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TOTAL SUSPENDED SOLIDS AND VOLATILE ORGANIC COMPOUNDS IN THE AIRSHED OF A RECONSTRUCTED ROAD ALONG LAGOS-IBADAN EXPRESS WAY

Fakinle Bamidele Sunday*
Department of Chemical Engineering, Landmark University,
Omu-Aran, Kwara State Nigeria

Oni Olufemi Sunday
Department of Chemical Engineering, Obafemi Awolowo University,
Ile-Ife, Nigeria

Olalekan Abiodun Paul
Department of Chemical and Petroleum Engineering, University of Lagos,
Akoka, Nigeria

Sonibare Jacob Ademola
Department of Chemical Engineering, Obafemi Awolowo University,
Ile-Ife, Nigeria

Okedere Oyetunji Babatunde
Department of Civil Engineering, Osun State University, Osogbo, Nigeria

Odunlami Olayemi Abosede
Department of Chemical Engineering, Covenant University, Ota, Nigeria
*Corresponding Author Email: fakinle.bamidele@lmu.edu.ng

ABSTRACT

This study examined the variation of Volatile organic compounds (VOC) and Total Suspended Particulate matter (TSP) emitted from a road reconstruction site along Lagos- Ibadan one of the busiest highway connecting Lagos, the commercial centre of Nigeria to its other parts. It has an approximate area of 0.6 km^2. Ambient VOC and TSP were monitored at ten different sampling points using the MultiRAE gas monitor and Metone GT 331 particle monitor respectively. The average measured VOC within the construction site ranged 1.30 – 9.50 ppm while that of the particulate were 213.50 – 589.78 µg/m^3.

An assessment of toxicity potential of VOC shows healthy air condition while it wasn't so for TSP at the construction site. This study establishes that road *construction contribute significantly to its host airshed degraded air quality thus calls for appropriate regulatory measure to protect host community and workers carrying out the construction work.*

Key words: Road construction, volatile organic compounds, total suspended particulate, toxicity potential

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1. INTRODUCTION

Due to urbanization, reconstruction of existing roads in Nigeria is of uttermost concern. This is important in other to easy the movement of its populace from one place to another in order to observe the daily activities required for their survival. During construction of roads the environmental impact is of concern as this activity emit substances into the atmosphere which have deleterious effect on plant, animals, humans and the environment.

The most emissions of concern during road construction are Volatile Organic Compounds (VOC) and Particulate matter. Volatile organic compounds (VOC) are a group of organic chemical compounds that contain at least one carbon atom. The only carbon compounds excluded from this definition are carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates and ammonium carbonate. The molecular composition of the VOCs gives them the properties to evaporate under normal temperature and pressure conditions [1]. Because of their composition, VOCs also usually have short lifetimes in the atmosphere, varying from hours to months and their direct impact on radiative forcing is rather small [2].

Another definition for VOCs is that they are organic compounds that have a boiling point under or equal to 250°C at normal atmospheric pressure 101.3 kPa. VOCs can also be divided into two different groups the very volatile organic compounds (VVOCs) and semivolatile organic compounds (SVOCs) by their boiling point, the lower the boiling point the higher the volatility [1]. VOCs usually affect climate indirectly with the usual effect occurring through the production of different organic aerosols and through photochemical reactions. In the reactions VOCs are components of reactions causing tropospheric ozone (O_3) production if there also happen to be nitrogen oxides (NOx) and sunlight present [2].

VOCs can be divided into two groups, anthropogenic and biogenic VOCs, based on their origins. The largest anthropogenic sources of VOCs are emissions that come from traffic as incomplete fuel combustion products and from fossil fuel production. In addition, industry and the still increasing trend of biomass burning has increased the amount of VOCs produced by anthropogenic sources [2].

Biological VOCs (BVOCs) on the other hand are the biggest group of VOCs and they emerge mainly from vegetation and small amounts can be emitted from oceans. The BVOC group contains the following compound groups: isoprenoids (isoprene, monoterpenes and sesquiterpenes), alkanes, alkenes, carbonyls, alcohols, esters, ethers, and acids [3]. The largest quantities of BVOCs are released as secondary metabolites from plants during photosynthesis and the BVOC with the largest emission rate is isoprene [4]. It has been found that isoprene emissions can be nearly 500 TgC per year [5]. Vegetation can also release a lot of BVOCs due to natural behaviour of plants or under different kinds of abiotic (e.g. increased temperature, pH, and ozone levels) or biotic (e.g. plant diseases or herbivore interactions) stress reactions [6, 7].

Some organic compounds contain chlorine or bromine substituents and have high tropospheric life time. These VOCs are stable enough to survive tropospheric removal processes, and to reach the stratosphere where they undergo the processes of stratospheric photolysis and hydroxyl radical destruction that leads to the release of active ozone-destroying chain carriers. VOCs that contribute to ozone depletion are termed ozone depleting substances (ODS) which includes many chlorinated solvents and refrigerants, and bromine-containing fire retardants and fire extinguishers [8].

2. METHODOLOGY

2.1. Study Area: Ibadan-Ogere Road Construction Site

The study area was the Lagos- Ibadan express road under reconstruction from Ibadan in Oyo State to Ogere in Ogun State located within kilometres 65 and 68 with geographical coordinates 6^0 56’ 0” North and 30 38’ 0” East (Figure 1). It is one of the busiest road in Nigeria with quite a number of vehicular activities.

There are ten sampling points (S1 to S10) with five sampling point taken from each of the two lanes. Each sampling point is 500 m from the other where the concentrations of volatile organic compounds were measured using a MultiRAE Plus gas detector. Sampling at these locations were done for consecutive two days.

Sampling Apparatus

The apparatus used for this experiment were the MultiRAE plus and Metone GT 331for Volatile Organic Compound and Particulate matter, respectively.

The MultiRAE plus multi gas counter combines a PID (Photo Ionization Detector) with the standard four gases of a confined space monitor(O_2, LEL and two toxic gas sensors) in one compact monitor with sampling pump. The multiRAE Plus gets the job done in more circumstances than any other gas detector. It measures 0-2000 ppm of VOC with 0.1 ppm resolution while the GT 331 is a unit of equipment from Met-One instruments, handheld, battery-operated and completely portable units measuring five mass ranges of particulate: PM_1, $PM_{2.5}$, PM_7, PM_{10} and Total Suspended Particulate (TSP). It has a concentration range of 0–1 mg/m^3, a sampling time of 5 min, a flow rate of 2.83 l/min and measures in μg/m^3.

Figure 1 The Studied Area in Ibadan - Ogere (Google map)

Sampling for VOC and TSP

During the 15 minutes sampling period at the designated point, the VOC monitor was positioned at a sufficient height above the ground level to prevent measurement of fugitive VOCs. Measurement was carried out at each sampling location for two different days consecutively.

To measure the ambient TSP, the GT 331 monitor is switched on in the environment of interest and the measured concentration is read directly on the LCD display. During this field study, the particulate monitor was positioned 1 m above ground level in order to prevent measurement of fugitive dust mobilized by tides. Measurement was carried out during the reconstruction of the road at each of the designated location at an averaging time of 8 h per day. The 24-hr averaging period extrapolated concentrations of the measured VOCs and TSP were computed using an atmospheric stability formula [9, 10] given in Equation (1) as:

$$C_o = C_1 \text{ x } F \qquad (1)$$

where C_0 = the concentration at the averaging period t_0

C_1 = the concentration at the averaging period t_1

F = factor to convert from the averaging period t_1 to the averaging period to = $(t_1/t_o)^n$

n = 0.28, the stability dependent exponent

Toxicity Potential

Toxicity potential is expressed as the ratio of measured ambient VOC concentration to the statutory limit of ambient concentration [11] is useful in assessing the deleterious effects of emissions on human health. It was computed using equation (2) taking into consideration the ambient air quality standards of VOC by the Federal Ministry of Environment (FEPA) of 6 ppm and 250 µg/m^3 for VOC and TSP, respectively.

$$\text{Toxicity Potential, TP} = M_{VOC}/S_{VOC} \qquad (2)$$

Where M_{VOC} is the measured VOC and S_{VOC} is the statutory limit set for VOC.

3. RESULTS AND DISCUSSION OF RESULT

The 15 min measured VOCs at the various sampling point is summarised in Table 1. The measured concentration ranged 1.20 – 9.80 ppm with average range of 1.30 – 9.50 ppm. The minimum measured VOC is at sampling point S9 while at sampling point S5 the maximum concentration of the VOC was measured. Sampling point S5 is the central point where the mixing of raw materials for the road reconstruction takes place, this activity at S5 could account for the maximum concentration of VOC at the point. The 8-hr measured TSP at the various sampling points were ranged 213.50 – 589.78 µg/m^3 with minimum TSP from sampling point S9 and maximum TSP at S5 (Table 2).

Computed from Equation 1, the extrapolated 24-hr averaging period for VOC and TSP at the study area were range 0.334 – 2.563 ppm, 156.97 – 433.61 µg/m^3, respectively. These are summarised in Table 3 and 4 respectively for VOCs and TSP.

Comparing the measured parameters with the 24-hour averaging period national ambient VOC and TSP standard in Nigeria, it was observed that none of the extrapolated concentration VOC breach the standard in all the two monitored days. At sampling point S3, S4, S5 and S6 the measured VOC concentration breached the set limited of 6 ppm by FEPA,

Table 1 Sampling points concentration data

Sampling Points	Day 1 (ppm)	Day 2 (ppm)	Average (ppm)
S1	1.60	1.70	1.65
S2	2.30	2.60	2.45
S3	6.90	7.10	7.00
S4	6.20	6.70	6.45
S5	9.20	9.80	9.50
S6	8.10	8.30	8.20
S7	4.80	4.90	4.85
S8	5.30	5.70	5.50
S9	1.20	1.40	1.30
S10	1.50	1.60	1.55

Table 2 8-hr TSP measurement in the airshed of the study area

Sampling Points	Day 1 (µg/m^3)	Day 2 (µg/m^3)	Average (µg/m^3)
S1	250.61	300.01	275.36
S2	400.72	265.89	333.31
S3	350.33	387.32	368.83
S4	440.25	320.12	380.19
S5	589.78	544.34	567.06
S6	291.45	334.78	313.12
S7	357.23	450.32	403.78
S8	233.76	254.31	244.03
S9	244.32	213.50	228.91
S10	226.21	217.44	221.83

Table 3 Extrapolated 24-hr Averaging period VOC from measured levels

Sampling Location	Day 1 (ppm)	Day 2 (ppm)	Average (ppm)
S1	0.445	0.473	0.459
S2	0.640	0.724	0.682
S3	1.922	1.978	1.950
S4	1.727	1.866	1.797
S5	2.563	2.730	2.644
S6	2.256	2.312	2.284
S7	1.337	1.365	1.351
S8	1.476	1.588	1.532
S9	0.334	0.390	0.362
S10	0.417	0.445	0.431

Table 4 Extrapolated 24-hr TSP in the airshed of the study area

Sampling Points	Day 1 (µg/m^3)	Day 2 (µg/m^3)	Average (µg/m^3)
S1	184.25	220.57	202.41
S2	294.61	195.48	245.05
S3	257.56	284.76	271.16
S4	323.67	235.35	279.51
S5	433.61	400.20	416.91
S6	214.27	246.13	230.20
S7	262.64	331.08	296.86
S8	171.86	186.97	179.42
S9	179.62	156.97	168.30
S10	166.31	159.86	163.09

these breach of set limit could be as a result of their close proximity to the mixing point of the raw material. For TSP, in all sampling point except S8 day 2 measurement, S9 and S10 were the set limit breached. The measured TSP been above the set limit is as a result of dust resuspension which is peculiar to road construction.

Table 5 and Table 6 shows the toxicity potential of the 24-hour averaging period extrapolated VOC and TSP concentrations. The toxicity potential for VOC in all the sampling points were below unity.

Table 5 Computed Toxicity Potential of the 24-hr VOC at the study area

Sampling Points	Day 1 (ppm)	Day 2 (ppm)	Average (ppm)
S1	0.0742	0.0788	0.0765
S2	0.1067	0.1207	0.1137
S3	0.3203	0.3297	0.3250
S4	0.2878	0.3110	0.2994
S5	0.4272	0.4550	0.4411
S6	0.3760	0.3853	0.3807
S7	0.2228	0.2275	0.2252
S8	0.2460	0.2647	0.2554
S9	0.0557	0.0650	0.0604
S10	0.0695	0.0742	0.0719

Table 6 Computed Toxicity Potential of the 24-hr TSP in the study area

Sampling Points	Day 1 (μg/m^3)	Day 2 (μg/m^3)	Average (μg/m^3)
S1	0.7370	0.8823	0.8096
S2	1.1784	0.7819	0.9802
S3	1.0302	1.1390	1.0846
S4	1.2947	0.9414	1.1181
S5	1.7344	1.6008	1.6676
S6	0.8571	0.9845	0.9208
S7	1.0506	1.3243	1.1875
S8	0.6874	0.7479	0.7177
S9	0.7185	0.6279	0.6732
S10	0.6652	0.6394	0.6523

Using the computed average the minimum toxicity potential for TSP is at S10 while the maximum was obtained at S5. The reason for this trend might be as earlier adduced for the measured TSP levels.

As indicated above, TP above unity poses great health challenges to the site workers where such is obtained. The highest TP at S5 which is at the middle the road construction calls for major concern since most construction workers will be exposed to the emission of TSP because most activities is concentrated at this point. The traffic gridlock being daily experienced along this road makes it more important for adequate attention to be given to location S3, S4, S5 and S7 so as to reduce the period transporters and site workers should be exposed to this degraded air quality. Diesel vehicle engines contribute significantly to ambient concentration of TSP. This can be controlled by making sure that vehicles manufacturing industries produce cars which filters it exhaust so as to reduce the emission of TSP and also the use of asphalt emulsions in place of cutback asphalt for road pavement.

4. CONCLUSIONS

The concentration of measured VOC and TSP showed great variations. The concentration of measured VOC ranged 1.20 – 9.80 ppm while that of TSP were 213.50 – 589.78 μg/m^3. The toxicity potential of Sampling point S3, S4, S5 and S7 were above unit using the FEPA set limit of 250 µg/m^3

The largest contributor to VOC and TSP levels of ambient construction site atmosphere was the asphalt pavement activities. Emissions from asphalt pavement activities accounted for most the measured VOC concentrations. Therefore, asphalting activities can be a significant VOC source for the urban atmosphere in general, as most asphalt applications are done during summer season, when traffic activity is at minimum. VOC emissions are enhanced by warm temperatures however, the volatilization of asphalt compounds are at the maximum. Also dust resuspension is one of the major contributor to ambient concentration of particulate at road construction site. This study shows that it is necessary to protect both the road users and road construction works from pollution associated with road construction.

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