

GASEOUS AIR POLLUTANTS EMISSIONS FROM OTA INDUSTRIAL ESTATE IN OGUN STATE, NIGERIA

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ABSTRACT

The interest in monitoring air quality status of Ota industrial estate was aroused by undesirable rapid corrosion of residential roofing sheets in the vicinity of the estate. This study aimed at assessing the air pollution status around Ota industrial estate situated in Nigeria by determining the levels of NO_x, CO, and SO₂ weekly for a period of one month. The assessment was done during the daytime at one hourly basis using standard methods of analysis. The concentrations of NO_x, CO and SO₂ were determined by colorimetric method. Traffic density data reported in this study was obtained by manual count. Average levels of $33.3 \pm 4.7 \mu\text{g m}^{-3}$, $246 \pm 32 \mu\text{g m}^{-3}$ and $15.6 \pm 5.3 \mu\text{g m}^{-3}$ were obtained for NO_x, SO₂ and CO, respectively. Level of NO_x in the area was below the national guidelines stipulated by the National Ambient Air Quality Standard (NAAQS) and that of US National Ambient Air Quality guidelines. Carbon monoxide level was not above the air quality limit of $11400 \mu\text{g/m}^3$, while that of SO₂ was above the limit set by FEPA. Thus, the atmospheric air at the industrial estate is potent to have deleterious effect on human health on account of SO₂ concentration. A strong positive correlations ($p=0.05$) were observed among NO_x, CO and traffic density. In addition to diesel powered vehicles and fuel combustion in the industries, vehicles plying the estate roads contributed to the emission of NO_x and CO.

Keywords: Nitrogen oxides; Sulphur dioxides; Carbon monoxide; Respiratory health; Automotive exhaust.

INTRODUCTION

Industrialization of society, introduction of motorized vehicles, and explosion of the population, are some of the factors contributing to the growing air pollution problem. Industrialization was identified to exhibit both the highest levels of air pollution and the largest targets of human impact (Fenger, 1999). Industrialization is perceived as a symbol of wealth and growth but known to be a major source of gaseous pollutants emitted into the atmosphere. The emission is usually accompanied by gross environmental problems resulting in health injuries on human, animals, vegetation, materials and buildings. For instance, severely pollution by smoke from the combustion of high-sulphur oil at petrochemical plants in Japan between the year 1950s and 1960s resulted to asthma-like attacks (Kawamoto *et al.*, 2011). Air pollution exposure had been associated to the cause of perinatal mortality (Preterm birth) (O'Neill *et al.*, 2013). One pollution study used closeness to an industrial source as an exposure proxy and estimated exposure using data from routine monitoring of gaseous and particulate pollutants (Lin *et al.*, 2001). The gaseous pollutants include carbon monoxide, sulphur dioxide and nitrogen dioxide. It is essential to provide data on

the levels of atmospheric pollutants in one's immediate environment in order to assess compliance of industries with regulatory limits, and to advise the public of current air quality levels and pollution warnings as necessary.

Nigeria, as one of the developing countries, has achieved significant strides in their quest for rapid economic growth through industrialization (Olade, 1987). A number of industries developed are sited haphazardly. This has been making the full compliance with the regulatory control somehow unattainable because of ineffectiveness of the air pollution monitoring by the regulatory body that is empowered to ensure prevention and control of such pollution through monitory measure. Also, the increased use of automobiles has become very common and traffic jams are everyday occurrences in Nigeria cities. Thus the impact of air pollution in the cities via automobile exhausts and industrial gaseous discharges is arousing public interest. Previous studies published so far on air pollution in Nigeria are on heavy metals in atmosphere using tree bark as indicator and airborne cement dust (Odukoya *et al.*, 2000; Onianwa, 2001; Gbadebo and Bankole, 2007). Estimation of air pollution arising from vehicular exhaust emission on Nigeria roads had

also been reported (Akeredolu, 1989; Oketola and Osibanjo, 2007; Oguntoke and Yussuf, 2008). Data from these studies are however insufficient and adequate to make a strong conclusion about the air quality status in Nigeria without considering the air pollution level in selected industrial areas in Nigeria city. Air quality data for most industrial areas in Nigeria are scarce and for proper management of the total environment, it is thoughtful to embark on air quality monitoring around industrial areas of the Nigeria. In addition, the inability of past studies to address air pollution problems and engage in frequent air monitoring studies for economic reason also spur our interest to embark on this study. The distribution of Polycyclic Aromatic Hydrocarbons (PAHs) in the air from Ota industrial estate had been reported with concentrations ranging from 89.2 to 96.48 ng/m³ (Saluudeen *et al.*, 2017). The health risk due to human exposure to particulate bound trace metals emitted from Ota industrial estate had been estimated. The cumulative lifetime cancer risk due to inhalation exposure for adults and children were found above Environmental Protection Agency acceptable range (Anake *et al.*, 2017). The estimate indicated the need to keep abreast of air quality information of such industrial area. Prominent among possible emitted pollutants associated with industries are NO_x, SO₂, and CO whose concentrations are scarce in environmental database particularly for Ota industrial estate. The available information on the parameters with respect to the industrial activities in the estate was obtained as estimate of air pollution load using Industrial Pollution Projection System (IPPS). IPPS is based on the use of industrial activity data from environmental and economic database for the estimation of pollution load (Odesanya *et al.*, 2012). The direct measurement was carried out in this study against the background of estimated concentrations of air pollutants for Ota industrial estate. Therefore, the objective of this study was to provide data on the levels of NO_x, SO₂, and CO of the day time and weekly variations of these air pollutants within the Ota industrial estate in Nigeria. This baseline data of the study area will be relevant for future air quality monitoring.

METHODOLOGY

Description of Study Area

Ota industrial estate, located between 6° 41'N

latitude and 3° 12'E longitude, was established in 1983 as one of the largest industrial estate in Ogun State, Southwestern region of Nigeria (Olukanni and Akinyinka, 2012). The estate covers an area of about 22.8 km² at Ota community (Etim and Onianwa 2013). The estate is for both industrial and residential purposes. The major route of the estate divides the low cost residential houses, which are on the left side and the industrial area on the right as one drives off Idiroko – Ota road. Few of the industries have staff housing co-located in the estate (Figure 1). In few of this close proximity to residential areas, particles and gaseous emissions from the stacks of the industries are dispersed within and around the dwelling houses. The industries in the estate engage in activities such as melting of aluminium, recycling of metal scraps and used batteries, manufacturing of plastics, galvanized pipes, chemicals, pharmaceuticals, cooking utensils and roofing sheets. Control site was also selected in Atan, 10 km away from the study area with

coordinate 6° 41'N latitude and 3° 8'E longitude.

The control site is remote from direct influence of traffic and industrial activities. Many cars and light trucks using gasoline and diesel respectively, are seen plying the main road of the industrial estate.

The sampling locations were selected within the industrial estate to reflect the following areas of interest:

- (i) high industrial activities with high traffic volume. This location was designated SP1(0m).
- (ii) high industrial activities with medium traffic volume. This location was designated as SP2(150m).
- (iii) low industrial activities with low traffic volume. This location was designated as SP3(300m).
- (iv) very low industrial activities with very high traffic volume. Most trucks that transport the finished products to town were first packed here before loading and the location was designated as SP4(450m).

Thus this study considered both vehicular and industrial emissions within the industries estate, as emissions from vehicles plying in the estate cannot be isolated from industrial emissions. The study

was conducted for four weeks in June, 2015. The study area showing sampling locations and control site is given in Fig 1.

Meteorological Condition:

Ota industrial state lies within the south-western part of Nigeria which experiences both dry and wet seasons. The area is dominated by the influence of both the north east wind and south west wind. During dry season, the north east wind is dusty and dry while wind from the south west is warm and moist. Wet season starts from April to October with generally lower temperature and dry season from November to March of the following year with midday temperatures that surpass 38 °C (Bada 2003).

Daily mean meteorological parameters for the period of study were obtained from Nigerian Meteorological Agency (NIMET). During sampling period, the annual rainfall was estimated to be about 1600 mm. Mean temperatures ranged between 29 °C and 30 °C. The average wind speed was 13 km h⁻¹ and relative humidity ranged

between 80.0 % and 84.0 %. Hence the sampling season was characterized by high temperature, high humidity, high atmospheric turbidity which might likely prevent penetration of solar radiation on the earth's surface.

Sample Collection

Air samples were collected from the selected locations and control site using an air sampling train connected to a vacuum pump for 1.0 hour. This hourly sampling was carried out for six times in a day at 30 minutes intervals to allow for the transfer of the absorbing solution into sample bottle. The sampling spanned through 9.00 a.m to 5.30 p.m at each day. The sampling train consists of impingers, each of which contains 10 mL each of absorbing solutions for the interested gaseous pollutants. Air samples were drawn into the impingers and the filter assembly at flow rates of 1259 mL min⁻¹ for NO_x, 555 mL min⁻¹ for SO₂, and 688 mL min⁻¹ for CO. Samples were collected at 2 m above the ground to minimize collection of dust from underlying surface.

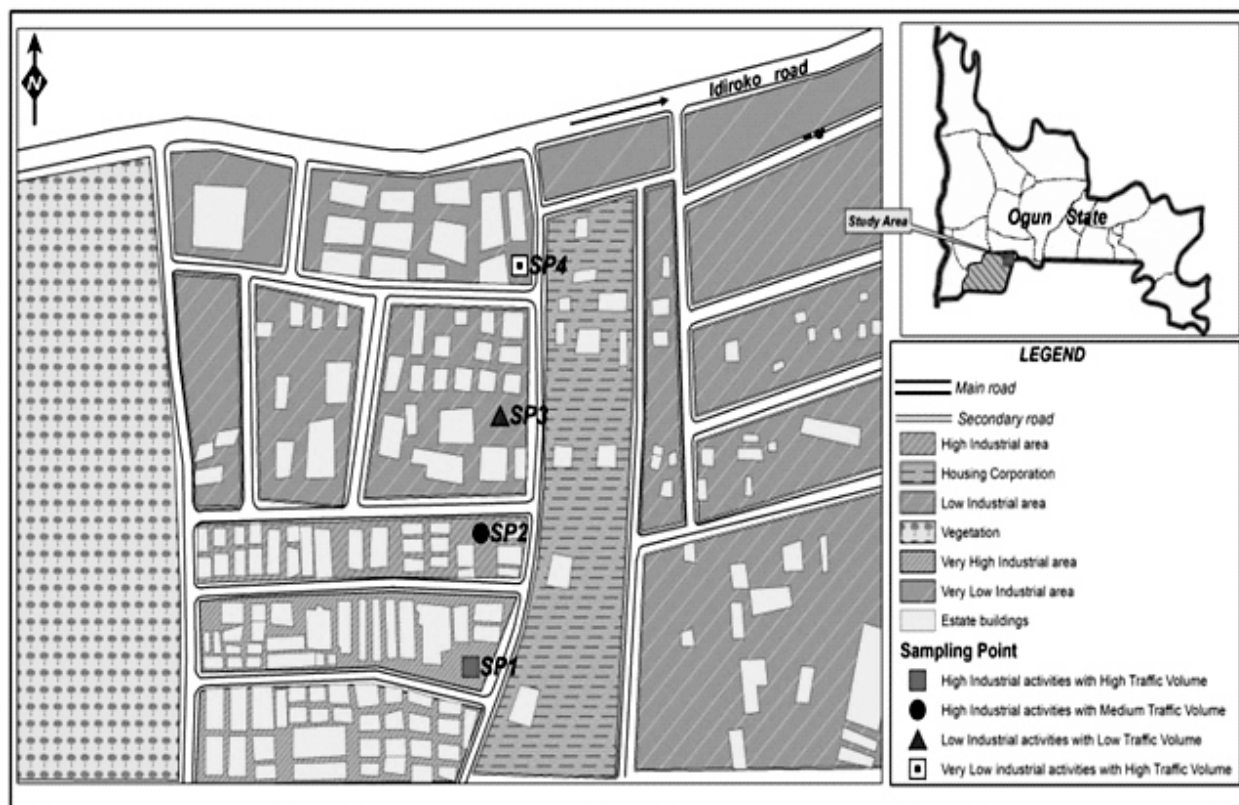


Figure 1: Map of Ogun state showing Ota industrial area and sampling locations

Chemical Analysis

NO_x was determined using the Griess-Saltzman (Saltzman, 1954) colorimetric method. Nitrogen monoxide was first oxidized to nitrogen dioxide by passing air through chromic acid. The technique is based on the reaction of nitrite ion with diazotizing and coupling reagents to produce a deeply coloured azo-dye whose absorbance is measured at 550 nm.

Sulphur dioxide was scrubbed in potassium tetrachloromercurate (TCM) to form dichlorosulphitomercurate complex which resisted oxidation by oxygen in the air. The complex was made to react with pararosaniline and formaldehyde to form an intensely coloured red-violet pararosaniline methylsulphonic acid. Concentration of SO₂ was determined colorimetrically at 560 nm using the West Gaeke method (Scaringelli *et al.*, 1967).

Carbon monoxide in the collected air samples were determined by an improved colorimetric method. This technique is based on the reduction of yellow silicomolybdate (Mo⁶⁺) to lower oxides. A reducing agent (CO) was used to reduce molybdate into colloidal molybdenum blue (Mo₈O₂₃H₂O). The stages of colour change (from yellowish green to green and finally to deep blue) were indications of the extent to which the reduction had been effected. The concentration of the resulting solution was measured colorimetrically at 660 nm (Rajwar and Ghosh, 1967; Khopkar, 2007).

All absorbing solutions were collected in pretreated sample storage bottles and stored in a cooler of ice at 4°C. Calibration curves were prepared from standard solutions. Reagents used were of Analar grade. Traffic densities at the locations were estimated by visual counts of 1 hr. traffic flow.

Vehicular volume

Vehicular volume was determined using manual count method (Curin, 2001; Al-Sobky and Mousa, 2016). The number of vehicles passing the road in 1 hr of sampling period was measured by manual count and recorded onto tally sheets. A stopwatch was used to monitor the time.

RESULTS AND DISCUSSION

Daytime Concentrations of NO_x, SO₂ and CO

The range and concentrations of NO_x, SO₂ and CO observed weekly during the monitoring are shown in Table 1. The air quality measurements in Ota industrial estate revealed average NO_x concentration to be 33.3±4.7 µg m⁻³. This was found to be lower than the national ambient air quality standard (NAAQS) and limit set by the US, India and California for NO_x (Table 2). Ideally, standards for environmental protection measures are set based on nationally generated environmental baseline data. However, experiences of limits from other developing countries such as India with possible climatic conditions and level of development as Nigeria may be considered for comparison when assessing air quality of the country. The observed low concentration of NO_x could be attributed to its possible photochemical transformation in the atmosphere, and as such its accumulation in the atmosphere within the estate is minimal. In the lower atmosphere, the conversion of NO to NO₂ by association reaction with peroxy radicals (RO₂) or OH radicals is a probable photochemical transformation, which could reduce the level of NO_x emitted to the atmosphere (Aneja *et al.*, 2001). The possible formation of gaseous nitric acid in the atmosphere from the dissolution of NO₂ in water vapour in the troposphere during the daytime can possibly account for the low NO_x level observed (Butkovskaya *et al.*, 2005). It is likely that cloud water that accumulates in this sampling area, condense and fall as rain would be acidic in nature. The environmental effect of this transformation could be deleterious on vegetation, building and human.

The average concentration of 246±32 µg m⁻³ was observed for SO₂ (Table 2). This level of SO₂ exceeded the prescribed limits of 26.0 µg m⁻³, 196 µg m⁻³ and 180 µg m⁻³ by the FMENV, US National Ambient Air Quality Standards (US NAAQS) and India Central Pollution Control Board (Indian CPCB), respectively. This is likely due to emissions from metallurgical industry located within the estate that is utilizing sulphur producing ore. The mean concentrations of CO was 15.6±5.3 µg m⁻³. This was noticed to be lower than the day time permissible limit of 11400 µg m⁻³ stipulated by the

FEPA but now called Federal Ministry of Environment. The observed level of CO is traceable to emissions from productions, diesel powered engines and emissions arising from influx of vehicles in the area. To investigate other anthropogenic source of air pollutants in the area, the traffic density was measured and the vehicular volumes were compared with SO₂, CO, NO_x

concentrations obtained. The study revealed strong correlation of traffic density CO ($r = 0.9731$) and NO_x ($r = 0.8951$). The necessity for the correlation arises from the fact that vehicular exhaust emission has also been recognized as a principal source of carbon monoxide (Kittelson, 1998; Kaur *et al.*, 2007).

Table 1: Average daily concentrations ($\mu\text{g m}^{-3}$) of pollutants for four weeks at sampling locations in Ota industrial estate

Location	Week 1			Week 2		
	NO _x	SO ₂	CO	NO _x	SO ₂	CO
SP1	41.2	330	10.9	43.9	307	21.9
SP2	36.0	262	10.8	31.1	284	12.7
SP3	34.4	284	9.67	34.2	239	9.18
SP4	27.5	262	9.54	25.2	216	8.97
Mean±SD	34.8±5.7	284±32	10.2±0.7	33.5±7.8	261±42	13.2±6.1

Table 1 contd: Average daily concentrations ($\mu\text{g m}^{-3}$) of pollutants for four weeks at sampling locations in Ota industrial estate

Location	Week 3			Week 4		
	NO _x	SO ₂	CO	NO _x	SO ₂	CO
SP1	34.6	182	15.7	37.5	330	36.7
SP2	33.2	148	11.5	30.7	284	33.7
SP3	31.3	125	10.3	31.6	296	28.2
SP4	31.0	102	7.13	29.8	284	12.2
Mean±SD	32.5±1.7	139±34	11.2±3.5	32.4±3.5	299±22	27.7±10.9

Pollutant concentrations in the table for SP1 to SP4 are average of six determinations at each location; SD- Standard Deviation

Table 2: Mean concentrations ($\mu\text{g}/\text{m}^3$) of pollutants at each sampling location for four weeks

Location	Averaging time	Concentration of air pollutants			Traffic density
		NO _x	SO ₂	CO	
SP1	-	39.3±4.1	287±71	21.3±11.2	1194
SP2	-	32.8±2.4	245±65	17.2±11.0	1165
SP3	-	32.9±1.7	236±78	14.3±9.25	1149
SP4	-	28.4±2.6	216±81	9.46±2.09	1351
Mean± SD	-	33.3±4.7	246±32	15.6±5.3	-
Control site	-	23.8±1.4	54±6	2.75±1.57	-
^a FEPA limit	1 hour	75-113	26.0	11400	-
^b California limit	1 hour	339	655	22904	-
^b US NAAQS limit	1 hour	188	196	40082	-
^c India CPCB limit	1 hour	80	180	-	-

US NAAQS = United State National Ambient Air Quality Standard; CPCB = Central Pollution Control Board
a= FEPA (1991); b= US EPA, 2012; c= India National Ambient Air Quality, 2009

Table 3. Ota industrial estate air pollutant levels compared with levels in industrial areas around the world

City/Country	Sampling period	Concentration of air pollutant ($\mu\text{g}/\text{m}^3$)			Reference
		NO _x	SO ₂	CO	
Ota, Nigeria	1 hour	33.3±4.7	246±32	15.6±5.3	This study
Incheon, Korea	1 hour	71.4	15.7	566	Yoo et al., 2011
Matsapha, Swaziland	1 hour	92.2	3.3	-	Chingakule, 2011
Kualar Lumpur, Malaysia	1 hour	176.9	202	13400	Norela et al., 2010
Port Harcourt, Nigeria	1 hour	141.1	25	5725	Ideriah and Stanley, 2008
Kaduna, Nigeria	1 hour	89.0	110	14640	Abdulkareem and Kovo, 2006

Vehicular engine constitutes a major source of NO_x since nitrogen oxides are also primarily formed in combustion processes (Restrepo *et al.*, 2004). Thus, concentrations of CO and NO_x measured in this study may be attributed to both industrial activities and vehicular emission occurring within the industrial estate. These two anthropogenic sources are identified as major sources of air pollution in Ota industrial area. The concentrations of NO_x, SO₂ and CO obtained at sampling points and those from the control site were significantly different.

The concentrations of SO₂ were found to be higher than NO_x due to emissions from processes involving material that contain sulphur. The fibre cement sheets cement and drug production in addition to construction works among others are some of the major activities being carried out within the Ota industrial estate. The levels of gaseous pollutants observed in the study were compared with corresponding levels recorded for industrial areas in some other countries (Table 3). The average concentration of SO₂ was noticed to be far above the SO₂ level observed in Incheon, Korea; Matapha, Swaziland and Kualar Lumpur, Malaysia, for where air samples were equally collected for one hour

Weekly Variations and Dispersion Pattern of

NO_x, SO₂ and CO

The average concentration of NO_x for week 1 > week 2 > week 3 > week 4 (Figure 2). Moving from a location with high industrial activities to an area with low industrial activities, the NO_x level decreased with distance except in the second week that sudden increase in NO_x level was observed at SP3. This is a location with low industrial activities and low traffic volume. Alhassan and Jimoh (2006) reported a reduction in NO_x with distance away from the point source. This is in accordance with the law of dispersion which states that there is a trend in the reduction of pollutant concentration with increasing distance (Alhassan and Jimoh, 2006; Baumbach, 2012).

The lowest concentrations of SO₂ were measured during the third week of sampling in all the locations (Figure 3). The concentrations of CO were equally decreasing with distance from where traffic volume was high to that of low traffic volume (Figure 4). The use of tall chimneys observed in most factories within the estate carry gaseous pollutants to a high altitude leading to widespread dispersion of the pollutants in the atmosphere.

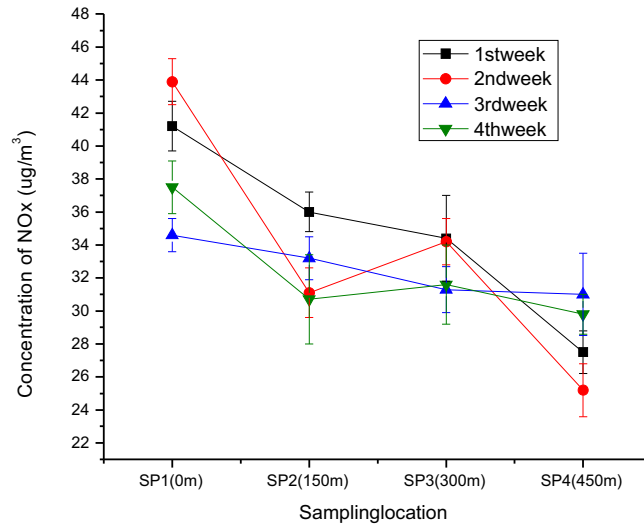


Figure 2: Weekly variations of NOx concentrations at sampling locations

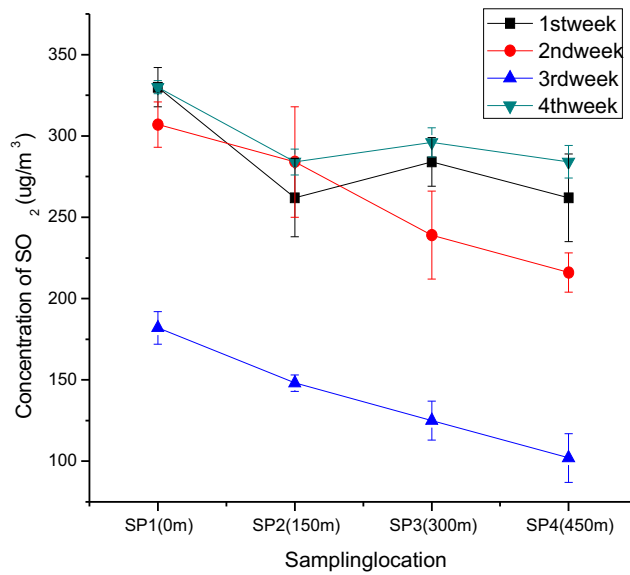


Figure 3: Weekly variations of SO₂ concentrations at sampling locations

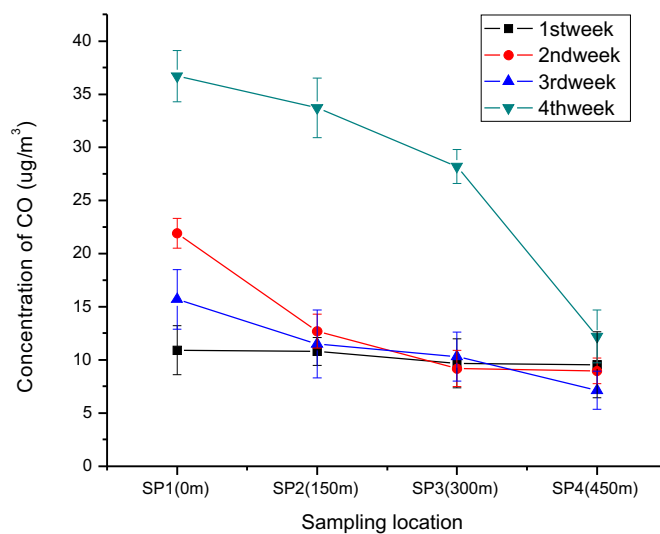


Figure 4: Weekly variations of CO concentrations at sampling locations

This is similar to the report of air pollution problems observed in Britain for several centuries, where height of industrial chimneys were increased to aid pollutants dispersion in the atmosphere (Woodin, 1989). This measure resulted in reduction in the concentration of air pollutants with distance outside the area of emission. Wenig *et al.*, (2003) reported that nitrogen oxides and sulphur dioxides emitted from a point source can travel long distance if they get entrained into the mid-latitude storm track after a period of local accumulation of sand in the sub-tropical high.. The importance of heterogeneous reactions of atmospheric gaseous HNO_3 on mineral dust has been reported (Hanke *et al.*, 2003). The observation indicated that the presence of mineral dust can have a strong impact on aerosol formation with a gas phase HNO_3 in the troposphere.

CONCLUSION

The levels of NO_x and CO from Ota Industrial estate were within the national regulatory limits for atmospheric gaseous pollutants while that of SO_2 was above the limit. Dispersion of atmospheric gaseous pollutants from the emission source was noticed during the daytime. Industries within the industrial estate should adopt clean technologies and ensure provision of appropriate protective covers, nose masks and also frequent health check-ups.

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