multiple logistic regression models for the different respiratory symptoms and diseases and the results are presented in Table 5. For usual cough, only block was included in the model since it was the only significant risk factor for usual cough.

The result shows that there was a significant difference between respondents from Block C and A as well as block D and A. Those in block C were 50% less likely to show symptoms of usual cough as compared to those in block A. Also those in block D were almost 90% less likely to show symptoms of usual cough as compared to those who reside in block A. This shows that those who reside in block A are at high risk of showing symptoms of usual cough. For usual phlegm, two variables, that is, block and History of occupational exposure to dust were included in the model.

Table 1. Participants demographic information (N=121)

	Male	Female
Age (years)	n(%)	n(%)
Less than 20	5(9)	4(6.1)
20 to 30 years	20(36.4)	28(42.4)
31 to 40 years	11(20)	13(1.5)
41 to 50 years	8(15)	9(16.4)
51 to 60 years	8(15)	5(7.6)
60 and above	3(5.5)	7(10.6)
Total	55	66
Marital status		
Married, (n) (%)	23(42)	13(20)
Widowed (n) (%)	0(0)	4(6)
Divorced (n) (%)	0(0)	2(3)
Separated (n) (%)	0(0)	2(3)
Never married (n) (%)	32(58)	44(68)
Total	55	65
Cigarette Smoking		
Ex-Smoker n (%)	4(7.4)	2(3.1)
Current Smoker n (%)*	20(37.0)	9(13.8)
Never Smoker n (%)	30(55.6)	54(83.1)
Total	54	65
Type of road passing by the house		
Gravel road	51(93)	57(86.4)
Tar road	4(7.0)	9(13.6)
Total	55	66
Occupational dust exposure > 1 year		
Yes	24(34)	2(3)
No	31 (56.4)	64 (97)
Total	55	66
Type of fuel used for cooking		
Solid fuel	9(16.4)	8(12.1)
Gas	2(3.6)	2(3.0)
Electricity	43(78.2)	56(84.9)
Paraffin	1(1.8)	0(0)
Total	**55**	**66**
Vehicle movement near house		
Constantly	21(38.2)	24(36.4)
Frequently	27(49.1)	38(57.6)
Seldom	7(12.7)	4(6.1)
Finds dust on indoor surfaces		
Constantly	12(21.8)	21(31.8)
Frequently	31(56.4)	31(47.0)
Seldom	10(18.2)	9(13.6)
Never	2(3.6)	4(6.1)
Missing	0 (0)	1 (1.5)

Furthermore, the result indicates that only those who were in block D were 80% significantly less likely to show symptoms of usual phlegm as compared to those in block A. This implies that block D is a much more protective place against symptoms of usual cough and phlegm. Those who had a history of occupational exposure to dust were 4.2 times likely to show symptoms of usual phlegm as compared to those with no history occupational exposure to dust. For episodes of cough and phlegm, only indoor dust was included in the model. The result indicates that respondents who frequently and seldom found dust in their indoors (80%) were significantly less likely to show symptoms of episodes of cough and phlegm as compared to those who constantly found dust in their indoors.

On shortness of breath, two variables, smoking status and vehicles passing close to residence were included in the model. Ex-smokers were significantly at higher risks of experiencing shortness of breath as compared to those who never smoked. Having vehicles frequently passing through the residence area was significantly at lower risks o f

Table 2. Seasonal variation of dust fallout mg/m^2/day in Rehoboth town January to October

Location	Season	Dust fallout in mg/m^2/day	
Block A	Wet season	**681.2**	**932.14**
Block B		121.8	377.7
Block C		**430**	208.6
Block D 1		175.7	111.8
Block D 2		**433.6**	244.9
Block E		**555.3**	**474.3**
Block F		**438.1**	**564.1**
Block A	Dry season	222.8	-
Block B		165	-
Block C		**831**	**-**
Block D 1		**868.7**	**-**
Block D 2		•	-
Block E		**390**	-
Block F		**486.9**	-

Reference standards for residential areas: American: 250 mg/m^2/day and German 650 mg/m^2/day

Table 3. Prevalence of respiratory outcomes

Respiratory symptoms	N=121
Usual cough n (%)	21 (17.4)
Usual phlegm n (%)	31(25.6)
Episode of cough and phlegm n (%)	31(25.6)
Breathlessness n (%)	20(16.5)
Wheezing n (%)	34(20)
Bronchitis	15(12.4)
Emphysema	6(4.5)
Asthma	10(8.3)
TB	9(7.4)
Chest illness n (%)	5(4)
Any respiratory symptoms* n (%)	81(66)
Any respiratory diseases, n (%)	33(27.3)

causing shortness of breath as compared to those who indicated that they constantly had vehicles passing through their residential area.

On wheezing, smoking status and indoor dust were considered in the model. The ex-smokers were significantly 5 times more likely to experience wheezy chest symptoms as compared to those who never smoked. Years at current residence (house) was determined as a risk factor for bronchitis, with those staying a period of between 10-20 years being 6.1 more likely to suffer from bronchitis as compared to those whose stay was less than 10 years. The longer the period of stay in the current residence, the higher the risk of suffering from bronchitis for the respondents that participated in the survey.

On suffering from emphysema, ex-smokers were 13.2 times more likely to suffer from emphysema as compared to those who never smoked. In terms of generally experiencing some respiratory symptoms, four variables were included in the model, namely; gender, block, occupational exposure history and indoor dust. Controlling for block, occupational exposure history and indoor dust, males were 3.2 times significantly more likely to experience some respiratory symptoms as compared to females. Blocks C and D were also significantly different from block A in terms of affecting the respondents' likelihood of experiencing some respiratory symptoms. Overall on experiencing some respiratory diseases, two variables were included in the model, viz: gender and block. Controlling for the block that the respondent resided in, males were 3.4 times significantly more likely to suffer from some respiratory diseases as compared to their female counterparts.

DISCUSSION

Particulate pollution is affirmed to be a leading cause of cardiopulmonary related morbidity globally, with the burden of respiratory diseases attributed to environmental exposure expected to increase in developing countries considering current industrialisation agenda. This study provides new evidence on the levels of particulate pollution and the prevalence of respiratory illness among Rehoboth residents. Most importantly, the study provide evidence on

Table 4. Respiratory outcomes and association with respondent's exposure variables

	age	Block	Distance from road	Smoking status	Gender	Occupational history of Dust exposure	Indoor dust	Period at current house	Vehicle movement near home
Usual cough	0.427	0.009*	0.6	0.7	0.4	0.5	0.1	0.7	0.1
Usual phlegm	0.996	0.04*	0.7	0.3	0.02	0.002	0.5	0.5	0.6
Episode of cough and phlegm	0.161	0.1	0.3	0.5	0.5	0.6	0.004*	0.8	0.02*
Breathlessness	0.159	0.1	0.6	0.03*	1.00	0.3	0.1	0.4	0.01*
Wheezing	0.870	0.3	0.6	0.05*	0.2	0.3	0.04*	0.4	0.5
Bronchitis	0.217	0.8	0.07	0.4	0.9	0.3	0.5	0.02*	0.7
Chronic bronchitis	0.362	0.7	0.3	0.6	0.2	0.4	0.8	0.9	0.4
Emphysema	0.584	0.2	0.6	0.005*	0.4	0.6	0.8	0.006*	0.2
Asthma	0.806	0.05*	0.6	0.06	0.5	1.000	0.6	0.4	0.2
TB	0.839	0.04*	0.9	0.6	0.07	0.4	0.4	0.5	0.4
Chest illness	0.915	0.01*	0.4	0.3	0.5	0.2	0.1	0.8	0.06
Any respiratory symptoms*	0.529	0.001*	0.8	0.3	0.05*	0.03*	0.003*	0.4	0.3
Any respiratory diseases,	0.492	0.02*	0.4	0.3	0.02*	0.2	0.7	0.9	0.4

* = Pearson chi-square test p-value <0.05,

association between particulate pollution and Rehoboth residents respiratory health, which was found to be significantly influenced by the individual location (block of the town in which individual resided).

The particulate concentration levels in the town varied across the two seasons of monitoring, within the residential blocks. The observed high concentration of dust fallout in both dry and wet season could be attributed to anthropogenic activities such as, building construction related activities and vehicular movement in the town. Moreover, the observed high particulate concentration in the wet season could be attributed to low rainfall rate received due to drought being experienced throughout the country and elsewhere. Our findings are consistent with other studies, which reported high concentration of particulate mass concentration in winter, which has been reported to be attributed to lower mixing height and poor dispersion rate in winter than warmer seasons (Meng et al., 2013).

The study also found high prevalence rate of self-reported respiratory symptoms such as wheezing, usual cough, phlegm and respiratory diseases such as Asthma, which are the most health outcomes affirmed to be worsened by exposure to air pollutants (Pope, 2000; Pope and Dockery, 2006). The residents' risk of developing respiratory symptoms was found to be greatly influenced by environmental related factors such as vehicle movement near the house, presence of dust on indoor surfaces, length of stay at current home, history of occupational exposure to dust and individual smoking status, which is in agreement with studies conducted elsewhere (Pope,2000; Pope and Dockery, 2006).

The residents of the upper class suburb (block D) were found to have a reduced risk of developing usual cough and phlegm symptoms when compared to those residing elsewhere in the town. The observed difference in risk of developing poor respiratory health in terms of place of resident could be explained by the presence of surfaced roads, limited vehicle movement as well as less use of biomass fuel in block D when compared to other blocks of the tow. Studies that investigated association between particulate pollution and health, reported that residents who resides near busy streets or those who use biomass fuel have increased risk of developing cardio pulmonary related illnesses (Clougherty, 2012; Wong et al., 2008; Davidson et al., 2005). This risk is attributed mainly to traffic movement and use of biomass fuel, which are the most activities reported to be the main contributors to particulate pollution, which is in agreement with findings from other studies conducted else were (Po et al., 2010; Torres-Duque et al., 2008; Wong et al., 2008; Davidson et al., 2005).

Moreover, the difference in resident risk of

Table 5. Symptoms Logistic Regression Models

Variables	Usual Cough (odds; 95% CI)	Usual phlegm (odds; 95% CI)	Episodes of phlegm and cough (odds; 95% CI)	Shortness of breath (odds; 95% CI)	Wheezy chest (odds; 95% CI)	Bronchitis (odds; 95% CI)	Emphyse ma (odds; 95% CI)	Respiratory symptoms (odds; 95% CI)	Respiratory diseases (odds; 95% CI)
Gender									
Female	-	-	-	-	-	-	-	1	1
Male	-	-	-	-	-	-	-	3.2(1.1-9.7)*	3.4(1.4-8.4)*
Smocking status									
Never smoked	-	-	-	1	1	-	1	-	-
Ex-smoker	-	-	-	11(1.6-77)*	5.0(0.8-30.3)	-	13.5(1.7-	-	-
Current smoker	-	-	-	2.0(06-6.6)	2.5(1-6.4)	-	105)*	-	-
							1.0 (0.1-1)		
Block									
Block A	1	1	-	-	-	-	-	1.	1
Block B	0.5 (0.2-1.6)	0.3(0.1-1.4)	-	-	-	-	-	0.6(0.2-2.8)	0.4(0.1-1.4)
Block C	0.1(0.04-0.5)*	0.7 (0.2-2.4)	-	-	-	-	-	0.2(0.05-0.8)*	0.3(0.1-1.1)
Block D	0.1 (0.02-0.3)*	0.2(0.03-0.9)*	-	-	-	-	-	0.1(0.01-0.3)*	0.2(0.04-0.7)*
Block E	1.6(0.4-5.8)	1.2(0.3-4.0)	-	-	-	-	-	0.7(0.1-4.0)	0.3(0.1-1.2)
		-							
Occupational exposure history									
Not exposed		1	-	-	-	-	-	1	-
Exposed		4.2(1.6-11.5)*	-	-	-	-	-	2.2(0.5-1.0)	-
INDOOR DUST									
Constantly	-	-	1	-	1	-	-	1	-
Frequently	-	-	0.2(0.1-0.5)*	-	0.2(0.1-0.5)*	-	-	0.2(0.4-0.6)*	-
Seldomnly	-	-	0.2(0.04-0.8)*	-	0.3(0.1-1.1)	-	-	0.7(0.1-3.5)	-
Never	-	-	0.2(0.2-2.0)	-	0.6(0.1-3.7	-	-	0.3(0.03-2.2)	-
Years at current house									
Less than 10 years	-	-	-	-	-	1	-	-	-
10-20 years	-	-	-	-	-	6.1(1.11-	-	-	-
21 to 30 years	-	-	-	-	-	33.0)*	-	-	-
31 to 40 years	-	-	-	-	-	7.6(1.4-42)*	-	-	-
41 and above	-	-	-	-	-	51(1.32124*	-	-	-
Cars									
Constantly	-	-	-	1	-	-	-	-	-
Frequently	-	-	-	0.2(0.1-	-	-	-	-	-
Seldomnly	-	-	-	0.6)*	-	-	-	-	-
				0.3(0.3-2.3)					

Table 5 Cont.

Distance from the road									
Less than 9m	-	-	-	-	-	1	-	-	-
Between 9 and 12 m	-	-	-	-	-	10.5(1.0-	-	-	-
More than 12m	-	-	-	-	-	107)*	-	-	-
		-	-	-		9(0.9-89)	-	-	-

* p-value<0.05,

developing poor respiratory health outcomes based on place of resident signal the role of socie economic status. The type of residential location has been reported by other studies to contribute to individual risk of developing poor health outcomes (Clougherty, 2012; Wong et al., 2008). Further, individual from low social class tend to settle in slums or areas which are less developed with limited access to proper road infrastructure, poorly constructed homes that exposes them to indoor pollutant from fossil fuel used for cooking and due to poor indoor air quality in their living and working environments (Sacks et al., 2010; Clougherty, 2012; Wong et al., 2008).

Findings from similar studies attributed the risk of cough and phlegm to vehicle movement near homes, which is in agreement with our findings (Sack et al., 2011; Alnawaiseh et al., 2014; Clougherty, 2012; Wong et al., 2008). This study found increased risk of experiencing episode of cough and phlegm and breathlessness, which is in line with findings from previous studies, which reported aggravated asthma, chronic bronchitis, chronic cough and breathing difficulties (Suhaimi and Jalaludin, 2014).

Our study found individual with history of occupational exposure to have increased risk for showing symptoms of usual phlegm. Although this is in agreement with previous studies, it differ in a sense that occupational exposure was found to be a greater risk factor for poor respiratory health, when compared to resident location accounting for the nature of road passing by the house. The observed association between history of occupational exposure to particulate and increased risk of poor respiratory health outcomes, is further explained by the fact that a large fraction of male respondents (34%) reported history of occupational exposure to pollutants, which increase their vulnerability to respiratory ailments, which is consistent with evidence reported from other studies (Wong et al., 2008).

Our study did not find significant gender difference with respect to the risk of developing poor respiratory health outcomes. However, men were found to be 3.2 time likely to develop respiratory symptoms mainly due to history of occupational exposure to dust and smoking, which is different from findings of study conducted elsewhere (Davidson et al., 2005). The observed gender difference in the risk of developing poor respiratory health outcomes in this study was found to be attributed to smoking, mainly because a lager fraction of the male (37%), respondents smoked cigarette when compared to female (13.8%) counterpart. This is further explained by the observed significant association between Smoking and breathlessness (p value=0.03). Smoking related studies affirmed that smokers had increased risk of developing poor respiratory health outcomes due to synergistic effect observed between smoking and dust exposure.

As previously reported by other studies, vehicle movement near homes was found to be a predicator for respiratory symptoms (Alnawaiseh et al., 2014; Chen et al., 1990; Davidson et al., 2005; Wilson et al., 2008). The majority of respondent reported to have unsurfaced road (gravel road) passing near their homes, which contribute to the increase of dust cloud in the location as well as the presence of dust on indoor surfaces, mainly due to vehicle movement, which was found to be a significant risk factor for residents experiencing episode of cough and phlegm (p value=0.004), wheezing (p value =0.04). Moreover, the study found that length of stay at current home increased resident risk for developing bronchitis, emphysema, cough and phlegm, which is in line with other studies which reported cumulative effect of particle pollution exposure (Chen et al., 1990; Meng et al. (2013). Similarly, the observed link between length of stay at current home and poor respiratory health outcomes could be attributed to factors such as poor indoor air quality likely to be caused by indoor related activities such as cooking and heating, dust settling inside from outdoor, the upkeep of the house, as well as the nature of the material from which the house is made from, which requires further investigation for the Namibian settings.

This study could not associate respiratory health outcomes to individual history of particulate exposure level, lung function loss or to individual time spend outdoor. Thus there is a need for follow up studies to conduct personal exposure to particulate pollutants in the living and working environment of respondents in Namibia, coupled with lung function assessment. Moreover, an improved monitoring strategy for particulate pollution is recommended, as the used method although cost effective does not account for particle size fraction. Doing so will eliminate misclassifications of personal exposure, while accounting for appropriate level of exposure to pollutants in the outdoor, living and working environment.

Although our dust monitoring was through in that it accounts for seasonal variation, the data on respiratory health was collected at one point in time, which may not represent health effects attributed to particulate pollution at different seasons of the year. Thus a longitudinal study using hospital visit related to pulmonary related complains and respirable fraction PM data is recommended to determine trends in respiratory health effects associated with particulate pollution among the residents of Rehoboth.

Conclusion

The study is among the few studies conducted in Namibia to establish the association between particulate pollution and respiratory health effects among the Namibian population, particularly in Rehoboth which is a small town with limited industrial activities. The study signals the extent of particulate pollution in the town as well as possible sources of pollutants and its impact on the Rehoboth resident health, it further signal the need for further investigations on pollution levels as well as health implication attributable to particulate pollution.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of the paper

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