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MODEL PREDICTION OF POLLUTION STANDARD INDEX FORFIVE STANDARD POLLUTANTS: A TOOL FOR ENVIRONMENTAL IMPACT ASSESSMENT

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ABSTRACT: Modeling pollution standard index (PSI) in Choba townfor five standard pollutants (NO2, SO2, PM2.5, PM10 and O3)is presented. The method used involved sorting all pollutants considered into standard forms of measurements in line with the PSI breakpoints. Results showed that the most critical pollutants in Choba junction are PM10, SO2 and O3. From the 5 day field observations,PM10 showed hazardous PSI level of 352 once, SO2 showed very unhealthy PSI level twice (253 and 228) and O3 showed very unhealthy PSI level twice (227 and 221). PSI models were developed for SO2, PM2.5, PM10 and O3 and they showed high coefficient of correlation of 0.99, 0.98, 0.93 and 0.95 respectively. When compared with the PSI model for CO it was discovered that wind speed showed significance for only the CO PSI model. The summary of these results showed that human activities in junctions can affect the type of pollutant which determines the PSI health category. It is recommended that government policies regulating retail sellers around junctions should be strictly enforced especially in the evenings/night periods when the atmospheric stability impedes dispersion of pollutants.

Key words – Pollution Standard index, standard pollutants, EIA, Government policies, Chobajunction.

1. INTRODUCTION

The urban areas are notable for a lot of human activities and this can be easily seen in the roads and junctions as vehicles deaccelerate and accelerate to navigate through junctions. In developed countries there are specialized traffic instruments put in place to help handle the flow of traffic and government policies put on activities that can be tolerated within these junctions. These instruments to handle traffic are traffic lights, zebra crossing, cameras to monitor and capture traffic activities and government policies that control the activities of retail sellers. Adopting the pollution standard index (PSI) to categorize health impact of pollution on the environment, the pollutant with the highest PSI value is the major pollutant which is considered in giving the environment a health category.

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From Jones and Bernett (2008) it is learnt that urban areas have most of its pollution contributed from vehicular emission and so CO should be expected as the major pollutant because vehicles produce 57% CO, 32 % NO_2, 21% VOC, 1% SO_2,9% $PM_{2.5}$, 10% PM_{10} and 8% ammonia (U.S EPA, 2010). The question is, will the same trend be observed in developing countries where there are hardly specialized traffic instruments and poor or lack of Government policies to control retailers (see Plate 1). The Government policies to control human activities at road junctions in Nigeria are very poor and observations in Choba junction are a practical example;and the junction also serves as a market place. Retailers of different products, sell beside the roads and most of these retailers are food sellers who most times burn fossils in the course of their activities (see Plate 2).

Plate 1 Choba junction showing vehicles struggling to navigate through the junction without traffic lights or zebra crossing

Plate 2 Choba junction showing retail sellers by the side of the junction.

Works of Henshaw and others (2016) which is part 1 of this study have considered the effect of vehicular CO in Choba junction and this was done on the basis that CO is the pollutant with the highest concentration like the case of developed countries (Xie, 2008). His findings showed high PSI values of CO in the evening with PSI category of unhealthy impact. With these results they tried to recommend solutions by creating bypasses to reduce the traffic impact at Choba junction.

This work considers other pollutants such as SO_2, NO_2, O_3, $PM_{2.5}$ and PM_{10} which would enable the investigator confirm if CO pollutant has the highest PSI index as the case of developed countries and if the negative impact of pollution on the junction is caused mainly from vehicular traffic or other human activities on the junction.

2. MATERIALS AND METHOD

2.1 Study Area

The study area for this work is Choba junction which is one of the major junctions in Port Harcourt, Rivers State of Nigeria. The junction serves as an exit point towards the western part of Nigeria and it has very high traffic activities within it. Some of the major facilities which make Choba junction known for its high traffic activities are the University of Port Harcourt three campuses within 1.5km radius, teaching Hospital, Indomine factory and 3 mini motor park/travel terminals. Figure 1 presents an abridgedmap of the study area.

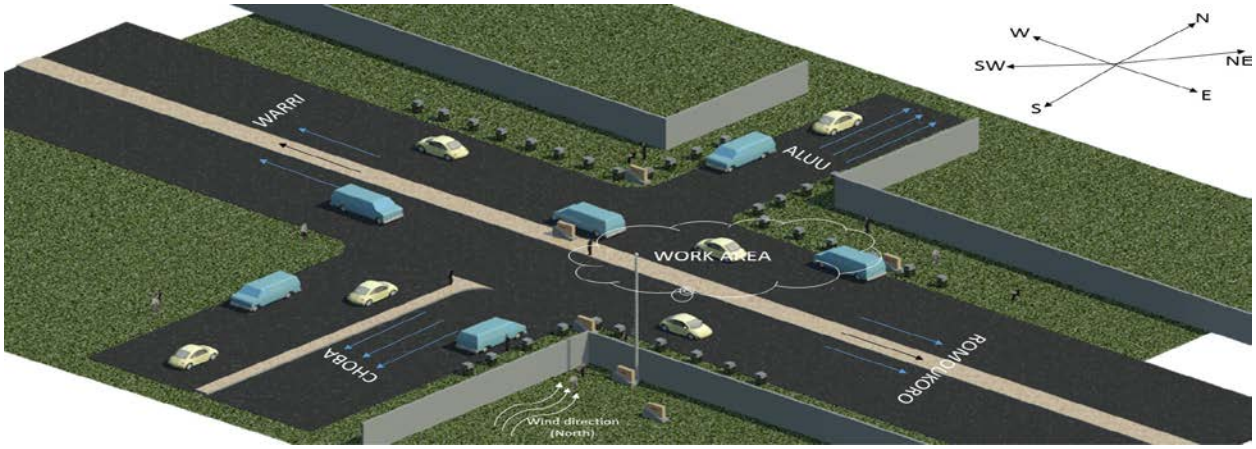

Figure 1 Map of the study area, Choba Junction, Port Harcourt Nigeria.

2.2 Measuring Equipment Used

The equipment used for this work are as listed in Table 1.

Table 1 List of Equipment for measurements

S/N	EQUIPMENT	NUMBER	PURPOSE
1	Surveillance cameras	4	To capture the traffic count
2	Surveillance camera recording station	1	To record the traffic activities
3	Weather station	1	To measure meteorological parameters
4	Solar radiation meter	1	To measure solar radiation
5	Aeroqual gas monitor	1	To measure pollutant gases
6	Aerocet Particulate matter	1	To measure particle matter

2.3 Procedure

A location was established at the middle of the junction where the air pollutants (CO, O_3, SO_2, and NO_2), solar radiation and Particulate matter ($PM_{2.5}$, PM_5, $PM_{7.5}$, and PM_{10}) where measured at every two hour interval for a 5 day duration. The surveillance cameras were mounted on a 5 metre pole by the side of the junction with the direction of each camera facing north, south, east and west respectively. The cameras were all connected to the recording station which was mounted in a temporary tent office. The weather station was also mounted on a 12 metre pole at the edge of the junction with its receiver mounted in the temporary tent office.

3. RESULTS AND DISCUSSION

3.1 Results and Analysis

A five day field observations atChoba junction covered traffic counts, solar radiation, wind speed and six pollutants as presented in Table 2. Table 3 showsPSI breakpoints used in defining six pollutants and Table 4 shows different colour codes to identify different PSI categories.

Table 2 Field observations of all pollutants from the study area

TIME	DAY	TRAFFIC COUNT	**SR** W/m^2	**WS** m/s	SO_2($\mu g/m^3$)	NO_2($\mu g/m^3$)	**CO** (mg/m^3)	O_3 ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10}($\mu g/m^3$)
10:00	MON	3378	240.1	4.8	940	122	0	380	33.4	102.3
12:00		3228	175.9	4.8	20	0	0.8	320	22.1	38.8
14:00		3158	372	8	160	125	5.2	20	28.8	207
16:00		3066	950.2	6.4	1440	160	4.7	20	16.2	116.8
18:00		2759	0.9	3.2	1370	69	22.5	30	50.7	220.1
20:00		1518	0	0	1610	126	12.2	270	88.7	276
22:00		822	0	0	2990	38	8.1	380	51.4	413.5
6:00	TUE	2298	0	0	610	55	10.3	270	113.2	330
8:00		3436	280	4.8	570	140	0.7	310	80.3	221
10:00		3556	350.9	9.7	460	78	0	260	26.1	171.4

12:00		3236	413.8	8	0	89	4	350	14.3	137
14:00		3470	1220	11.3	0	223	2.1	310	23	125.3
16:00		2999	600	12.9	170	56	15.1	350	35.4	261.9
18:00		2734	14	4.8	3370	99	15.5	490	38.7	251.5
20:00		1450	0	1.6	770	78	2.3	330	49.4	466
22:00		689	0	1.6	140	86	6.1	340	40.3	170.5
6:00	WED	2176	0	1.6	1350	76	5.8	320	99.1	1031.6
8:00		3393	240.6	4.8	1050	94	1.6	290	133.8	528
10:00		3522	151.2	4.8	0	49	0	320	53.4	511.5
12:00		3372	1025	6.4	300	172	10.5	380	33.6	388.5
14:00		3357	83	12.9	0	107	3.4	320	33.8	224.3
16:00		3104	37.8	6.4	1120	81	6.2	310	40.1	90.7
18:00		3070	12.4	1.6	2290	46	12.7	310	235.4	549.7
20:00		1614	0	0	1410	97	18	340	62.5	557.8
22:00		830	0	0	440	86	9.9	310	109.3	281.6
6:00	THUR	2204	0	0	1190	78	11.1	290	244.8	428.9
8:00		3416	14.1	0	2260	107	23.5	260	194	310.2
10:00		3377	21.9	1.6	400	163	7.1	360	29.1	59.6
12:00		3284	102	0	330	155	6.5	350	24.5	59.1
14:00		3252	250	4.8	760	150	3	390	58.3	358.9
16:00		3179	170.1	3.2	1440	144	10.4	370	25.5	83.5
18:00		2855	16	1.6	1760	81	28.3	330	70.3	193
20:00		1489	0	0	690	121	4.6	340	108.4	513.9
22:00		893	0	1.6	320	990	1.8	350	57.1	316.6
6:00	FRI	2301	0	0	840	105	6.1	290	121.9	451.3
8:00	8	3926	60.2	0	540	112	8.4	270	130.8	307.1
10:00	10	3754	341	1.6	0	162	10.2	350	72	408.6
12:00	12	3292	1092	4.8	0	190	3.7	380	43.5	145.8
14:00	2	3597	639	3.2	600	231	15.9	420	63.3	341.9
16:00	4	3468	422.5	11.3	1160	125	11.7	340	69.5	171.7
18:00	6	3192	79.2	4.8	1570	88	21.7	350	50.6	205.8

±SR-solar radiation; WS-wind speed

Table 3 Pollution standard index breakpoints for standard pollutants.

Index category	PSI	24-hr $PM_{2.5}$ ($\mu g/m^3$)	24-hr PM_{10} ($\mu g/m^3$)	24- hr SO_2 ($\mu g/m^3$)	8-hr CO (mg/m^3)	8-hr O_3 ($\mu g/m^3$)	1-hr NO_2 ($\mu g/m^3$)
Good	0-50	0-12	0-50	0-80	0-5	0-118	
moderate	51-100	13-55	51-150	81-365	5.1-10	119-157	
unhealthy	101-200	56-150	151-350	366-800	10.1-17	158-235	1130
Very unhealthy	201-300	151-250	351-420	801-1600	17.1-34	236-785	1131-2260
	301-400	251-350	421-500	1601-2100	34.1-46	786-980	2261-3000

Hazardous	401-500	351-500	501-600	2101-2620	46.1 – 57.5	981-1180	3001-3750

CPSI (2014).

Table 4 PSI colour Codes

S/N	PSI code	Colour	Health concern
2	0-50	green	good
5	51-100	yellow	moderate
7	101-150	orange	Unhealthy for sensitive groups
8	151-200	red	unhealthy
9	201-300	purple	very unhealthy
11	301-500	maroon	hazardous

Source – Zagha and Nwaogazie (2015)

The PSI can be computed with different pollutant concentrations and the linear interpolation function is presented as Equation (1):

$$I_P = \frac{I_H - I_L}{BP_H - BP_L}(C_P - BP_L) + I_L \quad \text{.......Equation (1)}$$

Where I_P = the index of pollutant p; C_P= rounded concentration of pollutant considering; BP_H = the breakpoint that is greater or equal to $C_P(upper\ limit)$; BP_L= the breakpoint that is less than or equal to C_P(lower limit); I_H=the PSI value corresponding toBP_H ; I_L = the PSI value corresponding to BP_L

With Equation (1) and the observed concentrations of pollutants monitored from the field, Table 5 is generated to show the PSI categories. Extracting the daily maximum concentrations of each pollutant, Table 6is also presented.

Table 5PSI categories for pollutants

TIME	MON	24 HOUR $PM_{2.5}$	PSI	24 HOUR PM_{10}	PSI	8 HOUR CO	PSI	8 HOUR O_3	PSI	HOURLY NO_2	PSI	24 HOUR SO_2	PSI
10:00										122	50		

12:00										0	50		
14:00						2	20	240	202	125	50		
16:00										160	50		
18:00										69	50		
20:00										126	50		
22:00		41.614286	85	196.35714	124	11.875	129	226.67	190	38	50	1218.57	253
6:00	**TUE**									55	50		
8:00										140	50		
10:00										78	50		
12:00										89	50		
14:00						3.42	40	300	213	223	50		
16:00										56	50		
18:00										99	50		
20:00										78	50		
22:00		46.744444	91	237.17778	145	9.75	100	377.5	227	86	50	676.667	172
6:00	**WED**									76	50		
8:00										94	50		
10:00										49	50		
12:00										172	50		
14:00						4.26	50	326	218	107	50		
16:00										81	50		
18:00										46	50		
20:00										97	50		
22:00		89	136	462.63333	354	11.7	129	317.5	216	86	50	884.444	212
6:00	**THUR**									78	50		
8:00										107	50		
10:00										163	50		
12:00										155	50		
14:00						10.24	114	330	218	150	50		
16:00										144	50		
18:00										81	50		
20:00										121	50		
22:00		90.222222	138	258.18889	155	11.275	129	347.5	222	990	50	1016.67	228
6:00	**FRI**									105	50		
8:00	8									112	50		
10:00	10									162	50		
12:00	12									190	50		
14:00	2					8.86	90	342	221	231	50		
16:00	4									125	50		
18:00	6	78.8	126	290.31429	171					88	50	672.857	172

Table 6 Maximum daily pollutant PSI categories

S/N	DAYS	PSI $PM_{2.5}$	PSI PM_{10}	PSI SO_2	PSI CO	PSI O_3	PSI NO_2	MAXIMUM PSI
1	MON	85	124	253	129	202	50	253(SO_2)
2	TUES	91	145	172	100	227	50	227(O_3)
3	WED	136	354	212	129	218	50	354(PM_{10})
4	THURS	138	155	228	129	222	50	228(SO_2)

5	FRI	126	171	172	90	221	50	221(O_3)

3.2 Model development and verification

Works of Henshaw & others (2016) had proposed a PSI model for Carbon monoxide (CO) which was dependent on Traffic, solar radiation and wind speed. The contributing factor of each parameter in the model had also been estimated to show that each factor has a significant effect on the model. Adopting the techniques in the development of model 3 in works of Henshaw and others (2016), PSI models were developed for SO_2, NO_2, $PM_{2.5}$,PM_{10} and $O_{3.}$A typical example of the model development is demonstrated for SO_2 (Equation 2). Table 7 shows 24 hour mean, Table 8 shows summary of the regression model, Table 9 shows values of the predicted model and the observed readings and Figure 2 shows a plot of the observed PSI against predicted PSI for SO_2.

Table 7 Twenty-four (24) hour mean parameters for SO_2

S/N	PSI SO	MEAN TRAFFIC	MEAN SR	MEAN WS	MEAN TRAFFIC * MEAN SR
1	0	0	0	0	0
2	253	2562	248.4	3.9	636400.8
3	172	2652	320	6.08	848640
4	212	2716	172	4.28	467152
5	228	2661	63.8	1.42	169771.8
6	172	3362	376.3	3.67	1265120.6
7	500	5704	0	0	0

Table 8 Result summary for multiple regression of SO_2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.993987
R Square	0.98801
Adjusted R Square	0.96403
Standard Error	28.19719
Observations	7

ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	4	131033.6	32758.39	41.20129	0.023836
Residual	2	1590.163	795.0815		
Total	6	132623.7			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	7.443628	26.24098	0.283664	0.803336	-105.462	120.3494
Mean Traffic	0.08749	0.006987	12.52168	0.006317	0.057427	0.117553
Mean Sr	1.944278	0.967679	2.009218	0.182255	-2.21931	6.107865
Mean Ws	-23.311	18.16535	-1.28327	0.328011	-101.47	54.84822
Traffic * Sr	-0.00061	0.000249	-2.46445	0.132661	-0.00169	0.000458

The model for SO_2 is presented as Equation (2)

$PSI_{SO_2} = 7.4 + 0.09 * mean\ traffic + 1.9 * mean\ SR - 23.3 * mean\ WS - 0.00061 * traffic * SR$ ……………………………. … Equation (2)

Table 9 Observed (actual) against predicted PSI values of SO_2

S/N	Observed (actual)	predicted
1	0	7.443628
2	253	235.3830352
3	172	202.181748
4	212	194.694164
5	228	227.5838164
6	172	175.8746434
7	500	506.372508

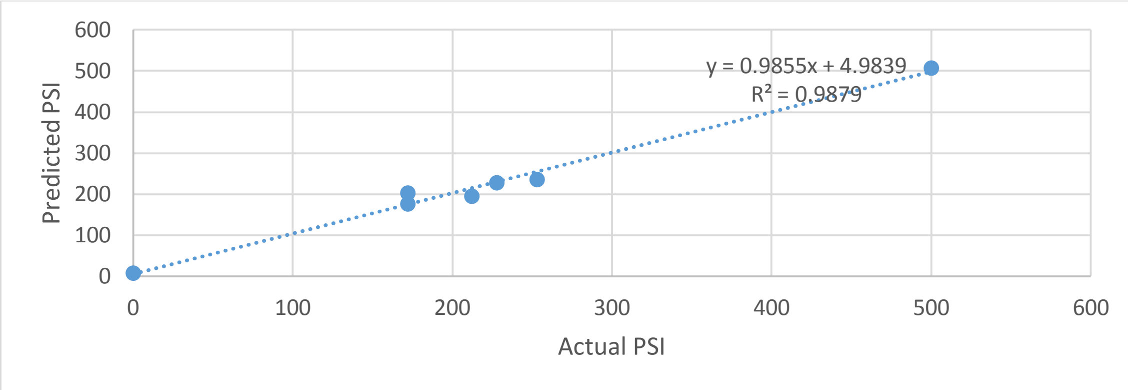

Figure 2 Plot of model verification of PSI model for SO_2.

The same technique was adopted in the development of PSI models for the other pollutants and Table 10 shows the summary.

Table 10 Summary of PSI developed models

S/N	Pollutant	PSI model	Goodness of fit, R^2 on development	Goodness of fit, R^2 on verification
1.	SO_2	$PSI_{SO_2} = 7.4 + 0.09 * mean\ traffic + 1.9 * mean\ SR - 23.3 * mean\ WS - 0.00061 * traffic * SR$	0.99	0.99
2.	O_3	$PSI_{O_3} = 14.19 + 0.08 * mean\ traffic + 0.68 * mean\ SR - 2.24 * mean\ WS - 0.0003 * traffic * SR$	0.95	0.95
3.	PM_{10}	$PSI_{PM_{10}} = -16.48 + 0.09 * mean\ traffic - 4.24 * mean\ SR - 90.33 * mean\ WS - 0.0009 * traffic * SR$	0.93	0.93
4.	$PM_{2.5}$	$PSI_{PM_{2.5}} = -21.64 + 0.09 * mean\ traffic - 0.44 * mean\ SR - 3.40 * mean\ WS - 0.00003 * traffic * SR$	0.98	0.97

3.3 DISCUSSION

The standard pollutants (Leton, 2005) have all been considered atChoba junction. Analysis has shown that carbon monoxide is not the most critical pollutant which determines the PSI category (see Figure 3). This contradicts the assumption made by Henshaw and others (2016) that carbon monoxide (CO) should be the most critical pollutant as in the case of developed countries. Table 11 shows a breakdown of U.S EPAs (2010) pollutants and possible sources with percentage expected.

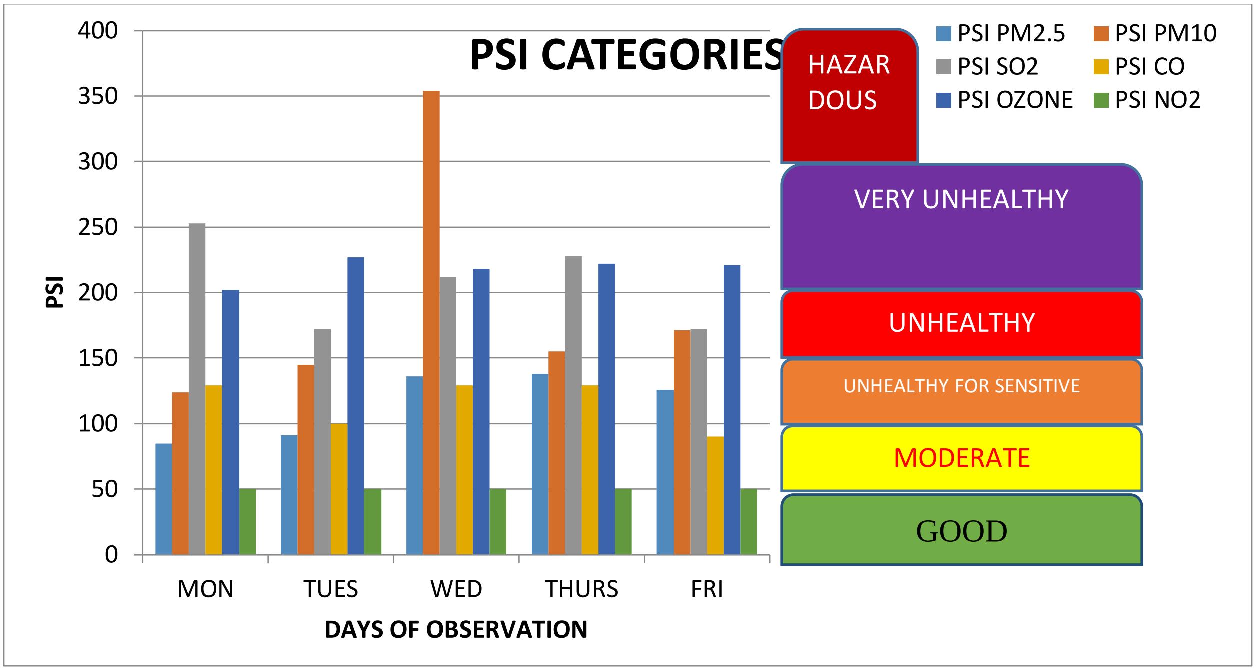

Figure 3PSI categories for Choba junction

Table 11U.S EPA sources of pollutants with percentage expected

S/N	SOURCES	NO_2 %	SO_2 %	$PM_{2.5}$ %	PM_{10} %	CO %
1.	Highway vehicle	32	1	12	9	57
2.	Non-road mobile sources	26	4	28	16	26
3.	Stationary fuel combustion	33	85	15	20	8
4.	Industrial and other sources	9	10	45	55	9

Source- Extracted from U.S EPA (2010)

From Table 6 and Figure 2 it is seen that the most critical pollutants that determine the PSI health category in Choba junction are SO_2, O_3 and PM_{10}. From Table 11 very high SO_2 should be expected from stationary fuel combustion and it is very abnormal that this high concentration is recorded in Choba junction. This confirms the effect of human activities at the junction such as burning of coal to heat up meat and running of generators to illuminate shops. It is also expected that very high PM_{10}(see Table 11) shouldcome from industrial areas but that is not the case in Choba junction.

Most of the contributed PM_{10} results from burning of waste which the sellers accumulate in the course of their activities during the day. The burnt waste generates high concentrations of PM_{10} in theatmosphere until sufficient atmospheric conditions come to disperse them (Henshaw& others, 2015; Ashrafi and Hoshyaripour, 2008; Zoras and others, 2006; Muhan and others, 1998; Ludwig, 1976; Iqbal, 1983; Sucevic and Djurisic, 2012).

The study on Choba junction has confirmed that ozone can be formed with very little NO_2. This little NO_2 combines with VOCs and sunlight to form very high unhealthy concentrations of ozone. Though field measurements did not cover VOCs in this study, works of Schneidemesser and others (2010) have confirmed strong positive correlations between VOCs and CO. With the high concentration of CO observed in the study area, it is certain that there is also high concentration of VOCs. Henshaw and others (2015) have pointed out very high solar radiation in this part of the world and this is also observed as an ingredient to the high ozone production. From observations in a crude oil extracting area (Abali, 2015), high amounts of NO_2 was recorded and ozone concentration was not as high as expected when compared to the concentrations noted in Choba with little NO_2 (see Table 12).

Table 12 Observations of Ozone production in oil and Non-oil extracting areas

S/N	LOCATION	NO_2 (mg/m^3)	CO (mg/m^3)	SOLAR RADIATION W/m^2	O_3 (mg/m^3)
1	Choba	0.099	15.5	1220	0.49
2	Obite$^{\pm}$	33.44	32.7	1049	0.64
3	Ebocha$^{\pm}$	19.1	4	100	0.36
4	Mgbede$^{\pm}$	33.3	0.034	126	0.36

5	Idu-1±	19.4	28.5	1080	0.49
6	Idu-2±	19	12.6	1020	0.61

±Crude oil extracting areas in Niger delta, Nigeria.

Given the pollutants concentration distribution (Table 12), it is fair to state that an unhealthy level of ozone formation only requires very little amounts of NO_2 or VOC. Improving driving patterns and providing bypasses will help reduce the air pollution incidence in Choba junction (Ozguvenand others, 2013; Hoglund and Nittymaki, 2008). However, if simple traffic instruments like traffic lights and zebra crossing are not put in place, then the small volume of vehicles that come to the junction can still cause a pollution episode.

From the PSI models developed, very high goodness of fit, R^2 were attained (see Table 10). The PSI model for NO_2 was not possible because PSI for NO_2 throughout the period of observation was 50 (good). At a more detailed look at the statistical parameters of the model development (see Table 13), it is seen that only the PSI model for carbon monoxide (CO)attains significant level for wind speed (Henshaw & others, 2016). It is for this reason that even with the high emission rate of carbon monoxide CO) from vehicular traffic, it is still not the most critical pollutant in Choba junction (see Table 6).

Table 13 Significance of Parameters in developed PSI models

S/N	**PSI Model development for pollutant**	**t-critical ($t_{0.95}$)**	**Estimate t**		
			Traffic	**Solar radiation**	**Wind speed**
1.	SO_2	1.94±	***12.52***	***2.00***	-1.3
2.	O_3	1.81±	***10.65***	***1.89***	-0.50

3.	PM_{10}	1.94±	***4.75***	-1.65	1.87
4.	$PM_{2.5}$	1.94±	***8.50***	-0.30	-0.12
5.	CO	1.81±	***8.00***	***1.82***	***-2.87***

±Extracted from Nwaogazie (2011). Bold numbers in italics are significant.

4. CONCLUSION

Based on the field observations and data analysis, the following conclusions can be drawn from this study:

i) PSI models have been developed for SO_2, $PM_{2.5}$, PM_{10} and O_3 and they attained very high goodness of fit, R^2;

ii) Carbon monoxide (CO) is not the most critical pollutant to look for in junctions of developing countries with poor traffic instruments as in Choba junction without traffic light, Zebra crossing, etc;

iii) Contaminants such as SO_2, O_3 and PM are the most critical pollutants that determine the PSI health categories in Choba junction;

iv) Sulphur dioxide, SO_2 and PM emissions are independent of traffic from vehicles but they are rather caused by other human activities around the junction such as burning of fossils and solid waste which are as a result of poor government policies;

v) Very little concentration of NO_2 or VOC is required to produce very unhealthy concentration of Ozone (O_3); and

vi) Simple traffic instruments like traffic light and zebra crossing can help improve driving patterns at junctions and this invariably will reduce emissions from vehicles.

5. RECOMMEDATION

Given the trend of events and activities at Choba junction, it is true to state that other human activities beside vehicles can affect the environment more negatively. It is for this reason that Government needs to make policies regarding activities allowed at junctions. It would also be necessary for Government to put in place mechanisms to checks and monitor such policies and ensure their strict compliance.

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REFERENCE

1. Abali, H. (2015): Assessment of some pollutants from gas flaring in Ogba/Egbema/Ndonilocal government area of Rivers State. M.Sc Thesis work ofthe University of Port Harcourt, Nigeria.
2. Ashrafi, K and Hoshyaripou, A. (2008): A model to determine atmospheric stability and its correlation with CO concentration. International scholarly and scientific research and innovation 2(8). Scholar.waset.org/1999.6/9007
3. CPSI (2014): Computation of the Pollutant standard index (PSI).Available at www.haze.gov.sg.
4. Henshaw, T., Nwaogazie, I.L. and Weli, V. (2015): Modeling surface solar radiation using a cloud depth factor. International journal of recent scientific research. Vol 6(10):6562-6569.

5. Henshaw, T., Nwaogazie, I.L. and Weli, V (2016): Model prediction of pollution standard index (PSI) for carbon monoxide: A tool for environmental impact assessment. British Journal of Applied Science and Technology (BJAST), Vol. 12(3)
6. Hoglan,P and Nittymaki, J. (2008). Estimating vehicle emissions and air pollution related to driving patterns and traffic calming. Conference for urban transport systems, Lund, Sweden.
7. Iqbal, M. (1983): An introduction to solar radiation. Academic press. Toronto.
8. Jones and Berlett (2008) Chapter 2 - sources and emission of air pollution. Available at sample.jbpub.com/.
9. Leton, T. G. (2005): Pollution control Engineering. Pearl Publishers, Port Harcourt, Nigeria.
10. Ludwig, F. (1976): comparison of two practical atmospheric stability classification schemes in an urban application. j.Appl.Meteor., 15,pp. 11172-1176.
11. Muhan, M. and Siddiqui, T. (1998): Analysis of various schemes for the estimation of atmospheric stability classification. Atmospheric environment. Vol. 32, pp. 3775-3781.
12. Nwaogazie I.L (2011): “Probability and statistics for science and engineering practice”. University of Port Harcourt press, Port Harcourt, Nigeria.
13. Ozguven, E. ,Ozbay, K., and Iyer, S. (2013). A simplified emission estimation methodology based on MOVES to estimate vehicle emissions from transportation assignment and simulation models. 92th meeting of the Transport and research board, Washington D.C.
14. Schneidemesser, E, Monks, P. and Plass-Duelmer, C.(2010): Global comparison of VOC and CO observations in urban areas. Atmospheric Environment, 44:5053-5064
15. Sucevic, N. and Djurisic, Z. (2012): Influence of atmospheric stability variation on uncertainties of wind farm production estimation. European wind Energy conference and exhibition.
16. U.S EPA (2010): outdoor pollutant emissions. Available at www.epa.gov
17. Xie, X., Huang, Z., Wang, J., and Xie, Z. (2005): The impact of solar radiation and street layout on pollutant dispersion in street canyon. Science direct. 40, 201-212.
18. Zagha, O. and Nwaogazie, Ify L. (2015): Roadside Air Pollution Assessment in Port Harcourt, Nigeria, Standard Scientific Research and Essays, Vol. 3(3): 066-074, ISSN:2310 - 7502.
19. Zoras, S.,Triantafyllou, A, and Deligiorgi, D.(2006): Atmospheric Stability and PM_{10} concentration at far distance from elevated point sources in complex terrain: worst-case episode study. Journal of Environmental management, 80, pp.295-302.