



ASSESSMENT OF THE IMPACT OF SAWMILL INDUSTRY ON AMBIENT AIR QUALITY AT UTU COMMUNITY IN AKWA-IBOM STATE NIGERIA

¹Pat-Mbano Edith, C. & ²Nkwocha Edmund, E.

¹Department of Urban and Regional Planning Imo State University, Owerri, Nigeria.

²Department of Environmental Technology, Federal University of Technology, Owerri, Nigeria

ABSTRACT

Ambient air pollution has become a major problem in most towns and cities in Nigeria. The study aimed at assessing the impact of sawmills industry on ambient air quality at Utu Community. The study was carried out within a period of 10 months that allowed the monitoring of gaseous emissions from the sawmill. Results show narrow and wide variations in the diurnal concentration levels of air pollutants monitored. Three of the monitored pollutants, namely CO₂, PM₁₀ and VOCs, exceeded established standards by 72%, 49% and 37% respectively. The test of homogeneity in mean variance using the single factor ANOVA revealed significant inequality as $F_{(15,79)} > F_{(3,87)}$ at $p < 0.05$. Further plots of group means using the post ANOVA mean plots that used temperature as predictor variable revealed that all the air quality parameters contributed to the observed inequality. Between temperature and some gases such as NO₂, SO₂ and CO the inequalities were mostly observed during the dry than in the wet seasons. The average results of the Pollutant Standard Index (PSI) indicated a value of 129 in which air quality at Utu could be described as unhealthy. The results obtained from this study justify the need for epidemiological studies to determine the health effects on workers in the sawmill and the local population from continuous exposure to these gaseous emissions over the years.

KEY WORDS: ambient air quality, air pollution, emissions, impact, pollutant standard index, sawmills.

INTRODUCTION

The problem of air pollution is a serious threat to environmental health in many cities of the world (Kan *et al.*, 2009, Wong *et al.*, 2008, McCarthy *et al.*, 2007, Cramer 2002). High concentration levels of air pollutants have been shown to have general adverse effects on human health (Allen *et al.*, 2009, Hulgiun *et al.*, 2007, Moshammer *et al.*, 2006). Ambient air pollution has been particularly associated with cardio-respiratory diseases (Miller *et al.*, 2007, Borm *et al.*, 2007, Schulz *et al.*, 2005, Peters 2005), adverse effect on human reproduction (Slama *et al.*, 2008), low birth-weight (Ashdown-Lambert 2005, Chen *et al.*, 2002), cancer (Vineis *et al.*, 2005) and the exacerbation of asthma especially in children (Nkwocha and Egejuru 2008, Schildcrout *et al.*, 2006, Konig *et al.*, 2005). Although the concentration of major pollutants vary from city to city, the most important sources in Nigeria include fuel consumption for power generation, motorized vehicles, incineration of solid and industrial wastes (Above 2006, Obadina 2002) and the flaring of associated gas (Nkwocha and Pat-Mbano 2010, Evoh, 2002). The establishment of new industries such as cement factories, metallurgical and petro-chemical industries and hot mix asphalt facilities has increasingly contributed to total national emissions for most of these air pollutants (Osuntokun 2004). 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 has been high increase in the establishment of sawmills in different parts of the country to satisfy the growing demand for wood (Aroofoor

2000). Sawmills accounted for 93.32% of total number of wood-based industries in Nigeria in 2001 (Fawupe 2003). These industries are mainly located in the wood producing rain forest areas of the country with largest concentrations sited in Lagos, Ekiti, Osun, Cross River, Akwa Ibom, Imo Ogun and Delta States, accounting for 90% of all sawmills in the country (Dosunmu and Ajayi 2002). The activities and processes in the sawmill industry produce known and unknown gaseous pollutants that are emitted into the atmosphere that may be hazardous to humans. Studies have shown that nasal cancer and asthma are highly associated with continuous exposure to wood dust and other substances used in the wood industry (Anavberokhai 2008). The increased activities in these sawmills as well as the continuous emissions of these pollutants in the South-South Nigeria over the years have not been properly examined especially in the context of their impact on the ambient air quality. It is in this context that this study was carried out.

MATERIALS AND METHODS

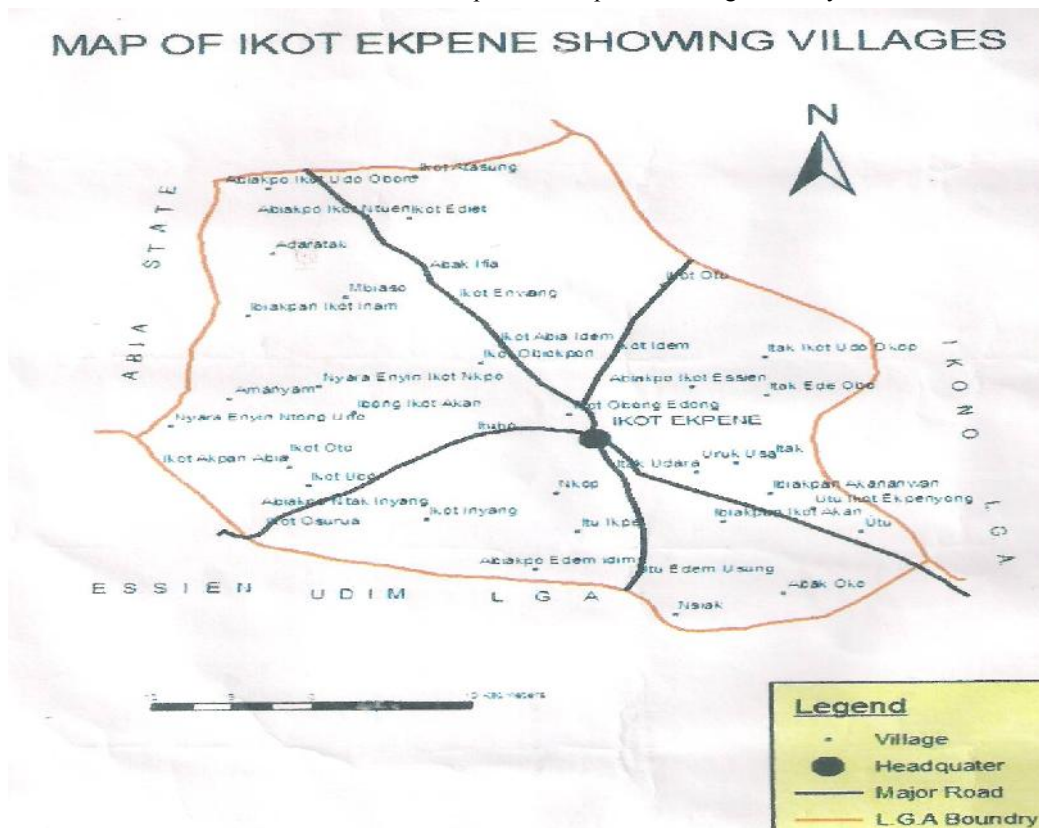
Study Area

The study was carried out in Utu village in Ikot Ekpene Local Government Area of Akwa-Ibom State, Nigeria. The area lies between Latitude 05°08' N and Longitude 07°41' E in the south-southern part of Nigeria (Appendix 1). The climatic condition of the area is typical of the tropical rainforest ecozone characterized by its distinct dry (November to March) and rainy (April to October) seasons. The wind direction was observed to be northeasterly and southeasterly indicating an overall easterly movement. Thus, the eastern part of the industry

is the most impacted of the emissions. The original vegetation is lowland rainforest, with some dominant species including mango trees, (*Mangifera indica*), Avocados (*Persea americana*), mahogany (*Azadirachta indica*), palm tree (*Palmae*), Umbrella tree (*Schefflera actinophylla*), etc. scattered all over the area. The vegetation has been heavily modified by human activities of logging and farming. Utu community is a regional commercial centre with a population of 143077 (NBS, 2009), noted for exporting palm produce (palm oil, kernel, raffia products), sweet palm wine, food crops (yam, cassava, maize etc) and wood works of different kinds. In

1980, a large sawmill industry (Utu Timber Market) occupying 108ha was established in the area to satisfy the growing demand for wood for the fast growing building construction industry in the state and in the Niger Delta Region. This sawmill generates a lot of wastes (saw dust, wood barks, palm shavings, wood rejects, etc) which are disposed of through in-situ burning. In addition, activities and processes in the industry produce various gaseous pollutants that are continuously emitted into the atmosphere which may be hazardous to human health and the environment. There is need to identify and reduce these gaseous emissions into the ambient air.

APPENDIX 1: Map of Ikot Ekpene Showing the Study Area



Source: Ikot Ekpene Local Government Council

Data Collection

Data was collected from five sampling points (designated SP1, SP2, SP3, SP4 and SP5) with SP5 serving as the control point. Each of these sampling points is located at 200m from each other, but the control point was located at 800m away from the study area. Data collection was done in-situ in accordance with a fixed sampling schedule at hourly intervals in the prevailing wind direction; but in the downwind direction for the control. 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 mainly on four criteria pollutants, namely, sulphur dioxide (SO₂), particulate matter (PM₁₀), nitrogen dioxide (NO₂) and carbon monoxide (CO) since they constitute a large proportion of emissions from a sawmill industry (LGAQTK, 2002). Other essential components monitored

include volatile organic compounds (VOCs), hydrogen sulphide (H₂S) hydrogen cyanide (HCN) and chlorine

(Cl₂). Measurements of the criteria pollutants were made using the Multi Gas Analyzer MRU (2002 Model) with electrochemical measuring principles and complete gas conditioning systems. Different gas monitoring equipments were used for other gases (Gasman Model 19812H for chlorine; Gasman Model 19773H for HCN, and Multi-RAE plus (PGM 50) for CO₂ and VOCs) and for relative humidity, wind speed and direction. Data were collected between 8.30am and 4.30pm on 8-hourly within one-hour and half-hour intervals on daily basis during the 10-month period. This helped to locate the sampling points with the highest and lowest concentration levels of individual pollutants at any given time. It also helped to identify pollutants that exceeded FEPA (2001) established Air Quality Standards. The sampling period (December

2010 to September 2011) covered the two seasons of the year (dry and rainy seasons) to enable the assessment of the influence of humidity and dry atmosphere on ground level concentrations of measured pollutants.

Statistical Analysis

Descriptive statistics were used to present data in numerical and graphical forms. Data were analyzed using mixed effect models with random subject effects accounting for repeated measures. In the first level of analyses, linear and logistic models were applied for the pollutant gases combined to know whether associations exist. The test of homogeneity in mean variance of the concentration levels of the monitored gases across the

sampling stations was conducted with analysis of variance (ANOVA). The interactions of these gases were explored with the Spearman Product Moment Correlation Coefficient (r). The Pollutant Standards Index (PSI) was calculated for an overall assessment of air quality within the area following the procedure adopted by Masters (2006).

The value of the PSI helped to know whether air quality was improving or worsening in the area, and the pollutant(s) exceeding national air quality standards (Appendix 2). All statistical analyses were completed using the software package SAS Version 9.1 (SAS Institute Inc., Cary, NC, USA).

APPENDIX 2: Pollutant Standards Index Values, Descriptors, And General Health Effects

PSI Value	Descriptor	General Health Effects
0-50	Good	None for the general public
51-100	Moderate	Few or none for the general public
101-199	Unhealthful	Mild aggravation of symptoms among susceptible people, with irritation symptoms in the healthy population
200-299	very Unhealthful	Significant aggravation and decreased exercise tolerance in persons with heart or lung disease; wide spread symptoms in the healthy population
≥ 300	Hazardous	Significant aggravation of symptoms in healthy persons; early onset of certain diseases; above 400, premature death of ill and elderly

Source: USEPA (1994b).

RESULTS

There were both wide and narrow variations in the diurnal concentration levels of air pollutants monitored in the area. Nitrogen dioxide (NO₂) ranged from 0.01 to 1.33ppm (0.16 ± 0.009), SO₂ varied from 0.01 to 0.40ppm (0.14 ± 0.006); H₂S varied from 0.03 to 0.80ppm (0.4 ± 0.009), while CO ranged between 0.60 and 26.00ppm (10 ±

11.20ppm (1.17 ± 0.134); Cl₂ came between 0.20 and 1.50ppm (0.46 ± 0.009); CO₂ range from 80.00 and 400ppm (249 ± 5.058); HCN between 0.20 and 2.00ppm (0.82 ± 0.327) and PM₁₀ varied from 18.5 to 65.6µg/m³ (48.2 ± 13.1). The ambient temperature ranged between 23 and 33°C (27.79 ± 0.167) while relative humidity ranged from 37% to 90% (53 ± 0.83) and wind speed between 2.3 and 3.5ms⁻¹ (2.8 ± 0.5) as indicated in Table 1.

0.358). It was further observed that the diurnal concentration levels of VOCs varied between 0.30 and

TABLE 1: Summary Statistics of Ambient Air Pollutants and Meteorological Data

Parameter (ppm)	Min (ppm)	Max (ppm)	Range (ppm)	Mean (ppm)	SE (ppm)	FEPA standard (ppm)
NO ₂	0.01	1.33	1.32	0.16	0.009	0.053
SO ₂	0.0	0.40	0.40	0.14	0.006	0.05
H ₂ S	0.03	0.80	0.77	0.43	0.009	0.008
CO	0.60	26.00	25.40	10.73	0.358	10.0
VOC	0.30	11.20	10.90	1.17	0.134	-
Cl	0.20	1.50	1.30	0.46	0.009	0.03
PM ₁₀ (µg/m ³)	0.20	21.60	21.40	9.23	0.311	150
CO ₂	80.00	400.00	220.00	249.45	5.058	280
HCN	0.20	2.00	1.98	0.82	0.327	0.01
Temp. (°C)	23.00	33.00	10.00	27.99	0.167	-
RH (%)	37.00	90.00	53.00	53.99	0.835	-
WS (ms ⁻¹)	0.20	2.75	2.55	1.25	0.033	-

SE = Standard Error, WS = Wind Speed.

Several air pollutants exerted significant influences on one another. At p<0.01, NO₂ correlated positively with SO₂ (0.42), with CO (0.37), with CO₂ (0.30) and with VOCs (0.75) at p < 0.05. In the same vein, SO₂ showed correlation property with H₂S (0.50), CO₂ (0.42) and HCN (0.56) at p<0.01. CO correlated positively with HCN

(0.52), CO₂ (0.44) and with VOCs (0.22) at p<0.01. Also, CO₂ showed positive association with HCN (0.54) as PM₁₀ did with CO₂ (0.28) at p<0.01. Some negative correlations were observed between some of these air pollutants and shown in Table 2. For example, NO₂, correlated negatively with RH (-0.95); PM₁₀ with RH (-0.37). The test of

homogeneity in mean variance using the single factor ANOVA revealed significant inequality as $F_{(15.79)} > F_{(3.87)}$ at $p < 0.05$. Further plots of group means using the post ANOVA mean plots that used temperature as predictor variable revealed that all the air quality parameters contributed to the observed inequality (Appendix 3). Between temperature and some gases such as NO_2 , SO_2 and CO the inequalities were mostly observed during the

dry than in the wet seasons. While maximum concentrations of NO_2 , SO_2 , VOCs, CO and PM_{10} were recorded during the dry season, especially in the months of January, February and March, the least concentration levels of the pollutants were recorded during the cold rainy season as observed in the months of June, July and September.

APPENDIX 3: Tables of Mean Plots of Some Pollutants

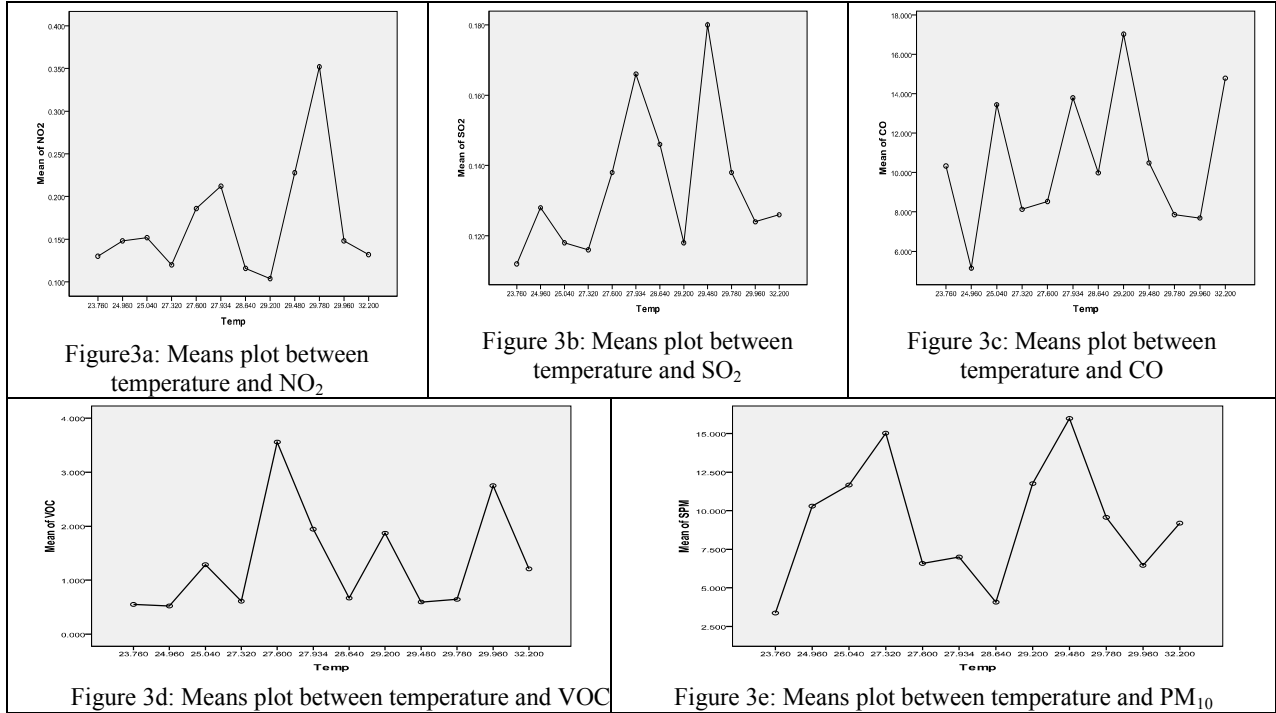


TABLE 2: Correlation matrix of ambient air pollutants

	NO_2	SO_2	H_2S	CO	VOC	Cl_2	SPM	CO_2	HCN	TEMP	Humidity
SO_2	0.424**										
H_2S	0.370**	0.504**									
CO	0.303**	0.481**	0.488**								
VOC	0.75	0.166*	0.050	0.224**							
NH_3	0.327**	0.435**	0.308**	0.428**	0.213**						
Cl_2	0.167**	0.300**	0.339**	0.283**	0.200**						
SPM	0.231**	0.183**	0.213**	0.223**	-0.059	0.247**					
CO_2	0.303**	0.422**	0.445**	0.442**	0.186**	0.300**	0.278**				
HCN	0.347**	0.564**	0.541**	0.520**	0.216**	0.323**	0.116	0.544**			
Temp	0.127*	0.133*	0.202**	0.181**	0.073	0.096	0.188**	-0.040	0.163*		
Humidity	-0.195	-	-	-	-0.116	-0.123	-	-0.48	-0.154*	-	
Ws	-	0.215**	0.345**	0.251**	-	-	0.374**	-	-	0.702**	
	0.171**	0.305**	0.336**	0.334**	-0.098	-	-0.002	-0.166*	-	-0.33*	-0.126
						0.179**			0.315**		

* = significant at $p < 0.05$, ** = significant at $p < 0.01$, WS = Wind speed

During the monitoring period, three of the pollutants, namely CO, PM_{10} and VOCs, exceeded the established standards by 72%, 49% and 37% respectively. Consequently there were 131 recorded exceedances for CO, 105 exceedances for SPM and 65 exceedances for VOCs. The average results of PSI indicated a value of 129 in which air quality at the sawmill and environs could be described as unhealthy. There was a progressive increase

in the value of PSI during the monitoring period, with 95% of the days showing values above 100 but never exceeded 200 in the five individual sub-indexes scale as shown in Appendix I. Only few days (5%) showed PSI values lower than 100 which mostly occurred during the rainy season or periods of prolonged industrial disputes between labour unions and government or extended holiday periods leading to cessation of activities in the sawmill.

DISCUSSION

The activities of wood processing and furniture making at Utu sawmill involve the use of various chemicals (adhesives, thinners, paints, preservatives, etc). These chemicals release VOCs into the ambient air, thus increasing the concentration levels of photochemical oxidants. The elevated association between VOCs and CO as shown in our results especially in terms of occupational health of workers in the sawmill is worrisome, although consistent with results obtained from previous works (Bean and Butcher, 2006; Ajao 2000). Elevated concentration levels of VOCs could lead to respiratory problems and may cause distress to asthmatics among workers in the industry. The findings of this research that particulate matter and other coarse materials (fly ash, dust) are deposited close to the sawmill within a distance of 0 to 70m were consistent with observations of Abulude (2006) in his studies on sampled sawmills in the South Western Nigeria. It was also observed that sawdust and wood wastes that constitute two-thirds of total wastes from this industry are not properly disposed of corroborating the findings of Bello and Miyinyawa (2010) from studies on other sawmills in the country. Consequently, the disposal of these wastes through open incineration led to the production of high concentrations levels of two major criteria pollutants: PM₁₀ and CO. The mean concentration level of PM₁₀ to the tune of 9045µg/m³ far exceeded the recommended standard of 150µg/m³ by large factors. This situation is expected to have adverse implications on the health of workers in the sawmill. Continuous exposure to high concentration levels of PM₁₀ 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 and PM₁₀ components during cooler months when, according to them, these components have higher concentrations as cool season averages were roughly twice those of warm season. However, results from this study are contrary to the above findings as high concentration levels of particulates were recorded during dry and warm season than during cold and wet (rainy) season in the area. The torrential rains that characterize the wet season accompanied with strong southerly winds all help to dilute and disperse to a large extent, the concentration levels of particulates in the ambient air. However, the high correlation between particulates from wood smoke and daily mortality as recorded by Fairley (2003) is a possibility in this case, and corroborates the findings of Hoek (2003) and Pope and Dockery (2006). In addition, Nwajei and Iwegbue (2007) in a study within the vicinity of the large sawmill in Sapele (Delta State) revealed that saw dust contains certain levels of Cd, Pb, Cr, As and Hg that exceeded permissible occupational levels for an 8-hr workday. Constant exposure to sawdust may constitute serious environmental health risk to workers within this sawmill as there are not much differences between sawdust produced in our case study and that of Sapele. The most preoccupying problem in the area is the high concentration levels recorded on CO whose mean value was 18.73ppm, which far exceeded the recommended limit of 10ppm daily average hourly. The high values of CO

obtained within and around the sawmill were not surprising considering the volume of fossil fuels consumed on daily basis to power different equipment, added to the disposal of sawdust and other wood wastes by open incineration. These activities emit many gaseous pollutants including CO that may cause irritation of respiratory tracts and lungs, adversely affect workers defense system against pathogens and elevate the risk of respiratory track infections (Akunne 2006; Mahalanabis *et al.*, 2002). Many researchers also reported that air pollution due to wood burning was positively associated with hospital emergency visits for pneumonia (Ozdilek 2006; Peel *et al.*, 2005). A mechanistic theory consistent with the findings of this study holds that the development of respiratory symptoms, preterm births, increased use of asthma medication and reduced lung function (Hertz-Picciotto *et al.*, 2007; Ritz *et al.*, 2007; Molitor *et al.*, 2007; Jarrett *et al.*, 2005) may be associated with the high value obtained on PSI which described the ambient air quality at Utu as unhealthful. It may also be of interest to comment on the high level of CO₂ emissions in the area, with a maximum value of 400ppm that far exceeded the reference standard of 280ppm in terms of its contribution to global warming. Opening burning of wood wastes contributes to high carbon intensity, through high emission of CO₂ that can amplify the potential for global warming (Masters 2006). From the above results, it has become imperative to conduct epidemiological studies in and around Utu community to determine the possible health effects from exposure to continuous gaseous emissions from this sawmill. The overall results are also suggestive that Utu community falls within the *non-attainment area* (Turk and Turk 1998) in terms of PM₁₀, CO and VOCs for the simple reason that they far exceeded the established standards necessary to protect public health.

CONCLUSION

This study has tried to assess the impact of sawmill industry on ambient air quality at Utu community. Results revealed that air quality is vitiated by various activities in the sawmill such as the use of different chemicals in wood processing and preservation, open burning of wood wastes, and heavy consumption of fossilized fuels (gasoline and diesel) to power various machines. Most of the gaseous pollutants monitored exceeded established standards for them. Results also showed a strong association between the identified gaseous pollutants. Three of these gases, namely CO, PM₁₀ and VOCs were most predominant as they recorded the highest levels of exceedances during the monitoring period. However, the overall assessment of air quality in the area indicated a result that would be described as unhealthful; meaning that the general health of workers in the sawmill and the local population is endangered by emissions from the sawmill. The level of emissions could be mitigated by adopting certain measures that are sustainable. Cottage industries can be set up to make use of high volume of wastes generated from the sawmill as raw materials. For example, sawdust can be used to produce chipboards and particle boards, or moulded into small sizes and sold to households as domestic fuel. Sawdust can also be used for composting biogenic wastes to produce excellent materials used for

soil conditioning. All these would help to reduce the level of emissions resulting from open burning of these waste materials and create jobs in the area. Also, short-term loans could be provided to enable existing and new factories acquire modern processing machines with protective panels that prevent the escape of wood dust into the air, with low noise and low fuel consumption levels. The results obtained in this study are not only useful in providing information on the prevailing air quality but also justify the need for epidemiological research in the area to ascertain the level of impact of continuous gaseous emissions from the sawmill on the population of Utu community.

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