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Time Series Analysis of Atmospheric Carbon Dioxide in the megacity of Kolkata, India

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Abstract
The present study was carried out for more than three decades (1990-2022) to evaluate the trend of atmospheric carbon dioxide level at three stations in the megacity of Kolkata. The city is experiencing high population density and horizontal expansion in recent times for providing space to housing complex, shopping malls, industries, offices etc., mostly at the cost of the producer community in the city. The spatial order of near surface atmospheric carbon dioxide level is Park Street (Stn.1) > Lake Town (Stn.2) > Garia (Stn.3). The percentage increase of atmospheric carbon dioxide is 12.22, 9.71 and 10.96 at stations 1, 2 and 3 respectively. Both at stations 1 and 2, the increase of atmospheric carbon dioxide per year is 1.39, while at station 3, the value is 1.24. The rising trend of carbon dioxide in the city has the probability to cause adverse effects on the ecology and environment of the city by way of increasing the ambient air temperature and other related negative impacts.

Keywords: Carbon dioxide, Industry, Kolkata, Population density, Vehicles.

1. Introduction

The megacity of Kolkata is the capital of the maritime state of West Bengal which has become significantly vulnerable in recent times due to several factors like (i) extremely high population density (24,000/sq.km), (ii) horizontal expansion of the city at the cost of urban forest, (iii) unplanned industrial expansion,(iv) exponential increase in the number of vehicles that basically run by diesel and petrol, (v) huge energy consumption by congested offices in certain pockets of the city, (vi) left over wastes in many areas of the city that decompose to generate carbon dioxide.

According to several researches in this domain"many studies have been carried out on the carbon sequestration potential of the urban trees in the city of Kolkata [2, 1, 10], without considering the spatio–temporal variation of the near surface atmospheric carbon dioxide in and around the city."On this background, the present study is a first order analysis of the atmospheric carbon dioxide level in three sites of Kolkata namely Park Street (Station 1), Lake Town (Station 2) and Garia (Station 3). The study was carried out for more than three decades (1990-2022) to analyse the temporal trend in the selected sites.

International agencies quote that "atmospheric carbon dioxide is the most significant anthropogenically sourced greenhouse gas (GHG) and its concentration in the atmosphere has been increasing from 280 ppm since the pre-industrial *era* to a level higher than 400 ppm at present globally [12]. The enhancement of atmospheric carbon dioxide has been known as one of the factors inducing global warming and playing an important role in climate change. Anthropogenic carbon dioxide emissions, 70% of which come from fossil fuel combustion and industrial activities[4], are the main driver of the increased level of carbon dioxide in the atmosphere that trigger the phenomenon of global warming. The current rate of increase of atmospheric temperature is 1.5^0C compared to pre-industrial *era* and this may accelerate climate extremes between 2030 and 2050[5]. Atmospheric carbon dioxide concentration, moreover, will be continually increasing as the rapid development of industrialization requires enormous energy."

To slow down the increase of atmospheric carbon dioxide level, many countries are taking technological and nature-based measures to reduce the level of the gas [6]. In this context, it is essential to develop a long-term data bank of carbon-dioxide level, to formulate a cost - effective management policy to control the rise of the gas.

"Human activities increase atmospheric carbon dioxide levels primarily through the burning of coal, oil, or natural gas in industry, heating, electrical power generation, and cement production [9]. Further, land use and land-use change impact the global carbon budget through deforestation and land clearing [4]. Deforestation and the slow warming of the oceans, also impact the capacity to absorb carbon dioxide and reduce their potential to act as sink. The natural carbon sinks are not able to bind or convert all the carbon dioxide that is additionally released into the atmosphere. Therefore, the carbon dioxide concentration in the atmosphere increases. There is 45% increase in carbon dioxide concentration over pre-industrial levels [5]. This increasing carbon dioxide concentration absorbs the infrared radiation emitted by the planet's surface and traps the solar heat radiating from the Earth toward space. Therefore, the Earth's climate heats up, melting both polar ice caps and mountain glaciers, which raises the oceans' water level and increases sea and river temperatures. Climate change is also likely to promote extreme weather phenomena like extreme summers and colder-than-normal winters, along with heat waves, drought, hurricanes, blizzards, and rainstorms."

The scenario of climate change due to rise of carbon dioxide is almost uniform throughout the world [5], and the megacity of Kolkata is no exception.

2. "Materials and Methods

2.1 Site Selection

Three sites were selected in the city of Kolkata, based on the degree of anthropogenic activities (Table 1).

Table 1: Geographical location of the selected sites"

Stations	Coordinates
Park Street (Station 1)	22º40'19"N; 88º20'42"E
Lake Town (Station 2)	22º 34'0"N; 88º22'0" E
Garia (Station 3)	22º27'57"N; 88º23'5" E"

2.2 Sampling

A portable carbon dioxide analyser (Lutron CO_2 meter) was used to measure the near surface atmospheric carbon dioxide concentrations in and around the selected stations during the study period (1990-2022). The month of April was selected in all the selected years, which comes under the pre-monsoon season in the state of West Bengal. The season is characterized with high air temperature along with considerable humidity. As a part of quality assurance, 10 readings were taken during afternoon hours at each site at 10-15 m apart and finally the average value for every selected site was considered for further statistical analysis.

3. Results

The link between human foot print and climate vulnerability are visible almost throughout the world. The level of atmospheric carbon dioxide is a direct function of human activities like pace of urban development, industrial emission, deforestation, tourism, functioning of energy demanding industrial sectors like cement manufacturing, power generation etc. The city of Kolkata is noted for increased pace of population growth with high population density (Fig. 1).

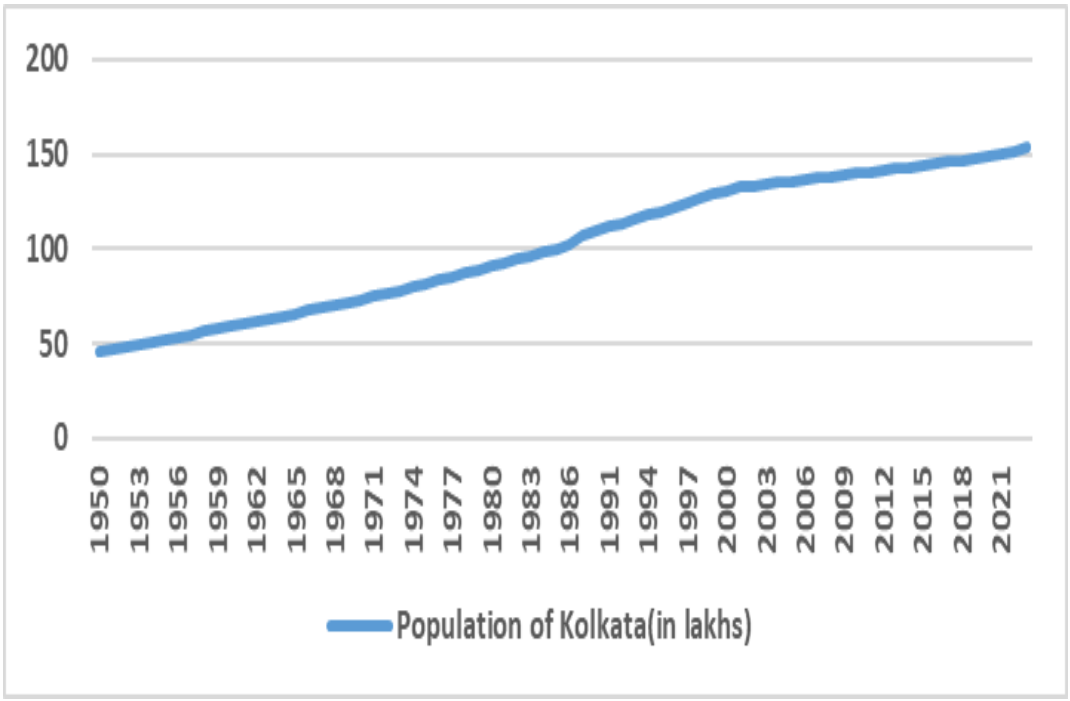

Fig. 1. Temporal trend of population in the megacity of Kolkata.

According to the Census report "the city with a population of about 15.5 million (https://www.populationu.com/cities/kolkata-population) is known for its high population density with a value of 24,000 persons per square kilometre [3]. The ambient air quality of the megacity is regulated largely by means of transport [11, 10]. Air quality in terms of carbon dioxide in the megacity of Kolkata is controlled by multiple factors viz. number of

vehicles plying, number of out-of-date vehicles, carrying capacity of the road, presence of several power plants and brick kilns adjacent to the city, poor greenery in majority of the areas etc. [11].

Industrialization is one of the most significant achievements of the modern civilization. Industrial pollution is the obvious consequence of industrial revolution throughout the world. Different industrial activities, whether it is the extraction of raw material, processing, manufacturing, or waste disposal, leads to significant environmental degradation. Industrial pollution has been proved to be the biggest threat not only for the human health, but also for the environment as well as the entire biodiversity of the planet. Hence, it is imperative to treat industrial pollution in a judicious way to save the environment, which can only be carried out if a long-term data base of pollutants (here carbon dioxide) is analysed with respect to space and time". The present study is an approach in this direction, where the major sources of atmospheric carbon dioxide have been pin-pointed along with its temporal trend.

Fig. 2 depicts that rise of carbon dioxide gas in the atmosphere of the city, which is keenly associated to industrial activities, vehicular movement, and urban development. These industries coupled with unplanned urban development and plying of large number of diesel and petrol-based vehicles are the sources of rise of carbon dioxide level in the atmosphere of the city. There are several industries in and around the megacity of Kolkata that consume large quantum of electricity due to which the level of carbon dioxide hikes up (Table 2). However, these industries provide employments to a large percentage of population in different sectors and hence a balance must be maintained between the developmental activities and natural resource conservation as these industries are the sources of employments to a large percentage of population.

Table 2: "Major Large-Scale Industries / Public Sector undertakings in and around the megacity of Kolkata.

Sl. No.	Name of the unit
1.	M/s. Garden Reach Ship Builders', Garden Reach, Kolkata
2.	M/s. India Tobacco Co. Ltd., Garden Reach, Kolkata
3.	M/s. Paharpur Cooling Tower Ltd., Garden Reach, Kolkata
4.	M/s. General Electricals Co. Ltd., Paharpur, Kolkata
5.	M/s. India Foils Ltd., Taratala, Kolkata
6.	M/s. Hindustan Development Corpn. Ltd., Tiljala, Kolkata
7.	M/s. Kilburn Engg. Co. Ltd., Majherhat, Kolkata
8.	M/s. Siel Hardmetal Ltd., Behala, Kolkata
9.	M/s. Indian Oxygen Ltd., Taratala, Kolkata
10.	M/s. Willamson Magor Ltd., Majherhat, Kolkata
11.	M/s. Modern Bread Industry Ltd., Taratala, Kolkata
12.	M/s. Eveready Battery, Taratala, Kolkata
13.	M/s. Britania Biscuit Co. Ltd., Hide Road, Kolkata
14.	M/s. Balmer Lawrie & Co Ltd., Hide Road, Kolkata
15.	M/s. Calcutta Chemical Co. Ltd., Bandel Road, Kolkata
16.	M/s. Boroline Industries, Chiriamore, Kolkata
17.	M/s. Usha Fan Industry Ltd., Bansdroni, Kolkata
18.	M/s. Bharat Brake & Valves, S.M.Avenue, Kolkata
19.	M/s. Rescon India (P) Ltd., Behala, Kolkata
20.	M/s. Hindustan Levers Ltd., Garden Reach, Kolkata
21.	M/s. Polar Fan Industry Ltd., Behala, Kolkata
22.	M/s. Central Inland Water Transport Corpn., Dock Yard Road, Kolkata
23.	M/s. British Engg. Pumps Ltd., Taratala, Kolkata
24.	M/s. Bharat Process & Mechanical Engg., Ultadanga, Kolkata
25.	M/s. Greaves Foseco Ltd.,Taratala, Kolkata
26	Downstream units of HPL (10 Units)
27	Easy Fit Jewellery Pvt. Ltd.
28	Jute Mills (2 Units)
29	Mizan & Co.
30	Sree Ganesh Jewellery House Ltd.
31	HM Biscuits Industries
32	Gitanjali Gems Ltd."

It is to be noted in this context that nature-based solution is the most cost-effective road map to retard the pace of carbon dioxide rise in the city atmosphere, for which plantation of specific varieties of trees is of great importance [10, 7]. To achieve this goal, eco-friendly urban planning, building design and landscaping with appropriate floral species can provide sustainable strategies for mitigating the rise of GHGs.

Our study shows an increasing trend of near surface atmospheric carbon dioxide in all the three selected stations (Fig. 2). The sudden dip in the level of atmospheric carbon dioxide is the effect of COVID – 19 lockdown, when the anthropogenic foot prints reached at their minimum values [8] due to complete closure of the transport and industrial sectors.

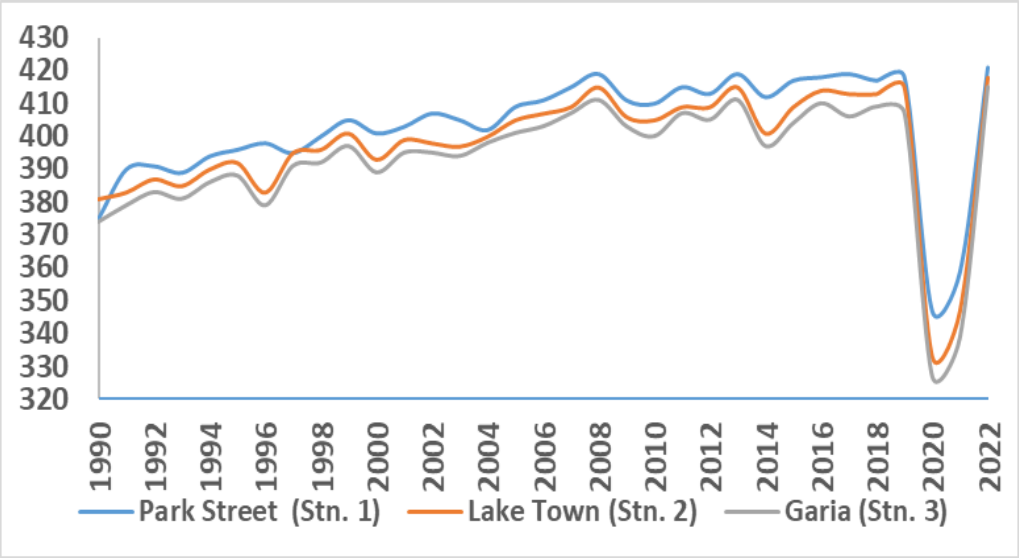

Fig. 2. Atmospheric carbon dioxide in various stations of Kolkata since last three decades.

The average atmospheric carbon dioxide level in these three locations followed the order Stn. 1 (403.06 ppm) > Stn. 2 (397.67 ppm) > Stn. 3 (393.42 ppm).

The increasing trend of atmospheric carbon dioxide is quite alarming as the percentage increase in these three locations are 12.22, 9.71 and 10.96 at Stn. 1, Stn. 2 and Stn. 3 respectively. The increment is equivalent to per year increase of 1.39 ppm at Stn. 1 and 2 and 1.24 ppm at Stn. 3 (Fig. 3 and Table 3).

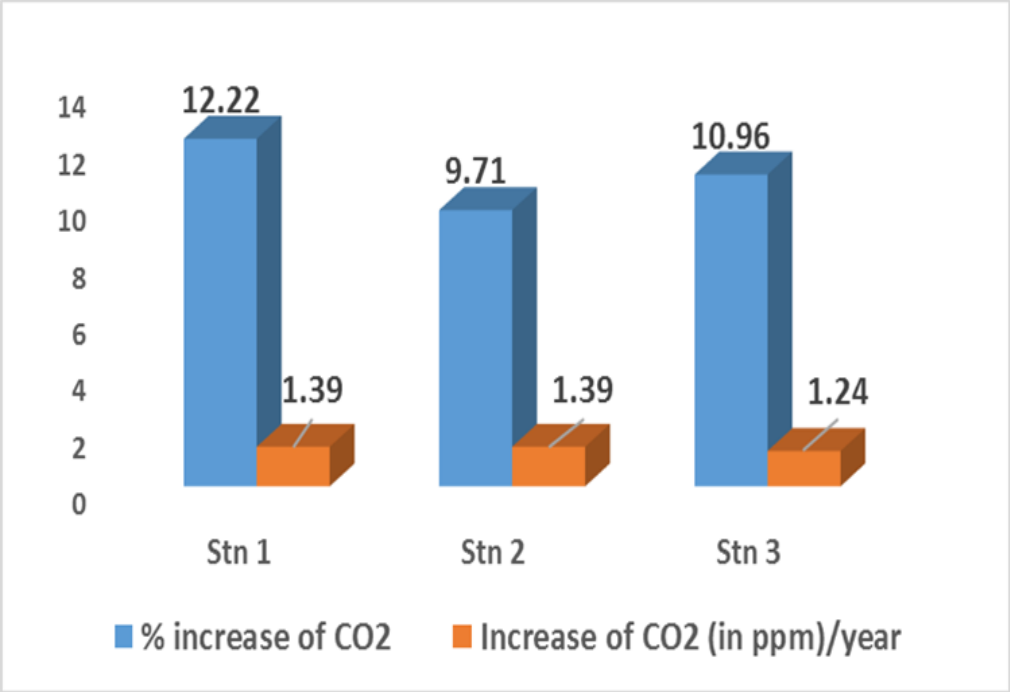

Fig. 3. Percentage and per year increase of carbon dioxide at three stations in the Kolkata City

Table 3: Average ppm and increase of carbon dioxide in three stations of Kolkata.

Station	Average ppm	Percentage increase of Carbon dioxide	Increase of CO_2 (in ppm) per year
Park Street (Stn.1)	403.06	12.22	1.39
Lake Town (Stn. 2)	397.67	9.71	1.39
Garia (Stn.3)	393.42	10.96	1.24

4. Discussion:

The rise of vehicles is another major cause of the emission of GHGs, preferably carbon dioxide in the city atmosphere. Most of these vehicles are not only very old, but also not maintained properly to meet the permissible level of emission. In addition to this, the narrow and damaged roads of the city often hinder the smooth movements of the vehicles leading to high emission.

At present, the number of vehicles in the city is around 19 lakhs (Fig. 4), which is far above the carrying capacity in terms of road space suitable for vehicular movements.

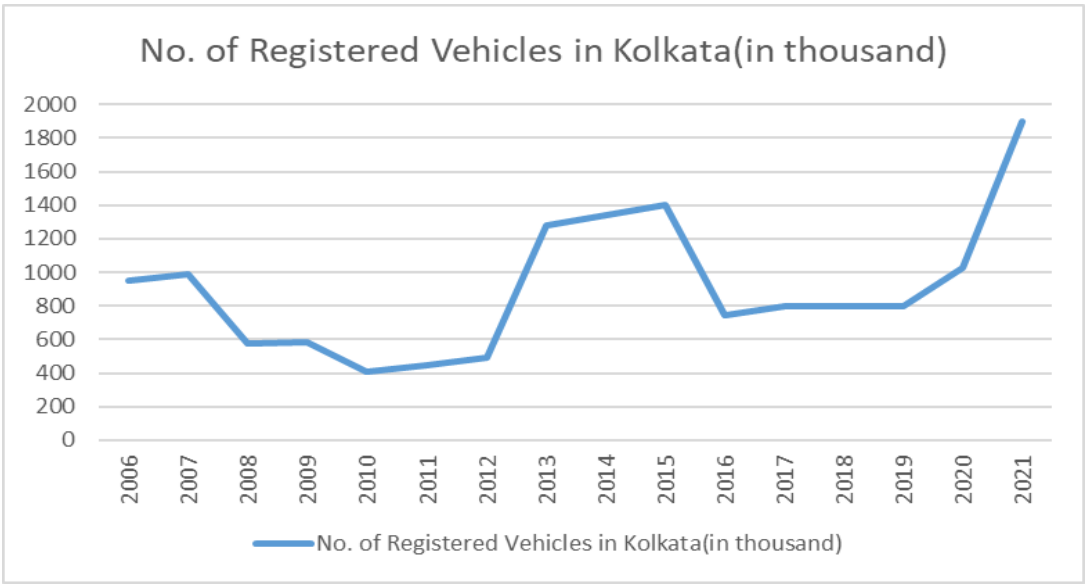

Fig. 4. No. of registered vehicles in Kolkata (from 2006 to 2021)

We carried out Analysis of Variance (ANOVA) to evaluate the difference in anthropogenic foot prints-based carbon dioxide levels amongst the selected three stations (Table 4), and observed significant variations between stations and years ($p < 0.01$).

"Table 4: ANOVA results computed from the atmospheric carbon dioxide data from 1990 – 2022.

Source of Variation	SS	df	MS	$F_{calculated}$	P-value	$F_{critical}$
Between Years"	22518438	3	7506146	13.1422	0.03123	9.276628
Between Stations	8302813	1	8302813	14.5371	0.03173	10.12 796
Error	1713438	3	571145.8			
Total	32534688	7				

The primary reason for such variation is the abundance/density of urban vegetation, which act as the potential scrubber of carbon dioxide gas. Park Street (Stn.1) has poor vegetation compared to Lake Town (Stn.2) and Garia (Stn.3). Moreover, most of the offices, academic institutes and market places are concentrated at Park Street due to which the striking spatial variation has been perceived amongst the stations.

5. Conclusion

The megacity of Kolkata is exposed to huge anthropogenic foot prints due to which the carbon dioxide level showed an increasing trend. The carbon dioxide level exhibited significant variations with space and time that is attributed to variations in carbon foot prints caused by human activities. The foot prints are more in Park Street compared to Lake Town and Garia which caused significant spatial variation. Vegetation cover also regulates the carbon dioxide level in the near surface atmosphere because of the carbon storage potential of the trees. The abundance or density of urban trees is extremely less in Park Street compared to Lake Town and Garia as the former area is occupied mostly by offices, shopping malls, markets, and restaurants, which are the point sources of GHG emissions. Hence, urban forest creation at the sensitive zones along with their conservation strategy can be an effective road map to reduce the rising trend of carbon dioxide in the atmosphere of the Kolkata city.

References

1. Agarwal,S.,Chakrabarty,S.P.,Zaman,S.,Pramanick,P.,Biswas,P.,Mukhopadhya,N.,Dutta,J.,Mitra,A.,:"Assessment of Carbon Storage Potential of Dominant Tree Species in an Educational Campus, Kolkata, West Bengal". Ela Journal of Forestry and Wildlife, Vol.10 (2): 869-878,2021
2. Banerjee, R., Pramanick, P., Zaman, S., Pal, N., Mitra, S., Mitra, A.,: "Impact of Urban Vegetation on Offsetting Carbon Emission: A Case Study from the City of Kolkata". Journal of Environmental Science, Computer Science and Engineering & Technology; Vol.4.No.3, pp 814-818.,2015
3. https://www.newgeography.com/content/002620-the-evolving-urban-form-kolkata-50-mile-city
4. IPCC. "Summary for Policymakers. In Climate Change 2013: The Physical Science Basis; Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change"; Stocker, T.F. et al.; Cambridge University Press; Cambridge, UK; New York, NY, USA,2013;Volume 3,pp.3-29,2013
5. IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK

and New York, NY, USA, pp. 3-24, doi:10.1017/9781009157940.001. 2018

6. Mitra, A., Zaman S.: "Blue carbon reservoir of the blue planet" published by Springer, ISBN 978-81-322-2106-7, XII, pp. 299. DOI 10.1007/978-81-322-2107-4,2015
7. Mitra, A., Bagchi, J., Thakur, S., Parkhi, U., Debnath, S., Pramanick, P., Zaman, S.: "Carbon sequestration in Bhubaneswar City of Odisha, India". International Journal of Innovative Research in Science, Engineering and Technology. Vol. 4, Issue 8; pp 6942-6947, 3297. 10.15680/IJIRSET.2015.0408184,2015
8. Mitra, A., "Impact of COVID-19 Lockdown on Environmental Health: Exploring the Situation of the Lower Gangetic Delta". Springer eBook ISBN 978-3-031-27242-4, XIII: pp. 310 DOI: https://doi.org/10.1007/978-3-031-27242-4, 2023
9. Mitra, A., "Sensitivity of Mangrove Ecosystem to Changing Climate". Published by Springer New Delhi Heidelberg New York Dordrecht London, ISBN-10: 8132215087; ISBN-13: 978-8132215080. ISBN 978-81-322-1509-7 (eBook), XIX, pp. 323, DOI: https://doi.org/10.1007/978-81-322-1509-7 2013
10. Mitra, A., Ahmed, S., Pramanick, P., Zaman, S., Pal, N.,: "Study on floral carbon storage potential in the megacity of Kolkata: A roadmap towards net-zero carbon emission". Journal of Environment and Sociobiology, Volume 19 (No. 2), pp 113-123, 2022.
11. Sengupta, S., Chaudhuri, T., Ahmed, S., Agarwal, S., Zaman, S., Mitra, A.,: "Status of the near surface atmospheric CO2 around the healthcare units in the megacity of Kolkata during two different COVID-19 lockdown phases "Status of the near surface atmospheric CO2 around the healthcare units in the megacity of Kolkata during two different COVID-19 lockdown phases"., Parana Journal of Science and Education. Vol. 8, No. 2, pp. 16-23. DOI: tiny.cc/PJSE24476153v8i2p016-023, 2022
12. World Meteorological Organization (WMO). Greenhouse Gas Bulletin, No. 13. Available online: https://public.wmo.int/en/media/press-release/greenhouse -gas-concentrations-surge-new-record