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DISPERSION MODELLING OF AIR EMISSIONS FROM ALL CEMENT PLANTS IN NIGERIA

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ABSTRACT

This study assessed the impacts of criteria air emissions from cement plants on ambient air quality of their host communities. The three-step process used in this study includes emission inventory, determination of the ground level concentrations of the identified air pollutants in their vicinity of operations using the ISCST-3 AERMOD view atmospheric dispersion model and comparing the ground level concentrations with the emission standards of World Health Organization (WHO), World Bank and Nigeria's Ambient Air Quality standard.

For all the existing and proposed cement plants results showed that the predicted ground level concentrations for 24- hour averaging period of PM_{10}, SO_2 , NO_X and CO were in the range of0.0005 – 3.0 µg/m^3, 0.0004 – 2.0 µg/m^3, 0.015 – 92 µg/m^{3}and 0.012 – 46 µg/m^3 respectively. When compared with ambient air quality standards, it was observed that the ground level concentration of criteria pollutants which ranged 0.001 % – 122.66% of the set limit.

Keywords: Criteria Air Pollutants, Air Quality, ISCST-3, Cement Plants, Ground Level Concentration.

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1. INTRODUCTION

Air quality around cement industries in Nigeria is of great concern due to its negative impacts on human health, animals and the environment. Exposure to these air pollutant can cause both acute (short-term) and chronic (long-term) health effects (EPA, 2012). Studies by Al -Neaimi*et al.* (2001) have shown that adverse respiratory health effects seen in the people exposed to cement dust, exemplified in increased frequency of respiratory symptoms and decreased ventilatory function, thus are likely to be caused by exposure to cement dust. Cement dust contains heavy metals which could be hazardous to the biotic environment, with adverse impact on vegetation, human and animal health and ecosystems (Baby *et al*., 2008). The population most exposed to cement dust pollution includes workers in cement plants, families of workers living in staff houses and the entire host and neighboring communities. Children studying in the schools located in proximity to the cement factories are particularly disposed to cement dust exposure. Several studies have demonstrated linkages between cement dust exposure, chronic impairment of lung function and respiratory symptoms in human population (Singh and Pandy, 2011).

Environmental contaminations due to dust particle coming from cement production activities, quarrying, stone crushing and thermal power plant etc., has drawn much attention because of their serious pollution problems and threats they pose to the ecosystem. According to Panda*et al*., (1996), dust particulates cause large scale deforestation destruction of biota and other natural resources. Accretion of cement kiln dust in large quantities around cement plants cause's changes in soil properties and similarly such deposition may affect the growth and biochemical characteristics of field crops. Several health problems such as respiratory disorders and allergies are attributed to gaseous emissions. Inhalation of NO_X interferes with the function of the human respiratory system and worsens the health condition of asthma patients even at low concentrations (Vallero, 2008 and Cheremisin off, 2002). Increased SO_2 levels in the atmosphere are responsible for degradation of agricultural productivity and death of some plants in early stages (Smith, 1993; Nijs, 2002; NAPAP, 1990).Carbon monoxide can be absorbed from the lungs into the bloodstream, which bound itself with haemoglobin in the blood in place of oxygen, forming carboxyhaemoglobin. The carboxyhaemoglobin causes decreased oxygen carrying capacity of blood, thus inducing toxic effects which are dangerous to health in man (WHO, 1999).

The main objective of the present study was to determine the change in the ground level air quality within 50 km radiusof identified cement plants in Nigeria in order to assess the impacts of the country's cement industry on host communities.

2. METHODOLOGY

Study Area

The cement plant to be assessed in this study are located in Nigeria, Twelve (12) existing Cement plants and three (3) proposed Cement plants were identified and considered for analysis. Five of the existing cement plants are located in Ogun State while Kogi, Benue, Enugu, Sokoto, Gombe, Edo and Cross river states has one plant each. The three proposed plants are to be located in Kogi, Ogun and Cross River State (Figurre 1).

Figure 1: Existing and proposed Cement plant in Nigeria.

The three-step process used in this study includes emission inventory, determination of the ground level concentrations of the identified air pollutants associated with the cement plants within 50 kilometers radius of operation using the ISCST-3 AERMOD view atmospheric dispersion model and determination of air quality impact by comparing ground level concentrations with required emission standards including those of World Health Organization (WHO), World Bank and Nigeria's Ambient Air Quality standard (Table 1).

Table 1 Ambient Air Quality Standards

Pollutants	Averaging time	Maximum Concentration (µg/m^3)		
		World Bank	WHO (1999)	FMENV
CO	24-Hr			11400
NO_X	24-Hr	150	40	75-113
SO_X	24-Hr	125	20	26
PM_{10} ($PM_{2.5}$)	24-Hr	80	50(25)	
TSP	24-Hr	80		250

World Bank (2007), FMEnv (1991)

2.1. Emission Inventory

The study considered emissions from equipment associated with the identified cement plants production activities. The equipment identified were the kiln, clinker cooler and cement mill as the point sources of emission. These point sources are single identifiable sources of air pollution released to the atmosphere through well-defined stacks. The stack parameters serve as model input (Table 2 and Table 3). The common air pollutants from the industry include carbon monoxides (CO), oxides of nitrogen (NO_X), particulate matter (PM_{10}), and sulphur dioxide (SO_2). For these equipments, emission rates were estimated using emission factor approach (Equation 1) with emission factors obtained from USEPA, 1989.

$$E = A \times EF \quad (1)$$

Where,

E = the air pollutant emission rate from the equipment (ton/hr);

EF = the emission factor (ton/ton) and A = the activity rate (ton/hr)

Table 2 The Proposed Cement plant Stack Parameters

Plant Name	Stack	Discharge Temperature (^{o}k)	Stack Diameter (m)	Exit Velocity (m/s)	Release Height (m)	Location	
						X(m)	Y(m)
E-Block Cement Plant, Ogun State	Kiln	435	4.0	17	120	66223.08	75900.38
	Clinker cooler	463	1.5	12	35	67733.55	77788.45
	Cement mill 1	383	1.0	10	25	69621.62	76651.61
	Cement mill 2	383	1.0	10	25	67355.93	75145.15
	Cement mill 3	383	1.0	10	25	66600.70	76277.99
Unicem Mfamosing, Cross river State	Kiln 1	430	3.5	16.8	89	93422.83	145381.49
	Clinker cooler	458	2.6	11.8	62	95730.48	144804.58
	Cement mill 1	378	2.0	9.89	25.7	92845.92	146535.31
	Cement mill 2	378	2.0	9.89	25.7	96307.39	147689.14
CinaFina Cement Plant Ofu, Kogi State	Kiln 1	435	4.0	17	120	232578.37	98188.72
	Clinker cooler	463	1.5	12	35	232127.96	96837.50
	Cement mill 1	383	1.0	10	25	235731.23	95486.27
	Cement mill 2	383	1.0	10	25	234830.41	93234.23

2.2. Dispersion modelling

The ISC-AERMOD view air pollution modeling tool was employed in the dispersion modeling study, using air pollution emission rates and stack parameters (stack height, diameter, gas exit velocity, discharge temperature). The resulting 24-hr ground level concentrations of pollutants from the Cement plants were determined using the ISC-AERMOD view version 8.2.0 with number AER00005543. The ISC-AERMOD view is a user friendly interface for three U.S.EPA air dispersion models: ISCST3, ISC-PRIME and AERMOD developed specially for Microsoft Windows and runs under Windows 95/98/Me/NT/2000 and XP

Table 3 The Existing Cement plant Stack Parameters

Plant Name	Stack	Discharge Temperature (^{o}k)	Stack Diameter (m)	Exit Velocity (m/s)	Release Height (m)	Location	
						X(m)	Y(m)
Lafarge cement Ewekoro, Ogun State	Kiln	435	4.0	17	120	10058.08	86473.61
	Clinker cooler	463	1.5	12	35	99830.85	87984.07
	Cement mill 1	383	1.0	10	25	101718.98	86851.22
	Cement mill 2	383	1.0	10	25	102474.16	85718.38
	Cement mill 3	383	1.0	10	25	99453.24	87228.84
Lafarge (Lakatabu) Cement Plant, Ogun State	Kiln	757.35	6.2	30	157	83971.01	99690.14
	Clinker cooler	806.10	2.3	21	55	84726.24	98179.68
	Cement mill 1	666.82	1.9	17	45	82838.16	97802.07
	Cement mill 2	666.82	1.9	17	45	86236.70	97424.45
	Cement mill 3	666.82	1.9	17	45	85103.85	96291.60
Purechem cement Onigbedu, Ogun State	Kiln 1	435	2.6	17	30.7	97187.54	102333.45
	Kiln 2	435	2.6	17	30.7	97942.77	100822.99
	Kiln 3	435	2.6	17	30.7	96054.70	101578.22
	Clinker cooler	463	1.0	12	25	98698.00	101955.84
	Cement mill	383	1.2	10	28	97942.77	101578.22
Lafarge cement Shagamu,	Kiln 1	345	3.0	13.5	72	140235.69	81186.99
	Kiln 2	345	3.0	13.5	72	140990.92	81564.61

Plant Name	Stack	Discharge Temperature (^{o}k)	Stack Diameter (m)	Exit Velocity (m/s)	Release Height (m)	Location	
						X(m)	Y(m)
Ogun State	Clinker cooler 1	366	1.0	9.5	25	141746.11	81186.99
	Clinker cooler 2	366	1.0	9.5	25	139480.46	79298.91
	Cement mill 1	303	1.0	8	21	141368.54	79298.91
	Cement mill 2	303	1.0	8	21	139102.85	79676.53
	Cement mill 3	303	1.0	8	21	142501.39	80054.14
DangoteCement Plant, Ibeshe Ogun State	Kiln 1	1032	8.4	40.4	214	58670.78	109885.76
	Kiln 2	1032	8.4	40.4	214	60936.47	111018.60
	Clinker cooler	2198	6.3	56.9	150	60181.24	109508.14
	Cement mill 1	1818.6	5.1	47.5	124	62069.32	109508.14
	Cement mill 2	1818.6	5.1	47.5	124	59803.62	107620.07
	Cement mill 3	1818.6	5.1	47.5	124	61691.70	110263.37
Ashaka Cement Plant	Kiln1	275	2.2	10.7	57	102670.80	162856.05
	Kiln 2	275	2.2	10.7	57	104389.60	164145.15
	Clinker cooler	293	1.0	7.6	20	103530.20	162856.05

Table 3 The Existing Cement plant Stack Parameters (Contd)

Plant Name	Stack	Discharge Temperature (^{o}k)	Stack Diameter (m)	Exit Velocity (m/s)	Release Height (m)	Location	
						X(m)	Y(m)
Benue Cement Company (BCC) Benue State	Kiln 1	688.5	5.6	26.91	142.8	175380.09	126866.91
	Kiln 2	688.5	5.6	26.91	142.8	174994.48	127252.53
	Clinker cooler	146.7	4.2	37.99	100.2	176151.32	124938.84
	Cement mill 1	606.2	1.69	15.83	41.2	175765.70	123781.99
	Cement mill 2	606.2	1.69	15.83	41.2	177308.16	125324.45
Dangote Cement Plant, Obajana Kogi State	Kiln 1	1176.2	9.5	45.96	244	162314.61	201782.72
	Kiln 2	1176.2	9.5	45.96	244	162765.02	198629.86
	Kiln 2	1176.2	9.5	45.96	244	167719.52	197278.63
	Clinker cooler 1	1877.9	5.4	48.67	128	164116.25	197278.63
	Clinker cooler 2	1877.9	5.4	48.67	128	165467.47	197729.04
	Cement mill 1	776.7	2.2	20.28	52.7	168169.93	198179.45
	Cement mill 2	776.7	2.2	20.28	52.7	168620.34	199530.67
	Cement mill 3	776.7	2.2	20.28	52.7	169971.56	199080.27
	Cement mill 4	776.7	2.2	20.28	52.7	163215.43	196377.81
CCNN, Sokoto State	Kiln	172	1.4	6.7	35	160824.73	190843.52
	Clinker cooler	183	1.0	4.7	12.5	163234.37	189397.73
	Cement mill	152	0.4	4.0	10	162752.44	187470.01
Bendel Cement Plant, Edo State	Kiln	120	1.0	4.7	25	176456.49	178549.79
	Clinker cooler	128	0.4	3	9	178316.39	177061.87
	Cement mill 1	106	0.3	3	7	177200.45	175945.93
	Cement mill 2	106	0.3	3	7	177572.43	178177.81
Nigercem Cement Plant Nkalagu, Enugu State	Kiln	155	1.3	6	32	86753.73	80846.31
	Clinker cooler	165	0.5	4.3	11.3	88577.34	79630.98
	Cement mill 1	136	0.4	3.5	9.3	87361.60	80238.44
	Cement mill 2	136	0.4	3.5	9.3	87739.27	79214.51
	Cement mill 3	136	0.4	3.5	9.3	86435.32	79866.48

Plant Name	Stack	Discharge Temperature (^{o}k)	Stack Diameter (m)	Exit Velocity (m/s)	Release Height (m)	Location	
						X(m)	Y(m)
	Cement mill 4	136	0.4	3.5	9.3	88065.25	79866.48
	Cement mill 5	136	0.4	3.5	9.3	87413.28	80518.46
	Cement mill 6	136	0.4	3.5	9.3	89043.21	79540.50

3. RESULTS AND DISCUSSION

Table 4 and Table 5 summarizes the anticipated emissions from identified sources for the existing and proposed cement plants, respectively. Since investigation of the contribution of criteria air pollutants to the ground level concentrations in surrounding community is the focus of this study, the location of the nearest community to the plant guided in the choice of area of interest for the modelling exercise (0-50km). The prediction of impacts on air quality of the host or neighbouring community has been carried out by using ISCST-3 Regulatory Model which is based on the famous Gaussian Plume Dispersion. For the 24-hr averaging periods, the maximum concentrations were obtained and the predicted ground level concentrations of the air pollutants were compared with required emission standards of World Health Organization (WHO), World Bank and Nigeria's Ambient Air Quality standard.

Table 4 Calculated levels of criteria air pollutants from the existing Cement plants in Nigeria

Plant Name	Emission source	PM	CO	SO_2	NO_X	Lead
		ton/annum	ton/annum	ton/annum	ton/annum	ton/annum
Lafarge Ewekoro	Kiln	32400.00	62.4	3240	1800	36.00
	Clinker Cooler	115.20	-	-	-	-
	Cement mill	12288.00	-	-	-	21.60
Lafarge Lakatabu	Kiln	53995.20	104.64	5395.2	2995.2	59.52
	Clinker Cooler	144.00	-	-	-	-
	Cement mill	38376.00	-	-	-	18.72
PurechemOnigbedu	Kiln	86.40	0.1728	9.072	5.04	0.10
	Clinker cooler	0.31	-	-	-	-
	Cement mill	62.40	-	-	-	0.03
Lafarge Shagamu	Kiln	8928.00	34.56	2995.2	2131.2	28.80
	Clinker cooler	211.20	-	-	-	-
	Cement mill	12960.00	-	-	-	9.60
DangoteIbeshe	Kiln	319536.48	621.12	31953.6	17750.4	354.72
	Clinker cooler	1070.40	-	-	-	-
	Cement mill	271171.20	-	-	-	132.48
AshakaGombe State	Kiln1	43195.20	81.6	4315.2	2395.2	47.52
	Clinker cooler	76.80	-	-	-	-
	Cement mill	2912.64	-	-	-	1.39
BCC Benue State	Kiln	37795.2	72	3777.6	2097.6	41.76
	Clinker cooler	475.2	-	-	-	-
	Cement mill	80688	-	-	-	39.36
Unicem Cross River State	Kiln	134995.2	264	13497.6	7497.6	148.8
	Clinker cooler	182.4	-	-	-	-
	Cement mill	65928	-	-	-	32.16
Dangote Obajana	Kiln	129600	249.6	12960	7200	144
	Clinker cooler	480	-	-	-	-

Plant Name	Emission source	PM	CO	SO_2	NO_X	Lead
		ton/annum	ton/annum	ton/annum	ton/annum	ton/annum
	Cement mill	354240	-	-	-	172.8
CCNN, Sokoto State	Kiln	638.4	2.4	221.76	151.68	1.92
	Clinker cooler	7.2	-	-	-	-
	Cement mill	542.4	-	-	-	0.38
Bendel Cement, Edo State	Kiln	312.48	1.2	108.48	74.4	1.01
	Clinker cooler	3.36	-	-	-	-
	Cement mill	264	-	-	-	0.19
NigercemNkalagu,	Kiln	513.6	2.016	177.6	120	1.68
	Clinker cooler	5.76	-	-	-	-
	Cement mill	436.8	-	-	-	0.3264

Table 5 Calculated levels of criteria air pollutants from the proposed Cement plants in Nigeria

Plant Name	Emission source	PM	CO	SO_2	NO_X	Lead
		ton/annum	ton/annum	ton/annum	ton/annum	ton/annum
E-Block Cement	Kiln	25348.80	48	2534.4	1406.4	27.840
	Clinker Cooler	84.96	-	-	-	-
	Cement mill	18758.40	-	-	-	9.120
Unicem Cross River State	Kiln	134995.20	264	13497.6	7497.6	148.800
	Clinker cooler	182.40	-	-	-	-
	Cement mill	65928.00	-	-	-	32.160
Cina Fina Kogi State	Kiln	354.72	0.672	35.52	19.728	0.394
	Clinker cooler	1.20	-	-	-	-
	Cement mill	263.52	-	-	-	0.096

3.1. Predicted ground level concentrations

The modeling outputs from the ISC-AERMOD view run for all the predicted concentrations of air pollutants considered in this study are summarized with selected pages from the model run due to the large sizes of the model output. Identified impacts on ambient air quality in the environment around the study areas were also presented. The dispersion outputs for only 24-hour averaging period concentration from all existing and proposed cement plants are reported and summarized in Figures 2 – 19.

For Benue Cement Company (BCC), the 24-hour averaging periods concentration of PM_{10}, SO_2, NO_X and CO were predicted to be in the range of 0.2 - 2.0 $\mu g/m^3$ (Figure 2a), 0.08 -0.50 $\mu g/m^3$ (Figure 2b), 2.5 – 28 $\mu g/m^3$ (Figure 2c), and 2.3 – 16 $\mu g/m^3$ (Figure 2d) respectively. For Ashaka Cement Company, the 24-hour averaging periods concentration of PM_{10}, SO_2, NO_X and CO were predicted to be in the range of 0.11 -1.0 $\mu g/m^3$ (Figure 3a), 0.2 – 2.0 $\mu g/m^3$ (Figure3b), 6.0 – 73 $\mu g/m^3$ (Figure 3c), and 5.0 – 46.0$\mu g/m^3$ (Figure 3d) respectively. While for the CCNN, the 24-hour averaging periods concentration of PM_{10}, SO_2, NO_X, and CO were predicted to be in the range of 0.0025 – 0.01$\mu g/m^3$ (Figure 4a), 0.003 – 0.03 $\mu g/m^3$ (Figure 4b), 0.2 – 3.0 $\mu g/m^3$ (Figure 4c) and 0.2 – 2.0$\mu g/m^3$ (Figure 4d) respectively.

While for Edo Cement Company, the 24-hour averaging periods concentration of PM_{10}, SO_2, NO_X and CO were predicted to be in the range of 0.0027 – 0.03 $\mu g/m^3$ (Figure5a), 0.003 – 0.07 $\mu g/m^3$ (Figure 5b), 0.2 – 6.0 $\mu g/m^3$ (Figure.5c) and 0.15 – 4.0 /m^3 (Figure 5d)

respectively. For Nigercem, the 24-hour averaging periods concentration of PM_{10}, SO_2, NO_X and CO were predicted to be in the range of 0.002 – 0.02 µg/m^3 (Figure6a), 0.0004 – 0.01 µg/m^3 (Figure 6b), 0.015 – 0.3 µg/m^3 (Figure 6c) and 0.015 – 0.2 µg/m^3 (Figure 6d) respectively.

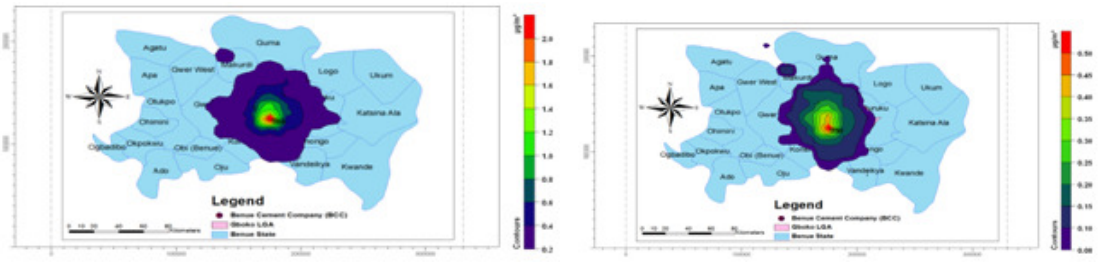
Cross River state has two cement plants, the existing and the proposed. For the existing Unicem cement plants, the 24 – hour averaging period ground level concentrations of PM_{10}, SO_2, NO_X and CO were predicted to be in the range of 0.2 – 2.0 µg/m^3(Figure 7a), 0.2 – 2.0 µg/m^3(Figure 7b), 4 – 92 µg/m^3(Figure 7c) and2.6 – 32 µg/m^3 (Figure 7d) respectively. Also, the 24 – hour averaging period ground level concentrations of PM_{10}, SO_2 , NO_X and CO were predicted to be of the range of 0.2 – 1.0 µg/m^3 (Figure 8a), 0.15 – 1.0 µg/m^3 (Figure 8b), 5 – 48 µg/m^3(Figure 8c) and 3 – 16 µg/m^3(Figure 8d) for the proposed Unicem plant respectively.

From the six cement plant in Ogun state, Lafarge Ewekoro, the 24 – hour averaging period ground level concentrations of PM_{10}, SO_2 , NO_X and CO were predicted to be in the range of 0.25 – 3.0 µg/m^3(Figure 10a), 0.05 – 0.20 µg/m^3(Figure 10b), 2 – 20 µg/m^3(Figure 10c) and1.5 – 6.0 µg/m^3 (Figure 10d) respectively. Likewise, Lafarge Lakatabu plant would generate the pollutants in the range of 0.15 – 1.0 µg/m^3 (Figure 11a), 0.06 – 0.4 µg/m^3 (Figure 11b), 2 – 19 µg/m^3(Figure 11c) and 1.8 – 11.0 µg/m^3(Figure 11d) respectively for PM_{10}, SO_2, NO_X and CO. For Purechem cement, the 24 – hour averaging period ground level concentrations of PM_{10}, SO_2 , NO_X and CO were predicted to be in the range of 0.0005 – 0.008 µg/m^3 (Figure 12a), 0.0008 – 0.01 µg/m^3 (Figure 12b), 0.03 – 0.6 µg/m^3(Figure 12c) and 0.02 – 0.30µg/m^3(Figure 12d). Equally, Lafarge Shagamu plant would generate 24 – hour averaging period ground level concentrations of PM_{10}, SO_2 , NO_X and CO in the range of 0.15 – 0.70 µg/m^3 (Figure 13a), 0.08 – 0.40 µg/m^3 (Figure 13b), 5.5 – 32 µg/m^3(Figure 13c) and 5 – 23 µg/m^3(Figure 13d) respectively. Also, Dangote cement plant, Ibeshe would generate a ground level concentrations of PM_{10}, SO_2 , NO_X and CO in the range of 0.55 – 2.0 µg/m^3 (Figure 14a), 0.4 – 1.0 µg/m^3 (Figure 14b), 8 – 27 µg/m^3(Figure 14c) and 6 – 17 µg/m^3(Figure 14d) for the 24- hour averaging time. The Proposed E-block cement plant would generate a ground level concentrations of PM_{10}, SO_2, NO_X and CO in the range 0.003 – 0.02 µg/m^3 (Figure 15a), 0.0015 – 0.02 µg/m^3 (Figure 15b), 0.13 – 2.0 µg/m^3(Figure 15c) and 0.15 – 1.0 µg/m^3(Figure 15d) respectively.

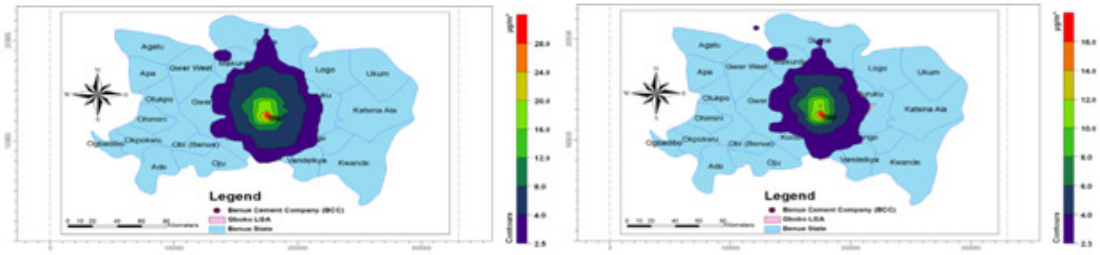
For the two cement plants in Kogi state, the existing Dangote cement plant in Obajana, 24 – hour averaging period ground level concentrations of PM_{10}, SO_2, NO_X and CO were predicted to be in the range of 0.14 – 0.50 µg/m^3 (Figure 16a), 0.13 – 0.40 µg/m^3(Figure 16b), 4.5 – 20 µg/m^3(Figure 16c) and 3.8 – 12.0 µg/m^3 (Figure 16d) respectively. Also, the 24 – hour averaging period ground level concentrations of PM_{10}, SO_2 , NO_X and CO are predicted to be in the range of 0.0008 – 0.02 µg/m^3 (Figure 17a), 0.0004 – 0.004 µg/m^3 (Figure 17b), 0.015 – 0.2 µg/m^3(Figure 17c) and 0.012 – 0.1 µg/m^3(Figure 17d) for the proposed Cina Fina cement plant.

3.2. Comparison with required standards

The maximum predicted Concentration of CO, SO_2 and NOx were compared with the FMEnv (1991) standard. The World Bank and WHO Standards were employed for PM_{10}since its standard does not exist in FMEnv (Table 6). The percentage concentration of the FMEnv

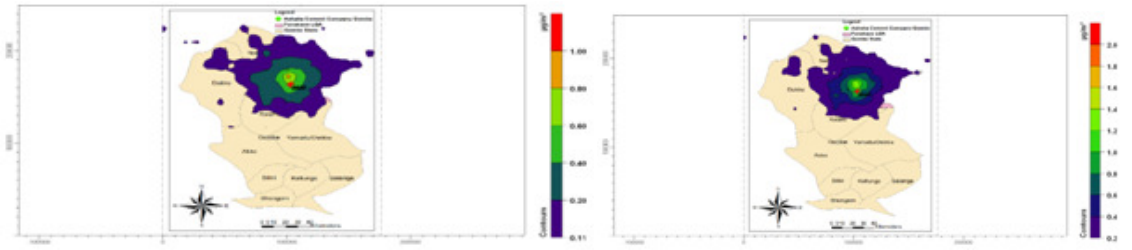


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

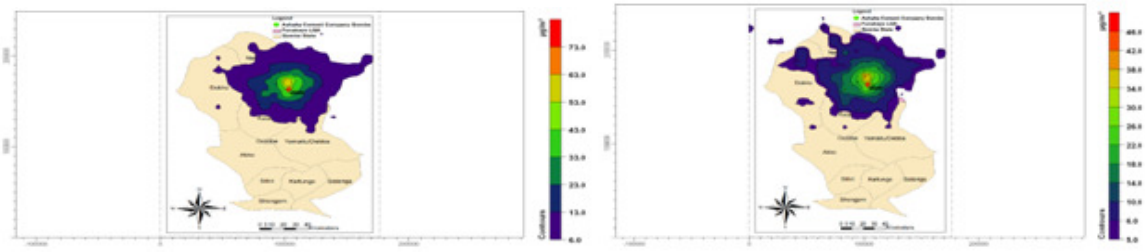


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 2: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from BCC, Benue State

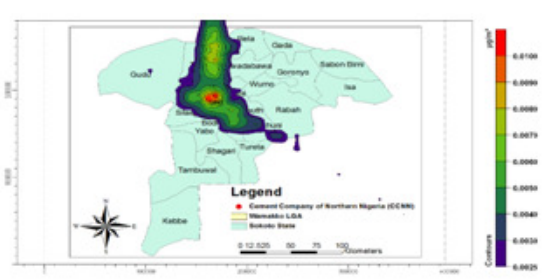


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

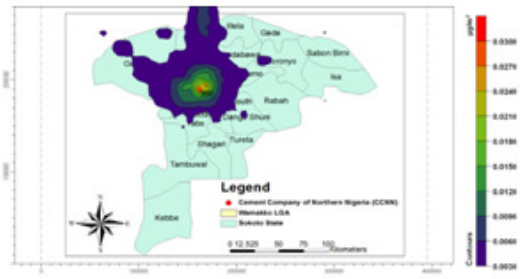


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

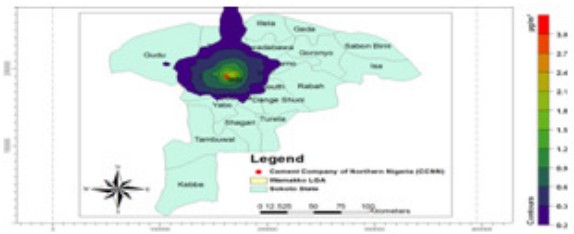
Figure 3: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Ashakacem, Gombe



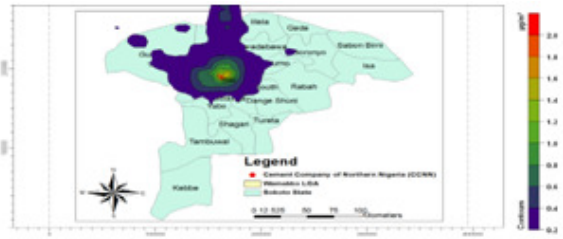
(a): Predicted 24-hr PM_{10} Concentrations



(b): Predicted 24-hr SO_2 Concentrations



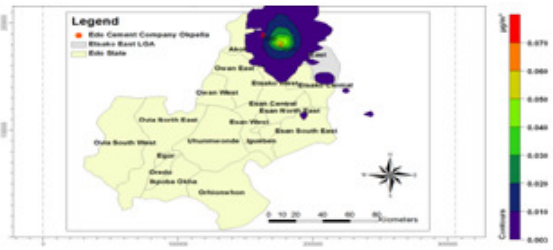
(c): Predicted 24-hr NOx Concentrations



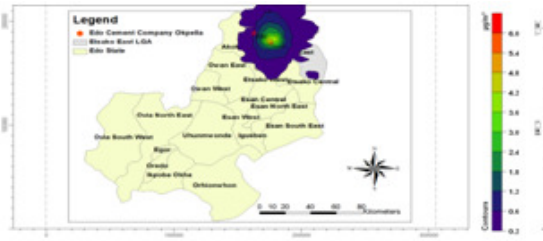
(d): Predicted 24-hr CO Concentrations

Figure 4: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from CCNN, Sokoto State

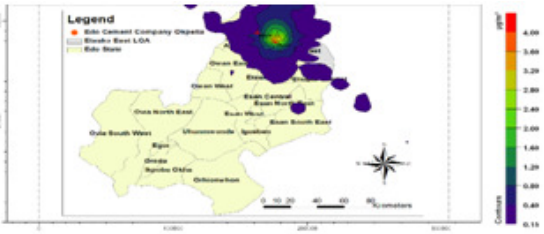
(a): Predicted 24-hr PM_{10} Concentrations



(b): Predicted 24-hr SO_2 Concentrations

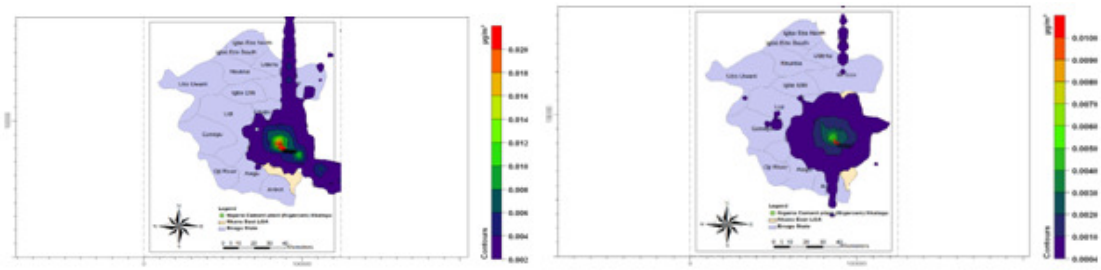


(c): Predicted 24-hr NOx Concentrations

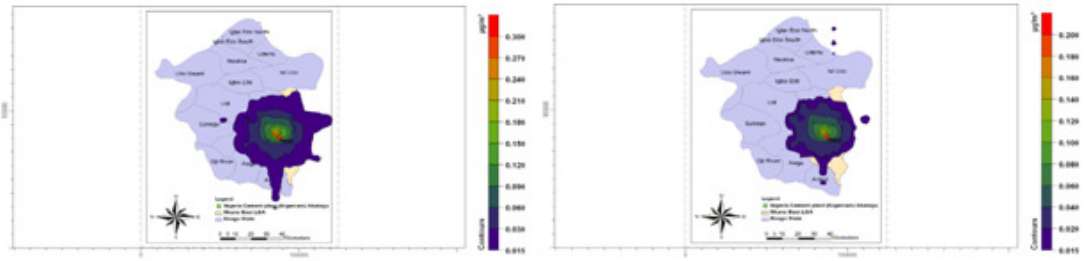


(d): Predicted 24-hr CO Concentrations

Figure 5: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Edo Cement Company

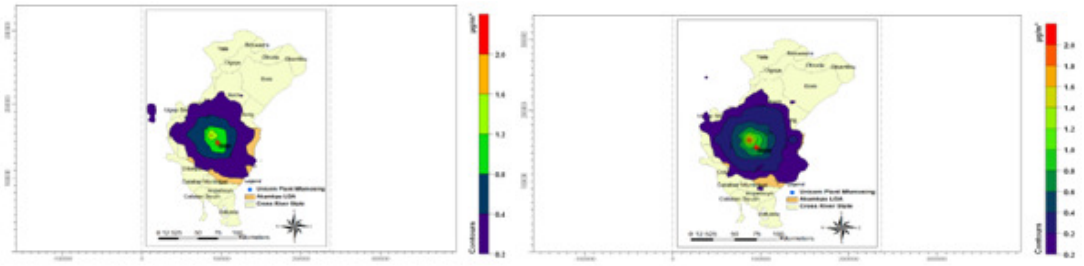


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

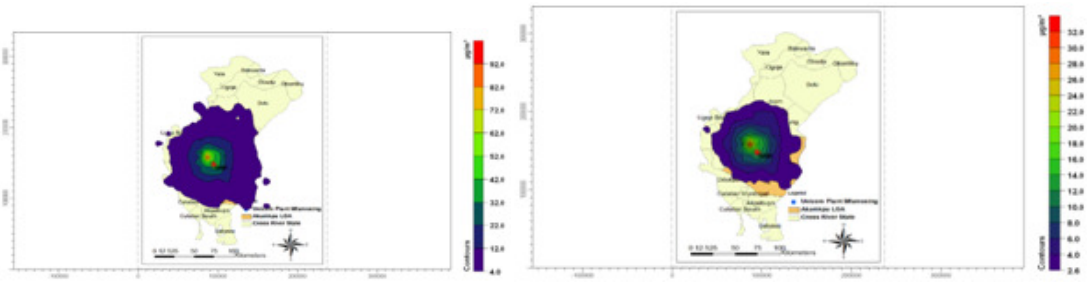


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 6: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Nigercem, Enugu State

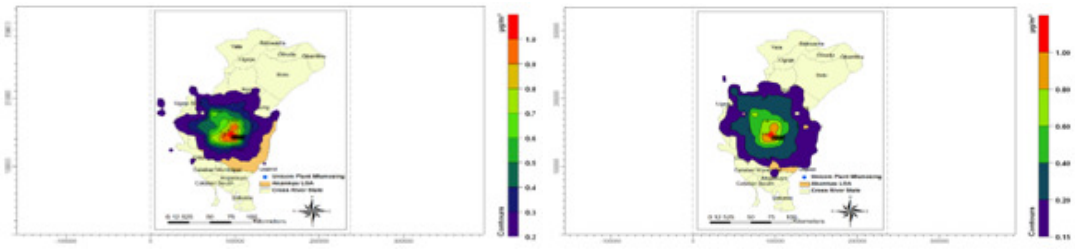


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

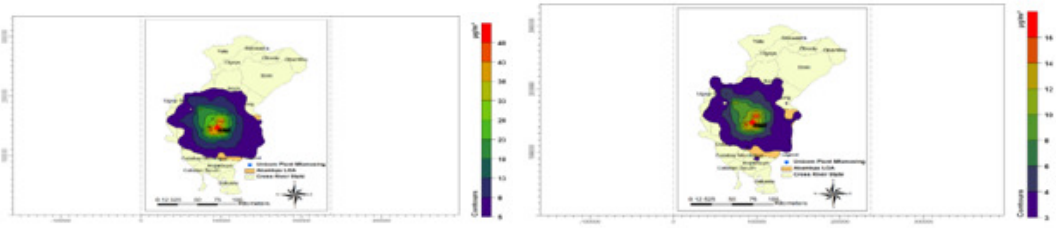


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 7: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from existing Unicem, Cross Rivers State

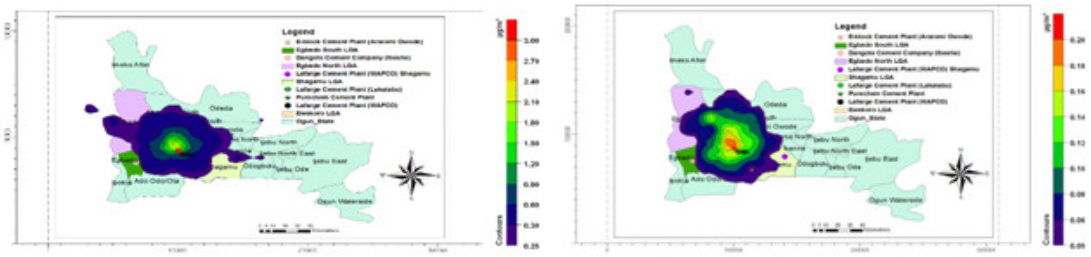


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

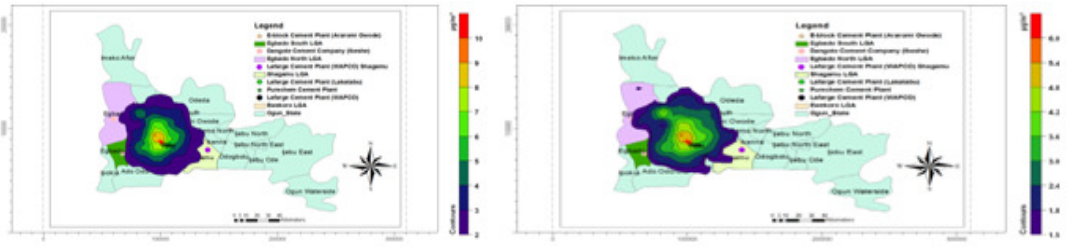


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 8: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from proposed Unicem, Cross Rivers State

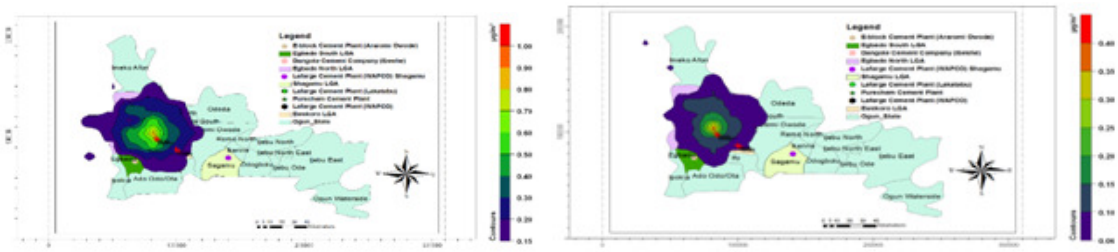


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

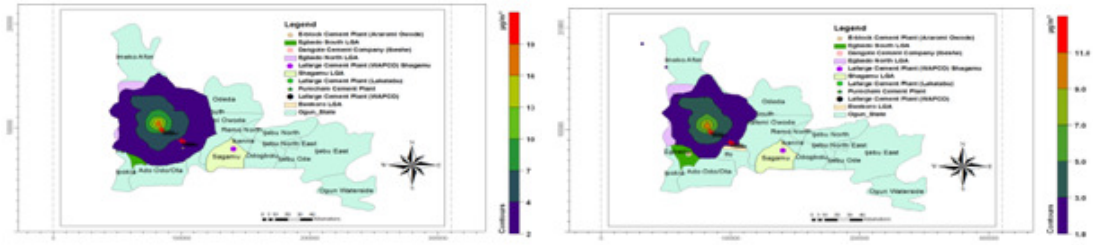


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 10: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Lafarge (WAPCO) Ewekoro, Ogun State

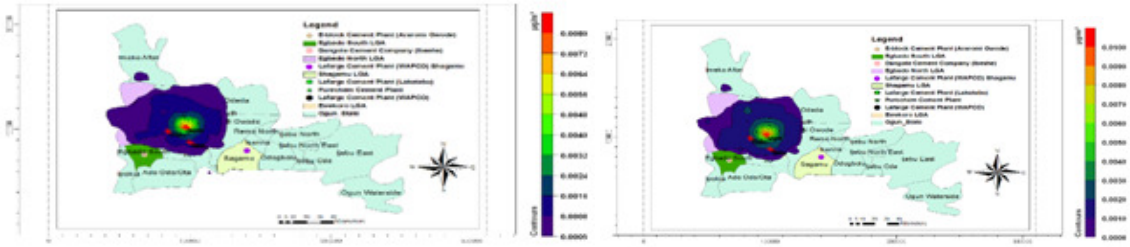


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

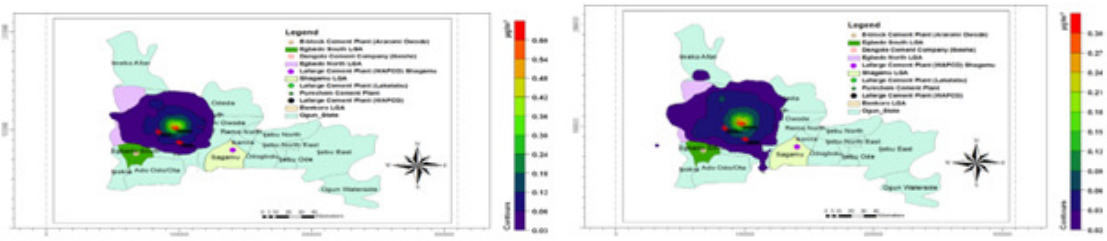


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 11: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Lafarge (WAPCO) Lakatabu Plant, Ogun State

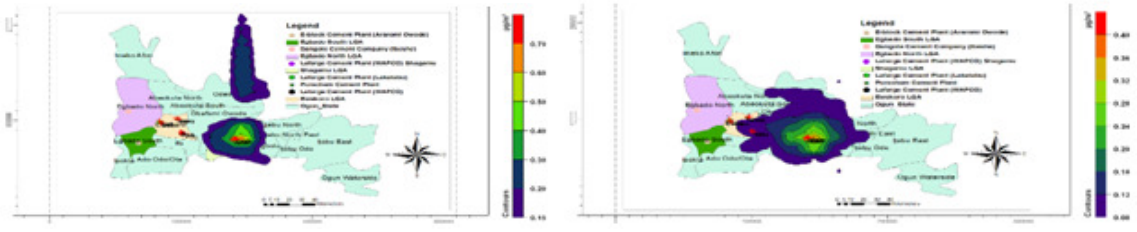


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

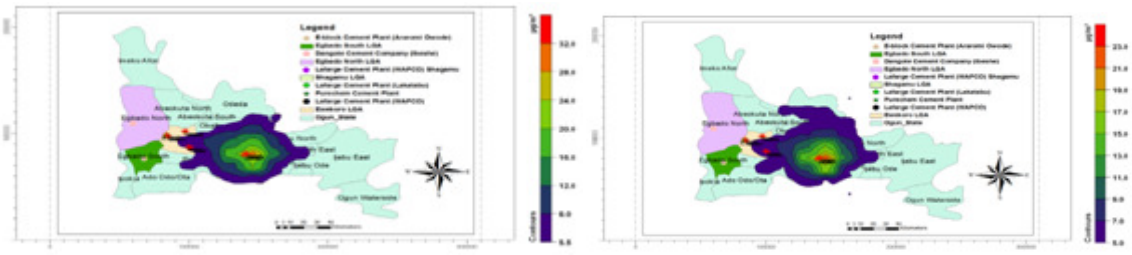


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 12: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Purechem, Onigbedu, Ogun State

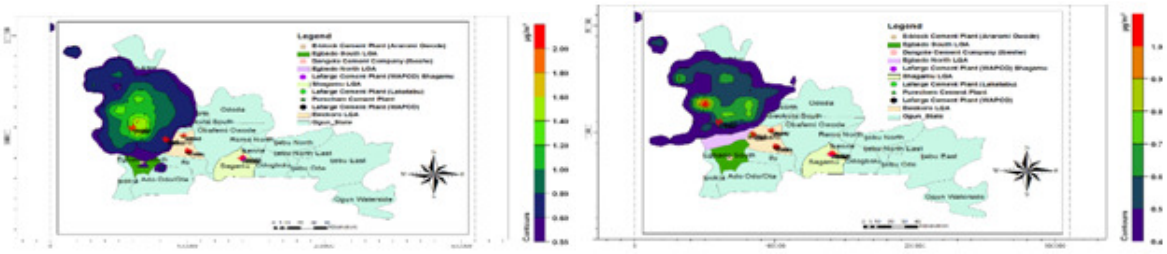


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

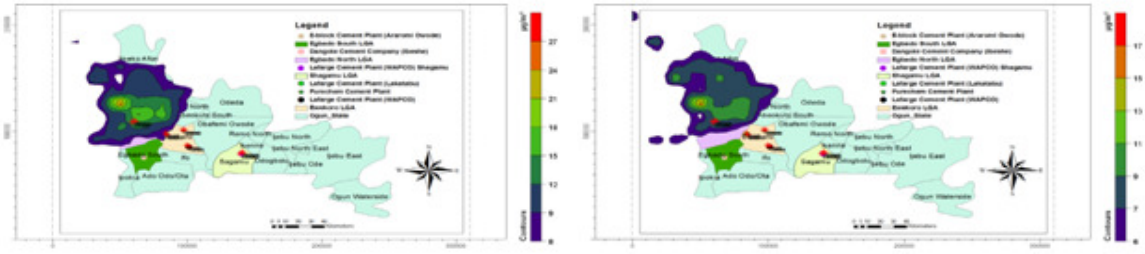


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 13: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Lafarge (WAPCO), Shagamu, Ogun State

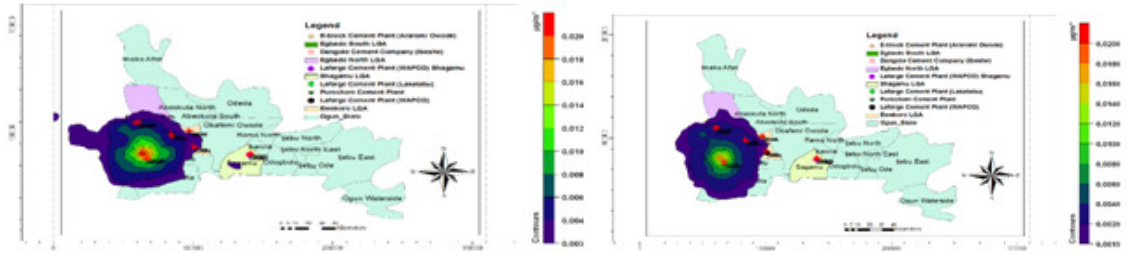


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

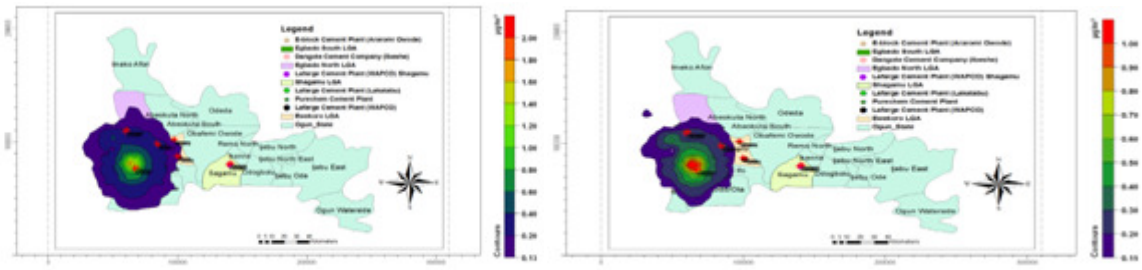


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 14: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Dangote Cement Plant Ibeshe, Ogun State

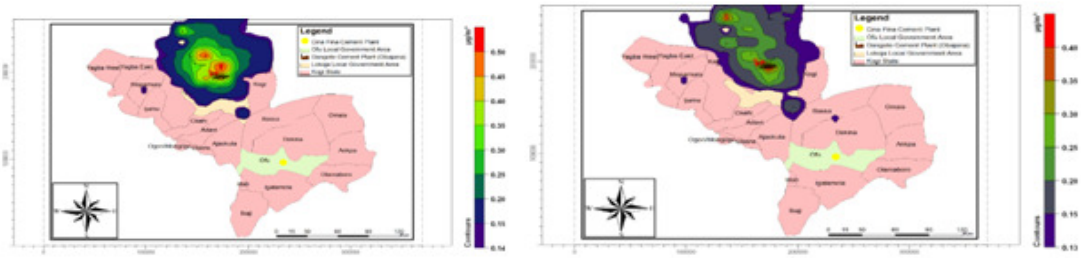


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

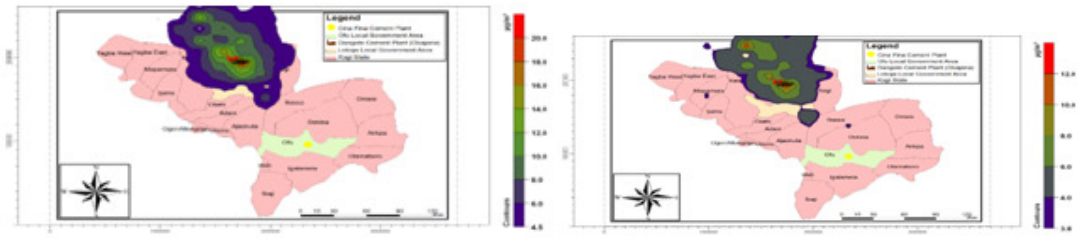


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 15: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from E-Block Cement Plant Araromi-Owode, Ogun State

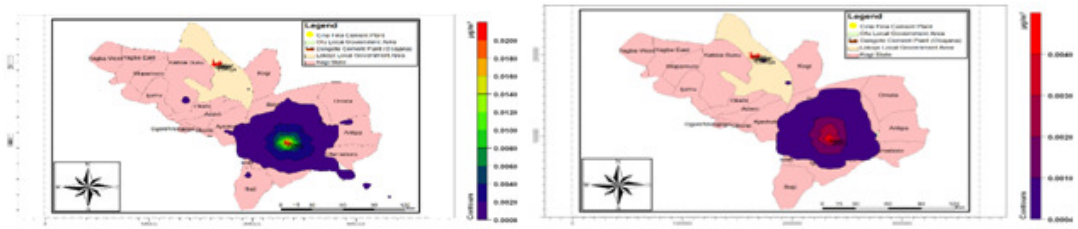


(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations

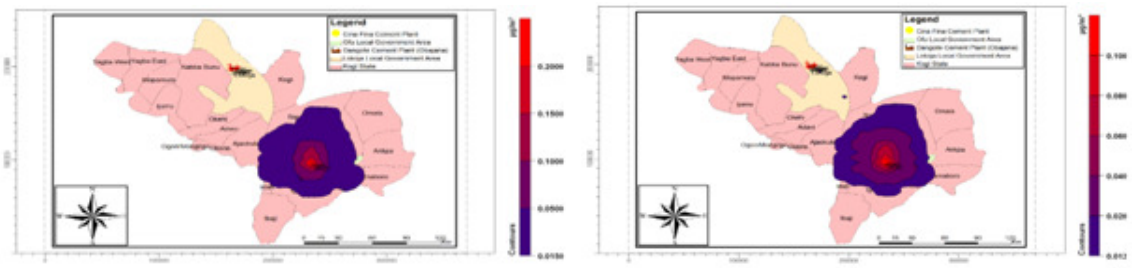


(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 16: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from Dangote Cement Plant Obajana, Kogi State



(a): Predicted 24-hr PM_{10} Concentrations (b): Predicted 24-hr SO_2 Concentrations



(c): Predicted 24-hr NOx Concentrations (d): Predicted 24-hr CO Concentrations

Figure 17: Maximum Predicted 24-hr Ground Level Concentrations of Criteria Pollutants from proposed CinaFina Cement Plant Ofu, Kogi State.

Standard were 0.001 – 0.400 fold, 0.015 – 7.692 fold and 0.2667 – 97.333 fold for CO, SO_2 and NOx respectively while the PM_{10} were 0.010 – 3.750 fold and 0.016 – 6.000 fold of the World Bank and WHO standards respectively.

Table 6 Comparison of pollutants with permitted standards

Cement Plant	Percentage Concentration of the Standard (FMEnv)			Percentage Concentration of the WB and WHO	
	CO	SO_2	NOx	PM (WB)	PM(WHO)
BCC	0.140	1.923	37.330	2.500	4.000
Ashaka Cement Company	0.400	7.692	97.333	1.250	2.000
CCNN	0.017	0.115	4.000	0.013	0.020
Edo Cement Company	0.035	0.269	8.000	0.038	0.060
Nigercem	0.002	0.038	0.400	0.025	0.040
Unicem (existing)	0.281	7.692	122.667	2.500	4.000
Unicem (proposed)	0.140	3.846	64.000	1.250	2.000
Lafarge Ewwkoro	0.053	0.769	26.667	3.750	6.000
Lafarge (Lakatabu)	0.097	1.538	25.333	1.250	2.000
PureChem	0.003	0.038	0.800	0.010	0.016
Lafarge Shagamu	0.202	1.538	42.667	0.875	1.400
Dangote Cement plant Ibeshe	0.149	3.846	36.000	2.500	4.000
Proposed E-block Cement	0.009	0.077	2.667	0.025	0.040
Dangote Cement Obajana	0.105	1.538	26.667	0.625	1.000
Cina Fina Cement Plant	0.001	0.015	0.267	0.025	0.040

From the dispersion modelling output, SO_2 and NO_X had the highest predicted maximum ground level concentration. Also, the 24 hour averaging period maximum concentrations of SO_2 predicted of 73 µg/m^3, 92 µg/m^3 and 32 µg/m^3 for Ashakacem, Unicem and Shagamu Cement plants respectively exceeded the WHO and FMEnv standard limit. The 24 hour averaging period maximum concentrations of SO_2 predicted in Benue cement plant, Dangote cement plant in Ogun State and Kogi state exceeded the WHO standard limit.

Comparing the ground levels concentration with the FMEnv, World Bank and WHO standards, the percentage set limits of criteria pollutants considered in all the cement plants range from 0.001% – 122.66 folds of the set limits. These shows the percentage impact of the set limits on the zones of influence.

4. CONCLUSION

The ISCST-3 model was used to assess the ground level concentration from the existing and proposed cement plants in Nigeria, purpose of air quality prediction. Emissions from different elevated point sources for criteria air pollutants were considered. The ground level concentrations were predicted over averaging period of 24-hr which the standards were available. The averaged period model-predicted concentrations have been compared with air quality limits as set by the World Health Organization (WHO), World Bank and Federal Ministry of Environment (FMEnv) in Nigeria. Comparing the predicted ground levels concentration of all cement plants considered, with the FMEnv, World Bank and WHO standards, the percentage set limits of criteria pollutants considered in all the cement plants range from 0.001 – 122.66% folds of the standard limits.

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