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Article

Particulate Matter and Respiratory Symptoms among Adults Living in Windhoek, Namibia; a Cross Sectional Descriptive Study

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Abstract: The study aimed to estimate the prevalence of respiratory symptoms and to assess respiratory health risks associated with Particulate Matter (PM) exposure among the residents of Windhoek, Namibia. **Objectives:** To measure particulate pollution concentration in Windhoek through monitoring of particulate matter concentration and to identify any associations between particulate pollution, individual location and respiratory health among the Windhoek resident's. **Methods:** an adapted standardized self-administered questionnaire was used to collect respiratory health related data as well as previous exposure, while PM monitoring was done using ASTM D1739 reference method. **Results:** A high prevalence was observed for cough (43%), breathlessness (25%), and Asthma (11.2%). PM was found to be a significant risk factor for episode of cough and phlegm, while high PM exposure category had increased odds ratio for episode of phlegm and cough (OR: 2.5, 95% CI: 0.8-8.0). No association was observed between location and respiratory health outcomes. **Conclusion:** The study found high levels of PM concentration across all Windhoek suburbs which were above the German, American and EPA. Enactment of legislation relating to the control and monitoring of PM related emissions at point of generation is required at country and city level.

Keywords: respiratory symptoms; PM exposure; residential location; Namibia; Windhoek

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1. Introduction

PM refers to a mixture of coarse and fine solid materials combined with liquid droplets with ability to remain suspended in the air (Pope III, 2000; Environmental Protection Agency (EPA), 2016). Particle pollutants are both primary and secondary in nature, with most primary particulate pollutants, especially the fine PM originating from anthropogenic activities such as combustion process at domestic and industrial settings (pope, 2000; Chow *et al*, 2012).

Particulate matter (PM) remains a major public health concern globally, but its impact on developing countries population health remains unclear. Health effects associated with PM exposure depends greatly on the PM size, morphology, elemental constiuents and frequency of exposure, which can be further influenced by individual socioeconomic status and lifestyle (Davidson *et al*, 2005; Sacks *et al*, 2011; Environmental protection agency, 2015; Neuberger and Moshammer,2004; Pope III, 2000). According to the World Health Organization (WHO) (2015), in 2012 the ambient air quality contributed to 3.7 billion premature deaths globally, accounting for 80% of premature deaths (defined as early end of individual life before expected age). Moreover in 2014, WHO reported that 14% of Chronic Obstruction Pulmonary Diseases (COPD) related deaths and acute lower respiratory infections and 6% of lung cancer related deaths globally, were attributed to poor air quality. Developing countries are reported to suffer most from particle pollution, probably due to the lack of

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control measures and lack of efforts to monitor and control pollution at the point of generation (WHO, 2015).

The evidence on the country (Namibia) burden of environmental related respiratory diseases has not been well established, the available literature is based on old data, reported as late as 2004. As at 2004, the country burden of diseases attributed to outdoor pollution was estimated to account for 10% of all deaths per year (WHO, 2015). Also in 2009, WHO reported that Namibian prevalence rate for COPD and Asthma was at 0.5 and 1.7 per 1000 population for the general population respectively (WHO, 2009; Health metric's, 2015; CDC, 2013). In 2004, the country (Namibia) mean for PM10 in Urban areas was reported at 50 ug/m^3, this figure is expected to have doubled due to increased industrial activities as well increased vehicle emissions.
Although there is sufficient evidence to confirm association between PM and poor health outcomes, such evidence is limited to studies conducted in developed countries, whose pollution levels and sources are different to that of Namibia, mainly due to the level and type of industries in such countries. Moreover, the country lack up-to-date data on particle pollution as well associated health effects. Although the country level of industries is relatively small, considering the country new developmental agenda, establishing current pollution levels as well related health effects is necessary to provide evidence to inform public health policy geared toward particulate pollution control and monitoring.

2. Study sites

The study was conducted in Windhoek, the capital city of Namibia. Windhoek was considered a suitable setting due to the level of industries and motor vehicles which are key contributors to particulate pollution. According to the World Bank surveyed conducted in 2009 as cited by Trading Economics (2016) 103 persons per 1000 Namibians owned cars. Further, it is estimated that 13% of the Windhoek residents owned cars, while the remaining 87% uses public transport, which includes city buses and taxis (Madejski et al, 2014). Windhoek is situated in the central region of the country, at elevation of 1,700 meters above sea level, with a total space of 645 square kilometers. The city has a population of about 325 858 people, with a growth rate of 3.9 and population density of 9.2 persons per sq.km (Namibia statistic Agency, 2011). The population composition is made up of 11% of fewer than five year old children, 16% of 5-14 age groups, and 69% of 15-59 age groups, while those falling in the age category of 60 and above makes up only 4% of the city population (census, 2011). The city accommodates 89 438 households with an average size of 3.7 persons per household. 39% of households are headed by females. In addition to that 1% of city households do not have access to potable and sanitary facilities, while 8% of households use wood and charcoal for cooking and for other energy required purposes (Namibia statistic Agency, 2011)

3. Methodology

3.1. study design

The study employed non experimental approach; a descriptive cross sectional study was used, using quantitative approach of data collection and analysis. This type of study design allows data collection at single point in time, allowing both the measurement of diseases prevalence and PM concentration at the same time (Levin, 2006).

3.2.participants selection and data collection procedures

The study populations were residents of Windhoek, who have lived in the city for a minimum of two years and are residents of any of the suburbs in which dust monitoring stations were placed. A total of 107 Windhoek residents who met inclusion criterial and agreed to take part, participated in the study. The study was conducted between July 2015 and March 2016.

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3.2.1. Sampling approach

The study used systematic random sampling approach to select households. One adult was selected per selected household based upon convenience. The number of households selected was proportional to the size of the suburb.

3.2.2. Sampling frame:

Windhoek has 11 suburbs' (constituencies) including one rural: to obtain the final sample size, the researcher used the 2011 country census frame to draw the sample, using the number of households per constituency

3.2.4. Recruitment

The potential participants were identified and recruited using house location, in the city of Windhoek map. The city map was used to identify the first respondent household , subsequent respondent were recruited using a pre-determined systematic approach of selecting every 5th house in the street situated near the PM sampling location, in case of locked house or if identified household would not participate, the immediate following house was selected instead. The sequence was followed until all required respondents were reached per suburbs.
Following sampling and identification of the household; the researcher approached the prospective respondent, presenting basic information on purpose of the visit to the house. Subsequently, participant information sheet (PIS) with details on the research project was presented if the adult was found to have met recruitment criteria; after giving the PIS the researcher spent maximum of 30 minutes with the prospective respondent to allow him/her to ask questions and for the researcher to answer questions

3.2.5. Data collection methods

3.2.5.1 Questionnaire data

An adapted standardized self-administered questionnaire was used to collect data on respondent's respiratory symptoms and diseases, family history on respiratory diseases, occupational exposure and history, type of fuel used for heating and cooking. The following adaptions were made; respondent house distance from main road, type of road surface for main street/road passing by the house, years spent at current house as well as total years that respondents had lived in WHK (See appendix 1). The adapted questionnaire was previously used to collect data related to respiratory health outcomes among cola workers in US and South Africa (Naidoo et al, 2004). Similarly, the questionnaire was translated in oshiwambo and Afrikaans and translated back to English to ensure consistency. The completed questionnaires were posted back to the researcher, using envelop provided with the questionnaire.

2.2.5.2. Pilot-testing

The questionnaire was tested in one suburb first using a sample of 10 residents, to test for consistency in questions and response (Bruce et al, 2008). The respondents were asked to complete questionnaire, which were then assessed for consistency. From the observation of data obtained, the researcher found no technical issue or ambiguous questions, all respondent's answers were consistent and no clarity was sought with reference to questions asked in the questionnaire.

3.2.5.3. PM concentration monitoring data

The ASTM D1739 reference method was used for the collection of PM concentration levels data and for final calculation of PM concentration level to determine PM concertation received over the sampling period (Malakootian et al, 2013). Particulate monitoring was conducted over a period of three

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months. The buckets were left open for a period of 30 days for each sampling month. The ordinary buckets with surface area of 0.043 m² were placed at various points across the selected residential areas, at the pole height of 2meters and were left open, collecting dust from irrespective of the wind direction. The buckets were filled with 5 liters of distilled water and hydrogen peroxide was added to prevent algae growth. Dust samples were transported to the Namibia University of Science and Technology, Environmental Health sciences laboratory, where the dust was extracted gravimetrically using the Buchner funnel apparatus. Filter papers used in the gravimetric analysis of collected dust were weighed both before and after filtration using a weighing scale with 6 digits. The final PM concentrations levels were calculated using the following formula: Fall-out rate (mg/m²/day) = (collected mass x 1)/(0.043 X days).
Monthly average PM Level was calculated and allocated to individuals living within 1 km of the particular station.

3.3. Ethical consideration and informed consent

The respondents were briefed in person about the study and given a participant information sheet describing the purposes of research. The questionnaire was left with the person and they completed it if they wished to. By completing the questionnaire they implied consent. Codes were used instead of participant's names to ensure anonymity, to ensure confidentiality questionnaires were stored in a lockable and secured cabinet at researcher's office at the Namibia University of Science and technology. In addition to that, all related documents were stored in a password protected file. The ethical approval was obtained from the ethics committee of the University of Liverpool and Ministry of Health and Social Services (Namibia) Ethics Committee.

3.4. Data Analysis

The obtained data were analyzed using statistical package for social scientist (SPSS) software version 21. The data was first cleaned through visual inspection as well as by means of basic descriptive analysis to look for odd values as well as characters not meant to be in the results. Explorative test were done to test for data normality distribution using graphic output such as histogram and boxplot to detect outliers. This was followed by descriptive statistics analysis for both continuous and categorical variables: Following explorative test for normality, the continuous variables such as age, distance from the road, number of cigarrete smoked and number of years spent at current home were described using mean and standard deviation, while skewed data were presented as median instead of mean. Categorical variables were analyzed and presented using counts and percentages, followed by group difference test for categorical variables (chi-square and cross tabulation) and descriptive tests results were summarized using frequency tables. To allow for group difference analysis continuous data were recoded into groups using tertiles, such variable's included age, distance from road and years at current homes. An exposure variable analyzed was PM concentration levels defined as low, medium or high, which was defined based on measurement results tertile. Outcome variables included response on whether the respondent had respiratory symptoms and diseases, of which expected answers were binary type of data (yes or no), which was then used in the test of differences using chi-square test as deemed appropriate. In addition to that, the overall prevalence of respiratory symptoms were calculated and also described in terms of individual location and PM levels and previous exposures. Continuous variables collected included age, PM levels, and length of stay at current house. Categorical variable gathered included location, education level, and respiratory symptoms among others. Moreover, logistic regression was used to estimate odds ratio with 95% confidence intervals of health outcomes. Multivariate logistic regression was used to test for associations between variables of interest. Significance test were be accepted at $p< 0.05$. Possible confounding factors collected through the questionnaire included: age, gender, TB, smoking, occupational exposure, Asthma, and type of fuel used. The analyses were adjusted for these confounding factors. Both gender, TB, smoking, occupational exposure, Asthma, and type of fuel used were obtained as categorical in nature, while Age was obtained as discrete, continuous variable.

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4. Results

4.1. Study Population Characteristics

Descriptive statistics was performed and the summary of the sample population general characteristic is described in Table 2. The majority of respondents fell in the age group of less than 30 years. Similarly the majority of respondents' were unmarried (73.8%) and only a small fraction of the respondents' reported to smoke cigarretes (7.5%) and there was no difference between the proportion of ex- smokers and current smokers in the studied population.

Table 2: Participants demographic information

Variables	*Frequency and percentages*
Age group	
18 to 30 years	56 (52.3)
31 to 40 years	20 (18.7)
41 and above	21 (19.6)
Gender	
Male	55 (51.4)
Female	52(48.6)
Marital status	
Married,	19(17.8)
Widowed	1(0.9)
Divorced	2(1.9)
Separated	5(4.7)
Never married	79(73.8)
Cigarette Smoking	
Ex-Smoker	8(7.5)
Current Smoker	8(7.5)
Never Smoker n	91(85)
Distance from road category (Meters)	
10 m and below	35(32.7)
10.1 to 90m	33 (30.8)
91 m and above	39 (36.4)
Years at current home,	
2 years and below	36 (33.6)
3 years to 6 years	36 (33.6)
7 years above	35 (32.7)
Total years lived in WHK,	
2 to 4 years	31 (29.0)
5 to 14 years	39 (36.4)
15 years and above	37 (34.6)
Employment status	
Employed	56(52.3)
student	21(19.6)
Unemployed	28(26.2)

4.2. History on environmental related PM exposure

Table 3 describes studied population history of PM exposure, which illustrates that 22.4% of respondent lives in areas with unsurfaced main streets/roads, while only 11% of respondent reported to have worked in environment which exposed them to dust for 1 year and above. Similarly, only 63.5% of respondent's used electricity as source of energy for cooking while the rest uses carbon fuel for cooking such as gas, wood and paraffin. The majority of respondent reported constant (43.9%) or frequent (39.3%) vehicle movement nears home or indoor dust observed mainly on surfaces (42.1%).

Tables 3: Relative frequency of environmental related exposure to PM

Variables		*N (%)*
Type of road passing by the house		
	Gravel road	24(22.4)
	Tar road	83 (77.6)
Occupational dust exposure > 1 year		
	Yes	12(11)
	No	95(89)
Type of fuel used for cooking		
	Solid fuel	1(0.9)
	Gas	32 (30)
	Electricity	68 (63.5)
	Paraffin	6 (5.6)
Vehicle movement near house		
	Constantly	47(43.9)
	Frequently	42 (39.3)
	Seldom	17 (15.9)
	Never	1 (0.9)
Finds dust on indoor surfaces		
	Constantly	45(42.1)
	Frequently	36 (33.6)
	Seldom	20 (18.7)
	Never	6 (5.6)

4.3. PM concentration levels across suburbs

The result for PM measurement is presented in table 4. High levels of particulate pollution were recorded across all suburbs regardless of the residential area classification for both monitoring periods; with the majority of dust levels recorded exceeding the recommend levels for residential area by the American Standard Test Method, ASTM D1739. With suburb's in high density area recording the highest PM levels for all three monitoring periods.

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Table 4: Particulate Matter (PM) concentration in mg/m2/day for sampling period 1 to 3.(N=45)

Surburb	*Residence type*	*PM in mg/m2/day) for sampling period 1*	*PM in mg/m2/day) for sampling period 2*	*PM in mg/m2/day) for sampling period 3*	*Mean PM in mg/m2/day) for the entire sampling period*
1. Windhoek west	medium density	1745.93**	789.61**		1267.8
2. Wanahenda	high density	2170.1**	1673.7**	1598.14**	1814.0
3. Onlympia	Low density	781.1	533.33+	444.31+	586.2
4. Okurganva	high density	2128.63**	3030.7**	-	2579.7
5. Khomasdal	medium density	2787.11**	1606.05**	-	2196.6
6. Havanna	high density	2453.56**	1777.44**	-	2115.5
7. Hochland	Low density	1171.29**	902.87**	-	1037.1
8. Hakahana	medium density	3387.43**	3102.02**	-	3244.7
9. Freedom Square	medium density	-	1039.15**	-	1039.2
10. Soweto	medium density	-	2285.04**	2128.76**	2206.9
11. Golgata	medium density	-	2079.07**	2350.85**	2215.0
12. Freedomland	medium density	-	2195.5**	1198.6**	1697.1
13. Ombili	medium density	-	2015.43**	1928.22**	1971.8
14. Ludwig/olyimpia	Low density	690.48**	427.13+	-	558.8
15. Kahandja park	high density	-	2068.06**	2767.11**	2417.6

**=Exceeded residential limit value, +=Within Limit, -=missing data

The Analysis of Variance (ANOVA) test showed a statistically significance difference in mean PM Concentration levels between the low density and high density area (p=0.002) (Table.5)

Table 5: Variance in Particulate Matter (PM) in concentration

(I) Residence type	(J) Residence type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
low density	medium	-576.72000	533.99306	.301	-1740.1909	586.7509
	high	-1466.06200*	385.06787	.002	-2305.0528	-627.0712
medium	low density	576.72000	533.99306	.301	-586.7509	1740.1909
	high	-889.34200	453.10813	.073	-1876.5798	97.8958
high	low density	1466.06200*	385.06787	.002	627.0712	2305.0528
	medium	889.34200	453.10813	.073	-97.8958	1876.5798

*. The mean difference is significant at the 0.05 level.

4.4. prevalence of respiratory symptoms

One of the study objectives was to determine the prevalence of respiratory symptoms and related illness among the residents of Windhoek, to achieve this objectives, descriptive analysis were performed for symptoms and related illness, and results are presented in table 6. High prevalence of respiratory symptoms was observed for cough (43%), breathlessness (25%), with Asthma recording the highest percentages for respiratory illness (11.2).

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Table 6: Prevalence of respiratory health outcomes (N=107)

Respiratory symptoms	*n (%)*
Usual cough	46(43)
Usual phlegm	19(18)
Episode of cough and phlegm	18(16)
Breathlessness	27(25)
Wheezing	18(16)
Bronchitis	5(4.7)
Emphysema	1(0.9)
Asthma	12(11.2)
TB	3(2.8)
Chest illness	2(1.9)
Any respiratory symptoms	61(57)
Any respiratory diseases,	17(15.9)

4.5. Association between respiratory disorders and PM Concentration, location and confounding variables.

To further analyze for association between respiratory disorders and PM concentration, location and key confounding variables, a chi-square test of association was performed and the results are presented in table 7-8 respectively. Among all tested respiratory disorders related variables, PM concentration was found to be only associated with episode of cough and phlegm (p=0.05). Moreover, a statistically significant association was observed between smoking (p=0.02); history of occupational exposure to dust and chemical for 1 year (p=0.02), age group (p=0.03) and episode of cough and phlegm for 3 months respectively. While asthma (p=0.01) and grouped prevalence of any respiratory diseases confirmed by doctor (p=0.03) were found to be significantly associated with smoking alone (Table 7).

Table 7: Chi-square test of association between respiratory disorders, PM concentration and confounding variables

Variables	*Smoking*		History of occupational exposure		*Age group*		*TB*		PM concentration	
Respiratory symptoms	*DF*	*P-Value*	*DF*	*P-Value*	*DF*	*P-Value*	*DF*	*P-Value*	*DF*	*P-Value*
Usual cough	1	0.2	1	0.9	4	0.7	1	0.07	1	0.07
Usual phlegm	2	0.7	2	0.3	8	0.2	1	0.08	1	0.6
Episode of cough and phlegm	1	**0.02***	1	**0.02***	4	**0.03***	**1**	**0.4**	**1**	**0.05***
Breathlessness	1	0.07	1	0.4	4	0.3	1	0.2	1	0.7
Wheezing	1	0.5	1	0.7	4	0.8	1	0.4	1	0.08
Bronchitis	1	0.6	1	0.5	4	0.2	1	0.1	1	0.3
Chronic bronchitis		0.3		0.8	4	0.8	1	0.03	1	0.7
Asthma	1	**0.01***	1	0.6	4	0.2	1	0.03	1	0.6
TB	1	0.3	1	0.7	4	0.8	-	-	-	0.4
Chest illness	1	0.7	1	0.8	4	0.8	1	0.05	1	0.1
Any respiratory symptoms	1	0.6	1	0.6	4	0.3	1	0.2	1	0.3
Any respiratory diseases,	1	**0.03***	1	0.4	4	0.5	1	0.004	1	0.9

df= Degree of freedom , * P-Value <0.05

No significant association was observed between all types of respiratory health outcomes (symptoms and respiratory related illness) and house heating, vehicle movement near home, type of road, years at current home or total year's respondent living in Windhoek, distance from main road or street and resident type of location (Table 8). A statistically significant association was observed between respondent type of energy used for cooking and cough symptoms (p=0.03).

Table 8: Association between respiratory disorders and PM concentration and Location

Variables	Type of Energy used for cooking		House Heating		Vehicle movement near home		Indoor dust		Types of road		Years at current home		Total years in Windhoek		House distance from main road/street		Location or place of residence	
	df	p-value	df	p-value	df	p-value	df	p-value	df	p-value	df	p-value	df	p-value	df	p-value	df	p-value
Cough	1	**0.03***	2	0.2	1	0.5	1	0.08	1	0.4	2	1.0	2	0.1	2	0.8	2	0.2
Usual Phlegm	2	0.6	4	0.9	2	0.8	2	0.3	2	0.8	4	0.4	4	0.5	4	0.5	4	1.0
Episode of Cough and phlegm more than 3months	1	0.2	2	0.8	1	0.5	1	0.4	1	0.2	2	0.5	2	0.4	2	0.7	2	0.4
Breathlessness	1	0.6	2	0.6	1	0.4	1	0.9	1	1.0	2	0.3	2	0.2	2	0.2	2	0.6
Wheezing	1	0.4	2	0.07	1	1.0	1	0.3	1	0.6	2	0.5	2	0.4	2	0.4	2	0.2
Attack of Bronchitis	1	1.0	2	0.9	1	0.6	1	0.3	1	0.7	2	0.2	2	0.8	2	0.3	2	0.3
Chronic bronchitis	1	1.0	2	0.5	1	1.0	1	0.6	1	0.4	2	0.1	2	0.6	2	0.2	2	0.4
Emphysema	1	1.0	2	0.4	1	1.0	1	0.8	1	0.8	2	0.4	2	0.4	2	0.3	2	0.08
Asthma	1	0.7	2	0.9	1	0.7	1	0.6	1	0.5	2	0.1	2	0.6	2	0.6	2	0.7
TB	1	0.2	2	0.9	1	1.0	1	0.4	1	0.5	2	0.4	2	0.07	2	0.4	2	0.06
Any other chest illness confirmed by the Dr	1	0.3	2	0.5	1	1.0	1	0.6	1	0.6	2	0.6	2	0.6	2	0.6	2	0.4
Respiratory symptoms[grouped symptoms]	1	0.1	1	0.5	1	0.3	1	0.1	1	0.9	2	0.8	2	0.1	2	0.4	2	0.08
Doctor diagnosis of respiratory diseases.	1	0.6	1	0.5	1	0.6	1	0.4	1	0.4	2	0.3	2	0.5	2	0.9	2	0.7

df= Degree of freedom , * P-Value <0.05

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4.6. Relationship between exposure variables and respiratory disorders

The respiratory disorders related variable that were found to be significantly associated with PM concentration, location and confounding variables were fitted to analyze the relationship between respiratory disorders and exposure variables using unadjusted logistic regression models and the Odds Ratios are presented in table 9. Association between PM concentration and episode of cough and phlegm had 2.5 odds ratio for high category and 0.5 odds ratio for medium category when compared to low category respectively. The association between type of energy used for cooking and cough had odds ratio of 2.4. Analysis on the relationship between history of occupational exposure to dust and chemical and history of smoking and episode of phlegm and cough indicates that respondents with history of occupational exposure to dust or chemicals had 0.2 odds ratio for experiencing episode of cough and phlegm, while those with a history of smoking regardless of current status had 0.25 odds ratio for episode of cough and phlegm respectively. The relationship between age group and episode of cough and phlegm was further analyzed, with high odds ratio of 4.4 observed for episode of phlegm and cough among the age group of 31 to 40 years and history of smoking had increased odds ratio for asthma (5.9).

Table 9: Odd ratios of selected respiratory disorders from unadjusted logistic regression Models.

Variables	*Usual Cough*	*Cough for more than 3months*	*Usual phlegm*	*Episodes of phlegm and cough*	*Shortness of breath*	*Wheezy chest*	*Asthma*	*Any Symptom*	*Doctor diagnosed diseases*
PM concentration	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Low PM	-	-	-	1	-	-	-	-	-
Medium PM	-	-	-	0.5 0.1-2.3	-	-	-	-	-
High PM	-	-	-	2.5 0.8-8.0	-	-	-	-	-
Never smokers	-	-	-	1	-	-	1	-	1
Ever-smoker	-	-	-	0.25 0.01-0.83	-	-	5. 9 1.6-22.2	-	0.14 0.04-0.48
age group	-	-	-	-	-	-	-	-	-
Less than 30	-	-	-	1	-	-	-	-	-
31 to 40 years				4.4 1.2-16.5	-	-	-	-	-
41 years and above				4.1 1.1-15.3	-	-	-	-	-
Not occupationally exposed				1	-	-	-	-	-
Occupationally exposed	-	-	-	0.2 0.1-0.8	-	-	-	-	-
Type of energy used	-	-	-		- -	-	-	-	-
Electricity	1	-	-	-	-	-	-	-	-
Biomass fuel and others	2.4 1.1-5.3	-	-	-	-	-	-	-	-

5. Discussion

The study found high levels of PM concentration across all suburbs. The observed high levels of PM concentration could be attributed to the vehicle exhaust emission and re-suspension of road dust, attributed to vehicle movements and close proximity of respondents' homes to the roads. This further explains the high PM concentration levels, across all suburbs', which were above the international recommended limits for residential areas. Other sources of observed high PM levels could be attributed to anthropogenic activities, of which its description is beyond the scope of this project. Moreover, the observed high PM levels might explain high prevalence of cough, breathlessness as well as asthma, although no statistical significant association was observed. The observed high prevalence of Asthma and to a certain extent bronchitic symptoms is in upkeep with findings of earlier studies (Pope, 2000).

The study found high prevalence levels of cough, breathlessness and asthma, of which none were found to be associated with either the PM concentration or resident location. This is different from previous studies results, which suggest that PM concentration was generally associated with acute and to a certain extent long term poor pulmonary related health outcomes, which was not associated with location, but only PM concentration being present across all suburbs (Pope III, 2000; Sacks *et al*, 2010). The Health effects attributed to PM exposure among Windhoek residents might be influenced by individual characteristics such as gender, age, socio-economic status and health status and effect might be further aggravated by time spent outdoors by individuals (Sacks *et al*, 2010). Among all the assessed respiratory disorders, only an episode of phlegm and cough was found to be associated with PM concentration, while the cough symptom was observed to be associated with the type of energy used for cooking at home; implying that regardless of one's residential location, as long as one resides in WHK, the of risk of developing poor respiratory health outcomes is not entirely based on PM concentration, location, or years at current home or total years that one had lived in WHK. This could be explained by the observed high PM concentration levels across all suburbs, which could be further attributed to resident's movement across the city as well as indoor related exposure to biomass fuel and environmental tobacco exposure (Sacks et al, 2011). Similarly, the observed association between PM and an episode of phlegm and cough supports earlier findings by Pope III (2000) which associated episodic respiratory symptoms such as cough to PM concentration.

PM exposure causes irritation of the airway, with those exposed to higher PM concentration reporting increased risk for cough, with those exposed to gases having been reported to have a higher risk for wheezing than coughing, which is in agreement with this study (Joad *et al*, 2007).

In this study, the risk of experiencing cough symptoms was found to be associated with the type of energy used but not with PM concentration levels outside or indoor related pollutants. Although this is in agreement with many primary studies on indoor air quality and smoke exposure, it differs from PM related studies that reported association between PM and cough (Joad et al, 2007).

Indoor air quality at home is primarily compromised by energy sources / type used for cooking, with those using solid fuels reported to be at greater risk for poor respiratory health, mainly because of exposure to smokes and other emission's resulting from burning of fossil fuel(Pope and Dockery, 2006).

The association between cough and type of energy used observed in this study is consistent with other studies. Such association may be due to the fact that the use of solid fuel or fossil fuel such as paraffin, gas or charcoal reduces the indoor air quality, while increasing user's exposure to PM and other associated gases formed during the burning process (Pope and Dockery, 2006). Although previous studies reported risk differences for health effects associated PM concentration (Clougherty, 2012; Wong et al, 2009), this study did not find any association between poor respiratory health and gender, which could be due to the small sample size which may not be sufficient to detect gender differences. With respect to PM concentration and the observed high prevalence of respiratory outcomes, the study results are consistent with those conducted elsewhere (Clougherty, 2012; Wong et al, 2009; Wilson et al, 2008).

The results however suggest that, residential PM concentration alone is not responsible for poor respiratory health among WHK residents', but other factors such as age, smoking history, as well the history of occupational exposure to dust or chemical may increase population vulnerability to poor respiratory health outcomes. The study found that, WHK residents' risk for poor respiratory health outcomes is multifactorial; which may include factors such as environmental exposure to tobacco and poor indoor air quality both at home and at the work place. Furthermore, other studies reported synergistic impaired effect between occupational exposure to dust or chemical pollutants and smoking on individuals' lungs, while smoking alone is proven to affect the lungs; contributing to the reduction of lung functioning capacity and risk for poor respiratory health (Fang et al,2010; Down *et al*, 2007; Imboden *et al*, 2009). Similarly, individuals' age is proven to increase individuals' vulnerability to poor respiratory health outcomes mainly due to a weakened immune system and poor lung function, which render individuals to be susceptible to developing respiratory related symptoms and illness (Down *et al*, 2007; Imboden *et al*, 2009). Thus the effect of other factors such as smoking, occupational exposure and personal exposure to indoor pollutants needs to be quantified for the Namibian population to establish the overall country burden of respiratory diseases due to both indoor and outdoor pollutants.

6. **Limitation of the Study**

Although the study is the first of its kind to be conducted in Windhoek and it provides snapshot types of evidence on both particle pollution levels in the city and prevalence of self-reported respiratory symptoms among the city residents, the study results need to be interpreted with the following limitations in mind. The study sample size was generally small and the method used to monitor particulate pollution levels does not account for PM size fraction and may not provide shorter PM concentration, it however ideal for repeated measurement for medium or long term trends on overall particle pollution monitoring in selected localities, which is in line with the objectives of this study. The study may also not provide conclusive evidence on association between PM exposure and respiratory outcome, as those who might have been affected by PM exposure could have been in hospital and could not be reached during the assessment time. Future studies should be conducted with increased sample size and improved long term PM monitoring methodology, which can provide trends on PM levels, which can be linked to respiratory related mortality and morbidity.

7. Conclusion

The study found high levels of PM concentration across all Windhoek suburbs, as well as high prevalence levels for cough, breathlessness and Asthma. The observed high prevalence levels of respiratory symptoms was not found to be associated with PM or individual location or house distance from road or years that one had lived at current home or in WHK. Only Episode of cough and phlegm was found to be associated with PM, with those exposed to high levels observed to have increased odds ratio of experiencing episodes of phlegm and cough. The type of energy used was observed to be a significant risk factor for cough symptoms among the residents, while history of smoking was a risk factor for asthma. Reduction of observed high PM levels and respiratory disorders requires enactment of legislation which address both the control and monitoring of PM related emissions at point of generation. Moreover, health promotion interventions are needed to address risk factors such as smoking and use of biomass fuel which were identified to increase population risk of poor respiratory health outcomes.

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References

1. Clougherty JE. A Growing Role for Gender Analysis in Air Pollution Epidemiology. *Environmental Health Perspectives*. 2010, 118(2),167-176. doi:10.1289/ehp.0900994.
2. Chow JC, Watson JG, Mauderly JL, Costa DL, Wyzga RE., at el. Health effects of fine particulate air pollution: lines that connect. Journal of the Air & Waste Management Association.2006, 56(10),1368-1380; doi: 10.1080/10473289.2006.10464545.
3. Centre for Diseases Control (CDC), CDC in Namibia, 2013. [Online] available from: http://www.cdc.gov/globalhealth/countries/namibia/pdf/namibia.pdf (accessed 15 March 2015).
4. Davidson CI, Phalen RF & Solomon PA. Airborne Particulate Matter and Human Health: A Review. Aerosol Science and Technology. 2005, 39 (8), 737-749., doi: 10.1080/02786820500191348.
5. Downs SH, Schindler C, Liu LJ, Keidel D, Bayer-Oglesby L, Brutsche MH. Reduced exposure to PM10 and attenuated age related decline in lung function. N Engl J Med. 2007, 6,357(23),2338-47.
6. Environmental protection agency, Particles, 2015.available from online: http://www.environmental-protection.org.uk/committees/air-quality/about-air-pollution/particles/ accessed on 17 December 2015.
7. Fang SC, Cassidy A, Christiani DC. A Systematic Review of Occupational Exposure to Particulate Matter and Cardiovascular Disease. *International Journal of Environmental Research and Public Health*. 2010,7(4),1773-1806. doi:10.3390/ijerph7041773..
8. Imboden M, Schwartz J, Schindler C, Curjuric I, Berger W, Liu SL, et al. Decreased PM_{10} Exposure Attenuates Age-Related Lung Function Decline: Genetic Variants in *p53*, *p21*, and *CCND1* Modify This Effect. Environ Health Perspect. 2009,117, 1420–1427;http://dx.doi.org/10.1289/ehp.0800430.
9. Joad JP, Sekizawa S and Bonham AC .Air pollutants and cough. Pulm Pharmacol Ther. 2007,20(4), 347-54.
10. Levin, KA. Study design III: Cross-sectional studies. *Evidence-Based Dentistry*.2006, 7, 24–25. doi:10.1038/sj.ebd.6400375.(online) available from: http://www.nature.com/ebd/journal/v7/n1/full/6400375a.html (accessed on 03 February 2016).
11. Madejski E, Simbi Y, Shangheta B. Public Transport in Namibia: What is the customer satisfaction experience? .2014. Available from; http://ir.nust.na/bitstream/handle/10628/528/Madejski.%20Public%20transport%20in%20Namibia.pdf?sequence=1&isAllowed=y.(acccessed on 05 October 2016).
12. Maynard RL and Waller RE. Suspended particulate matter and health; new light on an old problem. Thorax.1996, 51, 1174-1176. Available at: http:/thorax.bmj.com (accessed 08 June 2015).
13. Malakootian M, Ghiasseddin M, Akbari H and Fard NAJH. Urban Dust Fall Concentration and Its Properties in Kerman City, Iran. JHealth scope.2013, 1(4), 192-198. Doi: 10.17795/jhealthscope-8507.
14. Namibia Statistics Agency - Government of the Republic of Namibia: Namibia census report 2011.http://nsa.org.na/microdata1/index.php/catalog/19/related_materials. Accessed on 18 December 2015.

15. Naidoo RN, Robins TG, Seixas N, Lalloo UG, Becklake M. Respirable coal dust exposure and respiratory symptoms in South African Coal Miners: A comparison of current and Ex-miners. J Occup Environ Med.2006, 48(6), 581-590.
16. Nachman KE and Parker JD. Exposures to fine particulate air pollution and respiratory outcomes in adults using two national datasets: a cross-sectional study. *Environmental Health.* 2012, **11**-25. **Doi:** 10.1186/1476-069X-11-25
17. Neuberger M and Moshammer H. Suspended particulates and lung health. Wien Klin Wochenschr. 2004, 116, 1:8-12.
18. Pope III CA. Epidemiology of Fine Particulate Air Pollution and Human Health: Biologic Mechanisms and Who's at Risk? *Environ. Health Perspect.* **2000**, *108*, 713–723.
19. Pope III CA and Dockery DW. Health Effects of Fine Particulate Air Pollution: Lines that Connect. J Air Waste Manag Assoc. 2006, 56(6), 709-742.
20. Po JY, FitzGerald JM, Carlsten C. Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and meta-analysis. Thorax. 2011 ,66(3), 232-9. doi: 10.1136/thx.2010.147884.
21. Simoni M, Carrozzi L, Baldacci S, Scognamiglio A, Di Pede F, Sapigni T, Viegi G. The Po River Delta (North Italy) Indoor Epidemiological Study: Effects of Pollutant Exposure on Acute Respiratory Symptoms and Respiratory Function in Adults.*Archives Of Environmental Health.* 2002, 57(2), 130-6.
22. Sacks JD, Stanek LW, Luben TJ, Johns DO, Buckley BJ, Brown JS, Ross M. Particulate Matter–Induced Health Effects: Who Is Susceptible. Environ Health Perspect. 2011, 119, 446–454. .doi:10.1289/ehp.1002255.
23. Trading economics, Motor vehicles (Per 1; 000 people) in Namibia, 2016. Available from: http://www.tradingeconomics.com/namibia/motor-vehicles-per-1-000-people-wb-data.html (accessed on 05 October 2016).
24. World Health Organization: Namibia: Country profile of Environmental Burden of Disease.http://www.who.int/quantifying_ehimpacts/national/countryprofile/namibia.pdf?ua=. (2015). Accessed on 18 December 2015.
25. World Health Organization, Namibia health profile, 2009. [online] available from; http://www.who.int/quantifying_ehimpacts/national/countryprofile/namibia.pdf (accessed 20 March 2015)
26. World Health Organization, 7 million premature deaths annually linked to air pollution, 2014. [Online] available from; http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/ (accessed on 20 march 2015)
27. World Health Organization, Global Health Observatory (gho) data, 2015.. Online, available from: http://www.who.int/gho/phe/outdoor_air_pollution/en/.
28. World Health Organization, Namibia: Country profile of Environmental Burden of Disease ,2015. http://www.who.int/quantifying_ehimpacts/national/countryprofile/namibia.pdf?ua=(accessed on 18 December 2015)
29. Wilson D, Takahashi K, Pan G, Chan CC, Zhang S, Feng Y, et al. Respiratory symptoms among residents of a heavy-industry province in China: prevalence and risk factors.. Respir Med. .2008, 102(11), 1536-44. doi: 10.1016/j.rmed.2008.06.010.
30. Wong CM, Yang L, Thach TQ, et al. Modification by Influenza on Health Effects of Air Pollution in Hong Kong. *Environmental Health Perspectives*. 2009, 117(2), 248-253. doi:10.1289/ehp.11605.