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Measurement of carbon dioxide and detailed emission inventory preparation from different sources over Madurai, India

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Abstract

This paper analyzes diurnal, monthly, seasonal variations of CO_2 along with the meteorological parameters at Madurai (9° 92'' N and 78° 12'' E), an urban site from January-2015 to December-2015 by using a Non-dispersive infrared sensor (NDIR) based instrument. The highest hourly two peaks are observed in noon (476.8 ± 12.9 ppm between 12-1 PM) and in night (478.5 ± 13.7 ppm between 7-8 PM) respectively. The CO_2 concentration is lower (437.93 ± 2.77 ppm) in early morning 5-6 AM. As far as, the monthly variation of CO_2 is also concerned high in the month of May (487.19 ± 28.3 ppm) and low in July (444.70 ± 18.2 ppm). The seasonal variation is observed to be maximum in summer (478.33 ± 13.03 ppm) and minimum in the post-monsoon season (448.27 ± 16.8 ppm). An emission inventory is prepared based on the transportation and the electrical consumption in household activities by using a bottom-up approach method. The CO_2 emission estimated from transportation is around 85.1 tonnes /day and 10289.5 kilo tonnes /year. By the consumption of electricity, the total emission of CO_2 is approximately 3.3 tonnes /day and 1.2 kilo tonnes /year is estimated. Statistical analysis is carried out to find the relationship between carbon dioxide concentration and meteorological parameters observed in this study. Based on the results of statistical analysis, not only the meteorological parameters change varied the carbon dioxide concentration but also by traffic flow, types of vehicles and road types the concentration differs in this city.

Keywords: Greenhouse gas, Carbon dioxide, NDIR Sensor, TRMM data, Emission factor.

Introduction

Urbanization and economic growth results, increasing air pollution in the worldwide experience is an important environmental issue. Anthropogenic greenhouse gases (GHG) emissions have progressively increased the radiative forcing of the atmosphere which causes global warming, particularly carbon dioxide and methane leading to impacts on the system of climate and human society (IPCC, 2013; 2014a, b; Stocker *et al.*, 2013). During recent decades, an increase of GHG emissions is contributed by emerging economies like China and India. In 2010, India became the world's third largest GHG emitter, after China and USA (Edgar, 2011. According to 2014 global CO_2 budget, global CO_2 emissions are from fossil fuel usage and cement production it is observed that 36 GT in 2013 and this is 61% higher than 1990. According to the Kyoto Protocol this CO_2 emission is 2.3% higher than 2012. Increasing the level atmospheric carbon dioxide considered as the emerging driving force of climate change studies. These greenhouse gases are strong absorbers of infrared energy which causes the mean surface temperature of the earth to be warmer than the radiative temperature. In other words, these greenhouse gases assist to balancing of the earth's climate in the atmosphere (Pidwirny 2006). The level of carbon dioxide is increasing decade by decade and the researchers suggest that it is because fossil fuels are being burned at an enhanced rate and the ocean's diminishing absorption of CO_2 (Canadell *et al.*, 2007). Air pollution is one of the serious criteria among the worldwide distribution and a serious threat to the environment which leads to global warming and climate changes. Among the many air pollution sources, the transport sector, the fastest growing contributor, causes air pollution in the urban areas of the developed and developing countries. Emission inventory study is the amount of polluted emission discharged into the

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atmosphere and it contains some of the green house gases from all sources in a certain area within a specific time span and year.The emission inventory is prepared depending upon the vehicle technology, the age of the vehicle, fuels used, emission control level and emission factor (Sahu *et al*., 2011). This emission inventory is used to study the distribution of pollutants with connection with local meteorology, topography, and composition of pollutants. In developing countries, vehicle ownership is rising due to the increasing economic growth and demand for transportation facility results in more cars and motorcycles fighting for the limited space on limited roads (Guttikunda 2008).

The objective of the present study is (i) To study the diurnal, monthly and seasonal variations of carbon dioxide from the different local zones of the study city (ii) To prepare a detailed emission inventory for vehicle sources and electricity consumption in the study city. Based on this observation, the study helps to mitigate the effects of pollution level in a regional scale and also provides a valuable tool for urban planners by developing pollution free environment in the study area.

Material and Methods

Study area: Madurai city (9° 92' N and 78° 12' E) with the elevation of 101m above MSL, one of the oldest cities India, now emerging as most densely populated city situated on the banks of River Vaigai. Figure 1 shows the location map for the study area. The urban area covers 248 km^2 with estimated population of 2.94 million in 2017. The city is experiencing hot and dry climate for eight months of the year. According to the statistical handbook (2015) report, the maximum temperature is about 42°C and a minimum of 19°C. Most rainfall occurs in the city during the month of October and December. Table 1 shows the characterization of sampling zones in Madurai city. The sampling zones are dominated by various commercial, residential, some large and small scale industries and educational institutes. Since most of the developments are multiplied without scientific planning, the air pollution activities are heterogeneous and widespread all over the city. Ambient air quality in urban areas reflects mainly the releases of pollutants from human activities as well as the effects of meteorological parameters, landscape and topography.

Data collection and analysis

An instrument based on NDIR sensor is used to measure the ambient CO_2, along with temperature and relative humidity, from January-2015 to December-2015. Wind speed data is collected from the Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2) satellite with the spatial resolution 0.5^o x 0.625^o. It is also provides air temperature, air pressure, relative humidity data sets. Rainfall data is collected from Tropical Rainfall Measuring Mission (TRMM) which is a Joint program conducted by the US and Japan. It measures the tropical and subtropical rainfall with the spatial resolution of 0.5° longitude and 0.5° latitude by using Precipitation Radar, TRMM Microwave Imager and the Visible and Infrared Scanner (Kummerow *et al*., 2000; Kaufman *et al*., 2005). Statistical analysis like Pearson correlation and multiple linear regression analysis are carried out to find the relationship between carbon dioxide with meteorological parameters in this study.

Calculation method for an inventory study

The common methodology for preparing emission inventory is estimated by two main approaches (ie) top–down approach and the bottom-up approach. In this study, the emission inventory is prepared by using bottom up approach method from transport sector and household activities (consumption of electricity). Bottom up approach method is, used to estimate the emission level for individual sources and sum all the sources to find out the regional/ country level. The results are more accurate while compared with top–down approach. The urban population in Madurai is mainly dependent on road transport. As per RTO report, the total registered vehicles in Madurai (Central, North & South) are 40126 (commercial vehicles) 696921 (Non-Commercial vehicles) in the year 2015-2016 (Figure 2). The inventory is derived by collecting information using the questionnaire method (face to face interview) during 2015. The data is collected in two different days (weekdays and weekend) from the different zones in Madurai. In the present study, randomly 1500 vehicle samples are collected, it includes two Stroke and four Stroke two-wheelers (600 samples), three-wheelers (600 samples) and

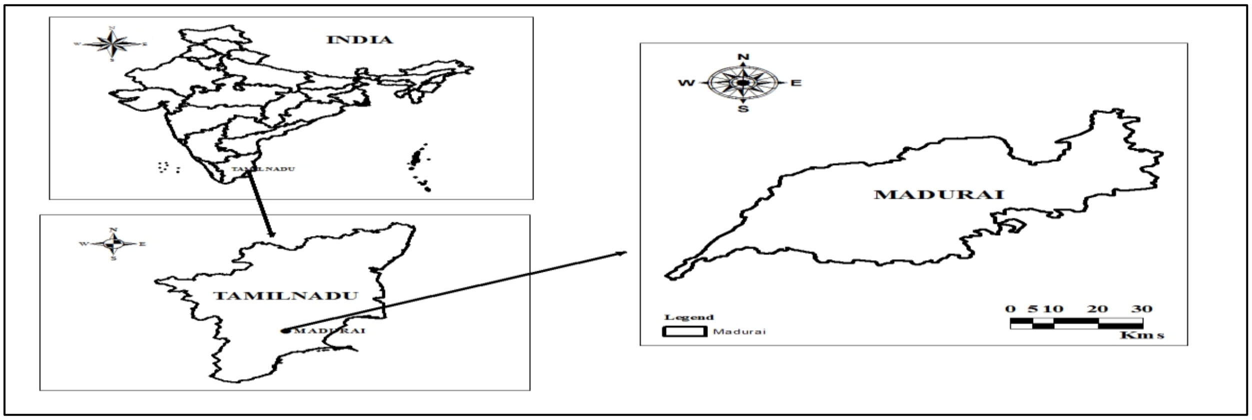

Figure 1: Location Map

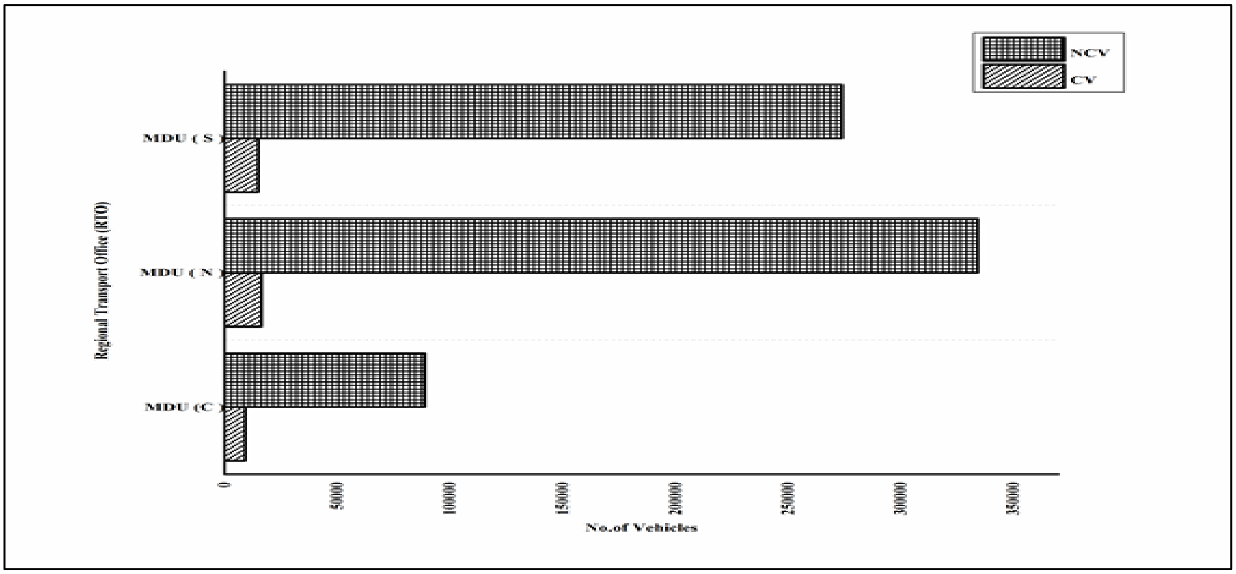

Figure 2: Total number of registered vehicles in Madurai (upto-2016)
Mdu (C) – Madurai Central; Mdu (N) – Madurai North ; Mdu (S) – Madurai South
NCV- Non-Commercial Vehicle; CV- Commercial Vehicle

Table 1: Characterization of sampling sites in Madurai city

Sampling Site	Area where
Jaihindpuram	Residential zone
Palanganatham	Residential zone
Kalavasal	Traffic cum residential zone
Goripalayam	Traffic cum residential zone
Periyar bus stand	Traffic cum commercial zone
Simakkal	Busy commercial zone
Madurai Kamaraj University	Institutional zone

four-wheelers (300 samples). The emission inventory formula is discussed for the total emissions from vehicles in the study area. Fuel and kilometer calculation for per day and per year are derived by using this formula for the vehicles. (Sahu *et al*., 2011).

$$Et = \sum (Veh/F \times Veh/D) \times EFC \quad \text{-------- (1)}$$

where Et is emission calculated for day/year, Veh/F is the Fuel usage per vehicle, Veh/D is the distance travelled per vehicle and the EFC is the specific EF for carbon dioxide for different types of vehicle. Randomly house hold (350 samples) was selected for collecting information of their electricity consumption by questionnaire method. It includes the usage of electrical appliances by number of hours. The data collection takes place by collecting information from lower annual income families. The common household appliances such as tube light, fan, air conditioner, refrigerator, television and personal computer were used in this inventory. The carbon dioxide emissions produced by household energy was calculated for a period of one year (2015). By using the formula (2), the energy consumption of electricity is calculated as per day and year. The emission inventory for electrical consumption as per day and year is calculated by using the formula (3).

$$E(Kwh/d) = P(w) \times t(h/d) / 1000(k/wk) \quad \text{-- (2)}$$

where E (Kwh/d) is Energy in kilowatt-hours per day, P (w) is power in watts, t (h/d) is time in hours per day

$$Et = ECE \times EFC \quad \text{-------- (3)}$$

where Et is emission calculated for day/year, ECE is Energy Consumption of electricity (activity data), EFC is specific EF for carbon dioxide. Table. 2. Shows the technical emission factor (g/km) used for the transport sector and household (for electricity).

Results and discussion

Statistical analysis: Tabel.3. shows the descriptive statistical analysis of carbon dioxide observed in Madurai city. The maximum average CO_2 concentration is found at Simakkal followed in decreasing order by Goripalayam, Kalavasal, Periyar, Palanganatham, Jaihindpuram and Madurai Kamaraj university respectively. The maximum standard deviation was observed for Goripalayam followed in decreasing order by Kalavasal, Simakkal, Periyar, Palanganatham, Madurai Kamaraj university and finally for the Jaihindpuram. The coefficient of variance (CV) is calculated between two ranges of data (Standard deviation/Mean concentration) of observed CO_2 concentrations is 2.11%, 2.81%, 3.31%, 4.46%, 4.14%, 4.66% and 2.35% for the zones Jaihindpuram, Palanganatham, Periyar, Kalavasal, Simakkal, Goripalayam and Madurai Kamaraj university, respectively. Pearson correlation is studied to identify the link of carbon dioxide with other meteorological parameters. Table.4. shows the correlation coefficients (r) between monthly averages CO_2 and corresponding meteorological parameters over the study area. Positive correlation found between carbon dioxide with temperature (0.6) and negative correlation found between carbon dioxide with wind speed (-0.7) it shows a negative correlation. Relative humidity shows negative correlation between temperature (-0.5) and positive correlation between rainfall (0.7). Regression analysis is carried out for the measured carbon dioxide and meteorological parameters over Madurai city. The R^2 value shows 50% variability of the dependent variable carbon dioxide (CO_2) is explained by the meteorological parameters (temperature, wind speed, rainfall & relative humidity). Based on the sum of square analysis, the significant information explains the variability among the carbon dioxide with the meteorological parameters.

Seasonal variation of carbon dioxide: Table.5. shows the seasonal variations of carbon dioxide and meteorological parameters over Madurai city. The overall seasonal variation of carbon dioxide is observed high in summer (March-May) and low in post-monsoon (October-December) season. During summer, the level of carbon dioxide is high due to high temperature and solar flux results a quite specific action on transformation rates and encourage the efficiency of atmospheric chemical reactions, leading to the conversion of CO to CO_2 (Daniel and Kumar 2016). In this season, festival time of the temple city attracts more tourist and local people for shopping and other activities in and around Madurai city. (Thangamani and Srividya 2017). Photosynthetic activity and the respiration rate of plants are both high in this season as well as

Table 2: Technical emission factors used for transport sector (g/km) and household (for electricity Kg/kwh)

Pollutant	Model year	2W (2S/4S) P	3W (2S/4S) P	3W (D)	3W (G)	4W (P)	4W (D)
CO_2 (Transport Sector)	1991–1996	23.48	-	-	-	-	-
	1996–2000	24.17/23.25	54.5	140.87	44.87	106.96	129.09
	2000–2005	29.62/33.83	62.1/57.4	173.85	68.15	126.37	154.56
	Post 2005	38.54/42.06	71.5/73.8	131.61	68.15	172.95	148.76
CO_2 (Household , Electricity Consumption)	0.82						

Source: CPCB (Central Pollution Control Board), ARAI (Automotive Research Association of India)

Table 3: Descriptive statistical analysis of carbon dioxide in different zones

Zones	Mean	SD	CV
Jaihindpuram	449.6	9.48	2.11%
Palanganatham	452	12.7	2.81%
Periyar	453.4	15.01	3.31%
Kalavasal	457.1	20.37	4.46%
Simakkal	476	19.7	4.14%
Goripalayam	472.2	22.01	4.66%
MKU	436.2	10.25	2.35%

Table 4: Correlations coefficients (r) between carbon dioxide (ppm) and meteorological parameters

Parameters	CO_2	Tem	Rain	Wind	RH
CO_2	1				
Tem	0.57	1			
Rain	-0.01	0.144	1		
Wind	-0.736	0.043	-0.233	1	
RH	-0.2744	-0.5	0.775	-0.274	1

Table 5: Seasonal Variations of carbon dioxide and meteorological parameters over Madurai city

Parameters	JF	MAM	JJAS	OND
CO_2	453.23	478.33	453.1	448.27
Tem	28.98	31.26	31.69	27.96
Rain	5.28	316.51	384.84	451.9
Wind	5.05	4.08	5.31	4.59
RH	50.14	54.65	53.76	64.04

*CO2 (ppm); Tem (C°); Rain (mm/m); Wind (ms^{-1}); RH (%)

the decomposition rate of microbes which contributed high atmospheric carbon dioxide in this season. Depending upon the radiative forcing, the temperature level may vary from one season to another. Temperature variation may also takes place depending upon the local circulation of the anthropogenic activities. Higher temperatures cause organic matter in the soil to release more carbon dioxide, while low moisture limits photosynthesis in plants (Medvedev 2004).It is well known that the high variability in precipitation results in high variability in vegetation production in arid and semiarid ecosystems. It is seen that the post monsoon is the main rainy season in this region, which provides the water for the vegetation as well as soil moisture for the rest of the season when it is generally dry. Plants clearly require CO_2 to grow; water and higher humidity make plants more efficient at drawing in carbon. It is due to the absorption of carbon dioxide by the green plants in the atmosphere due to photosynthetic activity. Increasing plant growth and carbon uptake is due to enhanced rainfall and humidity. So the level of the carbon dioxide is low in post monsoon when compared with the summer season. Variations of local meteorological conditions, such as solar intensity, wind speed, direction and precipitation can influence high/low level of pollutant in the atmosphere. The climate scenario is likely to have serious implications mostly on the regional carbon cycle under the regional climate assessment over India. The carbon sources and sinks are from neighboring regions during different seasons, and the strengthening and weakening of monsoonal flows (Cherchi *et al*., 2011).

Monthly variation of carbon dioxide:

Figure 3 (a-g) shows the monthly variations of carbon dioxide for different zones in Madurai city. The maximum carbon dioxide concentration is observed in the month of May in all study zones. Minimum values of carbon dioxide varied by month in all study zones. Depending upon the local meteorological parameters, the carbon dioxide values are varied by different zones in this city. The overall highest level found in the month of May and low in the month of July for this city. Common festivals in this city such as Chithirai Thiruvizha and Alagar Vaigai Elenthuarulal most often occur during April and May month. People from various parts of the world take place in that celebration. Mainly in Simakkal and Goripalayam zone, the carbon dioxide level was high. Events of Meenakshi Thiruvizha and Alagar entry are placed in Simakkal and Goripalayam junction in and around the south banks of Vaigai River. The roads are not in good condition, overcrowd, slow movement of vehicles and the release of human respiration lead the carbon dioxide level high in these junctions. The increased CO_2 concentration in the month of May is also occurring by the enhanced soil respiration (Sreenivas *et al*., 2016). Figure 4 shows the monthly variation of carbon dioxide and meteorological parameters over Madurai city. High wind velocities and changes in the wind direction in July month allow the pollutant to disperse from one place to another. The wind speed versus carbon dioxide plot clearly shows that the wind speed is low the CO_2 concentration is high, whereas, when the wind speed is high the concentration begins lower. The temperature versus carbon dioxide plot shows that it differs by the local activities and depending upon the incoming and outgoing solar radiation. Likewise, the rainfall versus the carbon dioxide plot clearly shows that the rainfall is higher, the level of carbon dioxide becomes low and also the temperature becomes low. Both air temperature and rainfall vary, these two parameters must have a signature in vegetation response too (Kumar *et al*., 2016). Mostly Tamilnadu receives major rainfall in October, November and December months. It is due to increased saturation of the soil, before the heavy monsoon even began which leads the high vegetation growth helps in the trapping of carbon dioxide for their photosynthesis (Venkitaswamy and Bhaskar 2015).

Diurnal mean variations of carbon dioxide in different zones: Figure 5 shows the diurnal average values for carbon dioxide in Madurai from January to December, 2015. The diurnal variation of carbon dioxide differs from season to season and it is mostly depending upon the sunrise time which is related with the starting of photosynthesis process and the rise of boundary layer height (Chandra *et al*., 2015). Throughout the study period the overall lowest value of CO_2 (437.93 ± 2.77 ppm) in the year 2015 is observed during 5-6 AM. The fewer amount of the vehicle flow and less congestion results the lower carbon dioxide level in the study area. Slightly, the carbon dioxide rise occured from 6-7 AM due to the activities of local

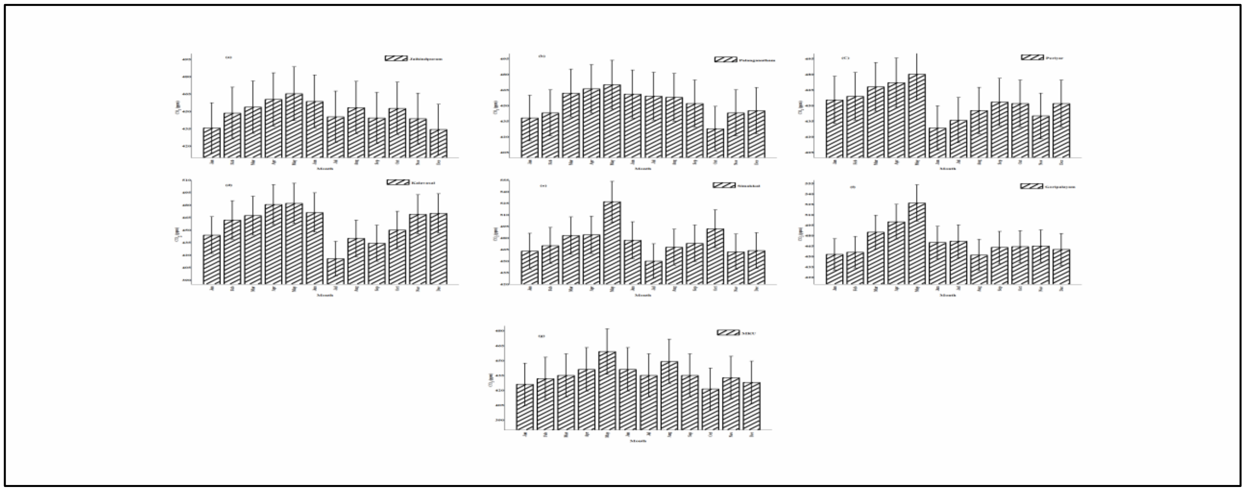

Figure 3 (a-g): Monthly mean carbon dioxide concentrations for different sites in Madurai-2015

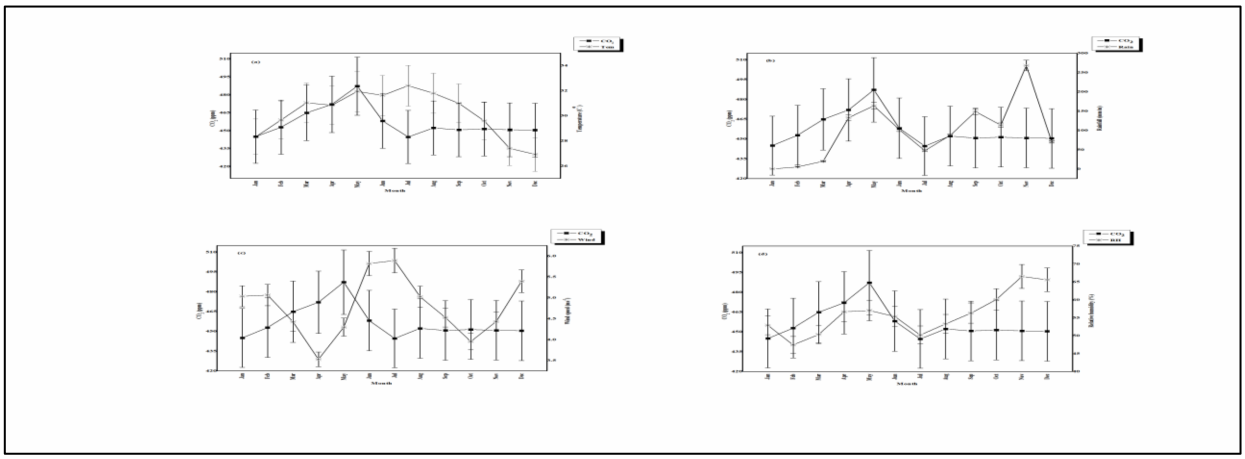

Figure 4 (a-d): Monthly variation of carbon dioxide and meteorological parameters over Madurai-2015
(a) CO2 vs Temperature ; (b) CO2 vs Rainfall ; (c) CO2 vs Wind speed ; (d) CO2 vs Relative humidity

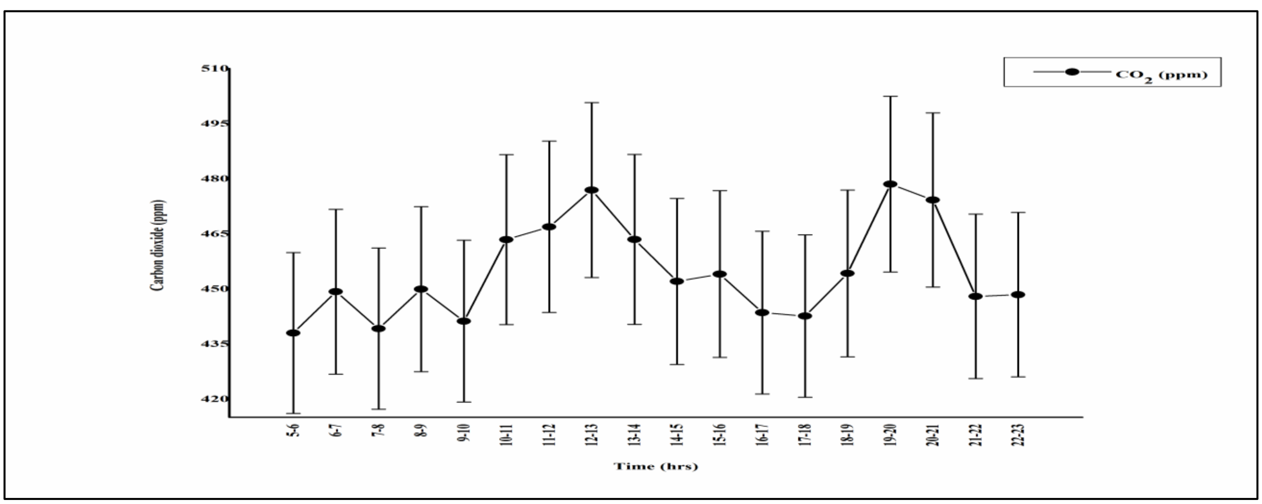

Figure 5: Diurnal variation of average carbon dioxide over Madurai-2015

marketing peoples and the accumulation of institutional buses in the city. The overall highest value of CO_2 (478.5 ± 13.7 ppm) in the same year is observed during 7-8 PM. During peak hours, with the slow movement of vehicles, long waits at the signals and rush driving mode of operation results the pollutant rate high (Bhaskar *et al*., 2010) and also in night hours, the rate of respiration dominates due to the absence of photosynthetic activity (Chandra *et al*., 2015). The second highest peak found at noon (476.8 ± 12.9 ppm) is due to high temperatures, which leads enhanced respiration rate of plants as well as the decomposition rate of microbes which contributed high carbon dioxide level in 12-1 PM (Sreenivas *et al*., 2016). In this city, the entry timing for a heavy tonnage vehicle is between 11am to 3pm. The rush movement of heavy tonnage vehicles (Lorries & trucks) and also the continuous movement of the government buses emits large amount of carbon emissions. The overall carbon dioxide concentration for the year 2015 (456.68 ± 13.64 ppm) is measured in the city.

Carbon dioxide concentration in different zones

The highest concentration of carbon dioxide is observed in Simakkal (476.03 ± 19.7 ppm), which is a busy commercial zone. The roadway is congested, so the traffic flow is much higher. Four wheelers and two wheelers passed through this zone. Depending upon the bad road condition and heavy traffic jam releases more amount of pollutants in this zone. Average temperature is observed to be 35.9°C. After Simakkal, the highest value is observed in Goripalayam (472.27 ± 22 ppm) which is a center zone of Madurai city. The average temperature was observed in this zone is about 34.9 °C. Moreover, all city buses touched in this zone. Peak hours as well as non-peak hours the traffic flow is steady. All types of vehicles passed in this zone. This zone is near to government hospital, more over the incineration activities of unwanted wastes are taking place in this zone results pollutant level high. In a traffic cum residential zone (Kalavasal), the level of carbon dioxide (457.13 ± 20.03 ppm) and the mean temperature (33.53 °C) is obsereved. Most heavy tonnage vehicles such as Lorries and trucks are passed in this zone which is the route to the industrial areas and not only in peak hours and also in non- peak hour the traffic flow is much larger. Tall commercial buildings with narrow space is an important parameter for characterizing the transport and dispersion of pollutants. The next level is observed in Periyar bus stand (453.45 ± 15.01 ppm), here the traffic flow is heterogeneous; all types of vehicles are passed in this zone. It is very narrow and a continuous traffic flow and hence the traffic movement is slow. In this place the average temperature level is about 34.01 °C. The emissions of carbon dioxide released from nearby hotels and platform shops by using fuels for their cooking activities. Palanganatham (residential zone) the carbon dioxide level is observed about 452.08 ± 12.7 ppm. Mostly some small scale industries and emissions from household activities are high in this zone. The mean temperature observed is about 32.9 °C. In Jaihindpuram (449.61 ± 9.48 ppm), a congested residential zone observed in the next level in this city. The average level of temperature observed in this congested zone is about 33.8 °C. Mostly in this zone, small hotels and more amounts of share auto flow and mini buses were high leads the carbon dioxide level. Finally, Madurai Kamaraj University (436.23 ± 10.25 ppm) is observed the low level in the above study zones. The low level observed in this zone because the campus is surrounded by Nagamalai forest with various trees and plants and also the vehicle movement is very low compared to other zones. The mean temperature also low is about 31.5 °C. Trees were helpful to absorb the level of carbon dioxide in this zone.

The nature of the city is based on tall buildings on both sides that appear urban canyon environment which affects the local meterological parameters, leads less dispersal of pollutants. Modification in urban area (vegetation removal) results less evapotranspiration, which leads Urban Heat Island (UHI) effect. Due to this effect, the city also drops the shading and cooling effects of trees and mainly the removal of carbon dioxide (Gorsevsk *et al*., 1998; Santos 2013). Shafiullah and Suhatharahima (2017) studied the landuse and land cover changes (1976-2014) in Madurai city, the observation results that the fallow land increased upto 12.15% to 23.22%. It is due to construction of buildings and roads, sophisticated lifestyles of human beings, leads the cutting of trees and decrease of agricultural practices which results the increasing of carbon dioxide level observed in this city. The

Table 6: Emissions level of carbon dioxide for various vehicles over Madurai during 2015

VT	S/F	CO_2	
		E (t/d)	E (t/y)
2w	2	0.5 ton/d	62.5 kilo ton/y
	4	0.4 ton/d	52.3 kilo ton/y
3w	P	12.7 ton/d	1543 kilo ton/y
	D	16 ton/d	1941 kilo ton/y
	G	2.1 ton/d	264 kilo ton/y
4w	P	36 ton/d	4356 kilo ton/y
	D	17.1 ton/d	2068 kilo ton/y
Household appliances		3.3 ton/d	1.2 kilo ton/yr

Table 7: Carbon dioxide emission from various emission inventories (Electricity Consumption)

Previous studies	Level of carbon dioxide
Krittayakasem *et al.,* (2011)	67 million tons of CO_2
Ramachandra *et al.,* (2015)	Delhi- 9237.73 Gg of CO_2
	Mumbai- 8474.32 Gg of CO_2
	Kolkata- 6337.11 Gg of CO_2
	Chennai- 8617.29 Gg of CO_2
	Bangalore- 4273.81 Gg of CO_2
	Hyderabad- 2341.81 Gg of CO_2
	Ahmedabad- 2544.03 Gg of CO_2
Ahmad *et al.,* (2015)	Delhi- 238.31 kg of CO_2
	Mumbai- 198.92 kg of CO_2
	Kolkata- 136.62 kg of CO_2
	Chennai- 258.11 kg of CO_2
	Bangalore- 128.24 kg of CO_2
	Hyderabad- 164.93 kg of CO_2
Allinson *et al.*, (2016)	1748 kg of CO_2
Wu *et al.,* (2017)	668.52 kg of CO_2

main reason of increasing pollutants in this region, there is an abundant increase in the number of vehicles on the roads, while comparing with the past two decades data. But the road pattern (length, width and quality) has not developed with the growth of vehicles may also lead the accumulation of pollutants in this region (Daniel and Kumar 2016).

Direct emission inventory from transport

By using this formula (1), the emission inventory results for transport sector were tabulated in Table.6. The total carbon dioxide emissions are calculated from different types of vehicles as per day and year. The total CO_2 emissions for different category of vehicles estimated around 85.1 tonnes/day and 10289.5 kilo tonnes /year. The calculated emission for two wheelers (2-stroke) is approximately 0.5 tonnes /day and 62.5 kilo tonnes /year. The calculated emission for two (4-Stroke) wheelers is approximately 0.4 tonnes /day and 52.3 kilo tonnes /year. Likewise for three wheelers (Petrol) the calculated emission was approximately 12.7 tonnes /day and 1543 kilo tonnes /year. Similarly for three wheelers (Diesel) the calculated emissions are approximately 16 tonnes /day and 1941 kilo tonnes/year. For three wheelers (LPG) the calculated emissions are approximately 2.1 tonnes /day and 264 kilo tonnes/year. For four wheelers (Petrol) the calculated carbon dioxide emissions is around 36 tonnes/day and 4356 kilo tonnes/year whereas four wheelers (Diesel) the calculated carbon dioxide emissions is around 17.1 tonnes/day and 22068 kilo tonnes/year. The major factor such as topography of the city, unpaved and constricted roads, traffic flow, lack of maintenance of vehicles, burning activities on road sides and also the lack of awareness in the public are responsible for the raise air pollution in the city. Mainly, local meteorological parameters and local anthropogenic activities play an important role in the pollutant level in this city. Non commercial vehicles are high in this study region. According to TST (Tamilnadu State Transport) 2016 report, the registered number of auto rickshaws is high in Chennai (74,026 in No) metro city and the next place to Madurai (15,710 in No). Mainly commercial vehicle such as auto rickshaws (3W) have high demand for the transportation of public from one place to another. As per RTO report, the number of non-commercial vehicles is high which emits more emissions compared to that of commercial vehicles. Heavy tonnage vehicles emit large amounts of pollutants compared with two wheelers and three wheelers. There is no proper maintenance and control measurements of the vehicles in the study area are due to lack of awareness to the public. In addition, the increasing of population density results the increasing of the vehicle population. Stricter emission control, introducing in vehicles seems the decrease in the pollutant rate, but increase in vehicle population might probably counteract the impact in the emissions (Sharma and Pundir 2008).

Indirect emission inventory from electricity consumption

During electricity generation, combustion of fossilfuels in thermal powerplants results in the emission of greenhouse gases in the atmosphere. The major source of energy utilization in the urban household is electricity consumption due to activities such as lightining, heating and household appliances. (Ramachandra *et al*., 2015). By using this formula (2 & 3), the emission inventory results for household consumption of electricity are tabulated in Table.6. The total CO_2 emissions for different household appliances are estimated approximately 3.3 tonnes /day and 1.2 kilo tonnes /year. Depending upon the household activities, availability and improvements of infrastructure in the buildings may vary the usage of electrical consumption and it can have large impacts on carbon emissions. Members who stayed inside home may increase the carbon emission for their appliance use compared to outside source (Allinson *et al*., 2016). In metropolitan cities, the electricity consumption constitutes the highest share of household emissions. The effective reduction of emissions from electricity usage will provide by the planning of building construction for the ventilation and other infrastructures. The usage of renewable energy would act as a tool for the reduction of emissions in household activities and in various sectors. (Chua *et al*., 2013; Santamouris, 2013; Kleerekoper *et al*., 2012).

Emission inventory from previous studies

Many researchers done the emission inventory study and it is complicated to compare with the present study. The present emission inventory study is compared with the all inventory study over the world. Wang *et al*., (2010) developed a bottom approach method proposed by combining different vehicle emission inventory model in 2005 (SVEM, COPERT 4, and IVE) for Chinese cities for light-duty gasoline vehicles. The total running carbon dioxide emissions of these vehicles in the Beijing are about COPERT (52,596 ton/day), IVE (53,504 ton/day) and SVEM (42,827 ton/day). The road transport emission of CO_2 in the province of Turin using the bottom-up approach by Pallavidino *et al*. estimated 3878 kt/yr. Petrol driven vehicles in Madurai city is emitted more pollutants reported by Jeba et al. The estimated level of carbon dioxide emission is differing from 0.27% to 5.52% in all the vehicle categories. In 2014, the emission inventory study conducted in the same city for the transport sector reports that the estimated emission of carbon dioxide is about 32.6 tonnes/day and 4.3 mega tonne/year (Venkitasamy and Bhaskar 2016). Several emission inventory studies have been carried out to calculate the greenhouse gas emissions from the electricity consumption for which large amount of fossil fuels are used for the production of electricity. Table 7 shows the amount of carbon dioxide emissions from various emission inventories in domestic, commercial based on the electrical consumption. By improving these types of emission inventory study results more information about the low consumption of fuels and driving activities, less electricity consumption, to encourage the usage of renewable sources and creates awareness to the public to improve the air quality status for the city.

Conclusion

In the present study continuous carbon dioxide are measured from an urban area, Madurai from January-2015 to December-2015. Diurnal, seasonal and monthly variations are observed in different zones in the Madurai city for the year 2015. In diurnal variation, two highest peaks are observed in this study region (12-1 PM and 7-8 PM) and lowest peak is observed in early morning 5-6 AM. For the year 2015, the overall average carbon dioxide level (456.68 ± 13.64 ppm) is observed. The monthly mean carbon dioxide level is observed for all different zones in Madurai. Simakkal (Busy commercial zone) is observed high level carbon dioxide followed by Goripalayam > Kalavasal > Periyar > Palanganatham > Jaihindpuram. The lowest level of carbon dioxide is observed in the Madurai Kamaraj University (Institutional zone). In overall the maximum level of CO_2 is found in the month of May and low in July for this city. The maximum seasonal variation of carbon dioxide is observed in summer and low in post-monsoon season. Climatological parameters play an important role in the movement and dispersal of the atmospheric pollutants and the statistical analysis results clearly shows the relationship between the pollutants and weather parameters. Emission inventory is also prepared for the transport sector and electricity consumption for this city during 2015. The carbon dioxide emission is calculated for per day and per year. This emission inventory is compared with previous emission inventory studies. This city experience lot of traffic problems due to encroachment of roads by parking personalized vehicle, narrow roads with high population density with vehicle congestion, improper roads facilities which results large amount of pollutant emissions. Using public transport and consume less amount of fossil fuels and use the renewable energy in the eco-friendly manner is the best remedy for the reduction of carbon dioxide. Mainly the conservation of energy must starts from the household level by turn off the electric appliances when not in use. Not only for carbon dioxide, but all the pollutant levels are reduced due to by plantation. This study results creates the awareness to the public to avoid deforestation and to encourage afforestation.

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