Human Health Risk Assessment of Inhalable Air Borne Wood Dust in Timber Milling Industry in Imo State, Nigeria

[1]Ubuoh E. A., [2]Nworuh, B.O. and [3]Ogbonna P.C.
[1&3] Department of Environmental Management and Toxicology (EMT),
Michael Okpara University of Agriculture, Umudike (MOUAU), Abia State.
[2]Dept. of Public Health, Federal University of Technology, Owerri, (FUTO) Imo State.

Abstract
Health risk assessment in timber milling industry was conducted using $PM_{2.5}$ as air quality indicator in Umuoayali timber market in Mbaitoli Local Government Area of Imo State to evaluate its impact on timber workers. Determination of ambient air quality was by application of hand-held Multi Gas Analyzer to sample $PM_{2.5}$. The mean result of the ($PM_{2.5}$) in the six workshops ranks viz: $WS_4>WS_2>WS_3>WS_5>WS_6>WS_1$ due to the effect of temperature, relative humidity and wind speed in the area that shown significant relationship with $PM_{2.5}$ ($p<0.05$), and the mean results compared to FMENV STD for good air quality. Health Risk Index (HRI) Air Quality Index (AQHI) was used to assess the level of risk and health implication of exposure to $PM_{2.5}$ respectively. The result of $PM_{2.5}$ when compared to FMENV STD indicated that, the 20 sampled locations for wood dust ranged between 0.33-4.95 µg/m^3 above the 0.25 µg/m^3 FMENV STD. Health risk assessment result indicated that WS_1, WS_5 and WS_6 (0.22-0.64 µg/m^3) were within the risk scale of 0- signifying timber workers within this range are bound to experience low risk ,and WS_2, WS_3 and WS_4 (95.4-118.5 µg/m^3) were within the risk scale of >10 indicating very high risk (VHR) , and health implication showing poor in the selected workshops: (WS_1,WS_5, WS_6) to very poor : (WS_2,WS_3,WS_4) workshops showing tendency for respiratory disease for exposed sensitive population in and around timber market. This then calls for application of best management practices like local exhaust ventilation (LEV), respiratory protective device (RPD), and enforcement of rules and regulations to mitigate wood dust generation.

Keywords: Health risk, wood dust, timber, air borne, particulate matter

Introduction

Dust from wood works is one of the most common organic dusts workers' are exposed to in the furniture manufacturing industry through wood machining processes, such as shaping, routing and sanding produce particularly high levels of dust emission. In the same vein, the wood dust exposure levels is influenced by the airflow field in the working area, worker inhalation rate and ventilation system, while the level of its toxicity varies with the characteristics of the wood dust, such as the wood specie and size of dust particles (Mikkelsen *et al*., 2002; Pat-Mbano and Edmund, 2012).

Studies have found that exposure to wood dust can cause health effects from nasal mucosa damage, irritation and sino-nasal cancer, while deep lung deposition leads to lung cancer and impaired respiratory function (WHO, 2005; Ravikumar *et al,* 2014). Although, there are existing dust emission control regulations within countries , the stipulated standard is often exceeded due to improper dust extraction system and poor machining conditions (Tobin *et al*, 2016). Nevertheless, reports on the wood dust generation are sparse and hence, efforts to control dust emission is hampered (Ratnasingam and Scholz, 2008). Based on the above, therefore study is required to provide the necessary

information to both timber millers, managers, policy makers as well as the general public, to ensure greater attention is given to the workers safety and health concerns.

Ambient air pollution has been particularly associated with cardio-respiratory diseases (Miller *et al.,* 2007, Borm *et al.,* 2007, Brook et al, 2010). A recent study contended that the greatest air pollution problem in the Nigerian environment is atmospheric dust arising from many industrial processes including sawmill industries (Farombi, 2008). Due to the fast growth recorded in the building construction sector, there have been high increase in the establishment of sawmills in different part of the country to satisfy the growing demand for wood (Aroofor 2000). Sawmills accounted for 93.32% of total number of wood based industries in Nigeria in 2001 (Fawupe 2003).

However, particulate matter in general is considered to be a risk to our health and environment (Chen et al, 2008; WHO, 2013). Particles in the atmosphere have received much interest in the last decade due to the fact that increasing epidemiological and experimental evidence reflects a negative impact on human health and the environment (WHO 2003; EPA, 2004). The effect of coarse material on human health is still indistinct (Allen *et al.,* 2009, Hulgiun *et al.,* 2007, Moshammer *et al.,* 2006).

In Nigeria, the effect of particulate matter on human health has been noted by several scholars, for instance Okecha (2000) and Efe (2005), asserted that high rates of respiratory diseases occasioned by increased PM concentrations were experienced by residents of most urban areas. There is a large body of evidence linking short term and long-term exposures of particulate matter to increased cardiopulmonary morbidity and mortality (Chen *et al,* 2008: Weinmayr *et al*, 2010; Brook *et al*, 2010). The coherence of effects observed across studies done in European cities (Katsouyanni *et al,* 2003; U.S.EPA, 2011) and various cities in Canada (Goldberg *et al*, 2001; Weinmayr *et al*, 2010), China (Qian *et al,* 2008: Wong et al, 2008) and Japan (Omori *et al,* 2003) further substantiated the evidence for a causal association of particulate matter and cardiopulmonary morbidity and mortality. Ill-health from wood dust inhalation results in decreased work output and increased morbidity.

Despite the potentially hazardous nature of the work, there has been little attention given to the state of health and safety of the workers in the sawmill industry in Nigeria by government health departments (Tobin *et al,* 2016). Based on this, this work is focused on assessing health risk associated with inhalable wood dust in timber milling industry in the study area.

Materials and Methods

Study Area

The study is in Umuouajali Timber Market located at Mbieri in Mbaitoli Local Government Area, Owerri Zone of Imo State (Fig.1). The area is located between latitude 5^{o} 30'N and longitude 6^{o} 55'E, with the population of 143077 (NBS, 2000). The area located within the humid tropical rainforest belt of Nigeria with mean annual rainfall of about 1,500mm to 2,000mm (Igbozuruike, 1975). Massive amount of sawdust are generated as a result of the sawmill activities and to reduce the mountain of this sawdust, the millers resort to continual burning which causes great environmental impact on the inhabitants within its vicinity.

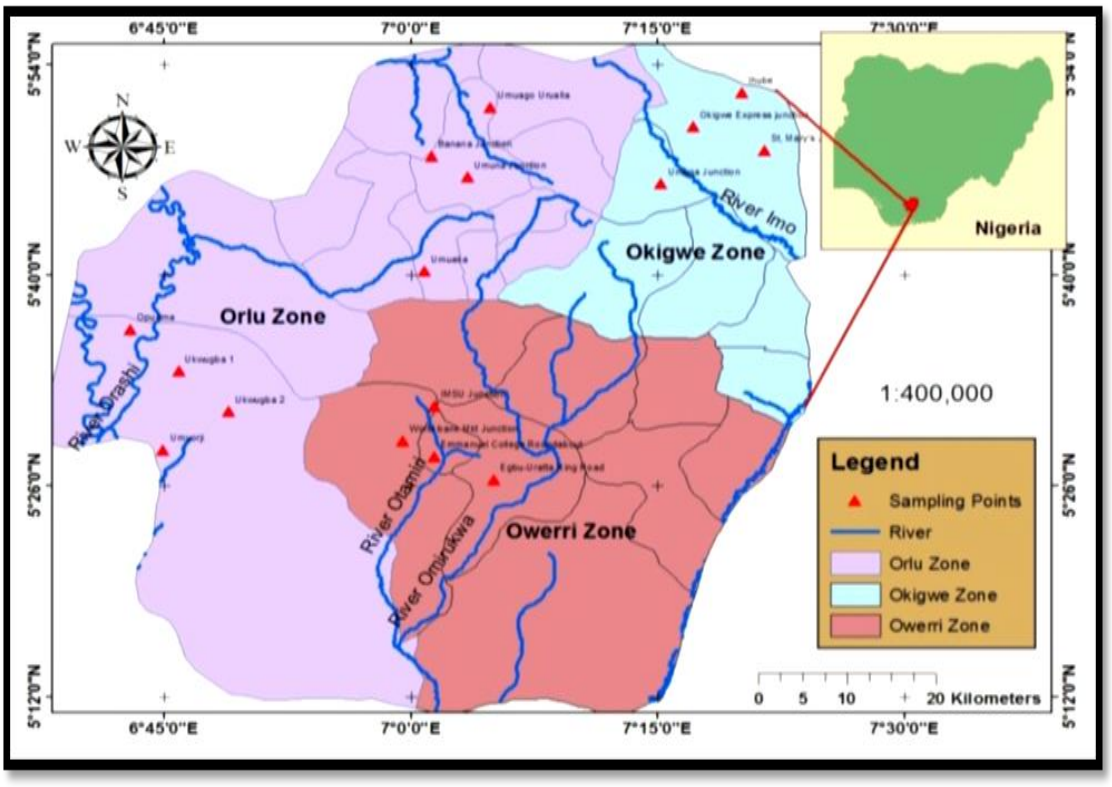


Fig 1: Map of Imo State showing Mbaitoli Local Government Area in Owerri Zone

Experimental Design

For the purpose of this study in the, six (6) sample sawdust signifying workshops (WS) viz: $WS1_1$, WS_2, WS_3, WS_4, WS_5, and WS_6 were established:

1. **WS_1:** Measurement was taken where sawdust was collected from general dust pile outside the mill.
2. **WS_2:** Measurement was taken where sawdust was collected at a main saw (2/16-inch kerf circle saw).
3. **WS_3:** Measurement was taken where sawdust collected from a 10-inch table saw in workshop.
4. **WS_4:** Measurement was taken where Sawdust was collected from a 2-inch wide thin kerf (<1/8 – inch) ripping saw blade.
5. **WS_5:** Measurement was taken from the workshop where 18 -inch trim saw (where lumber is cut to length) and
6. **WS_6:** Measurement was taken from 4 –inch plank where it was sand paper for frames.

Air quality sampling Procedure

Multiple sampling points were required to ensure reasonable coverage of the area and replicate measurements made at each sampling point. Air sampling was conducted focusing on one air pollutant, namely $PM_{2.5}$. Data were collected between 8:30am and 4:30am on 8 hourly basis within one-hour and half-hour intervals on daily basis during the dry season period. This helped to locate the sampling points with the highest and lowest concentration levels PM at given time. Measurements of the criteria pollutants were made using the Multi Gas Analyzer MRU (2002 Model) with electrochemical measuring principles and complete gas conditioning systems. It also helped to identify pollutants that exceeded

FEPA (2001) established air quality standards. The sampling period ranged (September – December, 2015), climate data was collected for relative humidity, wind speed and direction for these normally affect the pollutant concentrations in the atmosphere. Gas monitoring equipment was used for pm_{10} (Gasman Model 19773H} was used for temperature, relative humidity, and wind speed**.** All the instruments used were held at 1.7m above the ground level for accuracy.

Computation of the Air Quality Health Index (AQHI)

Under an assumption of additive health effects of $PM_{2.5}$, NO_2, and O_3, the equation of AQHI is constructed as the sum of excess daily mortality risk associated with these three pollutants, adjusted to a 0-10 scale. The AQHI formula according to Stieb et al, (2008) as follows:

$$AQHI = \left(\frac{10}{10.4}\right) * 100 * \left\{e^{(0.000871*NO_2)} - 1 + e^{(0.000537*O_3)} - 1 + e^{(0.000487*PM_{2.5})} - 1\right\}$$

(1)

To provide insights into the structure of the formula and to facilitate comparison to the AQI, we further simplified the above AQHI formula using Taylor series approximation (Hong and Copes, 2013) as follows:

$$AQHI = * \{(1 + 0.000871 * N0_2) - 1 + (1 + 0.000537 * O_3) - 1 + 0.000487 * PM_{2.5}) - 1\}$$

(2)

Substitution of equ 1 and 2 for $PM_{2.5}$ only:

$$AQHI = \left(\frac{10}{10.4}\right) * 100 * \left\{e^{(0.000487*PM_{2.5})} - 1\right\}$$

(3)

For particulate matter ($PM_{2.5}$) only :

$$\text{AQHI} = 10/10.4\ \text{X}100) + (1 + 0.000487\text{x}PM_{2.5}) - 1 \quad (4)$$

Human health risk (HHR) interpretation using AQHI scale

To communicate possible adverse effects of air pollution ($PM_{2.5}$) to the public based on the human health, the numeric air quality health index (AQHI) scale is subdivided into four categories: (1) low risk (0-3); (2) moderate risk (4-6); (3) high risk (7- 10); and (4) very high risk (>10) Categories were defined according to the relative frequency of the numeric AQHI scale across the Canadian cities in a time-series study (Hong and Copes, 2013). Also, health message for the AQI was employed to understand fully the health implications of being exposed to $PM_{2.5}$ for 24 hours using very good (0-15), good (16-31), moderate (32-49), poor (50-99) and very poor (100+) (Hong and Copes, 2013).

Statistical Analysis

Total, mean and ranking systems were used in order to understand how each of the workshops and saws contributed $PM_{2.5}$ to ambient air quality during timber operations in the area**.** **Data** were statistically analyzed for variance (ANOVA), and significant means were compared using Duncan multiple range test. Paired t-test was used to compare means of the PM2.5 and climatic variables all tests, a threshold of *P* =0.05 was used to define statistical significance

Results

Fine particles ($PM_{2.5}$) consist of a complex mixture of anthropogenic as shown in Table 1 indicated total, mean ranking of results of particulate matter ($PM_{2.5}$) and meteorological data. Table 2 shown summary Statistics of $PM_{2.5,}$ meteorological data and Federal Ministry of Environment Air Quality standard for $PM_{2.5}$. Table 3 indicated computation of human exposure to $PM_{2.5}$ using AQHI and Table 4 shown health implications of exposure to $PM_{2.5}$ using AQI in Timber Industry respectively.

Table 1:Total, mean ranking of results of $PM_{2.5}$ and meteorological data in Timber Industry

Workshop/ Sampled No	Particle size of six sawdust samples from different saw					
	Daily Mean Values					
	WS_1	WS_2	WS_3	WS_4	WS_5	WS_6
1	0.20	21.60	21.40	23.34	0.23	0.20
2	0.21	20.23	22.23	23.33	0.24	0.16
3	0.22	22.34	22.19	22.34	1.24	0.21
4	0.23	23.21	20.34	21.91	0.19	0.22
5	0.23	21.21	21.22	23.06	0.24	0.19
6	0.20	20.20	22.09	22.19	1.21	0.21
7	0.24	21.00	23.11	23.21	1.32	0.19
8	0.19	23.34	21.13	22.21	0.91	0.22
9	0.21	21.23	21.23	23.22	0.45	0.21
10	0.22	21.23	20.12	21.21	0.67	0.22
11	0.19	20.12	21.07	22.23	0.37	0.17
12	0.21	20.22	20.17	21.22	1.42	0.23
13	0.23	22.13	22.06	20.23	1.20	1.23
14	0.21	21.11	21.11	22.12	0.82	0.23
15	0.21	23.09	23.03	23.23	0.35	1.09
16	0.23	21.04	20.23	21.13	0.22	0.23
17	0.21	22.21	21.03	22.34	0.23	0.24
18	0.23	21.22	22.14	21.15	0.21	0.19
19	0.21	22.21	23.01	23.12	0.56	1.23
20	0.23	21.51	22.15	22.18	0.46	0.23
Total	4.31	430.06	348.1	444.97	12.54	5.77
Mean	0.22	21.50	17.41	22.25	0.63	0.24
RANKING	6^{TH}	2^{ND}	3^{RD}	1^{ST}	4^{TH}	5^{TH}
Meteorological Factors						
Temp. (^oC)	34.37	34.31	32.41	31.23	25.34	26.8
RH (%)	37.21	38.01	45.56	51.12	61.5	60.95
WS $(M/S)^{-1}$	0.22	1.23	2.34	1.34	0.33	1.67

From Table 1, particulate matter ($PM_{2.5}$) saw SW1 ranged between 0.19-0.23 $\mu g/m^3$ with the mean value of 4.31mg/m^3 alongside the climatic variables of temperature 34.4^{o}C, relative humidity37.2% and wind speed 0.22m/S^{-1}. In WS_2 $PM_{2.5}$ ranged between 20.12-23.34mg/m^3 with the mean value of 21.50 $\mu g/m^3$ and climatic factors: temperature being34.3^{o}C, relative humidity 38.0%, wind speed 1.2$m/^{S-1}$. WS_3 recorded 20.12-23-03 $\mu g/m^3$ with the mean value of 17.4 $\mu g/m^3$ alongside temperature being32.4^{o}C, relative humidity 45.6%, wind speed 2.3$m/^{S-1}$. Sw4 ranged between 20.23-23.34 $\mu g/m^3$ with the mean value of 22.25 $\mu g/m^3$ with temperature recording 31.2^{o}C, relative humidity51.1% and wind speed 1.3$m/^{S-1}$. WS 5 recorded the range between 0.19-1.42 $\mu g/m^3$ with the mean value of 0.63 $\mu g/m^3$ with temperature being 25.3^{o}C, relative humidity 61.5% and wind speed 0.33$m/^{S-1}$, and WS_6 having the range between 0.17-1.23 $\mu g/m^3$ with the mean value of 0.24 $\mu g/m^3$ and temperature being

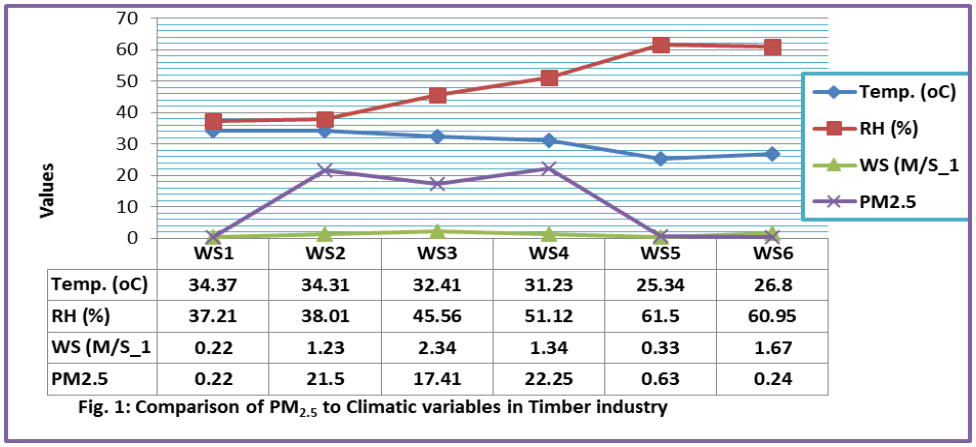
27^{o}C, relative humidity 61% and wind speed recorded 1.7 m/s-1. Above all, ranking of the $PM_{2.5}$ based on the sawdust generated from the application of saws are in order of **WS_4>WS_2>WS_3>WS_5>WS_6>SW_1** respectively.

Table 2: Summary Statistics of Ambient air pollutants and meteorological data from Timber Industry

Wood waste Location	Particle size of six sawdust samples from different saw					
	Min	**Max**	**Range**	**Mean**	**SE**	**FMENV std**
1	0.20	23.34	23.14	11.16	4.91	**0.25mg/m^3**
2	0.21	23.33	23.12	11.07	4.87	
3	0.21	22.34	22.13	11.42	4.86	
4	0.19	23.21	23.02	11.02	4.84	
5	0.19	23.06	22.87	11.03	4.85	
6	0.20	22.19	21.99	11.02	4.69	
7	0.19	23.21	23.02	11.68	4.90	
8	0.19	23.34	23.15	11.33	4.95	
9	0.22	23.22	23.00	10.09	4.83	
10	0.22	21.23	21.01	10.61	4.58	
11	0.17	22.23	22.06	10.69	4.68	
12	0.21	22.23	21.01	10.58	4.46	
13	0.23	22.13	21.9	11.18	4.61	
14	0.21	22.12	21.91	10.93	4.70	
15	0.21	23.23	23.02	11.83	6.24	
16	0.22	21.23	21.01	10.51	4.60	
17	0.22	23.34	23.12	11.04	4.84	
18	0.21	21.22	21.01	10.86	4.76	
19	0.21	23.12	22.91	11.72	4.94	
20	0.23	22.18	21.95	11.06	4.81	
Temp. (^{o}C)	25.34	34.37	9.03	30.74	1.57	
WS (M/S^{-1})	37.21	51.12	13.91	49.06	4.38	
RH (%)	0.22	2.34	2.12	1.19	0.33	

From the sampled locations that ranged between WS_1 – WS_6 in Table 2, it is observed that, the minimum value of particulate matter in the study area ranges between 0.17 – 0.23 µg/m^3 with temperature (25.34^{o}C), relative humidity (37.21%) and wind speed (0.22m/s) being minimum respectively (Fig.1). In the study area, other variables like particulate matter that ranged between 21.22 – 23.34 mg/m^3, temperature of 34.37^{o}C, relative humidity of 51.12 % and wind speed of 2.34 m/s recorded the maximum values respectively. In all the study locations, their mean values were above the 0.25µg/m^3 Federal Ministry of Environmental adapted from Environmental Protection Agency (2014). This high concentration in $PM_{2.5}$ is suspected to be an increased in atmospheric temperature, increased in wind speed and decreased rate of relative humidity in the atmosphere

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	WS1	WS2	WS3	WS4	WS5	WS6
Temp. (oC)	34.37	34.31	32.41	31.23	25.34	26.8
RH (%)	37.21	38.01	45.56	51.12	61.5	60.95
WS (M/S_1	0.22	1.23	2.34	1.34	0.33	1.67
PM2.5	0.22	21.5	17.41	22.25	0.63	0.24

Fig. 1: Comparison of $PM_{2.5}$ to Climatic variables in Timber industry

Table 3: Computation of Human Exposure to $PM_{2.5}$ using health risk (HR) scale in Timber Industry

Health Risk		$PM_{2.5}$ ($\mu g/m^3$) from wood dust					
	Risk SCALE	**WS_1**	**WS_2**	**WS_3**	**WS_4**	**WS_5**	**WS_6**
Low risk	0-3	-	-	-	-	-	-
Moderate Risk	4-6	-	-	-	-	-	-
High Risk	7-10	-	-	-	-	-	-
Very High Risk	>10	95.4	116.7	112.7	118.5	96.0	95.8
Mean values ($PM_{2.5}$)		0.22	21.50	17.41	22.25	0.63	0.24

Using health risk (HR) scale, the result of $PM_{2.5}$ shown that wood dust randomly sampled from six workshops indicated that WS_1, WS_5 and WS_6 are within the risk scale of 0-3 that ranged between 0.22-0.64 $\mu g/m^3$ signifying timber workers within this range are bound to experience low risk of being exposed to $PM_{2.5}$ because WS_1 stock-piled waste in an opened place that helped in dispersing the dust, WS_5 is workshop where 18 -inch trim lumber is cut to lengths the produced less sawdust and WS_6 is the workshop where 4 –inch planks were sand papered for frames in a well ventilated space.WS_{2-4} recorded values that ranged between 95.4-118.5 $\mu g/m^3$ indicating very high risk (>10) scale. The high risk from the three was due to sawdust collected at a main saw (2/16-inch kerf circle saw) (WS_2), sawdust collected from a 10-inch table saw in workshop (WS_3)and sawdust was collected from a 2-inch wide thin kerf (<1/8 – inch) ripping saw blade (WS_4), with poor ventilation respectively (Table 3).

Table 4: Health implications of Exposure to $PM_{2.5}$ using AQHI in Timber Industry

AQI	RANGE	$PM_{2.5}$ $\mu g/m^3$						HEALTH IMPLICATION
		1	2	3	4	5	6	
VERY GOOD	0-15	-	-	-	-			Sensitive population may want to exercise caution
GOOD	16-31	-	-	-	-			Sensitive population may want to exercise caution
MODERATE	32-49	-	-	-	-			People with respiratory disease at some risk
POOR	50-99	95.4	-	-	-	96	95.4	People with respiratory disease should limit prolonged exertion
VERY POOR	>100		116.7	112.7	112.7			Serious respiratory effects even during light physical activity

From Table 4, susceptible groups with pre-existing lung or heart disease, as well as elderly people and children, are particularly vulnerable. For example, exposure to PM affects lung development in children, including reversible deficits in lung function as well as chronically reduced lung growth rate and a deficit in long-term lung function (Copenhagen, 2011). The results of health implications indicated that $PM_{2.5}$ in WS 1, 5 and 6 was poor that falls within AQI range (50-99) having values between 95.4-96.0 µg/m^3, and very poor (>100) with WS 2,3 and W_4 having values that ranged between 112.7-118.5 µg/m^3. From the result, there is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur. The exposure is ubiquitous and involuntary, increasing the significance of this determinant of health, because from 0-5, >100 sensitive populations are advised to exercise cautions when outside.

Table 5: Analysis of Variance (ANOVA) of the $PM_{2.5}$ and Climatic Variables in the Timber Market

Item		Sum of Squares	Df	Mean Square	F	Sig.
WS1	**Between Groups**	2538.515	3	846.172	4230859.000	.000
	Within Groups	.001	4	.000		
	Total	2538.516	7			
WS2	**Between Groups**	1654.147	3	551.382	2756911.583	.000
	Within Groups	.001	4	.000		
	Total	1654.148	7			
WS3	**Between Groups**	2094.262	3	698.087	4471336.607	.000
	Within Groups	.001	4	.000		
	Total	2094.263	7			
WS4	**Between Groups**	2559.209	3	853.070	4265348.333	.000
	Within Groups	.001	4	.000		
	Total	2559.210	7			
WS5	**Between Groups**	4995.323	3	1665.108	323321.864	.000
	Within Groups	.021	4	.005		
	Total	4995.343	7			
WS6	**Between Groups**	4852.520	3	1617.507	314078.977	.000
	Within Groups	.021	4	.005		
	Total	4852.541	7			

The result of ANOVA explained that, the F cal (4853) is ≥ the Ftab (18.51) at 0.05, with Ho being rejected that there is no significant relationship existing between the atmospheric $PM_{2.5}$ and climatic variable in the timber market (Table 5). This indicated that the concentration of the $PM_{2.5}$ in the atmosphere is influenced by climatic variables like temperature, wind speed and relative humidity. The result is consistent with the finding of Amos et al (2010) who reported that particulate matter with diameter of 2.5 mm or less ($PM_{2.5}$) is a major air quality concern because of its effects on human health. $PM_{2.5}$ concentrations depend on meteorological conditions, suggesting that climate change could have significant effects on $PM_{2.5}$ air quality. Higher relative humidity (RH) promotes the formation of ammonium nitrate, but an increase in precipitation causes a decrease in all $PM_{2.5}$ components through scavenging (Dawson *et al*., 2007;

Pye *et al*., 2009; Ubuoh and Akhionbare, 2011).

Discussion

Continuous exposure to high concentration levels of particulate matter (PM) may cause throat and lung irritation, bronchitis and possibly premature death (Karr *et al.,* 2007). Ostro *et al.,* (2007) found stronger and more frequent association between mortality or morbidity and particulate matters. Long-term exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality (Pope *et al,* 2002; Belen *et al.*, 2008; Krewski *et al*., 2009). From the results obtained, $PM_{2.5}$ from different saw blades in timber mills varied among selected workshops that ranked in order of WS_4 > WS_2>WS_3>W_5> W_6>W_1 respectively. The mean values and standard error of particulate matter sampled from twenty locations were above the 0.25 mg/m^3 of the Federal Ministry of Environment standard. WS_1, WS_5, WS_6 ranging between 0.22- 0.66 $\mu g/m^3$ were below the FMENV guideline of 0.25 $\mu g/m^3$ for total inhalable wood dust. The result of this is suspected to be due to the management of the wood waste and the size of the saw used. While this finding is obviously not due to the existence of dust extraction systems in the sawmills, the most likely explanation may be the fact that the study sites, being open sheds, have a good supply of natural ventilation, which serve to readily disperse the dust (Tobin *et al,* 2016). WS_2, WS_3 and WS_4 (21.50 $\mu g/m^3$, 17.41 $\mu g/m^3$, 22.25 $\mu g/m^3$) exceeded the FMENV guideline of 0.25 $\mu g/m^3$ for total inhalable wood dust for an 8-hour work- shift, this is suspected to be due to build-sheds and trees that blocked the wind for dispersion. The values were lower than what was obtained in a study in Calabar (31.75 $\mu g/m^3$) (Osuchukwu et al, 2015), higher than 10 mg/m^3 obtained in Austria (Neuberger et al, 2003). The high value of the $PM_{2.5}$ in the atmosphere is due to saw mill operations that are influenced by ambient temperature, decreased relative humidity and high wind speed in the study leading to health problems incurred by saw mill workers. The result of the application of air quality health index (AQHI) in study of health risk based on human exposure to $PM_{2.5}$ falls within very high risk (VHR) within WS1-WS6 that ranged between 95.4-118.5 $\mu g/m^3$ with WS4 recording the highest value due to the use of ripping saw blade for sawing planks, with the least being WS_1 due to the mixture of wood waste from the dumpsite leading to high risk of respiratory problem. Tobin *et al* (2016) reported higher prevalence of respiratory symptoms among wood dust worker in Nigeria, given the impression that occupational exposure to wood dust may expose workers to a higher risk of developing pulmonary disorders. This finding is in agreement with results from other comparative studies (Oppligor *et al,* 2005; Sripaiboonki *et al*, 2009; Bhatt *et al,* 2011). Tobin *et al* (2016) furthered reported a higher prevalence of cough, and phlegm expectoration compared to chest pain, chest tightness, wheeze or breathlessness. The implication is that upper respiratory tract involvement was more likely compared to lower respiratory tract involvement, the latter presenting with wheeze, chest pain, breathlessness and tightness. This finding, which has been similarly reported by other investigators (Eriksson *et al,* 1996; Demers *et al,* 2000; Douwes *et al,* 2000), might be as a result of the fact that wood dust, made up of cellulose and other soluble chemicals including acetic acid and resins, is largely of large diameter fibers that irritate the cough receptors in the trachea and cause mucostasis in the upper respiratory tract, leading to cough and phlegm production. This is supported by the present study which showed concentrations of PM2.5 above that stipulated standard, with clear absence of any form of dust control mechanism in place (Tobin *et al*, 2016). Application of air quality index (AQI) on human exposure to $PM_{2.5}$, WS_1, WS_5 and W_6 fall within the range of 50-99 characterizing poor air quality and WS_2, WS_3, WS_4 within ≥100 characterizing very poor air quality in the timber milling industry leading to sensitive population suffering from respiratory disease if not cautioned.

Conclusion

Production of wood products often results in the generation of fine airborne wood particles and dust called $PM_{2.5}$. Typical wood-working activities that produce dust are machining operations, for example sawing, routing, turning) and hand or machine sanding. From the results from the $PM_{2.5}$, timber workers exposed to wood dust at work are at greater risk of developing nose, sinus, throat, lung, and skin conditions. Health problems may take a short and long time to develop, and are most common in people who have spent many years at workplaces exposed to high concentrations of wood dust (for example, indoor workplaces with inadequate dust extraction systems. For comprehensive health risk assessment, NO_2 and O_3 should be sampled and used for computing Air Quality Health Index (AQHI) in Timber industry in the study area. Based on these, the following recommendations are made concerning managing of the risk associated with wood dust:

When other dust control measures are not practicable, a respiratory protective device (RPD) suitable for particulates should be worn to protect timber workers

Air quality within timber industry and it's environ should be monitored regularly to ensure the status of air people breath in order to avoid the adverse health and environmental consequences.

Ultimately, timber workers should be sensitized on the effects of $PM_{2.5}$ on human health to ensure safety at work.

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