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Exhaust in heavy and medium automobiles

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ABSTRACT

Respirable suspended particulate matter (RSPM) is an important subtype of particulate matter (PM), a causative agent of air pollution with aerodynamic diameter ≤10 µm, thus also named as PM_{10} (Gilbert, 2007). These fine particles in combination with other pollutants are linked to a number of health problems like premature death, aggravated asthma, chronic bronchitis and decreased lung function. As per NAQMP, the RSPM Level at Kilpauk and T.Nagar are increased from 81 and 85ppm, in the year 2007 to 131 and 132ppm in the year 2014 respectively and crossing the maximum permissible level of 100 ppm. This causes numerous health hazards to the road users (Central Pollution control board, Air quality assessment, 2015). Most of the present automobiles plying on the road is having exhaust level at 0.4 to 0.6 m with respect to road level. Generally, maximum exposure of RSPM to road users occurs at road level between 0 to 2.5 m. This paper presents the results of study that can be obtained in reduction of RSPM concentration by modifying the existing design of exhaust from 0.4 to 0.6 m height to ≥2.75 m i.e. vertical exhaust to the Heavy and Medium Automobiles. This RSPM reduction will further reduce the respiratory problems and carcinogenic effect on humans especially to the road users, traffic managers, etc. The analysis of RSPM is carried out for T.Nagar Bus Stand / Depot Traffic Intersection in Chennai, capital city of Tamil Nadu. Ambient air pollutant concentrations obtained at the specified breathing level are compared between the original exhaust and the extended vertical exhaust at roof level. Commercial vehicles driven by diesel fuel having minimum height of 2.75m and above only are considered in the study. RSPM (PM_{10}), SO_x and NO_x levels were observed under three cases i.e., without vehicle exhaust, with a heavy commercial vehicle having existing exhaust and with the same heavy commercial vehicle fitted with the modified exhaust to the roof level at 3.0 m from road. ISCST3 Modelling software is used to corroborate the results of present exhaust arrangement and the extended vertical exhaust at roof level for T.Nagar Bus Stand / Depot Traffic Intersection. The results obtained are encouraging and RSPM levels are lower than the present exhaust arrangement.

Keywords: Heavy and Medium Commercial Vehicles, Vertical Exhaust, RSPM Concentration, ISCST3 Modelling.

INTRODUCTION

Air and its importance: Clean air essential for existence of life. Major pollutants that are present in air is the particulate matter (PM), which are particles found in the air, including dust, dirt, soot, smoke and liquid droplets of various sizes and contains particles too small to enter the human respiratory tract. They are the deadliest form of air pollution due to their ability to penetrate deep into the lungs and blood streams unfiltered, causing permanent DNA mutations, heart attacks and premature death(Salam, 2005). RSPM is one of its subtypes produced from combustion process, vehicles and industrial sources.

Nomenclatures		Abbreviations	
atm	Atmosphere	ISA	International Standard Atmosphere
bar	0.986 atmosphere or 100 kPa	WHO	World Health Organization
g	Gram	IARC	International Agency for Research on Cancer
^{O}C	Celsius, = 273.15 ^{0}K	NTP	National Toxicology Program
h	hour	NIH	National Institutes of Health
m	Meter	CDC	Centers for Disease Control and Prevention
min	Minute	FDA	Food and Drug Administration
s	second	NIOSH	National Institute for Occupational Safety and Health
RSPM	Respiratable Suspended Particulate Matter	NAQMP	National Ambient Air Quality Monitoring Program
PM_{10}	Particulate Matter of less than 10 micron size	HCV	Heavy Commercial Vehicle
So_x	Sulpher di oxide	MCV	Medium Commercial Vehicle
No_x	Nitrogen oxide	BDL	Below Detectable Level
C	Ambient air pollutant concentration in g/m^3		
Q	Source strength or emission rate in g/s		
u	Average plume transport velocity in m/s		
H	Effective discharge height in m		
σ_y	Cross wind dispersion coefficient in m		
σ_z	Vertical dispersion coefficient in m		
η_v	Volumetric efficiency in %		

Reasons for Vehicular Air Pollution: Automobiles are one of the major air pollution sources in major cities like Chennai (Thilagaraj, 2014). The heavy smoke pollution experienced in all traffic intersections at Chennai is on the rising, causing severe respiratory problems. Increase of vehicular air pollution in Chennai is attributed by the following reasons:
a) High vehicle density especially, during peak hours.
b) Aging of the vehicles.
c) Poor maintenance of Vehicles results in high emission of air pollutants.
d)The high volume of two stroke two / three wheelers.
e) Fuel adulteration.
f) Bad road conditions.
g) The attitude of public using own vehicles for commuting to workplace.
h) Increased migration from rural to urban centres for studies and jobopportunities.

The vehicle population details obtained from Transport Commissionerate is given in Table: 1

Table.1.Vehicle Population as on February, 2015 (Tamilnadu government portal. Transport commisionerate report2015)

Location	Heavy Commercial Vehicles	Medium Commercial Vehicles	Total
Tamil Nadu	3,69,578	90,194	4,59772
Chennai City	15,874	6584	22,458

Need and objectives for the study: As a Chennai city commuter, everybody in Chennai are experiencing heavy smoke emanating from diesel engine driven vehicles at every traffic intersections especially during peak hours, which can be avoided in the human or road users respirable level of 0 to 2.5 m from the road by modifying the existing ground level exhaust to roof level vertical exhaust in the Medium and Heavy Commercial Vehicles having a roof height of 2.75 m and above.

The same idea was reiterated by the Rtd. Scientist of CPCB in Hindu dt.07.08.2013.The objectives of the study are
1. To measure the RSPM / PM_{10}, So_x&No_x in a test location without any vehicle emission for base line value.
2. To measure the RSPM / PM_{10}, So_x&No_x at 2.0 m and 4.5 m with emission from horizontal exhaust of Heavy Commercial Vehicle at 0.6 m from ground level.
3. To measure the RSPM / PM_{10}, So_x&No_x at 2.0 m and 4.5 m after modifying the present ground level exhaust as roof level Vertical Exhaust in the Heavy Commercial Vehicle where the roof level will be 2.75 Mtrs and above.
4. Corroborating the RSPM / PM_{10}, So_x&No_x results to the T.Nagar Bus Depot traffic intersection using ISCST3 model.

Several dispersion modelling studies have been carried out in India especially Chennai and surrounding industrial zones like the one in the vicinity of Thermal power station at Ennore and Manali.

Literature Survey

Nguyen Thi Kim Oanh, 2003 designed an Upward Extended Exhaust Pipe of Diesel-Powered Vehicles. The exhaust pipe of an diesel-powered, six-wheeled air conditioned bus was extended from the original level at 0.52 m height to the bus roof level, around 4 m. Effects of the extension on the street level of air pollutants (CO, HC, PM10) at the sitting breathing level (1 m height) and 3 m from the traffic lane were assessed by both monitoring and modelling methods. Maximum ambient air pollutant concentrations at the specified breathing level were compared between the original exhaust and the extended exhaust cases (Nguyen Thi Kim Oanh and PrapatPongkiatkul,2003).

Williams, 1987, listed the possible health effects of diesel exhaust as given in below Table 2.

Table.2.Possible Health Effects of Diesel Exhaust (Williams, 1987)

Type	Effects
Non-cancerous	Respiratory ailments, Asthma, Headache, Runny eyes & nose, and Nausea
Carcinogenic	Increased risk of lung cancer
Mutagenic	Increased rate of mutations

As reported in Environment Reporter, (1998) Exhaust emissions come from mobile sources, stationary area sources (oil & gas production and industrial), and stationary point sources including industrial, electric utilities, and commercial-institutional sources. From mobile sources, heavy duty engines emit 60 percent of NO_x, 17 percent of hydrocarbons and close to 90 percent of total particulate emissions. Several national and international agencies study substances in the environment to determine if they can cause cancer.

The International Agency for Research on Cancer (IARC) is part of the World Health Organization (WHO). Its major goal is to identify causes of cancer. IARC classifies diesel engine exhaust as “carcinogenic to humans,” based on sufficient evidence that it is linked to an increased risk of lung cancer, as well as limited evidence linking it to an increased risk of bladder cancer (Diesel Engine Exhaust Carcinogenic, 2012).

The National Toxicology Program (NTP) is formed from parts of several different US government agencies, including the National Institutes of Health (NIH), the Centres for Disease Control and Prevention (CDC) and the Food and Drug Administration (FDA). The NTP has classified exposure to diesel exhaust particulates as “reasonably anticipated to be a human carcinogen,” based on limited evidence from studies in humans and supporting evidence from lab studies.

The National Institute for Occupational Safety and Health (NIOSH) is part of the CDC that studies exposures in the workplace. NIOSH has determined that diesel exhaust is a “potential occupational carcinogen”.

MandaKarunakar, 2011 analysed the Air Quality Status of Respirable Particulate Levels at Selected Traffic Junctions along the Section of Lateral Highway in Hyderabad. A cascade impactor has been used to measure the size function range of $PM_{2.5}$ apart from $PM_{10}$of atmospheric dust particles in air being $PM_{2.5}$ is concern with respect to effect on human health and is able to tend deeply into the respiratory tract reaching the lungs. It is observed that weight % of $PM_{2.5}$values are in the range of 40% - 60% of $PM_{10.}$ It is concluded that free flow of traffic is main concern and maintenance of road should be carried out during low traffic hours.

Sateesh. N. Hosamane, 2013 explained the urban air pollution trend in India. The most watched pollutants include particular matter(PM), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon dioxide (CO_2). The annual average concentration of suspended particulate matter (PM_{10}) is very high in Indian cities. Exposure to air pollutants is largely beyond the control of individuals and requires action by public authorities at the national, regional and even international levels. The norms for ambient air quality have been revisited and various industry specific emissions standards are to be revisited and notified from time to time.

P.Thilagaraj, calculated the air quality index in four places of Chennai such as Anna Nagar, Adyar, T.Nagar, Kilpauk. The pilot survey was conducted based on the questionnaires from various categories of people such as vendors, auto drivers and passersby. The impact on human health is then presented.

Methodology

In this study, the T.Nagar Bus Depot Traffic Intersection is selected because of the highest RSPM / PM_{10} at the location among other locations. In this study, it is not all the automobiles such as two wheelers three wheelers, passenger cars, light commercial vehicles, etc. are considered for this vertical exhaust modification, because their roof level itself falls within the human respirable level of road dwellers to the sitting bus passengers in a bus i.e. 0 to 2.5 meters above ground or road. Hence, the vehicles having minimum roof heights of 2.75 meters and above are only considered for this study.

In this study: The road traffic survey with respect to heavy and medium commercial vehiclesduring peak hours are taken at T.Nagar Bus Stand / Depot Traffic Inter Section,Ambient Air Quality for RSPM / PM_{10}, So_x and No_x are measured in a testlocationwithout vehicle exhaust at 2.0 m level from road, with vehicle exhaust at 2.0 m and at 4.5 m levels from road level using TATA truck with its original exhaust at 0.6 m from road level and with vehicle exhaust in the same test location at 2.0 m and 4.5 m levels fromroad using TATA truck with its original exhaust temporarily modified to theroof level at 3.0 m as vertical exhaust,Dispersion modeling is done using the above data for T.Nagar Bus Stand/Depot Traffic Inter Section.

Experimental Observations

Location of this study: In this study, the T.Nagar Bus Depot Traffic Intersection is selected because of the highest RSPM / PM_{10} at the location among other locations. (Since the TNPCB is monitoring the ambient air quality for T.Nagar under NAQMP at T.Nagar Bus Stand/ Depot building, this location is taken for this study)

In this study, the vehicles having a minimum roof heights of 2.75 meters and above are only considered for this study.In the T. Nagar traffic intersection, the number of heavy commercial vehicles such as Buses, Water Lorries, municipal solid waste handling Trucks and the medium commercial vehicles such as Tempo Travelers, Vans, Omni buses were counted per hour on 14.03.2015 and found that during peak hours, the Commercial Vehicles involved in this study are HCV: 176 per hr. and MCV: 24 per hr.

Vehicle used for the study: A heavy commercial vehicle of TATA 2518C having a engine volume of 15,108 cc and 183 bhp is used for this study. The exhaust pipe is located at the right hand side of the truck at 3.2 m from the front end, 0.6 m above road and 90^0 perpendicular to the vehicle traverse axis.

Samplers used: Two numbers Respirable Dust Sampler with SO_x and NO_xAnalyser of Envirotech make Model: No:APM-460-411are used in this study.

Measurement of RSPM, So_x&No_x level: The field experiments were conducted, samples were analysed in the laboratories and reports were furnished as in Table 3.

Table.3.Ambient Air Quality under case 2a, 2b and 2c conditions

Sl.No	Description	RSPM/PM_{10}	So_x	No_x
1	Ambient Air Quality without vehicle running in μg/m^3	88.37	5.02	BDL
2 a	Ambient Air Quality with vehicle at 1200 rpm & exhaust at 0.6 m height from road / ground level in μg/m^3	205.43	6.27	83.0
2 b	Ambient Air Quality with vehicle at 1200 rpm & exhaust at 0.6 m height from road / ground level in μg/m^3	140.65	6.02	9.6
3 a	Ambient Air Quality with vehicle at 1200 rpm & exhaust at 3.0 m height from road / ground level in μg/m^3	168.22	5.5	10.1
3 b	Ambient Air Quality with vehicle at 1200 rpm & exhaust at 3.0 m height from road / ground level in μg/m^3	105.70	BDL	BDL

Analysis of RSPM: The observed data were graphed for better understanding of the results in Fig.1. It can be inferred from the graph that the RSPM / PM_{10} reduction gap increases between 0.6 m exhaust and the roof level 3.0 m exhaust i.e. increases from 18.11 % at 2.0 m receptor height to 24.8 % at the 4.5 m receptor end, which shows that this modified roof level exhaust not only reduces the road users level RSPM / PM_{10} but, the RSPM / PM_{10} of elevated heights also, which is happy news for the road side or near traffic dwellers. The test results are shown in Table 4.

Table.4.Test Result showing ConcentrationReduction

Exhaust level (m)	ReceptorHeight (m)	RSPMμg/m^3	So_x inμg/m^3	No_x inμg/m^3
0.6	2.0 / 4.5	205.43	6.27	83.0
3.0	2.0 / 4.5	168.22	< 5.0	< 9.0

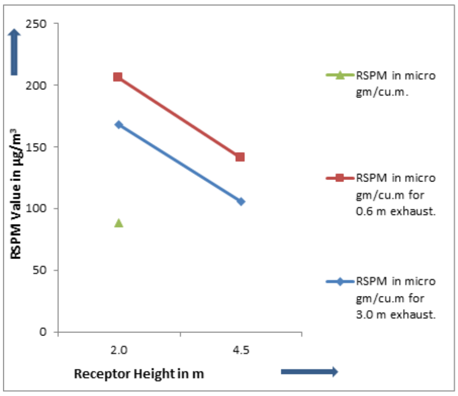

Fig.1.Graphical representation of Receptor Height Vs RSPM

$$(x,y,z.H) = \frac{Q}{2\pi u \sigma_y \sigma_z}\left[exp\frac{-y^2}{2{\sigma_y}^2}\right][exp\frac{-(z-H)^2}{2{\sigma_z}^2} + exp\frac{-(z+H)^2}{2{\sigma_z}^2}]$$

where,

C = Ambient air pollutant concentration in g/m^3

Q = Source strength or emission rate in g/s

u = Average plume transport velocity in m/s

H = Effective discharge height in m

σ_y = Cross wind dispersion coefficient in m

σ_z = Vertical dispersion coefficient in m

Pre-modelling Observation at T.Nagar Intersection: Before modelling, the traffic scenario in the T. Nagar bus depot inter section was observed during peak hours on 14.03.2015 to ascertain the number of heavy and medium commercial vehicles halts and crosses in the traffic signal every time.The traffic signal arrangement at T.Nagar Bus Depot is as follows.

1. Towards East ie.Burkit Road is one way,

2. Other three directions towards EswaranKoil Street and both directions of

South Usman Road is two way.ie. West and South Usman Road towards South and North are two way. The vehicles are allowed from South of South Usman Road, then from EaswaranKoil Street for 55 seconds each and then from North of South Usman Road for 117 seconds.In this signal arrangement, maximum number of vehicles are observed during a green signal from South to other directions for 55 seconds i.e. 7 to 9 heavy commercial vehicles and 2 to 3 numbers of medium commercial vehicles are observed, which is shown in the figure 2, since it will be the highest emission situation in the T.Nagar Traffic Inter Section for which the modelling has been done.

ISCST3 Modelling:

Gaussian Plume Modelling: Gaussian dispersion models have become a uniquely efficient tool of air quality management and have been successfully used for a wide range of studies of air quality in urban and industrial areas (Complete hazardous air release model, 2015). The basis of the model is a single simple formula which assumes constant wind speed and reflection from the ground surface. The horizontal and vertical dispersion parameters are a function of downwind distance and stability. The model was developed for routine applications in air quality assessment, regulatory purposes and policy support.

Software Modelling: The software model used for this study is Industrial Source Complex 3 Short Term Model (ISC3ST). It is the software developed by US Environmental Protection Agency, Office of Air Quality Planning and Standards (OAQPS) Emissions, Monitoring, and Analysis Division Research Triangle Park, North Carolina 27711. It is a Gaussian model used to assess pollutant concentrations from a wide variety of sources associated with an industrial complex.The Gaussian plume equation was used for the truck / bus / HCV as a continuous point source. Ambient concentrations at various distances from the truck were estimated using this model

Based on modelling: In the modelling part, the receptors are fixed at points shown in the corners of the four roads in the T.Nagar Bus Depot Traffic Intersection at a height of 2.0 m and 4.5 m from the road level and thereby modelling is done for eight locations. Here, the modelling results are shown as facial distribution diagrams in Fig.3 and Fig.4.

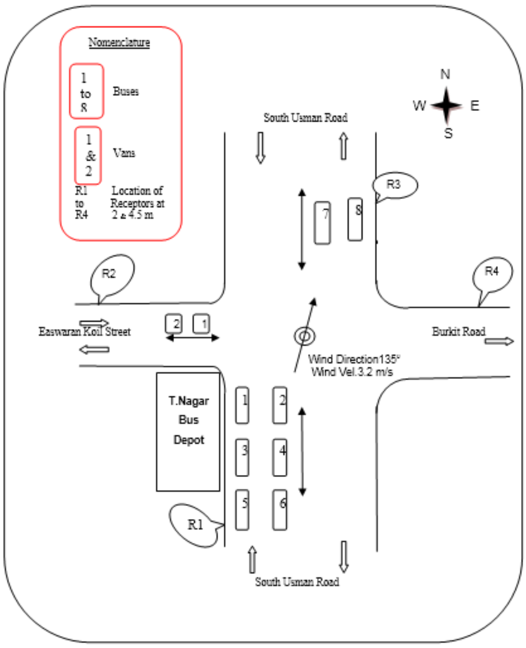

Figure.2.Schematic Diagram of T.Nagar Intersection for Modeling

RESULTS AND DISCUSSION

The road users like walkers, 2 wheeler riders, 3 wheeler passengers and drivers, LCV, MCV and HCV passengers, Traffic Police are undergoing the increased road pollution caused by all type of vehicles, in which, if the HCV and MCV's ground level exhaust pollution in terms of RSPM / PM_{10} reduces through 18.11 %, So_x reduces through 12.28 % and No_x reduces through 87.83 % because of modified roof level vertical exhaust. In this study, the following are observed based on the field experiments conducted. The test results are shown in Table 5.

Table.5.Test Result showing Concentration Reduction

Description	Receptor at 2.0 m		Receptor at 4.5 m	
	Exhaust at 0.6 m	Exhaust at 3.0 m	Exhaust at 0.6 m	Exhaust at 3.0 m
RSPM/PM_{10}	205.43	168.22	140.65	105.70
So_x	6.27	5.5	6.02	BDL
No_x	83.0	10.10	BDL	BDL

The Ambient Air Quality with HCV ie., Tata Truck at stationary condition and at the present exhaust position of 0.6 m from the floor level at the same receptor location for RSPM / PM_{10} at 2.0 m high receptor is 205.43 µg/m^3, So_x is 6.27 µg/m^3 and No_x is 83.0 µg/m^3. From this it can be understood that RSPM / PM_{10} level in the vicinity of the vehicle in a traffic intersection increases from 88.37 µg/m^3 to 205.43 µg/m^3. At the same time So_x increased marginally from 5.02 µg/m^3 to 6.27 µg/m^3 but, the No_x is increased enormously from Below Detectible Level (BDL) to 83.37 µg/m^3, which is an alarming figure related to negative impact on health.At the same time, the receptor at 4.5 m height gave the RSPM / PM_{10} level for the same condition as 140.65 µg/m^3, which shows that greater reduction in RSPM, maximum reduction in No_x from 83.0 µg/m^3 to 9.6 µg/m^3 due to the greater dispersion distance and height and little reduction in So_x ie.to 6.02 µg/m^3 from 6.27 µg/m^3 and also shows that So_x is not easily gets dispersed or influenced by wind velocity and direction.

After modification of the vehicle exhaust to the roof level i.e. to 3.0 m height, RSPM / PM_{10} for 2.0 m height receptor is reduced to 168.22 µg/m^3 from 205.43 µg/m^3, high reduction in No_x from 83.0 µg/m^3 to 10.10 µg/m^3, which is great news for the road users and for the general public. This proves the statement of this research and hence validates the findings.At receptor height of 4.5 m with the modified roof level exhaust, the RSPM / PM_{10} reduced from 140.65 µg/m^3 to 105.70 µg/m^3. So_x is also greatly reduced from 6.02 µg/m^3 to BDL ie. Below Detectable Limit which is < 5.0 µg/m^3 and No_x also greatly reduced from 9.6 µg/m^3. These are the great news to the road users and the travelling passengers especially in the traffic intersection, where the vehicle induced turbulence is zero and the dispersion is only depends upon the atmospheric stability, wind velocity and its direction, in simple words, it depends on the metrological conditions alone.

In the modelling part, the receptors are fixed at points shown in the figure 2 at the corners of the four roads in the T.Nagar Bus Depot Traffic Intersection at a height of 2.0 m and 4.5 m from the road level and thereby modeling is done for eight locations.The ISCST3 model for these eight locations were run with the metrological inputs got from RMD, Nungambakkam and with the field experimental data. The modelling results are shown as facial distribution diagrams in Fig.3 and 4. Due to the wind direction and the wind velocity, the Receptors R 1, R2 and R 4 are with lowest RSPM and R 3 is the location where the highest concentration of RSPM is seen. Here also, the RSPM level reduces by 28.28 % for the modified roof level exhaust at 3.0 m height.

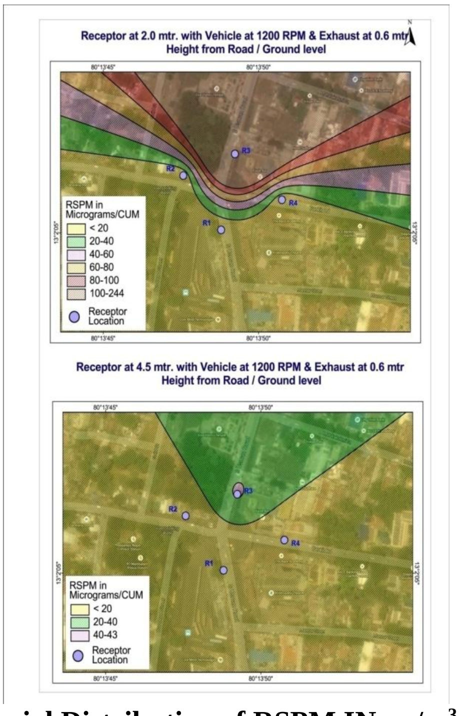

Fig.3.Facial Distribution of RSPM IN µg/m^3 for 0.6 m Exhaust

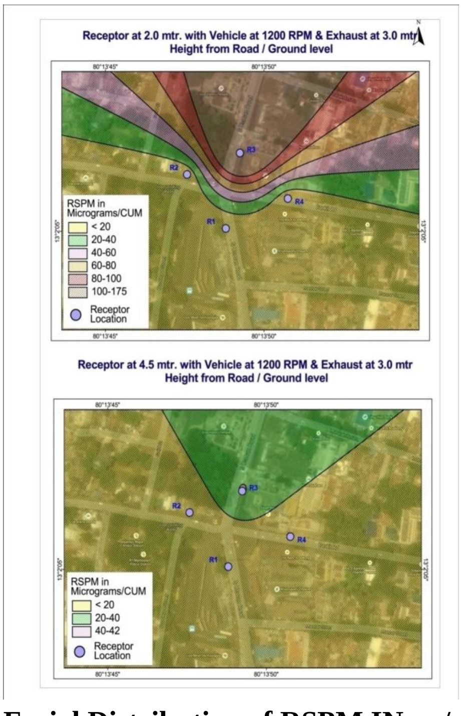

Fig.4.Facial Distribution of RSPM IN µg/m^3 for 3.0 m Exhaust

CONCLUSION

The analysis of RSPM is carried out for T.Nagar Bus Stand / Depot Traffic Intersection in Chennai, capital city of Tamil Nadu. Ambient air pollutant concentrations obtained at the specified breathing level are compared between the original exhaust and the extended vertical exhaust at roof level. Commercial vehicles driven by diesel fuel having minimum height of 2.75m and above only are considered in the study. RSPM (PM_{10}), SO_x and NO_x levels were observed under three cases i.e. without vehicle exhaust, with a heavy commercial vehicle having existing exhaust and with the same heavy commercial vehicle fitted with the modified exhaust to the roof level at 3.0 m from road. ISCST3 Modeling software is used to corroborate the results of present exhaust arrangement and the extended vertical exhaust at roof level for T.Nagar Bus Stand / Depot Traffic Intersection. The results obtained are encouraging and RSPM levels are lower than the present exhaust arrangement.

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