INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

CASE REPORT

Evaluation of 8-hour average ground level Ozone in the city of Visakhapatnam and its impact on Human Well-being and Environment

Dileep Geddam[1]*, Dr. Viswanadha Kumar Giduturi[2], Vijaya Ratna[3]

1 Assistant Professor, Department of Architecture,, College of Engineering (A), Andhra University, 530003
2 Professor, Department of Architecture, College of Engineering (A), Andhra University
3 Student of Master of Environmental Planning, Department of Architecture, College of Engineering (A), Andhra University

OPEN ACCESS

Received: 07-05-2020
Accepted: 10-07-2020
Published: 27-07-2020

Editor: Dr. Natarajan Gajendran

Citation: Geddam D, Giduturi DVK, Ratna V (2020) Evaluation of 8-hour average ground level Ozone in the city of Visakhapatnam and its impact on Human Well-being and Environment. Indian Journal of Science and Technology 13(26): 2593-2600. https://doi.org/10.17485/IJST/v13i26.532

***Corresponding author**.
Dileep Geddam
Assistant Professor, Department of Architecture,, College of Engineering (A), Andhra University, 530003
dileep9geddam@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

Abstract

Objectives: The present study was focused on the 8-hour average concentration of ground-level ozone in the city of Visakhapatnam for three years in a row, i.e. 2017, 2018, and 2019, and the effects of ozone on human life, the environment, and building materials. **Method**: The data of 8-Hour average ground-level ozone concentration was collected for the study from the Central Control Room for Air Quality Management – All India, Central Pollution Control Board. Data available from the source were analyzed and compared to the NAAQS, India and the data was tabulated and showed specifically the number of times the 8 Hour average ground-level ozone surpassed in a month, for a clearer understanding. **Findings:** Study results show that the air quality of ozone levels during winters showed maximum unhealthy hours. The trends of maximum recorded 8-Hour average concentration of ozone levels in a day are also increasing year by year. **Recommendations:** It is recommended to be safe indoors during high ozone days for the people with comorbidities, children, Women in pregnant, people active in outdoor activities and it is further advised to reduce ozone exposure it's safe to wear washable 6-layer N99 and PM2.5 face mask during winters especially from November to February. Schools may be cautioned to discontinue the open-air physical activity during this period. Creating ozone forecasts accessible to the public is important, and the local and national laws should be strengthened to combat ozone pollution.

Keywords: Asthma; contamination; ecosystems; urban vegetation; ozone; mortality

1 Introduction

Air to be considered as indispensable an asset like water or food. The typical adult exchanges gases every day about six times higher than the regular consumption of food and water to stay alive. That is the reason we give incredible significance to air quality [1]. Air quality is significant worldwide concern in industrialized emerging nations. In most major cities of India, urban air quality has worsened and is fueled by population growth, industrialization, and increasing usage of automobiles. Even after pollution control regulations, pollution levels reached unsafe levels because of increased emissions of sulfur dioxide (SO_2), Oxides of Nitrogen (NOX), Carbon monoxide (CO), Particulate matter, (VOCs), Lead, and Ground-level ozone, etc. [2]. This study focuses on ground-level ozone. Ozone is both protector and a problem for us. Ozone in the stratosphere safeguards us from dangerous UV-radiations, and it serves as a strong oxidizing agent in the lower atmosphere causing damage to crops, vegetation, fabrics, etc. and harm to human beings [3]. Surface ozone is known among the most prominent air pollutants because of its health risks [4]. In recent decade's troposphere, ozone has been at the center of air quality research due to its negative impact on human health and the well-being of the ecosystem. Ozone on the ground is a secondary pollutant [5] Ozone is developed by photochemical reaction of sunlight and nitrogen oxides, facilitated through several volatile organic compounds (VOCs), which are photochemically reactive hydrocarbons [6]. Since the reaction requires sunlight, ground ozone shows as a diurnal pattern with high concentration trends in midday or mid-afternoon. A seasonal cycle also occurs if intense UV radiation with higher degrees of ozone in spring and early summer [7]. Ground-level ozone persists once developed and can be carried over interminable distances and even rural areas can experience high ozone levels [5]. Ground-level ozone can strengthen respiratory susceptibility, causing COPD, cough, the nose, throat irritation, and headaches (during exercise). Ozone sensitivity is likely related to premature mortality, and it increases the risk of ozone exposure for children since the children receive a high dose per body mass, and in the children lungs continue to develop [8]. Several reports like US EPA science assessment have already shown increased school absences, extended visits to emergency rooms, and increased hospital admissions on high ozone days. As pointed out in the WHO Guideline and the EPA Ozone standard individuals with prior respiratory problems such as asthma and COPD, children and elderly individuals and active outdoor people (outdoor workers) are more sensitive to exposure to ozone [8]. Too much ozone exposure affects crops and trees, especially slow-growing crops and long-lived trees. About, 90% of North America's plant loss is largely attributed to troposphere ozone. The plants showed lower plant growth and lower yields. As per America's United States office of technology assessment (OTA), a seasonal average of 120 μ.g / m3 of 7-hour mean ground-level ozone levels, can trigger crop yield reductions of 16-35% for cotton, 0.9-51% for wheat, 5.3-24% for soybeans and 0.3-5.1% for maize. Apart from physiological damage, ground-level ozone could contribute to lower fungal resistance, bacterial, viral resistance to insects, decreased production, prevented yields, and reproductive capacity. These effects may lead to a reduction in the quality of crops and a slump in biodiversity in the natural ecosystems [9]. Ozone concentrations have been rising in India because of the increasing emissions of ozone precursors [10]. Most of the people attribute that the primary air pollutants are particulate matter, nitrogen dioxide, and sulfur dioxide, but ground-level ozone is also a considerable threat to public health and biodiversity. Ground-level ozone concentrations in India have increased by 27% from 124 μg/m3 in 1990 to 144 μg/m3 in 2016 [11]. In this study, an effort was made to understand the ground-level ozone guidelines, short-term and long-term effects on human ozone exposure, and the environmental and building material affects, taking the severity of ground-level ozone discussed.

1.1 Ground level ozone guidelines

Ground ozone levels at 120 μg/m3 for an 8-hour daily average was the guideline set by WHO Air Quality Guidelines for Europe (WHO AQG, 2000) but various investigations revealed that there are several health effects on humans at concentrations below 120 μg/m3. Thus, in 2005, the WHO Air Quality Guidelines AQG reduced the cutoff from 120 μg / m3 to 100 μg / m3 (the daily maximum mean of 8 hours). In some sensitive individual health effects may occur below the new guideline level. Studies in the time series show an increase of 0. 3–0. 5 percent in daily mortality in 8-hour ozone concentrations above the estimated baseline level of 70 μg / m3 for every 10 μg / m3 increment [12]. Accordingly, for any 8-hour monitoring period, the mean concentration of ozone in ambient air must be less than 100 μg / m3 and fewer than 180 μg / m3 in hourly monitoring. This should be met with 98 percent of the time in a year, and in 2 percent of the time, they may exceed the limits, but not on two consecutive monitoring days [13].

1.2 Effects of ground-level ozone on humans

The ozone we take in from air can harm our well-being, particularly in hot radiant days when ozone arrives at undesirable levels. Even low degrees of ozone can have well-being effects. Asthma-containing individuals, youngsters, older adults, and people active in the outside air, specifically open-air laborers, are the most vulnerable to ozone. Also, individuals with certain hereditary highlights and the individuals who have a diminished dietary admission, for example, nutrients C and E, are bound to be a more serious hazard when presented to Ozone [14]. The epithelial permeation of the lung was modified after 18-20 hours of exposure with Ozone [15]. Ozone also stimulates the mucocidal function of the lung [16]. These effects can make people susceptible to bacterial respiratory infections. India has premature mortality13 times higher than Bangladesh and twenty-one times higher than Pakistan's because of ozone pollution. [17].

1.3 Effects of short term exposure to Ozone

Inflammation markers in the lungs have risen during 6.6 hours of exposure to troposphere ozone concentrations [18]. The reduction in lung function is caused by short-term exposure to environmental level concentrations of ozone. Young kids are susceptible to ozone, as significant postnatal lung development continues [19]. Small to moderate lung function and symptom effects, along with lung injury and inflammation, may be experienced by an outdoor worker on an 8-hour exposure to 120 to 140 μg / m3 ozone [20]. In children under the age of 2 years, hospital admissions have risen by 6.6 percent for a change of 19 μg / m3 in 1-hour daily maximum ozone [21].

1.4 Effects of Long term exposure to Ozone

The long-term ozone exposure is linked with reduced lung growth, asthma worsening, and is probably one of the numerous causes of asthma. Long-term exposures to higher ozone levels may also be associated with permanent lung damage, such as children's abnormal pulmonary development. Daily exposure to the ozone over 4 days results in attenuating some aggressive neural effects of subsequent exposures within 1-2 weeks (for example, changes in lung function and symptoms) [20]. Several studies on chronic animal exposure, especially in rats and monkeys, support the likelihood of chronic damage to lungs from prolonged ozone exposure [22].

1.5 Environmental effects of ground-level ozone

Ground-level Ozone can have negative effects on ecosystems and plants. This will alter the ability of sensitive plants to produce and store food, to improve their susceptibility to certain conditions, insects, other pollutants, competition and harsh weather, to damage the leaves of trees and other plants, to adversely affect the appearance of urban flora and greenery in national parks and leisure areas, and to reduce forest growth and growth in crop yields, potentially impacting species diversity in ecosystems [23].

1.6 Effects of ground level-ozone on building materials

The principal toxins influencing elements are sulfur dioxide, and sulfates, nitrogen oxides and nitrates, chlorides, carbon dioxide, and ozone. The substances generally susceptible to contamination are calcareous structure stones and ferrous metals. Signs of damage shows loss of mass, changes in porosity, staining, and embrittlement [24]. As of late, the impact of ozone in blend with sulfur, and nitrogen contamination has been exposed to orderly examinations. The impact of acidifying air toxins further complicates the situation. Ozone applies an immediate destructive impact on characteristic elastic, plastic materials, textiles, paint, and surface covering [25].

2 Visakhapatnam City

Visakhapatnam is a seaside city on the eastern side of peninsular India and the monetary capital of Andhra Pradesh. The city is a port city – it has the most established shipyard which is the natural harbor on the eastern bank of India. It is the home office of the Indian Navy's Eastern Command. The Greater Municipal Corporation of Visakhapatnam has approximately 700 km^2 area, including the Gajuwaka, Anakapalle and Bheemunipatnam areas. It is one of the most populated cities in the state, with a population of about 2 million in 2011 [26]. Visakhapatnam has several tourist destinations that vary from heritage as well as beaches to many other tourist destinations in the greater region thanks to its location [27].

2.1 Air pollution in the city

The MoE&F study shows that Visakhapatnam is one of the critically polluted industrial areas found among 43 cities in 16 states in India with a CEPI index score of 52.31 [28]. And the city is also one of India's 95 non-attainment cities in 23 states [29]. Geographically, Visakhapatnam can be cosidered a bowl region as it is encompassed on three sides by Eastern Ghats, and on the other side ocean. In this way, reversal conditions because of the negative adiabatic pass are that here. The rising air pollution level in the bowl area is due to industries and increasing number of vehicles. Air pollution is a major challenge for citizens' safety because of a high annual vehicle growth rate of 9% and coal handling at the Visakhapatnam Port, Steel Plant Operations, and diesel-operated para transit [30]. According to the superindent of Visakhapatnam TB Hospital, the total number of respiratory cases is increasing as the air is contaminated. In the city, respiratory disorders such as allergy, asthma, lung cancer, and tuberculosis are on the ascent. Nearly 100 patients were registered daily in the TB hospital for the past few years. Yet there were already nearly 200. Around 50 percent of them are aged between 18 and 40. The biggest cause of these diseases is the rise in motor vehicles. When the volume of vehicles grew, health-hazardous items also grew. In 1995, the total of motor vehicles in the city was 1.75 lakh, and in 2014 the figure was 5 lakh and increased to 12 lakhs in 2019 [31]. The overall air quality index is an important aspect, and we already knew that the city is listed as one of the most polluted cities in India concerning particulate Matter and various studies revealed that the human health is affected not only because of particulate Matter but also to short-term and long-term exposure to surface ozone. As studies revealed an increase in 8-hour average ozone concentration by 100 μg/m3 is expected to induce a 25% increase in symptom exacerbation among adults and asthmatics involved in normal activities and 10% increase in hospital admissions for respiratory conditions [14]. Here, we have made an attempt to study and understand the concentration of an 8-hour average ground-level ozone in the city of Visakhapatnam.

3 Data collection and methods

Greater Visakhapatnam Municipal Corporation, Visakhapatnam – Andhra Pradesh Pollution Control Board is a continuous air quality monitoring station present on the busy central core of the city has been preferred for this investigation and the data collected was daily 8-hour average concentrations of ozone (μg/m3) monthly data for the years 2019, 2018 and 2017 available from Central Control Room for Air Quality Management – All India, Central Pollution Control Board. We tabulated data available showing year, month, 8 hr avg. ozone (μg / m3) concentration in the month, numerous times 8 hour Avg. ozone concentration exceeded permissible limits per month, maximum and minimum 8- hour avg. ozone concentration recorded in the month. The data from the source were analyzed and compared to the NAAQS, India the tabulated data indicated specifically the number of times the 8-hour average ground-level ozone surpassed in a month, for a clearer understanding.

4 Results

The tabulated data of 8-hour Avg. ozone (μg/m3) concentration shows the air quality.

4.1 Trends of 8-hour avg ozone (μg/m3 concentration for the year 2019

The results from the [Table 1] indicates the 8-hour Avg. ozone (μg/m3) concentration exceeded the revised National Ambient Air Quality Standards (NAAQS) and WHO Air quality guidelines 2005 i.e ≥100 μg/m3 standard by forty times (equivalent to 320 Hours i.e. 13.3 days) with a maximum ozone recorded is 186.65 μg/m3 and the minimum recorded is 0.99 μg/m3 in January and March 2019. Ozone also exceeded its Permissible Limits ≥100 μg/m3 in February, November, and December, and from March to October 2019, the pollutant is within the permissible limits.

Table 1. Concentration of ozone at GVMC, Visakhapatnam, Andhra Pradesh during 2019

Month	Days	NOR	NOR (μg/m3)				NOR avg	
			≥100 (APL)	90-99 (LTE)	70-89 (LTE)	0-69	Max.	Min.
Jan	31	93	33	7	17	36	186.65	1.54
Feb	28	76	4	4	7	61	104.39	1.54
Mar	31	91	0	0	0	91	57.68	0.99
April	30	86	0	0	0	86	60.32	1.14
May	31	89	0	0	0	89	50.76	5.42
June	30	88	0	0	0	88	62.32	5.34
July	31	85	0	0	0	85	41.48	2.81
Aug	31	77	0	0	0	77	44.22	2.15
Sept	30	73	0	0	0	73	53.94	7.65
Oct	31	85	0	0	2	83	87.45	9.28
Nov	30	86	2	8	28	48	106.82	11.08
Dec	31	90	1	10	39	40	101.19	10.46
Total	365	1019	40	29	93	857	–	–
8-hour avg. ozone concentration recorded in a year in percentage			3.92	2.85	9.12	84.11		

NOR : Numerous times the 8-hour avg. ozone recorded in a month
NOR (μg/m3) : Numerous times 8-hourAvg. Ozone Concentration recorded in a month in (μg/m3)
APL : Above Permissible Limits
LTE : Long-term exposure can deteriorate health condition
NOR avg : 8-hour avg. ozone recorded in the month (μg/m3)

4.2 Trends of 8-hour avg Ozone (μg/m3 concentration for the year 2018

The outcomes from the [Table 2] shows the 8-hour Avg. ozone concentration surpassed the reasonable guidelines the worst with thirty-seven times within December, fourteen times in January, eleven times each within October and November and three times in February all put together, it came around seventy-six times in a year (comparable to 608 Hours i.e. 25 days in a year) with most extreme ozone concentration recorded was 180.12 μg/m3 within December and least is 0.65 μg/m3 recorded within February. March to September Ozone concentration is within the permitted limits.

4.3 Trends of 8-hour avg Ozone (μg/m3 concentration for the year 2017

The outcomes from the [Table 3] shows the 8-hour Avg. ozone concentration with the information available from the source for the months January to March, November, and December, Ozone concentration exceeded the guidelines most extreme with twenty-one times in December, eighteen times in November, sixteen in January with greatest concentration recorded are 175.46 μg/m3 in January and least recorded is 5.17 μg/m3 in March 2017.

Table 2. Concentration of ozone at GVMC, Visakhapatnam, Andhra Pradesh during 2018

Month	Days	**NOR**	**NOR (μg/m3)**				**NOR avg**	
			≥100 **APL**	90-99 (**LTE**)	70-89 (**LTE**)	0-69	Max	Min.
Jan	31	83	14	9	15	45	111.24	3.92
Feb	28	83	3	3	9	68	109.28	0.65
Mar	31	93	0	2	5	86	90.88	3.64
April	30	87	0	0	1	86	74.41	2.77
May	31	86	0	0	0	86	59.65	4.45
June	30	71	0	0	3	68	80.29	7.69
July	31	90	0	0	0	90	35.03	2.64
Aug	31	67	0	0	0	67	40.39	3.31
Sept	30	90	0	0	1	89	73.23	6.66
Oct	31	89	11	5	11	62	140.6	4.25
Nov	30	61	11	3	7	40	142.96	7.67
Dec	31	76	37	7	12	20	180.12	17.09
Total	365	976	76	29	64	807	–	–
8-hour avg. ozone concentration recorded in a year in percentage			7.78	2.97	6.56	82.69		

NOR : Numerous times the 8-hour avg. ozone recorded in a month
NOR (μg/m3) : Numerous times 8-hourAvg. Ozone Concentration recorded in a month in (μg/m3)
APL : Above Permissible Limits
LTE : Long-time exposure can deteriorate health condition
NOR avg : 8-hour avg. ozone recorded in the month (μg/m3)

Table 3. Concentration of ozone at GVMC, Visakhapatnam, Andhra Pradesh during 2017

Month	Days	NOR	NOR (μg/m3)				NOR avg	
			≥100 (APL)	90-99 (LTE)	70-89 (LTE)	0-69	Max	Min
Jan	31	91	16	9	24	42	175.46	7.41
Feb	28	83	0	0	3	80	84.29	5.88
Mar	31	87	0	0	8	79	82.33	5.17
April	30	NA	NA	NA	NA	NA	NA	NA
May	31	NA	NA	NA	NA	NA	NA	NA
June	30	NA	NA	NA	NA	NA	NA	NA
July	31	NA	NA	NA	NA	NA	NA	NA
Aug	31	NA	NA	NA	NA	NA	NA	NA
Sept	30	NA	NA	NA	NA	NA	NA	NA
Oct	31	NA	NA	NA	NA	NA	NA	NA
Nov	30	90	18	5	25	42	140.52	11.74
Dec	31	92	21	13	17	41	124.34	4.07
Total	365	443	55	27	77	284	–	–

NA- No data availablefrom the source
NOR : Numerous times the 8-hour avg. ozone recorded in a month
NOR (μg/m3) : Numerous times 8-hourAvg. Ozone Concentration recorded in a month in (μg/m3)
APL : Above Permissible Limits
LTE : Long-term exposure can deteriorate health condition
NOR avg : 8-hour avg. ozone recorded in the month (μg/m3)

5 Conclusion

Air quality in the study area (8-hour average ground-level ozone levels) shows a maximum of unhealthy hours during winters. The ozone crossed the permissible limits during October, November, December, January, and February months in all the examined three years. However, the year 2018 showed the most unhealthy ozone hours with a maximum of 7.78 percent of the total 8-hour Avg. ozone concentration recorded in a year. Our study shows that from April to September, the pollutant ozone did not show unsafe hours, not even a single day. Trends in ozone show that the peak concentration of 8-hour average ozone is increasing year after year, as the city recorded 175.46 μg/m3 in the year 2017, 180.12 μg/m3 in 2018 and the highest ever recorded is 186.65 μg/m3 in the year 2019. If these trends proceed, by the year 2030 and 2050 the city may encounter the greatest 8-hour avg. ozone as 249.94 μg/m3 and 365.59 μg/m3, i.e. 1.5 to 3.5 times more than permissible standard limits (Forecast by Linear Regression Method) and this transient exposure to ozone might lead to greater health risk to humans and potentially impacting the environment, species diversity in ecosystems. Although the ozone is inside the threshold levels from April to September during 2017, 2018, and 2019, the transitory addition of ozone during the winter may have some negative impact. Groups of individuals at risk are people engaged in active outdoor activities such as traffic police personnel, laborers, security guards, shopkeepers, children playing in playgrounds, food and other good's delivery personnel, and so on. Elderly citizens, women in pregnancy, children, and people already suffering from lung infections should avoid spending too much time outdoors during winter, especially from 9 AM to 6 PM as the ozone is at elevated levels during this period. Hence it is recommended to be safe indoors during high ozone days as much as possible and in unavoidable circumstances, to further reduce ozone exposure, it is safe to wear washable 6-layer N99 and PM2.5 face mask during winters, especially from November to February. Schools may be cautioned to discontinue the open-air physical activity in such times. Creating ozone forecasts accessible to the public will improve the effectiveness of such self-protection ways to avoid exposure to ozone. The problem of ozone pollution is expected to remain at the long-term level in developing countries and to combat ozone pollution local and national policies are to be strengthened.

References

1. Ignou . Unit-4 Development and Environment Pollution. in *Environment Concerns* (others . , ed.):129-129Ignou eGyanKosh 2019.
2. Ignou . Air Pollution and Health. *Ignou - egyankosh.* 2019:168-168.
3. IGNOU . Types of Air Pollutants. in *Block-1 Environment Concerns*Ignou - eGyanKosh 2020.
4. E WHOROF. Air quality guidelines global update. (Copenhagen)WHO Regional Office for Europe 2005.
5. Hamilton R, Kucera V, Tidblad J, Watt J. Ground-level ozone. in *The Effects of Air Pollution on Cultural Heritage*(Stockholm):21-22Springer Science + Business Media 2009.
6. Cheremisinoff NP. Ground Level Ozone. in *Handbook of Pollution Prevention Practices*:54-54Marcel Dekker, Inc 2001.
7. Hamilton R, Kucera V, Tidblad J, Watt J. *The Effects of Air Pollution on Cultural Heritage.* Boston, MA: Springer 2009.
8. Zhang JJ, Wei Y, Fang Z. Ozone Pollution: A Major Health Hazard Worldwide. *Frontiers in Immunology.* 2019;10:1-10.
9. Cheremisinoff NP. Chapter 2 Managing Hazardous Chemicals. in *Handbook of Pollution Prevention Practices*:58-58Dekker, Inc 2001.
10. Ghude SD, Kulkarni SH, Jena C, *et al.* Application of satellite observations for identifying regions of dominant sources of nitrogen oxides over the Indian Subcontinent. *Journal of Geophysical Research: Atmospheres.* 2013;118(2):1075-1089.
11. Institute HE. State of global air. 2018.
12. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide.
13. CPCB . 2012.
14. Agency EE. HEALTH EFFECTS OF EXPOSURE TO OZONE. 2020.
15. Foster WM, Stetkiewicz PT. Regional clearance of solute from the respiratory epithelia: 18-20 h postexposure to ozone. *Journal of Applied Physiology.* 1996;81(3):1143-1149.
16. Foster WM, Costa DL, Langenback EG. Ozone exposure alters tracheobronchial mucociliary function in humans. *Journal of Applied Physiology.* 1987;63(3):996-1002.
17. Mohan V. India tops list of countries in ozone pollution deaths. 2017.
18. Devli R, McDonell W, Mann R, *et al.* Exposure of Humans to Ambient Levels of Ozone for 6.6 Hours Causes Cellular and Biochemical Changes in the Lung. *American Journal of Respiratory Cell and Molecular Biology.* 1991;4(1):72-81.
19. Finkelstein JC, Johnston CJ. Enhanced Sensitivity of the Postnatal Lung to Environmental Insults and Oxidant Stress. *Pediatrics.* 2004;113(4):1092-1096.
20. Agency USEP. Health Effects of Ozone Pollution. 2020.

21. Burnett RT, Smith-Doiron M, Stieb D, others . Association between ozone and hospitalization for acute respiratory diseases in children less than 2 years of age. *American Journal of Epidemiology.* 2001;153(5):444-452.
22. Europe WHORO. ealth aspects of air pollution with particulate matter, ozone and nitrogen dioxide : report on a WHO working group, Bonn. 2003.
23. MNN . Ozone: Health and environmental effects. 2009.
24. Butlin RN. Effects of air pollutants on buildings and materials. *Proceedings of the Royal Society of Edinburgh. Section B. Biological Sciences.* 1990;97:255-272.
25. Fowler D. Transboundary Air Pollution: Acidification, Eutrophication and Ground-Level Ozone in the UK NEGTAP 2001. 2001.
26. Guttikunda S. City – Visakhapatnam (Andhra Pradesh, India). 2019.
27. GVMC . City Development Plan – Greater Visakhapatnam. 2015.
28. Subba S, , Gurung K, *et al.* Quantitative analysis of vegetation structure, composition and species diversity of moist Sal bearing tropical forest of Sumbuk reserve forest in South Sikkim, India. *Tropical Plant Research.* 2020;7:245-254.
29. N.A.M.P . Air Pollution - (N.A.M.P.). 2020.
30. MoUD G. The Smart City Challenge Stage 2, Smart City Proposal, AP-01-VIZ.
31. Correspondent D. 2014.