Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.17, 2015

Determinant Meteorological Factors Related to Quarry Industry in Ibadan, Nigeria

Gobo A E   Esosa E O   Abam T k S
Institute of Geosciences and Space Technology (IGST), RSUST, P.M.B. 5080, Port Harcourt

Abstract

Determinant meteorological factors are used to manage and control the release of pollutants into atmospheric environment. This is essential for the understanding and effective control of the fate and transport of air pollutants. Based on this, air quality assessment was carried out to determine the impact on quarry operations at the outskirts of Ibadan city, Nigeria. Air quality sampling stations within the quarry were at the blasting section, crushing section, asphalt section, transport section and a control point two kilometres upward away from the quarry. The sampling sites were monitored for various emissions for Particulate Matter Emissions and the prevalent conditions of relative humidity, temperature, wind speed and direction. Data poll was augmented with secondary macro climatic data which were collected from a weather station near the quarry Samonda, Ibadan. Results indicate that temperature increased the rates of chemical reactions, reduced the solubility of gases and since the ambient temperature decreased in the wet season, there was more gaseous pollution in the dry season as the high average temperature enhanced floatation and hence the dispersion of pollutants.. There was a significant increase in relative humidity during the wet season, while the wind speeds were maximum during the day and minimum at dawn.

The wet season wind rose showed that the months were dominated by the westerly and southerly winds; pollutants would be conveyed more by these winds in the wet season while the dry season wind rose showed dominance of the westerly and southwesterly winds.

Keywords: determinant, quarry, air quality assessment, meteorology, air pollution, emissions

INTRODUCTION

The state of the atmosphere is of prime importance in determining the dispersal and concentration of pollutants, and their consequences. The factors responsible for pollutants dispersal in the atmosphere include:

Wind direction (controls where pollution is transported),
Wind speed (determines the rate of pollutant dispersal)

Low wind speed leads to higher pollutants concentration in local area and a higher wind speed would lead to lower concentrations over wider area (Gobo, 2014).

Particulate matter in the air provide nuclei around which condensation takes place, forming droplets and thereby playing a role in snowfall and rainfall patterns, haze, dust, smoke and soot reduce the amount of solar radiation reaching the surface of the earth.(Abdulkarim *et al*, 2006). On prevailing meteorological conditions therefore pollution levels at a site are not constant

Wind is caused by differences in pressure in the atmosphere. The pressure is the weight of the air at a given point. The height and temperature of a column of air determines the atmospheric weight. Since cool and rapidly disperses them, but it can also bring pollution to otherwise clean lair weighs more than warm air, a high pressure mass of air is made of heavy cool air locations. A low-pressure mass of air is made of warmer, lighter air. Air moves from areas of high pressure to areas of low pressure, but the Coriolis Effect will cause it to move to the right in the northern hemisphere, and to the left in the southern hemisphere. Wind can dilute pollutants.

The tendency for pollutants to be transported upward to higher levels or remain at ground level. Dependent on vertical temperature distribution, which leads to the atmosphere to be either stable, unstable or in the neutral state. It is stable when there are no vertical lifting, except in the horizontal; unstable when there is turbulence which encourages mixing and hence vertical uplifting of pollutants and neutral when pollutants neither move horizontally or vertically due to the inhibition of turbulence activities (Benn, 2008).

There are three stages in the lifetime of a pollutant, these include:

1) Emission Rates of the pollutants,
2) Atmospheric transport and transformation, and
3) Sinks: Pollutants final destination (receptors)

Emissions vary according to the rate, type and the configuration of the source. Sources can be points (e.g. a factory or power station), lines (e.g. roads) or areas (e.g. a city), and may be mobile or stationary. Atmospheric transport and transformation is very important in understanding pollutants. The state of the atmosphere determines whether pollutants are concentrated or dispersed, and whether they are likely to remain in areas and concentrations that put life or health at risk.

Atmospheric processes may also transform primary pollutants into secondary pollutants (e.g. the formation of photochemical smogs), or allow the settling and removal of pollutants. Receptor response covers a wide range of effects, including health effects, vegetation damage, soiling of surfaces, or corrosion of metals or other materials (Benn, 2008).

During the dry season, there is an increase pollutants dispersion which was occasioned by the deposition of particulates, or dust raised, wind movement of dry particulates and aerosols from the Sahara desert into the northern states, and burning of anthropogenic substances etc. are the major factors that are responsible for this increase. Another cause of the pollution increase during Harmatan season is construction exercises, which take place mostly in the dry season. (Efe, 2008).

High local concentrations of respirable dust result in high exposures. A sampling carried out during a dry period of April 2006, and definitely the weather conditions will play an important part in dust level variability on this and similar sites. Dust concentrations were likely to be lower during wet periods and perhaps higher during spells of windy weather when fine, accumulated and settled dust becomes airborne (Semple *et al*, (2007). Table 1 give a typical conceptual moldel for human exposure pathways linked to quarry industry.

Table 1: A conceptual model for human exposure pathways linked to quarry industry.

Source	**Release Mechanism**	**Transport Medium**	**Transport Mechanism**	**Location(s) of Exposure**	**Route of Exposure**	**Exposed Population**
Active face of Quarry	Emissions during Blasting, Excavation, Loading	Outdoor Air	Wind Dispersion	Outdoor Air in Residential Area	Inhalation	Local Residents
			Settling	Local Soils in Residential Area	(This is a secondary source)	
			Infiltration	Air Inside Local Residences	Inhalation	House Occupants
			Settling	Surface Dusts Inside Residences	(This is a secondary source)	
Haul Roads	Emissions from Vehicular Traffic on Roads and from Transported Material	Outdoor Air	The transport mechanisms, exposure points, routes of exposure, and exposed populations relevant to this source are identical to those listed above for emissions from the active face of the quarry.			
Crushing and Milling Operations	Stack Emissions from Crushing and Milling	Outdoor Air	The transport mechanisms, exposure points, routes of exposure, and exposed populations relevant to this source are identical to those listed above for emissions from the active face of the quarry.			
Classification Operations	Stack Emissions from Classification	Outdoor Air	The transport mechanisms, exposure points, routes of exposure, and exposed populations relevant to this source are identical to those listed above for emissions from the active face of the quarry.			
Storage Piles	Emissions from Loading and Dumping	Outdoor Air	The transport mechanisms, exposure points, routes of exposure, and exposed populations relevant to this source are identical to those listed above for emissions from the active face of the quarry.			
Outdoor Soils	Wind Entrainment	Outdoor Air	The transport mechanisms, exposure points, routes of exposure, and exposed populations relevant to this source are identical to those listed above for emissions from the active face of the quarry.			
	Outdoor Residential Activities	Outdoor Air	The transport mechanisms, exposure points, routes of exposure, and exposed populations relevant to this source are identical to those listed above for emissions from the active face of the quarry.			

Sources: Division of Science, Research and Technology (DRST, 2004); New Jersey)

Air pollution does not always stay where it was generated at the source, they travel different distances depending on prevailing meteorological conditions but vary on several timescales, due to variations in output from sources and the state of the atmosphere (Gobo and Abam, 2002). Air born particulates are generally made up of a variety of biological and non-biological materials. In Ibadan, a community dominated by quarries, there is the likelihood of a significant concentration of rock particle in suspension.

Some outputs are more or less constant (e.g. power stations, refineries) while others vary on daily, weekly or seasonal basis (domestic fires, car use). Typical daily cycle of carbon monoxide exists in cities due to traffic: peak concentrations occur during rush hours. Additionally, pollution concentrations will change due to changing weather and the ability of atmosphere to disperse, concentrate, transform, and deposit pollutants.

Particulate matter concentrations, deposition rates, and potential impacts tend to decrease rapidly away from the source. A carefully prepared and implemented dust control plan can reduce impacts from dust (Kestner, 1994). Exposure of quarry workers to particulate pollution, coupled with the general non-use of protection gadgets predispose them to several respiratory ailments similar to health problems found prevalent among residents living near quarry sites. (Oguntoke *et al*, 2009).

Controlling fugitive emissions commonly depend~~s~~ on good housekeeping practice rather than control systems. Techniques include the use of water trucks, sweepers, and chemical applications on haul roads, control of vehicle speed, construction and planting of windbreaks. However, it has been difficult to achieve cooperation for air pollution control agents in developing countries like Nigeria, whose chief concern is to provide such basic needs such as food, shelter and employment for her populace.

The study determined the meteorological factors affecting the dispersion of these pollutants i.e. Particulate Matter emissions ($PM_{10,}$ $PM_{7,}$ $PM_{2.5}$ & PM_1); Total suspended solids and extraneous gases e.g. Sulphur Oxides (SO_x), Nitrogen dioxide (NO_2), Carbon monoxide (CO) at different locations in the study area.

Study Area

Ibadan, the capital city of Oyo State is located in the South Western part of Oyo State, Nigeria. It is about 145 km north-east of Lagos, the former Federal capital of Nigeria. Ibadan the capital city of Oyo State is located approximately on Latitude 7^o 22' N and Longitude 3^o 58'E of the Greenwich Meridian. Nevertheless, the expanse of land normally referred to as the metropolitan area lies in the portion lying between Latitudes 7^o 15' and 7^o 30' North of the Equator; and Longitudes 3^{o}45' and 4^{o}00' East of the Greenwich Meridian.

As a result of its location, Ibadan experiences two major seasons, dry and rainy season. The persistence of either season is influenced by the absolute fraction of time during an annual cycle that the line of the Inter-Tropical Convergence Zone (ITCZ) or the Inter-tropical Discontinuity (ITD), as it is called in West Africa, depending if it is below or above its line of latitude. The dry season (under the influence of the north-east trade winds, when the ITD is south of the city), on the average, starts around the middle of October and lasts until the middle of April and more pronounced between mid November and mid February (Raheem *et al*, 2005).

Rains initiated by predominance of southwest monsoon winds dominate the remaining six months of the year when the ITD lies north of the city. The dry season is characterized, not only by near absence of rain, but also by transport of dust haze from the Sahara Desert into the region. The winds are generally cold because they form part of the Hadley cell, which are known to move equator-ward from the poles at ground levels, and pole-ward from the equator at upper levels. The Harmattan period, being wintertime in Europe, implies that very cold air, drafted across Europe through the Sahara, arrives in the sub-region, carrying the Sahara dusts with it. The season is characterized by high ~~a~~^{A}tmospheric turbidity, which inhibits the penetration of a significant fraction of the solar radiation to the earth's surface (Raheem et al, 2005).

Sampling Methods

Meteorological Data

Two categories of meteorological data were used, the micro data for the study were generated on site at the study location while the macro climatic data, essentially secondary, were collected from a weather station in Samonda, Ibadan. The micro climatic scale refers to climates within or less than a few hundreds of metres, while the macro climatic scales refer to hundreds of kilometer in distance (Munn, 1970).

The wind speed, temperature and relative humidity for the study were measured with a digital hand held Cole-Parmer combination Anemometer. The instrument determines the wind speed via wind vanes that generates on revolution signal that is directly proportional to the wind force. Wind velocity and temperature of the ambient atmosphere is determined by holding this equipment to a height of about six feet, in the prevailing wind direction while for the wind direction a compass model m-73 was used to determine the direction of wind.

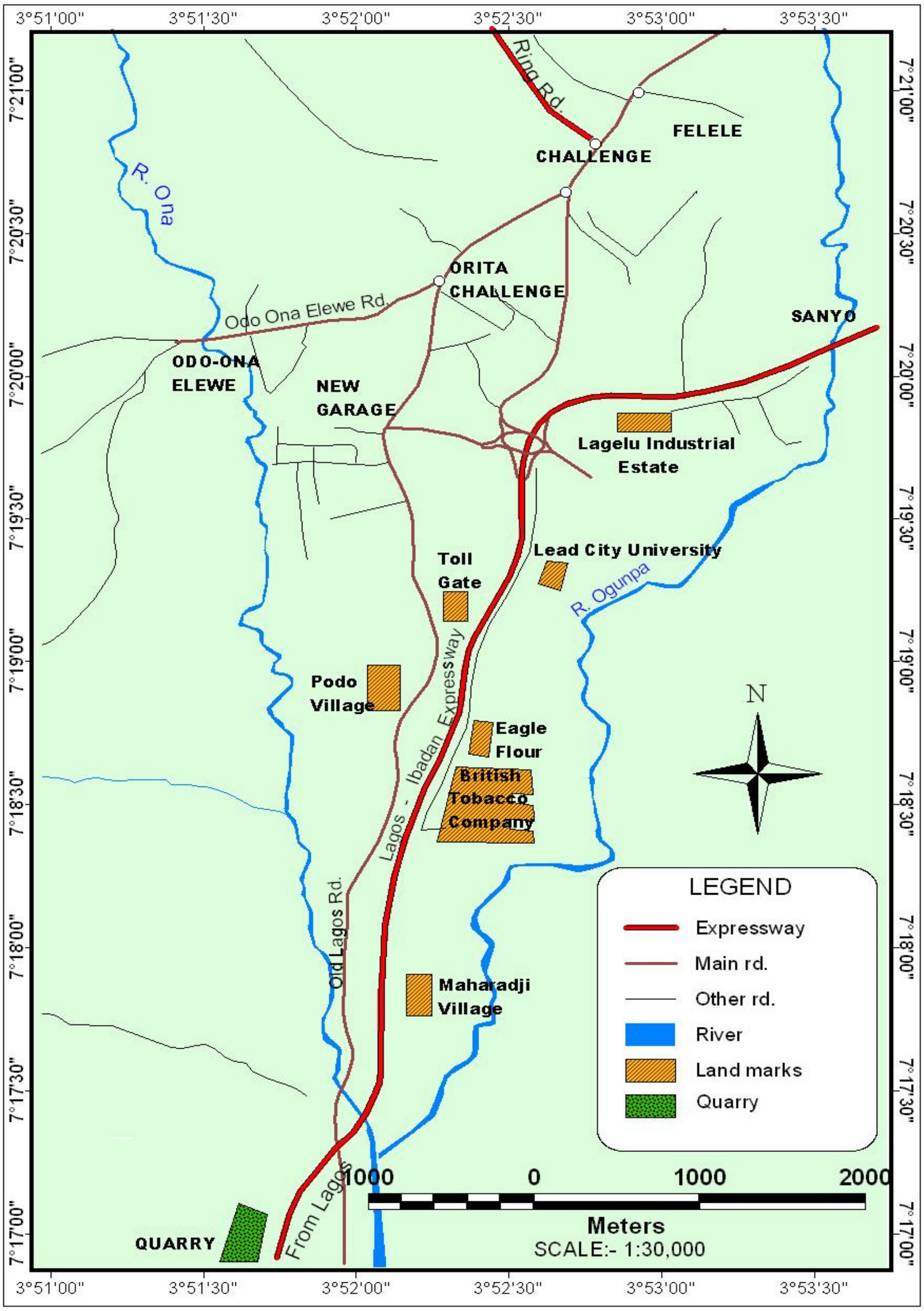

Fig 1: Map of Ibadan Showing Study Area and Environs.
Source: Cathography Department, University of Ibadan, 2009.

RESULT AND DISCUSSION

The study analyzed the concentration levels of potentially toxic and harmful elements contained in the airborne cement dust generated in the vicinity and farther away 500 m in the conventional four cardinal directions from the West African Portland Cement Company (WAPCO) factory mill, Sagamu area of southwestern Nigeria. The values obtained from the study site far exceeded the stipulated standard of $PM_{2.5}$ for personal exposure and also that the concentrations are higher at the 500m locations than at the 100m locations especially in the southern and western directions of the mills. This implied that resident time and mobility of the metals in the air would have resulted into the metals settling down at distances further away from the main source. Thus, the farther the distance the higher the deposition depending on the prevailing meteorological conditions. The higher concentration recorded in both the western and southern directions of the mill can also be attributed to the presence of the quarry at the southern end and production activities in the western part of the mill which invariably have increased the quantity of the dusts and also elemental concentrations at these locations and or directions. (Gbadebo *et al*, 2007)

Meteorological Results

Table 2 shows the result of a 24-hour measurement of relative humidity, temperature, wind speed and direction at the study area.

Table 2: Micro Weather records for Study Area (July, 2008)

GMT	R/H	Temp.	Wind/speed	Direction
00:00	93	23.7	2.3	SW
01:00	94	23.6	2.4	S
02:00	95	23.4	2.7	S
03:00	95	23.2	3.3	S
04:00	96	23.1	2.5	SW
05:00	96	23	2.9	N
06:00	96	22.9	2.7	SW
07:00	95	23.1	3.3	W
08:00	92	23.6	4.9	W
09:00	87	24.8	5.6	W
10:00	85	25.5	5.9	W
11:00	81	26.1	5.5	W
12:00	78	27	6.1	SW
13:00	77	27.1	5.2	SW
14:00	77	27.3	4.3	S
15:00	78	27.2	6	S
16:00	79	26.9	4.9	S
17:00	82	26.4	4.9	SE
18:00	86	25.7	5.7	W
19:00	89	25.1	5.1	W
20:00	91	24.7	4.7	W
21:00	92	24.4	4.3	SW
22:00	92	24.2	4.3	S
23:00	93	24.1	3.6	S

Table 3: Micro Weather records for Study Area (December, 2008)

GMT	R/H	Temp.	Direction	Wind/speed
00:00	84	25	NW	1.6
01:00	86	24.6	N	2.8
02:00	87	24.3	NW	1.9
03:00	89	24.1	W	1.8
04:00	89	23.8	W	2.3
05:00	89	23.6	W	1.7
06:00	90	23.8	W	1.7
07:00	88	23.7	NW	2
08:00	80	24.8	S	2.6
09:00	73	26.5	S	3.8
10:00	65	28.1	S	3.1
11:00	58	29.6	S	3
12:00	53	31	SW	3.2
13:00	51	31.6	SW	3.5
14:00	49	32	SW	5.7
15:00	48	32	N	4.1
16:00	51	31.2	N	5
17:00	59	29.7	W	2.9
18:00	66	28.1	W	3
19:00	71	27.4	W	2.9
20:00	74	26.7	W	3.5
21:00	77	26.2	NW	2.9
22:00	80	25.7	SW	2.2
23:00	82	25.4	SW	1.8

The mean monthly rainfall in Ibadan ranged from 8mm to 170mm, the highest rainfall was observed in the month September, while the lowest rainfall was observed in the month of January. Rainfall to a degree reduces the airborne pollutants in the atmosphere and it transfers the emissions to other spheres of the environment. Rainfall variation is the most important parameter for the determination of season Fig. (2).

The temperature in Ibadan ranged from 22.9°C to 28.1°C during the wet season while during the dry season, the maximum temperature observed was 35^{0}C recorded in the afternoon. Temperature speeds up rates of chemical reactions, reduces solubility of gases. The ambient temperature generally decreased in the wet season Fig (3).

Relative humidity is a measure of water vapour in the atmosphere. It is a quantitative approach to measuring the wetness or dryness of the air. In Ibadan, the relative humidity (Fig. 4) at the site ranged from 78.3% to 35.3% during the dry season while during the wet season, the maximum relative humidity observed was 95.5%, recorded at early hours of the morning while the minimum was 73% at 1400 GMT. Therefore, there was a significant increase in relative humidity during the wet season.

The wind speed ranged from at the site ranged from 1.8m/s to 4.6m/s during the dry season while during the wet season, ranged from 0.3m/s to 4.3m/s. The mean wind speed (3.1m/s) in the dry season is just slightly stronger than that of the wet season (2.4m/s), Fig. 5. Generally, the wind speeds were maximum during the day and minimum at dawn.

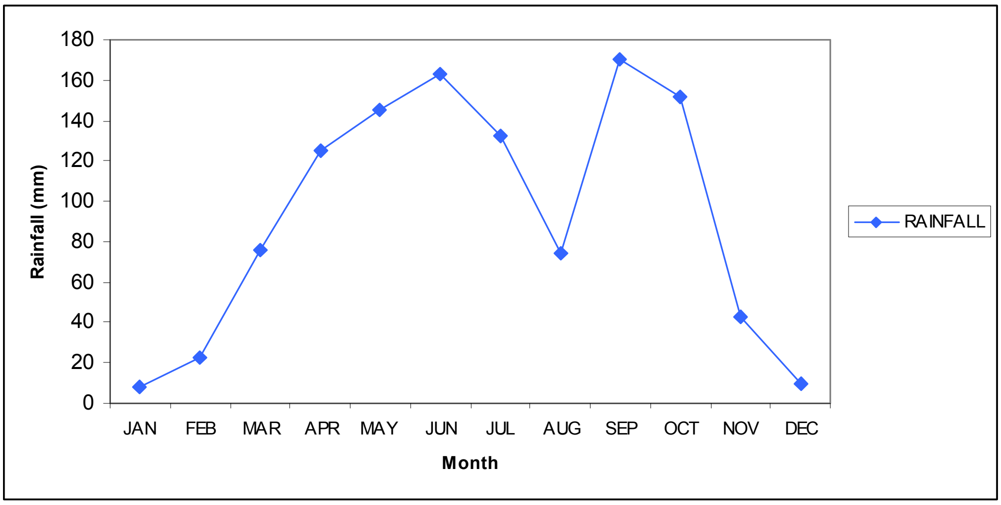

Fig. 2: Monthly Average of Rainfall Values for Ibadan (2008).

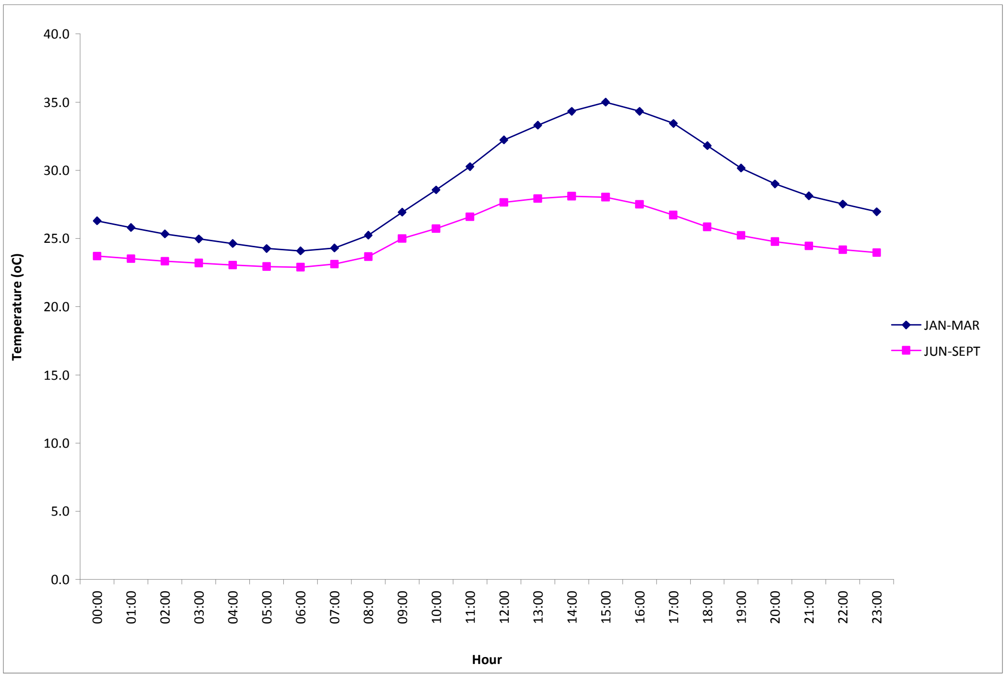

Fig. 3: Diurnal Average of Temperature Values for Ibadan between Jan-Mar and Jun-Sept (2008).

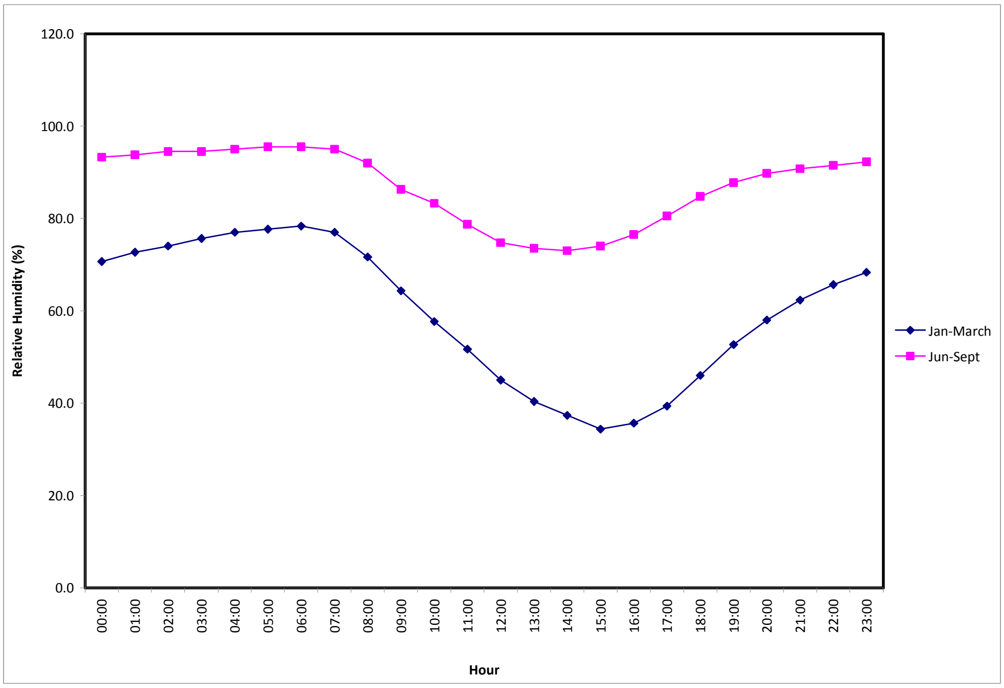

Fig. 4: Diurnal Average of Relative Humidity Values for Ibadan between Jan-Mar and Jun-Sept (2008).

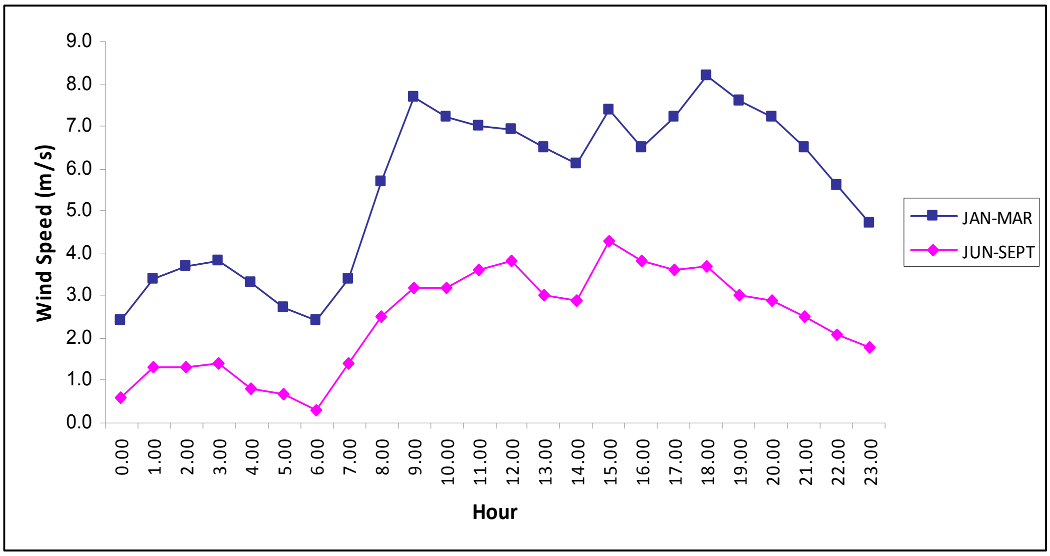

Fig. 5: Diurnal Average Wind Speed (m/s) for Ibadan between Jan-Mar and Jun-Sept (2008)

A comparison of the temperature and relative humidity shows that the period of June to October which has the lowest temperature (25.7^{o}C) correspond to the period of highest relative humidity (84.7% - 85.2%) while the warmest months of February to April occur just before the raining season.

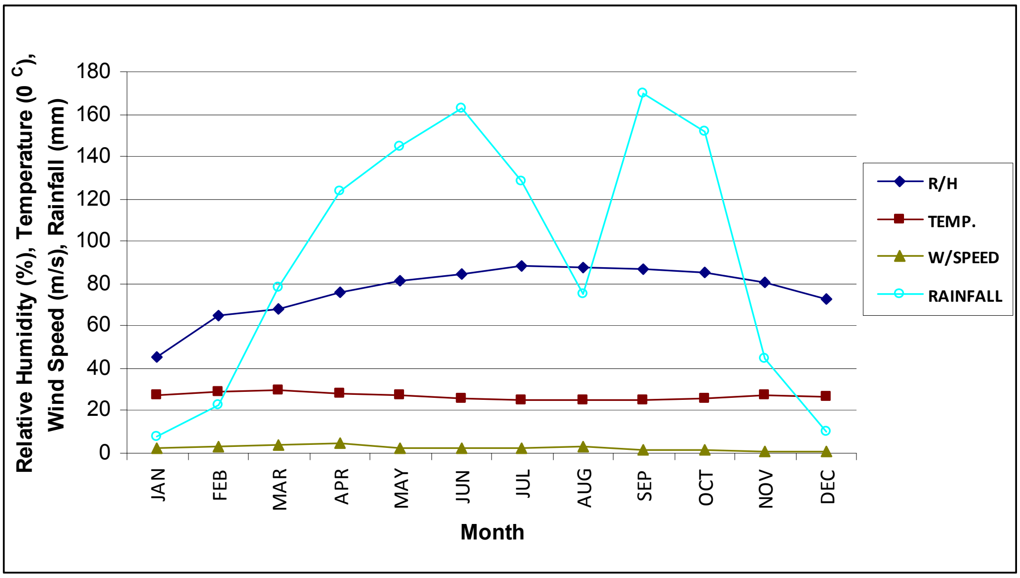

Fig. 6: Comparative Graphs of Mean Relative Humidity (%), Temperature (^{o}C), Wind Speed (m/s) and Rainfall (mm) (2008).

Wet Season Wind Rose

The dominant direction is Westerly and South-westerly. The prevailing wind distributions were westerly (27.6%), south-westerly (22.9%), southerly (19.9%), south-easterly (3.7%), north-westerly (3.4%) and easterly (1.5%) and as presented in the wind rose (Fig 4.14) Number of calms: 427 (18.4%). The area of greatest impact by the pollutants will be at the eastern parts of study location (Fig. 7)

Dry Season Wind Rose

The dominant direction is Westerly and Southerly. The prevailing wind distributions were westerly (20.2%), southerly (19.6%), south-westerly (13.9%), north-easterly (12.9%), easterly (7.8%), north-westerly (5.6%) and as presented in the wind rose (Fig 4.15). Number of calms: 239 (11.26%). The area of most impact by pollutants (Fig. 8) will be northern and eastern part of study location.

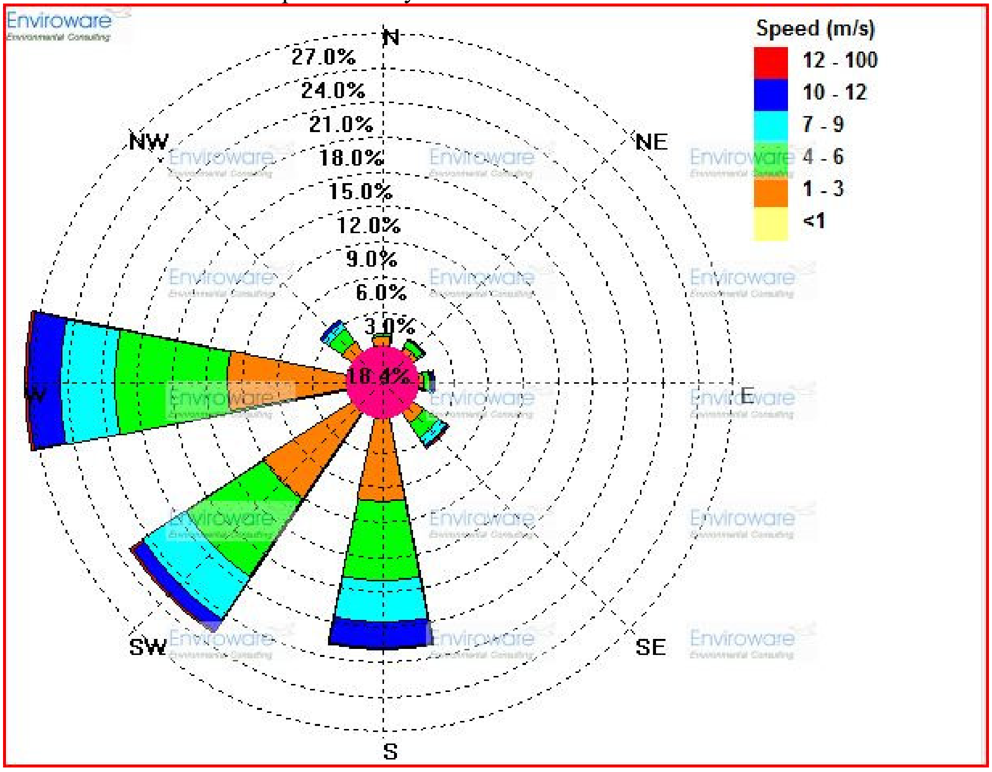

Fig. 7: Wind Rose Diagram for Wet Season (June – September, 2008).

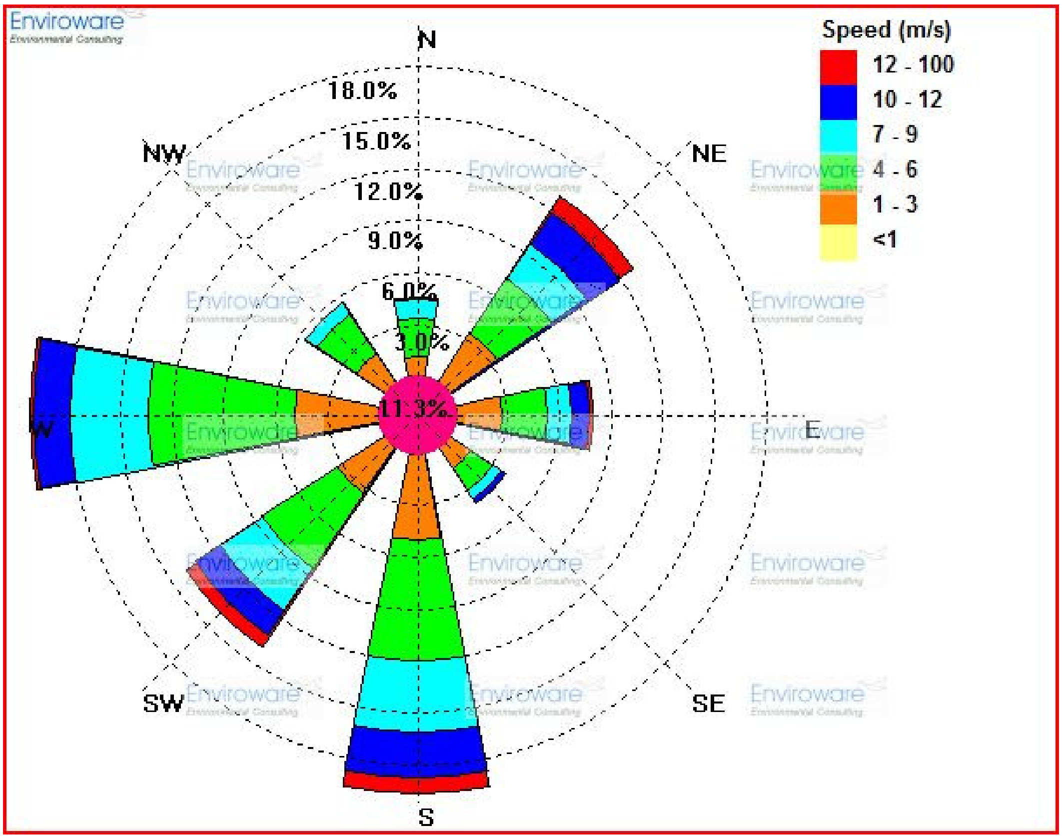

Fig. 8: Wind Rose Diagram for Dry Season (January- March 2008).

CONCLUSION

The process of pollutant transport, dispersion and concentration and reactions are dependent on meteorological/climatological conditions hence prevalent meteorological parameters is representative of the entire region of Ibadan, comprising temperature, relative humidity, wind speed were considered. The temperature increased the rates of chemical reactions, reduced the solubility of gases and since the ambient temperature decreased in the wet season, there was therefore more gaseous pollution in the dry season. There was a significant increase in relative humidity during the wet season, while the wind speeds were maximum during the day and minimum at dawn.

The dry season wind rose showed that the months were dominated by the westerly, southerly winds, and pollutants would be conveyed more by these winds in the dry season. The high average temperature would enhance floatation and hence the dispersion of pollutants. The wet season wind rose showed dominance of the westerly and south westerly winds.

REFERENCES

Abdulkarim B. I., Chiroma T. M. and Joseph T. (2007). Assessment of Co, Co_2 and suspended particulate matter emissions. *Leonardo Electronic Journal of Practices and Technologies,* Issue 11, 109-116

Aigbedion, I., Iyayi, S.E. (2007). Environmental effect of mineral exploitation in Nigeria. *International Journal of Physical Sciences*; 2: 33–8.

Banbridge District Council (2005). Air Quality Review and Assessment - Stage 2 and 3 Report to Banbridge District Council.

Benn D I, (2006) *'Climates and Weather Systems'* Report for School of Geography and Geosciences St Andrews.

Chandrasekaran, G.E.; Ravichandran, C.; Neetha Shetty (1997). Ambient air quality at selected sites in Bangalore city, *Indian Journal of Environment Protection*, , 17(3): 184-188.

D'Amato G., Liccardi G., D'Amato M., & Cazzola M. (2002). Outdoor air pollution, climatic changes and allergic bronchial asthma. *European Respiratory Society Journals Ltd* 2002. 20: 763-776

DSRT (2004). Division of Science, Research and Technology, Framework for Assessing Possible Risks Posed by the Presence of Asbestos and Related Structures from emission from Southdown Quarry, New Jersey.

Efe SI (2008). Spatial distribution of particulate air pollution in Nigerian cities: Implications for human health*, J. Environ. Health Res*., 7(2).

Folmer H., & Gabel H. L. (2006). *Principles of Environmental and Resource Economics*: A Guide for Students and Decision-Makers, Cheltenham.

Gbadebo A. M., & Bankole O. D. (2007). Analysis of Potentially Toxic Metal in Airborne Cement Dust around Sagamu Southern Nigeria. *Journal of Applied Science,* 7(1): 35-4

Gobo, A. E. and Abam, T.K.S. (2002). Analysis of some Meteorological Parameters pertinent to Air Pollution in Okrika-Onne axis of Rivers State, Nigeria. African Journal of Environmental Pollution and Health 1(1): 64 – 71.

Gobo, A. E. (2014). Mainstreaming Climate Change Adaptation and Mitigation Issues into Development Planning in Rivers State. US Open Climate Change Journal 1(1): 1-11.

Injuk J., and VanGricken, R. (1995). Atmospheric Concentrations and Deposition of Heavy Metals over the North Sea: a Literature Review. *Journal of Atmospheric Chemistry*, 20 (2), 179 – 212.

Kestner, M. (1994). Developing a dust control plan: Stone Review 10(1), 22-23.

Kneese, A. V., & B. T. Bower. (1976). *Environmental Quality and Residuals Management*. John Hopkins Press.

Munn, R.E. (1970). *Boimetrological Methods*. Academic Press, New York.

Nwibo, A.N., Ugwuja, E.I., Nwambeke, N.O., Emelumadu, O.F., and Ogbonnaya, L.U. (2012). Pulmonary Problems among Quarry Workers of Stone Crushing Industrial Site at Umuoghara, Ebonyi State, Nigeria. *The International Journal of Occupational and Environmental Medicine,* 3:178-185.

Oguntoke, O., Aboaba, A., & Gbadebo T. A. (2009). Impact of Granite Quarrying on the Health of Workers and Nearby Residents in Abeokuta, Ogun State, Nigeria. *Ethiopian Journal of Environmental Studies and Management* 2(1).

Raheem, A. M. O., Adekola, F. A., & Obioh, I. B.(2005). Determination of Sulphur (IV) Oxide in Ilorin City, Nigeria, during Dry Season, *Journal of Applied Sciences & Environmental Management*, 10, 5-10

Semple, S., Green, D. A., Cowie, H., McAlpine, G., Seaton A. (2007). Exposure to particulate matter on an Indian stone crushing site. *Occup. Environ Med*; 65:300–6.

Singh, S. K., Chowdhary1, G. R., Chhangani, V. D., & Purohit, G. (2007). Quantification of Reduction in Forced Vital Capacity of Sand Stone Quarry Workers, *Int. J. Environ. Res. Public Health*, 4(4), 296-300.

Smith, K. (1975). Principles of Applied Climatology London. McGraw Hill Book Company (UK) Ltd.

Tanimowo, M.O. (2000). Air Pollution and Respiratory Health in Africa: A Review; *East African Medical Journal,* 77; 29:8-10

Tripathi, A., and Tripathi, B.D. (1991). Measurement & Monitoring of SO2, NO3 & Suspended Particulate Matter in Air, *Proc. Ind. Sci. Congr. Assoc*., 1991, 78

Ugbogu, O. C., Ohakwe, J., & Foltescu, V. (2009). Occurrence of Respiratory and Skin Problems among Manual Stone-Quarrying Workers; Mera: *African Journal of Respiratory Medicine*; 3: 23–6

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar