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# Retrospective Analysis of a Theoretical Model Used for Forecasting Future Air Quality near The North Chennai Thermal Power Plant

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**ABSTRACT**

The trend of gathering of Baseline Air Quality data commenced in Chennai as early as 1981, as an academic exercise, undertaken by some post-graduate students of the Centre for Environmental Studies in Anna University, Chennai (1,2,3,4). The study revealed that the baseline air quality data were only at moderate levels, in respect of the three major air pollutants, namely, Sulphur Dioxide (SO2), Nitrogen Dioxide (NO2), and Suspended Particulate Matter (SPM), in Ennore-Manali Industrial area. All these pollutants measured for the respective averaging times, were below the National Ambient Air Quality Standards prescribed for each pollutant, respectively. Therefore, it was possible to convince the Department of Environment & Forests, Government of India, New Delhi that the Environmental Clearance be given, for the proposed establishment of the 3x210 MW coal-fired thermal power plant in the Ennore Island location, with the financial assistance from the Asian Development Bank to the Tamil Nadu Electricity Board. The present status of air quality in the same area needs to be assessed in the light of the Revised National Ambient Air Quality Standards, especially in view of the newly introduced parameters, namely, PM10 and PM2.5, which were not in force in the year 1986. There are a few more industries which have come up after 1986, and which have relevance to emission of air pollutants , namely, SO2, NO2, and SPM (inclusive of PM10 and PM2.5), having adverse effects on human health.

**KEY WORDS:** Retrospective, Analysis, Theoretical, Power Plant.

## 1. INTRODUCTION

In the year 1986, the Tamil Nadu Electricity Board (TNEB) arranged for conducting an Air Pollution Survey in the Ennore-Manali Industrial Area, when the establishment of North Chennai Thermal Power Plant in Ennore Island was being proposed. The Air Quality Report, prepared by Chockalingam (5), formed a part of the Environmental Impact Assessment (EIA)–Report, furnished by M/s Tata Consultancy Services, and submitted to the Government of India, for the purpose of obtaining Environmental Clearance of for the new project. Asian Development Bank authorities were consulted at the time of discussing the various steps to be pursued in the Environmental Management Plan. In the Air Pollution Survey carried out in 1986, the following methods were employed:

- Nine air-sampling stations were established for the measurement of the three major pollutants relevant to emissions from a coal-fired thermal power plant, namely, $SO_2$, $NO_2$ and SPM (Suspended Particulate Matter), which were continuously measured for 28-days. The lay-out of Air Sampling Stations is shown in Figure-1.

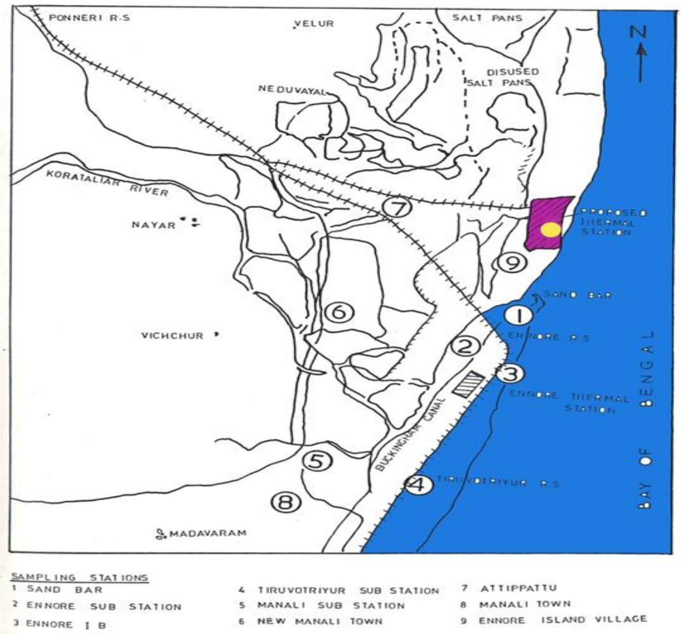



**Figure.1. Locations of Air Sampling Stations**

- The 9-Air Sampling Stations were located at distances varying from 1.0 Km to 13.0 Km, in the locations which are likely to receive the impacts of air-pollutant emissions from i) the Ennore Thermal Power Station ( ETPS, already existing), and ii) the proposed North Chennai Thermal Power Plant at Ennore-Island.

The Baseline Air Quality indicated moderate concentrations, in respect of all the three pollutants, namely, $SO_2$, $NO_2$, and SPM concentrations during the period of study.

The following trends were indicated in the measured baseline air quality :

- The 8-hour average $SO_2$-concentrations varied from 15.1 ug/m$^3$ to 30.4 ug/m$^3$.
- The 8-hour average $NO_2$-concentrations varied from 6.4 ug/m$^3$ to 20.4 ug/m$^3$.
- The 24-hour SPM –concentrations varied from 99.9 ug/m$^3$ to 110.3 ug/m$^3$.

(These concentrations are due to emissions from the major sources existing in the area at that time (1986), inclusive of the Ennore Thermal Power Station (ETPS).

**Theoretical Modeling:** Air Quality Predictions in 1986:

Appendix-1 presents some details of Charts and Tables used in the application of the Gaussian Diffusion Equations. Fiure-4 describes the Gaussian Diffusion Pattern towards groundlevel locations. Figure.2, gives an idea of visual effect of dispersion in atmospheric air, above the Chimneys (Stacks).

**Figure.2. Visual effect of Plume Dispersion**

Air Quality Modeling was done, using Computer-aided Simulation Techniques, using the Gaussian Diffusion Equation, for all the possible combinations of wind speeds and the relevant atmospheric stability classes (likely to occur in the Study-area), to assess the impact of emissions from the newly-proposed thermal power plant at North Chennai ( Ennore Island) location, during the following stages of commissioning :

- Stage-I, when the power plant is operating, initially with (3x210MW= ) 630MW, and
- Stage-II, when 2more 210MW units are added to increase the total capacity to 1050MW, and
- Stage-III, when 2-more units of 500MW units are added, to make it a Super- Thermal -Power Plant of a capacity of 2050MW, on the completion of Stage-III.

The predicted concentrations of pollutants were superimposed over the Baseline (Background) Air Quality, in order to predict the Future Air Quality, likely to occur in all the 9-Air Sampling Stations, which represent the immediate neighborhood of the proposed North Chennai Thermal Power Station.

The long term meteorological data applicable to the North Chennai, were obtained from the Indian Meteorological Department. The Wind Rose Diagram for a 5-year period (1980-1985) was drawn and were used for comparing the percentages of wind speed frequencies, as shown in Figure-3. Computer-aided modeling procedure was followed, with the probable combinations of stability classes under each wind-speed class, to compute the ground level concentrations of pollutants which are likely to occur at various downwind locations.

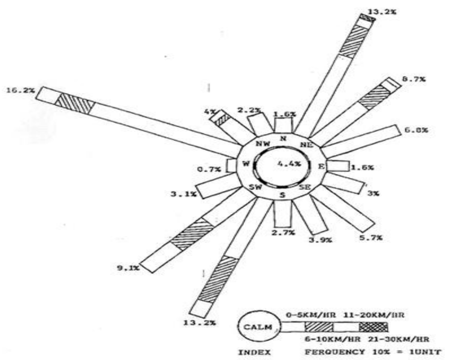



**Figure.3. Wind Rose Diagram (1980 -1985)**

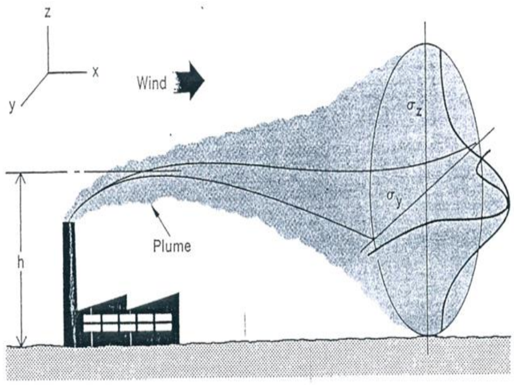


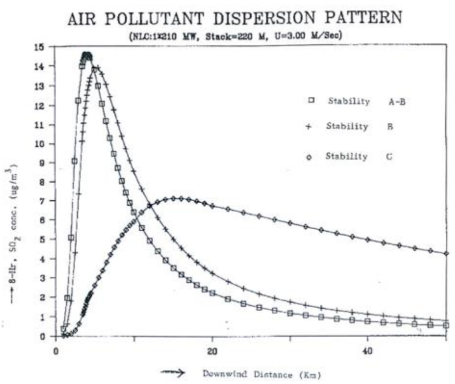

**Figure.4. Gaussian Model**

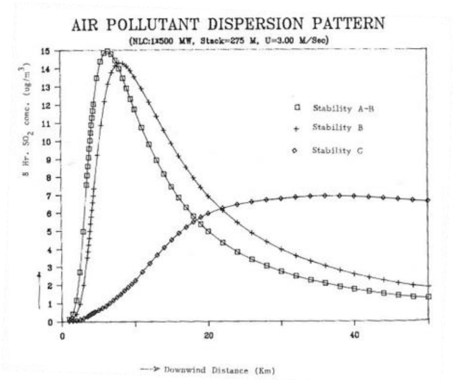
All probable combinations of wind speed classes and the relevant stability classes have been sufficiently taken into consideration in the modeling procedures. The most adverse meteorological condition was evaluated, in respect of the ground level concentrations likely to occur at various downwind locations.

The predicted pollutant concentration was added to the measured concentration at each sampling station, to arrive at the future air quality, likely to occur at that sampling location, during Stage-I, Stage-II, and Stage-III.

It was indicated that the Future Air Quality, so obtained, will be in compliance with the National Ambient Air Quality Standards prescribed by the Government of India, on the completion of Stages-I, II, and III, under the influence of the meteorological situations which are likely to occur in North Chennai Air Basin, considering the long-term meteorological situations likely to occur in the area.

The findings were approved by the Environmental Appraisal Committee of the Ministry of Environment & Forests, and the delegates of the Asian Development Bank appreciated the contents of the Air Quality Report. Summary of 1986-Studies and Relevance to the Present Situation




**Figures-5 & 6 : Pollutant Dispersion Patterns from Stack Heights of 220.0 m & 275.0 m**

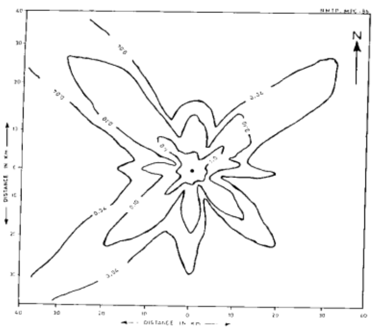



**Figure.7. Pollution Rose Diagram (Depicting annual arithmetic mean concentration of SO2 : Future Air Quality)**

- As a part of the Air Quality Modeling Work, Pollution Rose Diagrams were developed for the three pollutants, namely, Annual Average Concentrations of $SO_2$, $NO_2$, and SPM. The Pollution Rose Diagrams are helpful to assess the impact a specific pollutant on long-term exposure, such as one year, on human health. The Pollution Rose in respect of $SO_2$ is presented in Figure-7.

(There are several applications for the Pollution Rose - data, such as assessment of health effects/ property-damage estimates / epidemiological studies /town-planning guidelines formulation, etc, in an alert-society).

**Typical examples of pollutant dispersion:** The patterns of variation of ground-level 8-hour average concentrations of $SO_2$, along the downwind distances (shown from zero to 25 Km), due to emission from a 1x210 MW power generation unit, is presented in Figure-5, as an example, when the stack-height is 220.0metres, when the wind speed is 3.0m/sec(10.8 Kmph) occurs, under the stability classes of either A-B, or B, or C.

Figure-6 present the pattern of variation of ground-level 8-hour average concentrations of $SO_2$, along the downwind distances, due to emissions from 1x500MW power generation unit, when the stack height is 275.0metres, when the wind speed is 3.0 m/sec(10.8Kmph) occurs under the stability classes of either A-B, or B or C.

- It can be noted that the pollutant concentrations at a downwind (Receptor) location such as 20.0 Km, the ground-level $SO_2$ concentrations are different when the stability class is different, under the same wind speed class, namely, 3.0 m/sec.(10.8 Kmph) Three different stability classes can individually occur, one at a time, either, Stability class A-B (most favorable mixing), or under Stability class B (moderately favourable mixing), or under the third probability, namely, Stability class C ( satisfactorily favourable mixing).

The more is the mixing, the more is the dilution, thus resulting in lesser concentration.

Figures-5 & 6 sufficiently explain the importance of the stability class, in addition to explaining the effect of taller stacks.

**General discussion on the trends of dispersion pattern:** The following maximum 8-hour $SO_2$ concentrations occurred in downwind receptor locations: (comprehensive results)

- Stage-I: The maximum 8-hour $SO_2$ of 34.2 ug/m$^3$ at a downwind location of 6.0 Km, when a wind speed of 3.0 m/sec (10.8 Kmph) occurs under the stability class of E.
- Stage-II : The maximum 8-hour $SO_2$ of 36.7 ug/m$^3$ at a downwind location of 4.0 Km, when a wind speed of 4.17 m/sec(15.0 Kmph) occurs under the stability class D.
- Stage-III: The maximum 8-hour $SO_2$ of 39.6 ug/m$^3$ at a downwind location of 4.1 Km , when a wind speed of 4.17 m/sec, (15.0 Kmph), occurs under the stability class D.

The advantages of tall stacks, such as 220.0 metres for the 220MW-units, and 275.0 metres for the 500MW-units, enabling satisfactory dilution / mixing / dispersion are reflected in the results of the predicted concentrations.

## 2. RESULTS AND DISCUSSION

The predicted concentrations of pollutant concentrations were superimposed over the Background (baseline) concentrations measured at each Air Sampling Station, to obtain the Future Air Quality. As the 9-Air Sampling Stations represent the immediate neighbourhood of the North Chennai Thermal Power Plant, it can be concluded that the predicted Future Air Quality, after the completion of Stage-III, Will be well below the prescribed air quality Standards, in the case of all the three pollutants, as described below:

- The 24-hour average SO2 concentration, as a maximum, will be 59.0 ug/m$^3$.
- The 24-hour average $NO_2$ concentration, as a maximum, will be 54.8 ug/m$^3$.
- The 24-hour average SPM concentration, as a maximum, will be 108.0 ug/m$^3$.

(Ambient Air Quality Standards which were in force in June 1986 are presented in Appendix-2A). ). **Suggestion for future studies:** The Government of India, Ministry of Environment & Forests, have drastically revised the National Ambient Air Quality Standards, in November 2009. The averaging time for the measurement of the two major gaseous pollutants, namely, SO2 and NO2, have been revised as 24-hours, from the earlier yardstick of 8-hours. New parameters, such as NH3, CO2, CO, O3, PM10, PM2.5, etc., have been introduced. Therefore, it has become necessary to monitor the air quality currently prevailing in the Ennoore-Manali Industrial Area, to ascertain the validity of the theoretical modelling calculations, and to document the reliability of such methods adopted for forecasting future impacts. Such a study will be relevant to the protection of public health, in addition to safeguarding the environment and the ecology. Like what they do in advanced countries, to generate the national data bank on air quality, regional agencies must be identified for fulfilling this important objective.

**Appendix - 1**

**Conventional Gaussian Model On Air Pollutant Dispersion :**

$$C(x, y, z; H) = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp^* \left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \text{....(3,1)}$$

*C*: The contribution to the total pollutant concentration at a particular point at (x, y, z), where the x, y, z represent the coordiantes of the receptor point, with reference to the source

Q: the pollutant emission rate of the source, $(\mu g / \sec)$.

u: the mean wind speed at stack level, (m/sec).
$\sigma_y$ and $\sigma_z$ the horizontal and vertical dispersion co-efficients respectively. (m)

H: the effective stack height, (m)

**For computing Ground Level Concentrations(GLC), put Z = 0 in equation (3, 1), now the eqn.3.1 reduces to**

$$\textbf{C (x, y, 0, H)} = \frac{Q}{\pi u \sigma_y \sigma_z} \ \textbf{exp} \left(-\frac{y^2}{2\sigma_y^2}\right) \exp\left(-\frac{H^2}{2\sigma_z^2}\right) \text{......(2)}$$

**For computing Ground Level Concentrations (GLC) along with the center –line of the plume (i.e. Y = O; Z = O) equation the 3.1 reduces to**

$$C(x, 0, 0, h) = \frac{Q}{\pi u \sigma_y \sigma_z} \ \exp \ |-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2 \text{....(2)}$$

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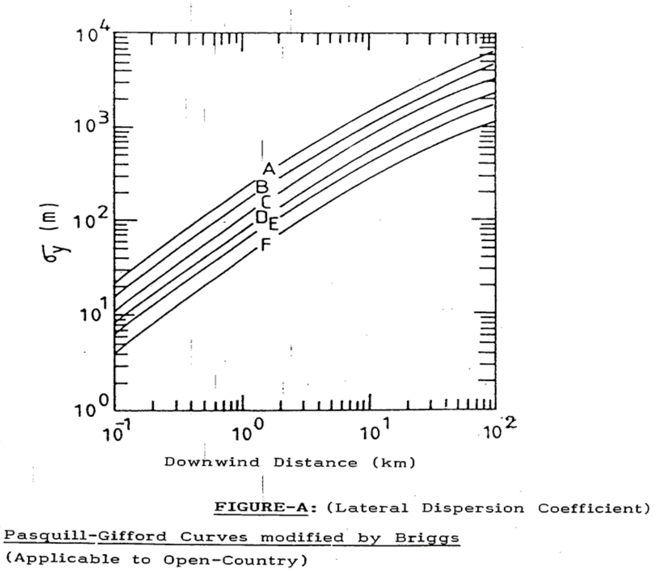


**Figure.A. (Lateral dispersion coefficient) Pasquill-Gifford curves modified by briggs (Applicable ot open-Country)**

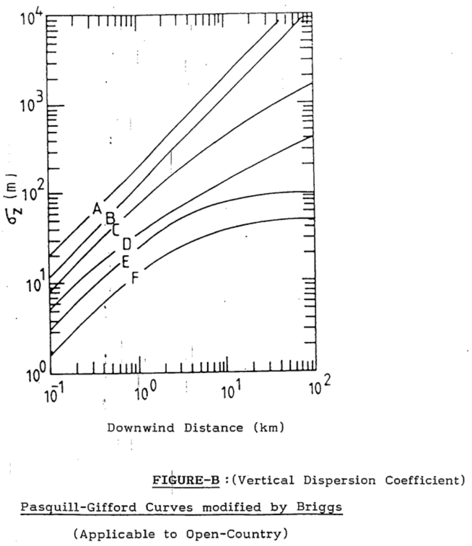


**Figure.A. (Vertical dispersion coefficient) Pasquill-gifford curves modified by briggs (Applicable to open-country)**

| **Meteorological conditions defining pasquill turbulence types** | | | | | |
|---|---|---|---|---|---|
| **Surface wind speed (m/sec)** | **Day time Insolation** | | | **Night time condition** | |
| | **Strong** | **Moderate** | **Slight** | **$C_L \geq 4/8$** | **$C_L \leq 3/8$** |
| $0 \leq U_s < 2$ | A | A-B | B | - | - |
| $2 \leq U_s < 3$ | A-B | B | C | E | F |
| $3 \leq U_s < 5$ | B | B-C | C | D | E |
| $5 \leq U_s < 6$ | C | C-D | D | D | D |
| $6 \leq U_s$ | C | D | D | D | D |

APPENDIX - 2A

AIR QUALITY STANDARDS IN INDIA

| Area | Category | Concentration in micrograms per cubic metre | | | |
|---|---|---|---|---|---|
| | | SPM | $SO_2$ | CO | $NO_2$ |
| A | Industrial and mixed use | 500 | 120 | 5,000 | 120 |
| B | Residential and Rural | 200 | 80 | 2,000 | 80 |
| C | Sensitive | 100 | 30 | 1,000 | 30 |

Reference : Air Quality standards prescribed by the Central Board for the prevention and control of Water Pollution Government of India, New Delhi, Vide Notification issued in the 47th Meeting held on November 11, 1982, and

Tamil Nadu Pollution Control Board's proceedings B.P.Ms.No.49 dated the 19th, July, 1984.

Note : The standards listed above shall include the condition that "when monitored uniformly over the 12 months of a year with a frequency not less than once in a week, a sampling time of 8 hours for any samples and analyzed according to procedures specified by the Board, the concentrations of the pollutants shall be, 95% of the time, within the limits adopted."

APPENDIX - 2B

EMISSION STANDARDS APPLICABLE TO THERMAL POWER PLANTS IN INDIA

(a) Standards for particulate matter emission

| Boiler size | Protected Area | other area | |
|---|---|---|---|
| | | Old (before 1979) | New (after 1979) |
| Less than 200 MW | 150 $mg/Nm^3$ | 600 $mg/Nm^3$ | 350 $mg/Nm^3$ |
| 200 MW above | 150 $mg/Nm^3$ | - | 150 $mg/Nm^3$ |

(b) Standard for Sulphur Dioxide Control (through stack height)

| Boiler size | stack height |
|---|---|
| Less than 200 MW | $H = 14 (Q)^{0.3}$ |
| 200 MW to less than 500 MW | 220 metres |
| 500 MW and more | 275 metres |

Ref: Tamil Nadu Pollution Control Board's proceedings B,P.Ms.No.68 dated the 28th February 1985.

**REFERENCES**

Ambalavanan K.V, Study of Air Pollution Pattern around Badin Bridge Power House, an M.E. Degree Thesis submitted to Anna University, Chennai, 1981.

Anbazhagan R, Satheesh B, Gopalakrishnan K, Mathematical modeling and simulation of modern cars in the role of stability analysis, Indian Journal of Science and Technology, 6 (5), 2013, 4633-4641.

Briggs G.A, Diffusion Estimates for Small Emissions, Atmospheric Turbulence and Diffusion Laboratoy, Contribution File.No.79, Oak Ridge, TN, 1973. (cited in, Fundamentals of Air Pollution,Third Ed,authord by Boubel R.W, Fox D.L, Turner D.B, and Stern A.C, Academic Pess, An Imprint of Elsevier,1994, 340.

Brindha G, Krishnakumar T, Vijayalatha S, Emerging trends in tele-medicine in rural healthcare, International Journal of Pharmacy and Technology, 7 (2), 2015, 8986-8991.

Brintha Rajakumari S, Nalini C, An efficient cost model for data storage with horizontal layout in the cloud, Indian Journal of Science and Technology, 7, 2014, 45-46.

Chockalingam M P, Air Quality Study for a 630 MW coal-fired Thermal Power Plant, a Technical Report Furnished to the Tamil Nadu Electricity Board, Chennai, under the University-Industry Interaction Programme between Annamalai University, Annamalainagar-608 002, and the TNEB, Chennai, 1986.

Gopalakrishnan K, Prem Jeya Kumar M, Sundeep Aanand J, Udayakumar R, Analysis of static and dynamic load on hydrostatic bearing with variable viscosity and pressure, Indian Journal of Science and Technology, 6 (6), 2013, 4783-4788.

Jagadeesan D, Air Pollution Survey around Basin Bridge Power House, an M.E. Degree Thesis submitted to Anna University,Chenna, 1982.

Jeyanthi Rebecca L, Susithra G, Sharmila S, Das M.P, Isolation and screening of chitinase producing Serratia marcescens from soil, Journal of Chemical and Pharmaceutical Research, 5 (2), 2013, 192-195.

Kerana Hanirex D, Kaliyamurthie K.P, An adaptive transaction reduction approach for mining frequent itemsets, A comparative study on dengue virus type1, International Journal of Pharma and Bio Sciences, 6 (2), 2015, B336-B340.

Khanaa V, Mohanta K, Saravanan T, Comparative study of uwb communications over fiber using direct and external modulations, Indian Journal of Science and Technology, 6 (6), 2013, 4845-4847.

Khanaa V, Thooyamani K.P, Udayakumar R, Cognitive radio based network for ISM band real time embedded system, Middle - East Journal of Scientific Research, 6 (12), 2013, 1798-1800.

Kumarave A, Rangarajan K, Algorithm for automaton specification for exploring dynamic labyrinths, Indian Journal of Science and Technology, 6 (5), 2013, 4554-4559.

Kumaravel A, Pradeepa R, Efficient molecule reduction for drug design by intelligent search methods, International Journal of Pharma and Bio Sciences, 4 (2), 2013, B1023-B1029.

Revision of National Ambient Air Quality Standards (NAAQS), vide Notification of the Central Pollution Control Board, 2009.

Sachithanantham P, Sa Nkaran S, Elavenil S, Experimental study on the effect of rise on shallow funicular concrete shells over square ground plan, International Journal of Applied Engineering Research, 10 (20), 2015, 41340-41345.

Sharmila S, Jeyanthi Rebecca L, Das M.P, Production of Biodiesel from Chaetomorpha antennina and Gracilaria corticata, Journal of Chemical and Pharmaceutical Research, 4 (11), 2012, 4870-4874.

Sharmila S, Jeyanthi Rebecca L, Naveen Chandran P, Kowsalya E, Dutta H, Ray S, Kripanand N.R, Extraction of biofuel from seaweed and analyse its engine performance, International Journal of Pharmacy and Technology, 7 (2), 2015, 8870-8875.

Tamil Nadu Pollution Control Board, Chennai, Ai Quality Report, 2015.

Thanam Jeya Veera Raj T, Experimental Assessment of Air Quality in the Basin Bridge Power House Area, an M.E. Degree Thesis submitted to Anna University, Chennai, 1985.

Udayakumar R, Khanaa V, Saravanan T, Saritha G, Cross layer optimization for wireless network (WIMAX), Middle - East Journal of Scientific Research, 16 (12), 2013, 1786-1789.

Vanangamudi S, Prabhakar S, Thamotharan C, Anbazhagan R, Dual fuel hybrid bike, Middle - East Journal of Scientific Research, 20 (12), 2014, 1819-1822.

Varadaraj N, Ambient Air Quality in the neigh bourhood of Ennore Thermal Power Plant, an M.E. Degree Thesis submitted to Anna University, Chennai, 1985.