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Correlation Analysis and Exceedence Factor among the Ambient Gaseous Pollutants and Particulate Matter in Urban Area

Authors:
Sarala Thambavani D[1],
Saravana Kumar R[2].

Institution:
1. Department of Chemistry, Sri Meenakshi Govt. Arts College for women, Madurai- 625 002. Tamil Nadu, India.

2. Department of Chemistry, N.P.R. College of Engineering and Technology, Natham, Dindigul- 624401.TamilNadu, India.

ABSTRACT:

Urban air pollution is rapidly becoming an environmental problem of public concern worldwide. It can influence public health and local or regional weather and climate. In the present study, an effort has been made to study the importance of gaseous pollutants with particulate matter. All the data were collected for a period of eight years (2002-2009) at three different locations (Fenner (I) limited, Highway building and Kunnathur chatram) representing industrial, residential and commercial cum traffic areas in Madurai city. The particulate pollutants SPM and RSPM concentrations were compared with gaseous pollutants SO_2 and NO_x concentrations. These particulate pollutants were highly compared with gaseous pollutants in all the sampling stations during the study period. It showed significant positive correlations with gaseous pollutants. The trends of pollutant levels follow the order of SO_2<NO_x<SPM<RSPM. The Exceedence factor was calculated for the pollutants at different sampling areas. It reveals that Madurai city is critically polluted by RSPM and SPM at residential and commercial cum traffic area. From these values, it is clear that the air quality is good at Fenner (I) Limited whereas it is low polluted and moderately polluted at Highway building and Kunnathur chatram respectively. The values of correlation co-efficient for all possible correlations among different pollutants are computed (range of r = -0.043 to 0.973). Highly significant correlation and linear relationship are obtained between the following pairs of pollutants SO_2-NOx and NO_x-RSPM at Fenner (I) Limited, SPM-RSPM at Highway building and Kunnathur chatram respectively.

Keywords:

Ambient air quality, Exceedence factor, Oxides of Sulphur, Oxides of Nitrogen, SPM and RSPM, Particulate Matter.

Corresponding author:
Saravana Kumar.

Email:
gsivasaravanan@gmail.com

Phone No:
99423-68797.

Web Address:
http://jresearchbiology.com/Documents/RA0210.pdf.

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INTRODUCTION

The origin of urban air pollution is mainly in anthropogenic emission sources, which include automobiles, industries, and domestic fuel combustion. The air pollutants so generated are detrimental to human health. In addition, they cause negative impacts directly or indirectly, if at elevated concentrations, on vegetation, animal life, buildings and monuments, weather and climate, and on the aesthetic quality of the environment (Stern, 1976; Godish, 1985; Takemura et al., 2007, Shen et al., 2009). The size of particulates is known to cause severe damage to the lungs. Finer solid particles and liquid droplets, collectively called suspended particulate matters, are present in the air in great numbers and at times they give rise to a serious pollution problem (Thambavani et al., 2012) In fact, the World Health Organization (WHO) reports that there is no safe level for particulate matter emissions (WHO, 1999). International studies have confirmed association between elevated levels of particulate air pollution and increase in respiratory symptoms such as cough, shortness of breath, wheezing and asthma attacks. Rapid industrialization and addition of the toxic substances to the environment are responsible for altering the ecosystem (Thambavani et al., 2011). Studies have also found associations between particulate air pollution and rates of hospitalization, chronic obstructive pulmonary disease and restricted activity due to illness (Dockery et al, 1993). Concentration of ambient air particulates has been found to be associated with a wide range of effects on human health (Dockery and Pope, 1994; Godberg, 1996; Schwartz, 1991; Schwartz, 1994). The high concentration of particulate matter in the environment has become a problem for many countries (Elbir et al., 2000). Air pollution can directly affect plants via leaves or indirectly via soil acidification (Steubing et al., 1989, Thambavani and Kumar 2011). Rates of increase of air pollutant concentrations in developing countries such as India are higher than those in developed countries and hence atmospheric pollution is often severe in cities of developing countries all over the world (Mage et al., 1996). Atmospheric particulate matter is the major air pollutant in India. At the same time, other chronic non-communicable diseases such as cancer, cardiovascular disease and respiratory disorders are becoming more dominant. Approximately 50,000 premature deaths occur annually due to PM10 pollution in India. In many Indian cities, the levels of particulate pollutants in the ambient air have been found to be above the permissible limit (Meenakshi and Saseetharan, 2004). Air quality in Madurai is deteriorating. In the present study, the levels of particulate air pollutants were measured at three stations in Madurai city and these particulate pollutants concentrations were statistically compared with gaseous pollutants. The present study area of Madurai city in Tamil Nadu consisting of large mixed use areas, having high traffic volume and also fast growing center for small scale industries and it was undertaken with following specific objective:

- To conduct air quality measurement at different high traffic volume location of Madurai city along with residential areas.
- To study the most common air pollutants like sulphur dioxide, oxides of nitrogen, suspended particulate matter and respirable particulate matter in different locations of Madurai city.
- To investigate the source of these pollutants and extent of their individual contribution to the pollution of ambient air.

MAJOR KINDS OF AIR POLLUTANTS

Suspended Particulate Matter (SPM)

SPM consists of different solid and liquid particles that are suspended in the atmosphere and includes soil, soot, lead, asbestos and sulphuric acid droplets. Suspended particulates reduce visibility by scattering and absorbing sunlight, they corrode metals, erode buildings and works of sculpture when the air is humid and soils clothing and draperies. Smaller particles are inhaled into the respiratory system and can cause health problems. Lead and asbestos particles are especially harmful.

Oxides of Nitrogen (NOx)

Oxides of Nitrogen were produced by the chemical interactions between Nitrogen and Oxygen. They consist mainly of Nitric oxide (NO), Nitrogen dioxide (NO2) and Nitrous oxide (N2O). Nitrogen oxides inhibit plant growth and when breathed, aggravate health problems, such as asthma. They are involved in the production of photochemical smog, acid deposition, global warming and they cause metal to corrode and textiles to fade and deteriorate.

Sulphur dioxide (SO2)

Sulphur dioxide was produced by the chemical interaction between Sulphur and Oxygen. SO2 is a colorless, non-flammable gas with a strong irritating odour and is emitted as a primary air pollutant. They corrode metals, damage stone and other materials, damage plants, and irritate the respiratory tracts of human and other animals.

Data And Analysis Techniques

Description of study area

Madurai is one of the important cities in South India. It is the seventh largest city in Tamil Nadu, situated at the banks of river Vaigai and its terrain is mostly flat. The ground rises from the city, towards outward, on all sides except the south, which is a gradually sloping terrain. It is surrounded on the outskirts by small and prominent hills. The city is about 100 meters above mean sea level and it is situated on 9055' NL and 7807' EL and the city is covering 51.96 sq.kms that comprises of a total population of 25,78,201 persons (Census 2011) whereas the Madurai Urban agglomeration comprising the city and surrounding settlements accommodates a population of 12,03,095 persons. The climate of Madurai town is hot and dry and the temperature range between a maximum and minimum of 42^0C and 21^0C respectively.

Madurai city has emerged as an important center for textiles and engineering industries. The sampling stations were selected keeping in view the important zone and the nature of activity. A total of three sampling stations, consisting of industrial, residential and traffic cum commercial were chosen for the present study. The description of sampling station is given in **table-1.**

For the present study, we used particulate and gaseous pollutant data collected by the Central Pollution Control Board (CPCB) at three sampling sites in Madurai city over a period of eight years from 2002 to 2009 and the observations made during the sampling period are listed in **table-2** and **figure-1 to 3.**

Calculation of Correlation Co-Efficient and Linear Regression

Statistical software SPSS (Statistical package for Social Sciences, Version 7.5) is used to compute the correlation (r values) for all possible correlations among air pollutants. The software is used to calculate the

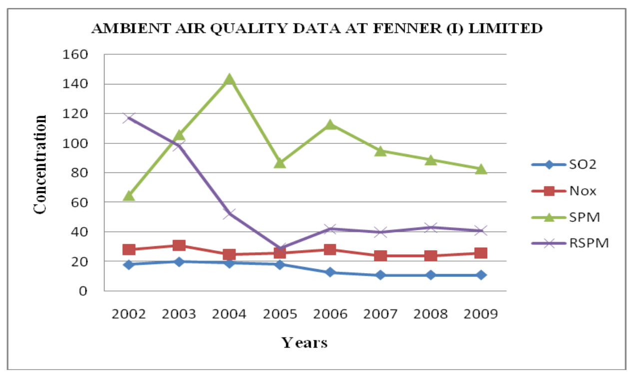

Figure 1: Ambient Air Quality Data at Fenner (I) Limited

Table 1: Sampling sites in Madurai city

S. No.	Location	Location description	Category
1	Fenner (I) limited	Industrial, residential area	Industrial
2	Highway building	Less traffic, residential area	Residential
3	Kunnathur chatram	High traffic, residential, commercial area and shopping complex	Commercial cum traffic

Table 2: Ambient air quality data of Madurai city from 2002-2009.

Year	Location	Type	AvgSO$_2$ (mg/m^3)	PI SO$_2$	Avg NOx (mg/m^3)	PI NOx	Avg SPM (mg/m^3)	PI SPM	Avg RSPM (mg/m^3)	PI RSPM
2002	Fenner (I) Limited	I	18	0.22	28	0.35	65	0.18	117	0.98
	Highway Building	R	10	0.17	26	0.43	214	1.52	137	2.29
	Kunnathur Chatram	C & T	9	0.15	40	0.66	228	1.63	148	2.47
2003	Fenner (I) Limited	I	20	0.25	31	0.39	106	0.29	98	0.65
	Highway Building	R	12	0.20	21	0.35	138	0.98	78	1.30
	Kunnathur Chatram	C & T	11	0.18	20	0.33	389	2.77	183	3.05
2004	Fenner (I) Limited	I	19	0.24	25	0.31	144	0.40	52	0.43
	Highway Building	R	10	0.17	20	0.33	110	0.78	50	0.83
	Kunnathur Chatram	C & T	10	0.17	24	0.40	397	2.80	180	3.0
2005	Fenner (I) Limited	I	18	0.22	26	0.32	87	0.24	29	0.24
	Highway Building	R	10	0.17	25	0.41	104	0.74	35	0.58
	Kunnathur Chatram	C & T	10	0.17	24	0.40	219	1.56	57	0.95
2006	Fenner (I) Limited	I	13	0.16	28	0.35	113	0.31	42	0.35
	Highway Building	R	10	0.17	26	0.43	106	0.76	37	0.62
	Kunnathur Chatram	C & T	10	0.17	27	0.45	126	0.90	34	0.57
2007	Fenner (I) Limited	I	11	0.14	24	0.30	95	0.26	40	0.33
	Highway Building	R	8	0.13	21	0.35	93	0.66	41	0.68
	Kunnathur Chatram	C & T	9	0.15	20	0.33	102	0.73	44	0.73
2008	Fenner (I) Limited	I	11	0.14	24	0.30	89	0.24	43	0.36
	Highway Building	R	9	0.15	22	0.37	82	0.59	38	0.63
	Kunnathur Chatram	C & T	10	0.17	24	0.40	92	0.66	44	0.73
2009	Fenner (I) Limited	I	11	0.14	26	0.32	83	0.11	41	0.34
	Highway Building	R	10	0.17	25	0.42	85	0.61	40	0.67
	Kunnathur Chatram	C & T	11	0.18	25	0.42	91	0.65	44	0.73

I-Industrial area, R- Residential area, C&T- Commercial cum traffic area, PI- Pollution indices.

regression parameters A and B of the straight line Y = A + BX by applying the well-known method of least squares (Wonnacott and Wonnacott, 1981, Gupta, 1974) to fit the experimental data to give straight line. The correlation co-efficient (r) values at different sampling sites and regression co-efficient values (A and B) are tabulated in **tables-3, 4, 5, 6, 7 and 8.**

Exceedence Factor

The air quality has been categorized into four broad categories based on an Exceedence Factor (EF).

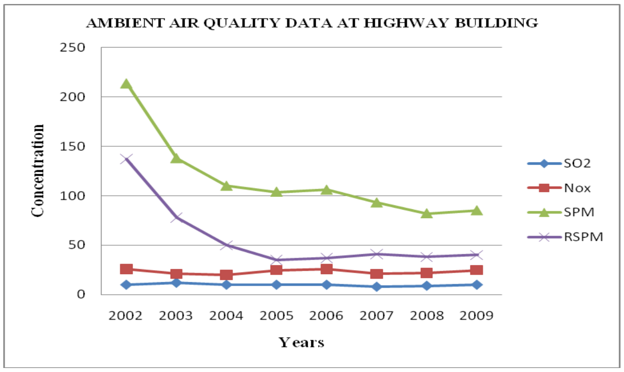

Figure 2: Ambient Air Quality Data at Highway Building

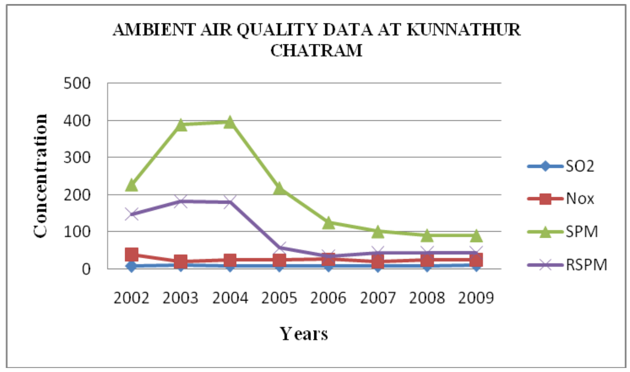

Figure 3: Ambient Air Quality data at Kunnathur Chatram

The four air quality categories for Exceedence Factor values are given in **table-9.** It is calculated as follows:

$$\text{Exceedence Factor} = \frac{\text{Observed annual mean concentration of criteria pollutant}}{\text{Annual standard for the respective pollutant}}$$

It could be seen from the above categorization, that the locations in either of the first two categories are violating the standards, although, with varying magnitude. Those, falling in the third category are meeting the standards but likely to violate the standards in future if pollution continues to increase and is not controlled. However, the locations in low pollution category have a rather pristine air quality and such areas are to be maintained at low pollution level by the way of adopting preventive and control measures of air pollution. Computed Exceedence factor categories for various pollutants at three sampling areas are tabulated in **table-10.**

RESULTS AND DISCUSSION

In the present study, the annual average value of SO2, NOx, SPM and RSPM in the ambient air of Madurai city at three sites, namely industrial, residential and commercial cum traffic areas were considered to determine the short-term air quality indices. Annual average values of critical parameters SPM, RSPM, SO2 and NOx, which generally persist in the air under the prevailing microclimate conditions, are considered.

Any correlation will be statistically significant only if its 'r' values are very close to +1 or –1. In the present investigation, tables-3, 4 and 5 show the correlation co-efficient of pollutants. High positive correlations were observed between SPM and RSPM (0.97) at Highway Building, and Kunnathur chatram (0.92) and NOx-RSPM (0.68) at Fenner (I) Limited whereas negative correlation were found between NOx and SPM (-0.042), SPM and RSPM (-0.26) at Fenner (I) Limited, SO2 and NOx (-0.45) and NOx-SPM (-0.055) at kunnathur chatram respectively. Tables 6, 7 and 8 show the regression co-efficient for all the possible pairs of pollutants.

Pairs having very high positive correlation between them show the dependency of one pollutant on

Table 3: Correlation co-efficient (r) between gaseous pollutants and particulate matter at Fenner (I) Limited

Parameter	Parameters (mg/m^3)			
	SO_2	NO_x	SPM	RSPM
SO_2	1	0.57815	0.25793	0.563495
NO_x	-	1	-0.04288	0.675964
SPM	-	-	1	-0.26226
RSPM	-	-	-	1

Table 4: Correlation co-efficient (r) between gaseous pollutants and particulate matter at Highway Building

Parameter	Parameters (mg/m^3)			
	SO_2	NO_x	SPM	RSPM
SO_2	1	0.063618	0.366364	0.335073
NO_x	-	1	0.30704	0.214817
SPM	-	-	1	0.973793
RSPM	-	-	-	1

Table 5: Correlation co-efficient (r) between gaseous pollutants and particulate matter at Kunnathur chatram

Parameter	Parameters (mg/m^3)			
	SO_2	NO_x	SPM	RSPM
SO_2	1	-0.44821	0.222074	0.09994
NO_x	-	1	-0.05539	0.172352
SPM	-	-	1	0.927693
RSPM	-	-	-	1

the other while pairs having negative correlation among them suggest increase in concentration of one pollutant represents decrease in other. The values of regression co-efficient (A and B) greatly help in finding out the regression equation between the two pollutants, which can be further extended in 95 % confidence limit.

In the present study at Madurai city, primary pollutants such as SO2 and NOx were found within the prescribed limit and SPM and RSPM were found to be exceeding the prescribed limit. That is the annual mean SPM level at all the three sites remained above Indian National Ambient Air Quality Standard. The annual average values of SPM, SO2, RSPM and NOx in the ambient air of Madurai city are considered to determine the pollution trends. This shows that maximum SPM levels were found in Kunnathur chatram with annual average concentrations of 397 and 389 mg/m3 during the year 2004 and 2003 respectively, which is observed three times above the standard value. The low concentration of SPM was found at industrial site Fenner (I) limited with annual average concentration of 65 mg/m3 in the year of 2002. But the level of pollutant SPM are within the prescribed limit throughout the year. The level of RSPM exceeded the prescribed limit during the year 2002 to2004 at the sampling station of Kunnathur chatram. The values of SPM are 148,183and180 mg/m3 respectively. The level of pollutant sulphur dioxide and oxides of nitrogen were found within the prescribed limit of CPCB throughout the years in all the study area.

Table 7: Regression coefficient (A and B) between gaseous pollutants and particulate matter at Highway Building.

Parameter pairs	A	B
NO_x and SO_2	0.140845	21.85915
NO_x and SPM	0.017753	21.18179
NO_x and RSPM	0.015207	22.38318
SPM and SO_2	14.02817	-22.0282
SPM and NO_x	5.310345	-6.96552
SPM and RSPM	1.192281	48.53998
RSPM and SO_2	10.47887	-46.4789
RSPM and NO_x	3.034483	-13.5517
RSPM and SPM	0.795343	-35.6574

Fenner (I) Limited

In the Fenner (I) Limited, the level of SPM is highest and SO2 is lowest. The trend of pollutants levels is SO2<NOx<RPM<SPM. It is found that the levels of SPM and RSPM have exceeded the standards in all the years. The correlation analysis reveals that there is no high positive correlation between the pollutants except correlation values of 0.57 and 0.68 are observed for NOx - SO2 and NOx - RSPM respectively.

Table 6: Regression coefficient (A and B) between gaseous pollutants and particulate matter at Fenner (I) Limited.

Parameter pairs	A	B
NO_x and SO_2	0.347238	21.24803
NO_x and SPM	-0.00433	26.92289
NO_x and RSPM	0.050911	23.55988
SPM and SO_2	1.535513	74.52537
SPM and NO_x	-0.425	109.0125
SPM and RSPM	-0.19577	109.0559
RSPM and SO_2	4.493799	-10.2187
RSPM and NO_x	8.975	-180.088
RSPM and SPM	-0.35132	92.09123

Table 8: Regression coefficients (A and B) between gaseous pollutants and particulate matter at Kunnathur chatram.

Parameter pairs	A	B
NO_x and SO_2	-3.75	63
NO_x and SPM	-0.00274	26.06394
NO_x and RSPM	0.01647	23.98886
SPM and SO_2	37.5	-169.5
SPM and NO_x	-1.11786	234.0054
SPM and RSPM	1.789247	41.33658
RSPM and SO_2	8.75	4.25
RSPM and NO_x	1.803571	45.75893
RSPM and SPM	0.480992	-7.09388

Table 9: Relative scale for Exceedence Factor values

Exceedence Factor values	Categories
> 1.5	Critical pollution
1.0 – 1.5	High pollution
0.5 – 1.0	Moderate pollution
< 0.5	Low pollution

Highway Building

In the Highway building, the level of SPM and RSPM is highest during the year 2002 and the values are 214 and 137 respectively. It is found that the level of pollutants are decreasing trend in all the years. The trend of pollutants is SO2<NOx<RSPM<SPM. High positive correlation exists for the following pair SPM and RSPM in this area.

Kunnathur Chatram

At Kunnathur chatram, the level of SPM and RSPM is higher than the level of sulphur dioxide and oxides of nitrogen. The trend of pollutant levels are SPM>RSPM>NOx>SO2. SO2 and RSPM, SPM and RSPM are positively correlated with r-values 0.92 for each. This shows that RSPM concentration increases with the concentrations of SO2 and SPM.

Comparison of Exceedence Factor values of all the sampling areas shows that the air quality is critically polluted by RSPM and SPM at residential and commercial cum traffic area for all the years. Industrial sites of Madurai city are moderately polluted from 2002 to 2009.The level of SO2 and NOx are quite clean in all the study areas. In order to control the pollutant levels in urban areas, urgent attention is required for controlling vehicular emission and industrial emission. Air pollution management for urban air quality monitoring and assessment should provide management approaches by deriving policies and strategies.

In the present study, the particulate pollutants SPM and RSPM are mostly above the permissible limit at Kunnathur chatram in Madurai city. The gaseous pollutants SO2 and NOx concentrations in Madurai city are found to be decreasing trend which is in accordance with Bhaskar et al., 2008, Bhaskar et al., 2010). It implies that particulate matters are produced by vehicles, industrial activities and combustion of conventional fuels for domestic and commercial purposes. The results of this study will be useful for further research on interactions between atmospheric aerosols, local and regional weather and climate in Madurai city.

Sustainable Development And Planning

- The preparation of Environmental Management Plan (EMP) studies should be taken up for tourism and environmentally fragile areas.
- The sustainable development plan requires the conservation of environment resources, like forest, natural gases flora and fauna and qualities to protect the interests of our future generations.
- The Environment Management Plans for urban areas

Table 10: Computed Exceedence factor categories for various pollutants at three sites during 2002-2009.

Sampling areas	Pollutants	Sampling Periods							
		2002	2003	2004	2005	2006	2007	2008	2009
Fenner (I) Limited	SO_2	L	L	L	L	L	L	L	L
	NO_x	L	L	L	L	L	L	L	L
	SPM	L	L	L	L	L	L	L	L
	RSPM	M	M	L	L	L	L	L	M
Highway Building	SO_2	L	L	L	L	L	L	L	L
	NO_x	L	L	L	L	L	L	L	L
	SPM	C	M	M	M	M	M	M	M
	RSPM	C	H	M	M	M	M	M	M
Kunnathur Chatram	SO_2	L	L	L	L	L	L	L	L
	NO_x	M	L	C	L	L	L	L	L
	SPM	C	C	C	C	M	M	M	M
	RSPM	C	C	C	C	M	M	M	M

should be targeted to provide planning solutions for the different kinds of urban areas wherein the environmental degradation has taken place and environmental risks are increasing (MoEF, 2000-2001).

- The concentrations of SPM observed in the present study are indicative and continuous monitoring at minimum five categories, that is residential, commercial, industrial, petrol pumps and traffic junctions is recommended as this will help in anticipating future concentration of SPM in the ambient air, formulating standard levels and decision pertaining to control air pollution (Gupta et al., 2005).

Recommendation

- As per the results, there are some suggestions, which can be adapted for prevention, abatement and control of air pollution. It may be understood that these measures are suitable to be applied at the source itself, since the pollutants are released in the atmosphere, it is only by virtue of the natural phenomena of wind, and thermal convection and rain wash out that their extent can be reduced.
- Vehicular pollution can be reduced or controlled through the implementation of Euro/Bharat norms and phase out of old and ill maintained vehicles.
- CNG may be introduced in lieu of petrol.
- Traffic rules should be implemented properly avoiding traffic jams, smooth traffic flow and it should be regularized by imposing nominal pollution tax for those who float the city traffic rules and regulations.
- Polluting industries should be away from the city. They should have one complex, where in all the industrial pollution norms are observed. Offices should not be concentrated in silence zone.
- Road should be well maintained. Bye-pass roads may be provided for inter city traffic. Flyover may be built to avoid traffic jams.
- Common diesel generator sets should be established in the light cut hours to avoid unnecessary air and sound pollution.
- Green belt may be provided throughout city. It will reduce excess CO2, provide health-giving oxygen, trap aerosols, supply biomass and timber and create social forestry.
- Pollution level may be monitored regularly. Increasing awareness among the people.

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