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Review

STUDY ON AIR QUALITY MANAGEMENT IN ADYAR RIVER BASIN: A REVIEW

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ABSTRACT

The air we breathe is a mixture of gases and small solid and liquid particles. Some substances come from natural sources while others are caused by human activities such as use of motor vehicles, domestic activities, industry and business. Air pollution occurs when the air contains substances in quantities that could harm the comfort or health of humans and animals or could damage plants and materials. These substances are called air pollutants and can be either particles, liquids or gaseous in nature. Keeping the air quality acceptable limit has become an important task for decision makers as well as for non-governmental organizations. Particulate matter and gaseous emissions of pollutants from industries and auto exhausts are responsible for rising discomfort, increasing airway diseases and deterioration of artistic and cultural patrimony in urban centers.

INTRODUCTION

Chennai, the fourth largest metropolis in India leads severe air pollution due to increase in number of vehicles (Beckett, *et al*., 1998). Local air quality reviews of key urban pollutants such as SO_2, NO_2 or Ozone produced by industrial activity and/or road transport.

In India, outdoor air pollution is restricted mostly to urban areas where automobiles are the major contributors, and to a few other areas with a concentration of industry and thermal power plants. Apart from rapid industrialization, urbanization has resulted in the emergence of industrial centers without a corresponding growth in civic amenities and pollution control mechanisms (Araujo, *et al*., 2008). In most of the 23 Indian cities with a million-plus population, air pollution levels exceed World Health Organization (WHO) recommended standards (Beckett, *et al*., 1998). In every city, the levels are getting worse because of rapid industrialization, growth in number of vehicles, energy consumption and burning of wastes (Beckett, *et al*., 1998). Several cities face severe air pollution problems with annual average levels of total suspended particulates (TSP) at least three times as high as the WHO standards (Beckett, *et al*., 1998). A study conducted by the World Bank indicates premature deaths of people in Delhi owing to high levels of air pollution. From the discussion of the scope of present study, i.e. motor vehicles, large population density and industries present in this area produce huge amount of pollutant which pollute the environment. Thus, the ambient air quality of the Chennai city is needed to be studied in detail as it is a major concern to care for the health of the people residing in Chennai resulting due to air pollution (Aunan, *et al*., 2009). But since we are concerned about the pollution level in Chennai we have considered the monitoring sites along the Adyar River Basin.

OBJECTIVES OF THE STUDY

The main aim of this study is to assess the Air quality in Adyar basin and to suggest suitable control options for improving the air quality at the basin.

Following are the objectives of the proposed study:

• Sources identification and quantification of pollutant emissions from Adyar River and other polluted wet lands in Adyar River basin.

• Monitoring of air quality of Adyar River basin at selected locations during summer, rainy and winter seasons.

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• Study of polluting sources contribution to ambient air quality using suitable models.

• To study the spatial and temporal dispersion of air pollutant concentrations in the study area.

• To suggest suitable control options for non-point source emissions.

• Dissemination of research findings and helping the implementing agencies to formulate appropriate policies for air quality improvement.

• Volatile organic compounds (VOC's)

Air pollution

Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damages the natural environment into the atmosphere (Araujo, *et al*., 2008). The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet Earth (Araujo, *et al*., 2008). Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems.

Air pollutants

The air pollutants can be classified as primary or secondary pollutants.

Primary air pollutant: The primary air pollutants are harmful chemicals which directly enter the air due to natural events of human activities.

Secondary air pollutant: A secondary air pollutant is a harmful chemical produced in the air due to chemical reaction between two or more components (Araujo, *et al*., 2008). That is primary pollutant combines with some component of the atmosphere to produce a secondary pollutant. Among the most common and poisonous air pollutants are sulphur dioxide (SO_2), formed when fossil fuels such as coal, gas and oil are used for power generation; suspended particulate matter (SPM), solid and liquid particles emitted from numerous man-made and natural sources such as industrial dust, volcanic eruptions and diesel-powered vehicles; and nitrogen oxides (NO_2), from natural sources such as lightning, fires. The pollutants those are under study, in this project

I. Sulphur dioxide

II. Nitrogen oxides

III. TSP

IV. Pm_{10}

I. **Sulphur dioxide:** It is a colorless gas with a pungent and suffocating odor. The gas is produced by the combustion of fossil fuels. Sources include industrial activities such as flaring at oil and gas facilities and diesel power generation, commercial and home heating and vehicle emissions. The amount of SO_2 emitted is directly related to the Sulphur content of the fuel (Bradshaw, *et al*., 1995).

II. **Nitrogen oxide (NO_2):** NO_2 represents the sum of the various nitrogen gases found in the air, of which nitric oxide (NO) and nitrogen dioxide (NO_2) is the dominant forms (Chow, *et al*., 1994). The emission sources are varied but tend to result from high temperature combustion of fuel for industrial activities, commercial and residential heating, and vehicle use.

III. **Total suspended particulate (TSP):** TSP refers to particles ranging in size from the smallest to a generally accepted upper limit of 50-100 microns in diameter (1 micron=1 millionth of a meter) (Beelen, *et al*., 2009). TSP is dominated by the larger sized particles commonly referred to as "dust" and is associated with aesthetic and environmental impacts such as soiling of materials or smothering of vegetation (Bradshaw, *et al*., 1995). The entire domain of particulate matter is known as total suspended particulate (TSP). This includes all airborne solid and liquid particles, except pure water, ranging in size from approximately 0.005 µm to 100 µm in diameter.

Particulate matter is a ubiquitous pollutant, reflecting the fact that it has both natural and anthropogenic sources (Chow, *et al*., 1994). Natural sources of primary PM include windblown soil and mineral particles, volcanic dust, sea salt spray, biological material such as pollen, spores and bacteria. Pm10 refers to particulate matter that is 10 µm or less in diameter. Pm_{10} is generally subdivided into a fine fraction of particles 2.5 µm or less ($Pm_{2.5}$), and a coarse fraction of particles larger than 2.5 µm (Chelani, *et al*., 2001). In the atmosphere the particulate matters (Pm) may be classed as either primary or secondary.

Primary particles are those such as carbon particles from combustion, mineral particles derived from abrasion and sea salt (City-specific Reports). Secondary particles are those that are formed in the atmosphere by the chemical reaction of gases which combine to form less volatile compounds, and then condense into particles.

SOURCES OF AIR POLLUTION

Sulphur dioxide

Sulphur dioxide, SO_2, enters the atmosphere as a result of both natural phenomena and anthropogenic activities.

• Combustion of fossil fuels

• Oxidation of organic material in soils

• Volcanic eruptions

• Biomass burning

• Solar action on seawater

Oxides of nitrogen

• Burning of fossil fuels

• N_2O is generated through microbial activities

• Combustion of gasoline in automobiles

• Combustion of coal and oil at electric power plants

EFFECTS OF AIR POLLUTION

Exposure to ambient air pollution has been linked to a number of different health outcomes, starting from modest transient changes in the respiratory tract and impaired pulmonary function, continuing to restricted activity/reduced performance, emergency room visits and hospital admissions and to mortality (Brook, *et al*., 2004). There is also increasing evidence for adverse effects of air pollution not only on the respiratory system, but also on the cardiovascular system (WHO, 2004). Physical damage functions relating health (mortality and morbidity) to air pollution levels have been estimated over a number of years in different countries. Although the net effect of pollutants on health is unclear, the committee of the medical effects of air pollution (COMEAP), set up by the UK government has found the strongest link between health and pollution to be for particulates (Pm_{10}), Sulphur dioxide (SO_2) and Ozone (O_3) (Brook, *et al*., 2004; Brook, *et al*., 2008). The causes and effects of air pollution are:

1) Greenhouse effect

2) Particulate contamination,

3) Increased UV radiation

4) Acid rain

5) Increased ozone concentration,

6) Increased levels of nitrogen oxides

Study area

The Adyar River is one of the several rivers in the Chennai Basin in Southern India. It starts from Chembarambakkam tank, a natural reservoir (Fig. 1 and 2). It flows through Kanchipuram, Tiruvallur and Chennai districts for a distance of about 42 km and enters into the Bay of Bengal near Adyar. Width of the Adyar River is 200 m. Depth varies from 0.75 m in its upper reaches to 0.5 m in its lower reaches. The course of the Adyar River from its source and its catchment area of 530 km². The concentration of industries and population of the major waterways and the adjoining coastal waters of Chennai due to adequate management of waste products. The river carries grey water and storm water, which contribute to the pollution load of the river. Apart from this Adyar river flows across the Chennai city and is heavily polluted by means of municipal and industrial waste waters. This leads to high concentration of organic matter which acts as a source for the generation of methane, carbon dioxide, nitrous oxide etc. All these gases are coming under greenhouse gases. Chennai is considered to

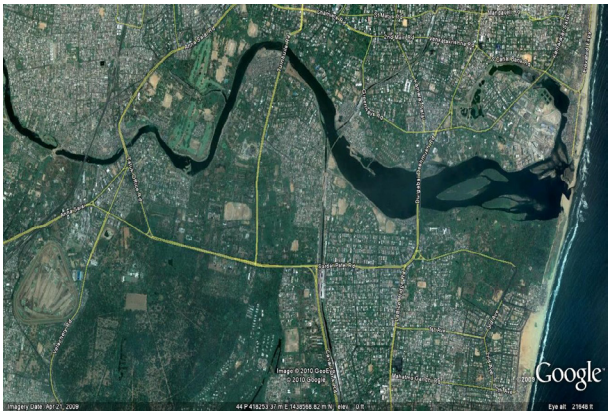

Fig. 1 Map showing the entire stretch of the Adyar River.

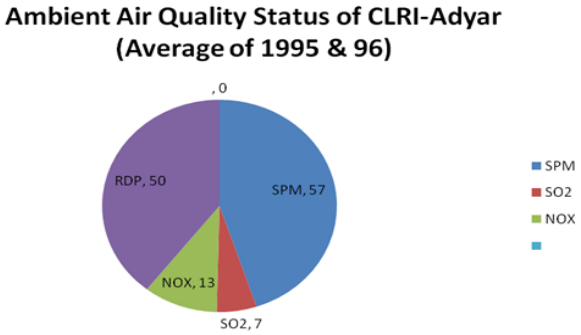

Fig. 2 Air quality status of Adyar River.

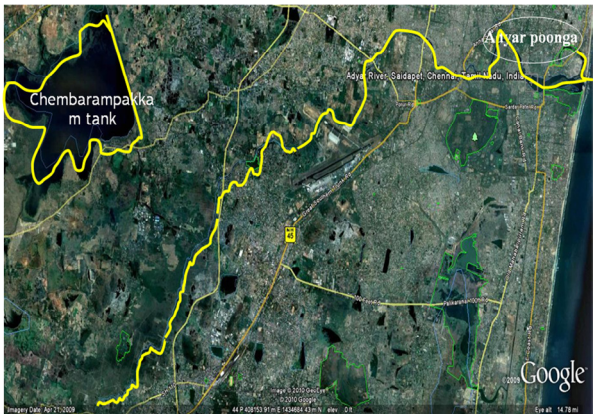

Fig. 3 View of Chemparabakkam lake in Adyar River basin.

be one of the cleanest metropolitan cities in terms of air quality status in the early 1990's but during last decade the situation has significantly deteriorated (Aunan, *et al*., 2009). Tamil Nadu pollution control board identified the major source of air pollution in Adyar is the emissions from vehicles (Brook, *et al*., 2004) (Fig. 3).

Monitoring sites

The main concern of the project is to measure the concentration of sulphur dioxide, nitrogen dioxide, TSP and particulate matter at different locations in Adyar River with the help of respirable dust sampler. These two critical gaseous pollutants and the particulate pollutants are in abundance in this study area since it is a high traffic congested area. The monitoring stations were chosen that there can be adequate safety measures as well as reduced interference of the local public with the devices used for the experiment. We investigated the decided sampling locations and found the possible problems and the possible precautions to be taken while handling and use of the device for the project work.

The monitoring stations chosen are:

1) Adyar Poonga

2) Malligaipoo Nagar, near Fortis Malar Hospital (Residential Zone)

3) Little Mount (Traffic Congestion Area)

4) Guindy Industrial Area

Monitoring locations

Adyar Poonga: Adyar Poonga (also known as Adyar Eco Park) is an ecological park being setup by the Tamilnadu road development corporation (TNRDC) and the Government of Tamilnadu in a 50-50 joint venture in the Adyar estuary area of Chennai, India. Once completed, it is claimed to be the first eco-tourism venture in the state. Not only that but it will also serve as a great landmark for the city. What were originally wetlands, turned landfill over years, has not been reclaimed and is starting to thrive.

Ecologically sensitive approach is given for the water and waste management. The sewage and the waste water which flows from the city to this creek is treated using ecological techniques (Fig. 4).

The estuary extends from the sandbar at the edge of the sea to the Adyar Bridge with small islands in-between and covers an area of approximately 358 acres. The creek begins near the Chettinad palace extends northward into the mainland and takes a complete U-turn near the foreshore estate bridge to terminate near mandavelipakkam. The creek covers an area of 58 acres land.

Fig. 4 Water and waste management.

Malligaipoo nagar: This is the residential area which is close to the Adyar River chosen for sample collection. This is the location which consists of more number of people residing and their occupation is mainly small business. Commercial spots such as Besant nagar beach and Guindy National park are situated. It is considered as one of the polluted area in the Chennai city since the river Cooum is very close to it.

Little mount: This is the traffic area chosen for sample collection and located on the banks of the Adyar River. Maraimalai bridge is close to this location and the river flows into it. Sewage mix with this river and it gets highly polluted. The main reason for the pollution is the vehicular emission since due to heavy traffic.

Guindy industrial area: Guindy is located on the south-western part of the Chennai city. It is the entry point or the gateway to the Chennai city from the southern parts of Tamilnadu. The Kathipara junction located here is one of the nodal points of road traffic in the Chennai metropolitan area. It is surrounded by Saidapet in the north, Kotturpuram Adyar towards east, Velachery in the south and St. Thomas mount in the west.

Important Landmarks in the stretch of the Adyar River basin

a. Guindy National Park

b. Raj Bhavan Chennai

c. Anna University Chennai

d. Indian Institute of Technology Madras

e. Children's park

f. Snake Park

g. Cancer Institute

h. Thiruvika Industrial Area

i. Gandhi Mandapam

j. Rajaji Memorial

k. Adyar Poonga

Site map

The monitoring sites chosen for sample collection in Adyar River basin are shown in the below map (Fig. 5).

Sources identified in the study region

a. Effluent outfalls

b. Dumping of solid wastes along the banks of river

c. Open burning of solid wastes such as plastics, polythene bags etc.

d. Gaseous emissions (due to chemical and biological) from the river

e. Domestic combustion (burning of wood, Kerosene)

Possible pollutants generated in the study region

a. Sulfur dioxide

b. Oxides of nitrogen

c. Carbon monoxide

d. Hydrogen sulphide

e. Hydrocarbons

f. Particulate matter

g. Volatile organic compounds

h. Methane (CH_4)

i. Ammonia gas

The following Table shows the latitudes and longitudes of the monitoring stations in the Adyar River Basin Tables 1 and 2.

Instruments used for sample collection

1. Pm_{10} Particulate sampler (Pm_{10} Pollutant)

2. Organic vapor sampler (VOC's)

3. Handy sampler (SO_2 and NO_2)

Volatile organic compounds

Volatile organic compounds are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. A wide range of carbon based molecules, such as aldehydes, ketones, and other light hydrocarbons are VOC's. The United States Environmental Protection Agency (EPA, 1998) defines as any organic compound that participates in a photoreaction. Volatile organic compounds are group of hydrocarbons results from burning of coal, oil and gasoline (Chow, *et al*., 1994). These and other sources, including solvents, cleaners and paints, all contribute to the baseline level of different VOC's found in ambient air. VOC's are of interest because they photo-chemically react (in sunlight) to cause ozone and smog and in high concentrations may impact on human health (Croxford, *et al*., 1996).

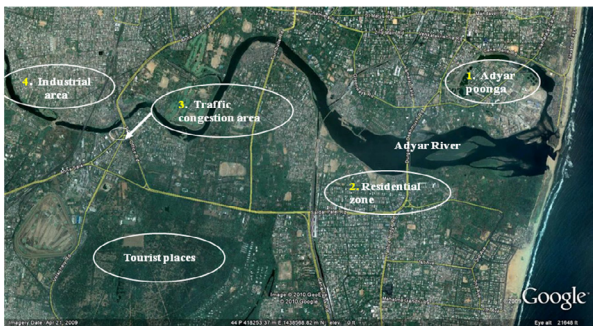

Fig. 5 Location of monitoring stations in Adyar River basin.

Table 1. Geological c in Adyar River basin

Sl. No	Location	Co-ordinates East	Co-ordinates North	Elevation (ft.)
1	Adyar Poonga	418672.69 m	1439507.89 m	9
2	Malligaipoo Nagar	419221.79 m	1438150.55 m	36
3	Little Mount (Saidapet)	416205.09 m	1439001.53 m	34
4	Guindy Industrial Area	414163.76 m	143885.18 m	43

The most common VOC is methane, a greenhouse gas sometimes excluded from analysis of other VOC's using the term non-methane VOC's. Non-methane VOC's can be categorized into two broad categories: natural and anthropogenic. Natural sources contribute 69% of the total non-methane hydrocarbons (NMHCs) emission while rest 31% is contributed by anthropogenic sources (Kaushik, *et al*., 2006).

Samples were collected in three different locations such as one in Residential Area, other in Traffic Congestion Area and other in Industrial Area. The samples are analyzed for Hexane, Ethyl Acetate and Acetonitrile by using Gas Chromatography mass spectroscopy method.

Concentrations were predicted in each of these locations using GC-MS method. Methane was not detected in any of the location from (4010.10 to 12.10.10). Major source of man-made VOCs are solvents, especially paints and protective coatings. Solvents are required to spread a protective or decorative film. Approximately 12 billion liters of paints are produced annually (CPCB, 2006). Typical solvents are aliphatic hydrocarbons, ethyl acetate, glycol ethers, and acetone. In the residential area, Acetonitrile is having high concentration 37.23 ppm which is due to some domestic combustion in household activities and tobacco smoke activities.

Table 2. Sampling location and number of days monitored in Adyar River basin

Sl. No	Sampling Location	Month	Pollutants	No of days Monitored
1	Malligaipoo Nagar (Residential Area)	October 2010	VOC's	2
2	Little Mount (Traffic Area)	October 2010	VOC's	2
3	Guindy (Industrial Area)	October 2010	VOC's	2
4	Adyar Poonga	-	-	-
5	Malligaipoo Nagar (Residential Area)	October, November and December	Pm_{10}	6
6	Little Mount (Traffic Area)	October, November and December	Pm_{10}	6
7	Guindy (Industrial Area)	October, November and December	Pm_{10}	6
8	Adyar Poonga	October, November and December	Pm_{10}	6
9	Malligaipoo Nagar (Residential Area)	October, November and December	Methane (CH_4)	6
10	Little Mount (Traffic Area)	October, November and December	Methane (CH_4)	6
11	Guindy (Industrial Area)	October, November and December	Methane (CH_4)	6
12	Adyar Poonga	October, November and December	Methane (CH_4)	6
13	Malligaipoo Nagar (Residential Area)	December	Traffic Data	2
14	Little Mount (Traffic Area)	December	Traffic Data	2
15	Guindy (Industrial Area)	December	Traffic Data	2
16	Adyar Poonga	December	Traffic Data	2
17	Malligaipoo Nagar (Residential Area)	December	SO_2 and NO_2	2
18	Little Mount (Traffic Area)	December	SO_2 and NO_2	2
19	Guindy (Industrial Area)	January 2011	SO_2 and NO_2	2
20	Adyar Poonga	January 2011	SO_2 and NO_2	2

Table 3. Collection of VOC's in different locations of Adyar River basin

Sample ID	VOC's	Concentration (ppm)
Malligaipoo Nagar	Acetonitrile	N. D
	Hexane	N. D
	Ethyl Acetate	N. D
Malligaipoo Nagar	Acetonitrile	37.23
	Hexane	14.42
	Ethyl Acetate	1.35
Little Mount, Traffic Area	Acetonitrile	1.66
	Hexane	1.61
	Ethyl Acetate	N. D
Little Mount, Traffic Area	Acetonitrile	1.70
	Hexane	1.43
	Ethyl Acetate	N. D
Guindy Industrial Area	Acetonitrile	N. D
	Hexane	1.64
	Ethyl Acetate	0.94
Guindy Industrial Area	Acetonitrile	1.85
	Hexane	N. D
	Ethyl Acetate	N. D
N.D-Not Detectable		

Hexane has concentration of 14.42 ppm which is mainly from the automobiles in the area street where the instrument has been fixed for sample collection

The following table shows the volatile organic compounds present in different locations in Adyar River Basin Table 3 (Fig. 6).

Particulate matter (Pm)

Particulate matter is a ubiquitous pollutant, reflecting the fact that it has both natural and anthropogenic sources. Natural sources of primary Pm include windblown soil and mineral particles, volcanic dust, sea salt spray, biological material such as pollen, spores and bacteria. Pm_{10} refers to particulate matter that is 10 µm or less in diameter (Donaldson, *et al*., 1998). Pm_{10} is generally subdivided into a fine fraction of particles 2.5 µm or less ($Pm_{2.5}$), and a coarse fraction of particles larger than 2.5 µm. In the atmosphere the particulate matter may be classed as either primary or secondary. Primary particles are those such as carbon particles from combustion, mineral particles derived from abrasion and sea salt (Dockery, *et al*., 1993; Ghosh, *et al*., 2010). Secondary

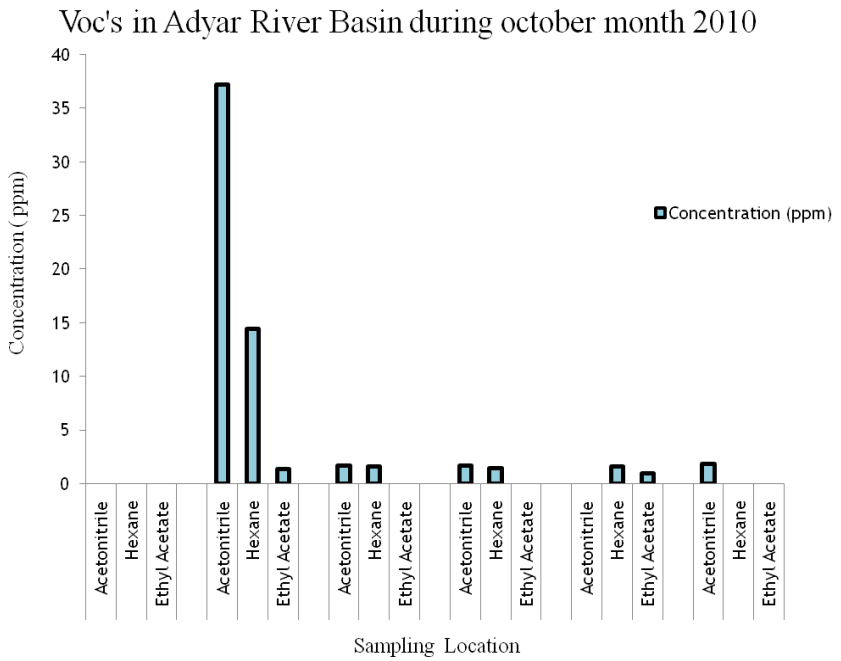

Fig. 6 Concentration of VOC's in Adyar River basin during October month.

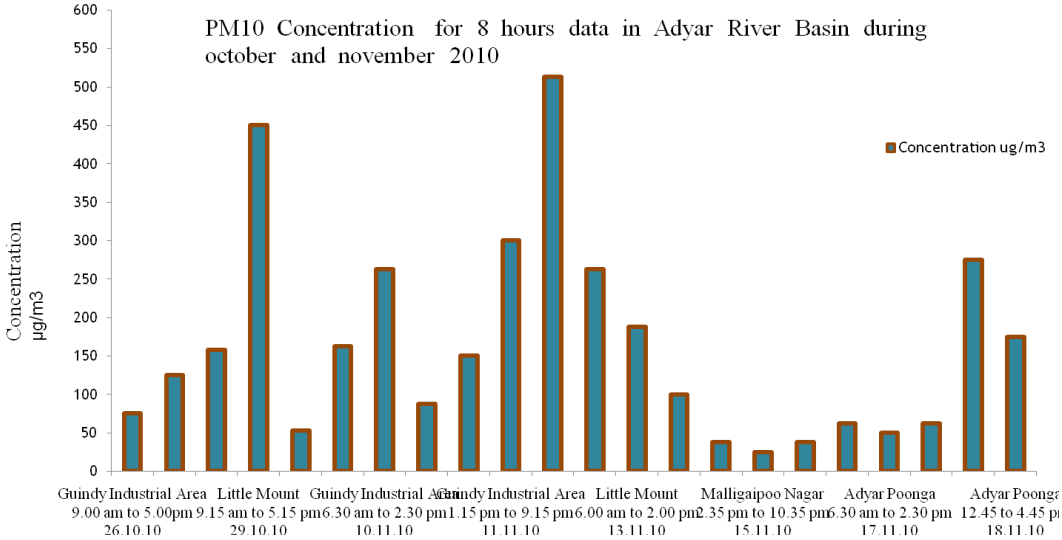

Fig. 7 P m_{10} concertation for 8 hours in Adyar River in October and November 2010.

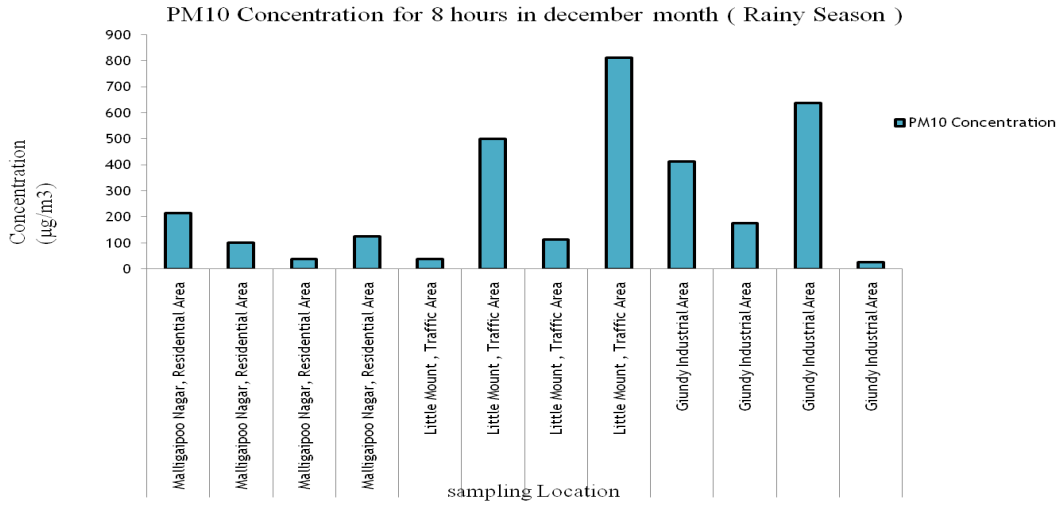

Fig. 8 P m_{10} concertation for 8 hours in Adyar River in December 2010.

Table 4. Calculated pollution load in different sectors in Chennai city

Sources	Pollutant (Tonnes/day)						
	SPM	SO_2	NO_2	HC	CO	Total	Percentage
Domestic	0.032	0.170	1.049	0.101	0.243	1.865	2.65%
Commercial	0.875	1.466	0.731	0.120	0.087	3.279	4.66%
Generator Sets	0.296	0.509	0.268	0.039	0.026	1.138	1.61%
Industrial	2.510	4.565	6.085	0.3119	0.4320	13.9039	19.78%
Vehicular	9.300	0.200	10.250	10.240	20.100	50.090	71.28%
Total (Tonnes/d)	13.280	6.910	18.380	10.810	20.880	70.260	100

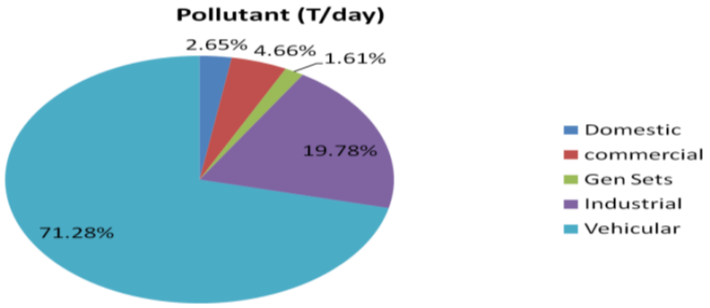

Fig. 9 Pollutants generated in different sectors in Chennai city.

particles are those that are formed in the atmosphere by the chemical reaction of gases which combine to form less volatile compounds, and then condense into particles.

Pm10 concentrations were predicted during rainy season and winter season. Samples were collected during September 2010 to December 2010 for each two days in one sampling location for each 8 hours in the morning and another 8 hours in the evening. September'10 to December '10 taken as rainy season data. The samples were collected each two days in Residential area, Traffic Congestion area, and Industrial area and in Adyar Poonga. The Pm10 concentrations were high in Traffic area and Industrial area exceeding the NAAQS Standards.

During October 2010, the Pm10 concentration is 162.5 µg/m^3 in residential area whereas in traffic it is 157.5 µg/m^3 (Fig. 7 and 8). The NAAQS standards for Pm10 are 60 µg/m^3 annual average and 100 µg/m^3 for 24 hours. But in all the locations the Pm_{10} concentrations exceeds the standards. This may be due to domestic combustion from houses in residential area and automobile exhausts in traffic area. The residential area is chosen very close to the Adyar River and the Pm_{10} concentration is high in this location. Similarly, Pm_{10} samples were collected for different months and the samples are analyzed and their concentrations were measured in each of the location Table 4.

The below pie chart shows the pollutants generated in different sectors in Chennai city (Hoffmann, *et al*., 2007; Hopke, *et al*., 1991; Health Effects Institute, 2009; Jitendra, *et al*., 1997). It is observed that vehicular emission occupies most of the emissions in the Chennai city when compared with industrial emissions (Jacobson, *et al*., 2006; Jacobson, *et al*., 2009; Jacobson, *et al*., 2007; Koren, *et al*., 2008; Kunzli, *et al*., 2005; Manning, *et al*., 1980; Masami, *et al*.,) (Fig. 9).

Sulfur dioxide and nitrogen dioxide

Samples are collected in all four locations during winter season. Samples are collected by using Handy Sampler instrument (Ministry of Road Transport and Highways, 2004; Miller, *et al*., 2007; QUARG, 1996; Nel, 2005; Simkhovich, *et al*., 2008; US EPA, 1999). The samples are analyzed by using UV probe Spectrophotometric method. Sox concentration in terms of µg/m^3 is below the detectable limit. Nitrogen dioxide is maximum 18 µg/m^3 in the industrial area which is also a limit in the NAAQs standard (Fig. 10 and 11). The following table shows the SO_2 and NO_2 concentration in terms of microgram per cubic meter present in the Adyar River Basin (WHO, 2006; Zhu, 2002).

CONCLUSION

The air pollutants in each location and its concentrations were measured. The maximum effect is on Sulphur dioxide in traffic area and this level should be minimized by reducing the usage of vehicles and widen of pavements and roadways. Vehicular pollution load is higher when compared with the other sources. The reason is due to heavy traffic in the peak hours and increasing number of vehicles. Proper monitoring measurements should

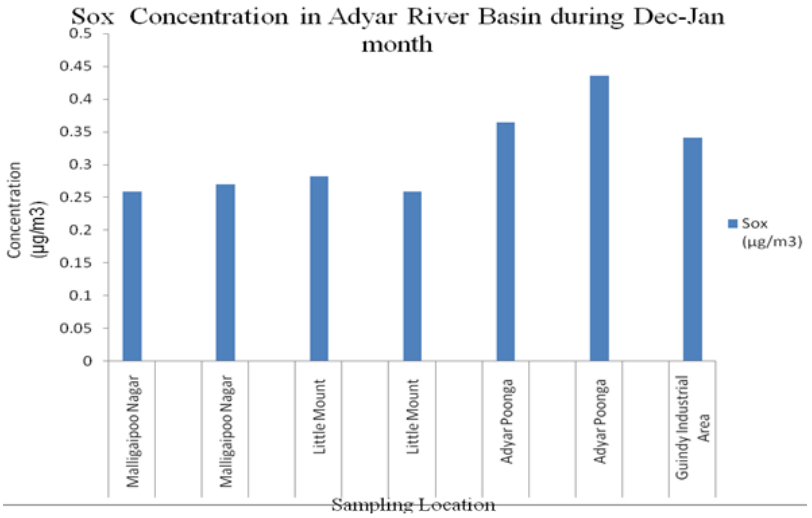

Fig. 10 Sulphur dioxide concentration for 8 hours in Adyar River.

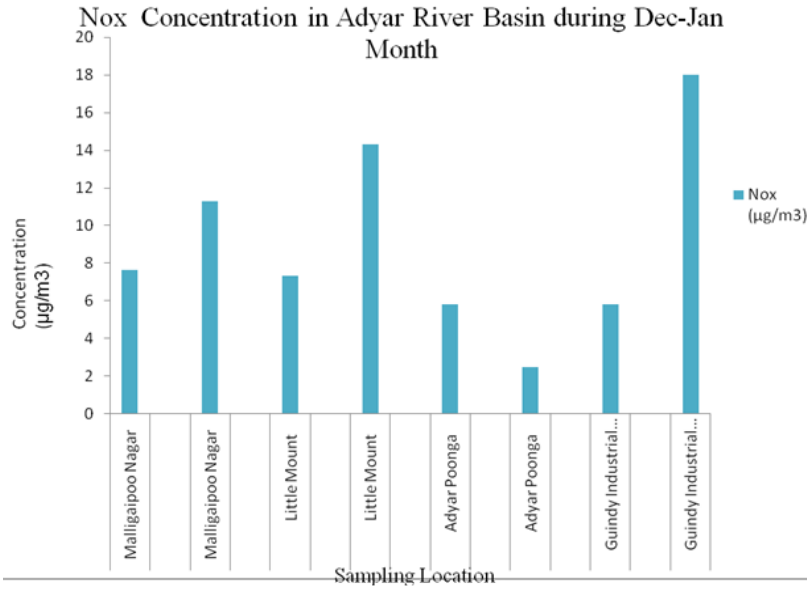

Fig. 11 Nitrogen dioxide concertation for 8 hours in Adyar River.

be needed to overcome the situation and all necessary actions should be controlled by the pollution control board.

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