Validation of Point Source Models for Determining Industrial Pollution and Integrating with IOT for vulnerability management

M.Selvakumar¹, V.Prasannakumari², S.Geetha*¹, S.Muthulakshmi¹
¹Professor, Department of Civil Engineering, Rajalakshmi Engineering College
²Professor, Department of Information Technology, Rajalakshmi Engineering College

*corresponding author-geetha.s@rajalakshmi.edu.in

Abstract. Awareness in Environmental pollution which was restricted to water and wastewater pollution has now been extended to air pollution. In Indian Scenario, the popularity of air pollution is gaining momentum day by day and all metro cities are facing this problem due to increase in traffic and industries located in the vicinity. The major contribution to air pollution is from traffic though there are other sources like smoke from factories and burning of any material. Monitoring stations are not provided in many places as it is a costly investment. Though there are very few monitoring stations in metro cities, the other areas still do not have any means to monitor the quality of air we breathe in. This work deals with validating point source models to predict the pollution due to thermal power plant emissions in Ennore, Chennai. The details of wind speed, wind direction, temperature and humidity play a major role in dispersing the air pollutants. Particulate air pollutant PM₂.₅, PM₁₀ and SO₂ were monitored and the variation of air pollutants during summer and winter were studied. The influence of meteorological parameters in the concentration of these pollutants were analysed by this study. AERMOD software was used to model the data and further predictions with the help of advanced technology are discussed in this paper. Deployment of a system using advanced sensors and systems has enabled us to assess the air quality by integrating IOT with sensors which could facilitate continuous monitoring of the pollutants.

Keywords: pollution; health hazard; threshold limit; monitoring; prediction

1. Introduction:
Industrial revolution and advancement in technology are the two parameters that contribute to the development of a Nation. Though economic growth can be brought about by these two aspects, it has a significant disadvantage in increasing the pollution and depleting the natural resources. Air pollution is directly connected with industrial revolution as the industries and transports are the major causes of air pollution [1]. This problem gets aggravated as the industrial areas keep expanding their boundaries to accommodate new industries[2]. One more issue leading to this pollution is that many industries still follow the traditional methods so that they get the desired output with minimum production cost. To prevent this pollution or at least control it we are in need of implementing environmental policies which could control these industries to minimize the pollution. Environmental policies can be enforced only if the clusters which contribute to the environmental pollution are identified [3], [4], [5]. This involves details about the existing pollution levels in that area. Hence monitoring pollution levels in the air we breathe is essential because it is finally the human health that is in risk due to air pollution.
The criticality of pollution in any area involves these three factors: (i) identifying the source of air pollution, (ii) monitoring the levels of pollution and the mode of pollution transport and (iii) the receptor affected by this pollution. Air pollution is due to the concentration of particulate matter which are suspended and respirable (TSPM and RPM), sulphur dioxide (SO2), carbon monoxide (CO) and nitrous oxide (NOx) [6], [7], [8], [9]. Prolonged exposure of humans to such pollutants mainly particulate matter have resulted in respiratory problems, allergies, lung disorders and many fatal health issues [10], [11].

A report from WHO has recorded that the death rate of people due to health hazards due to air pollution is 3.7 billion worldwide [12]. This death rate is expected to increase two folds in 2050. Researchers have reported that exposure to aerosols and gaseous pollutants are the main cause for lung cancer, respiratory and cardiovascular sickness [13], [14]. Climate change and quality of air is an interlinked phenomenon. It is clear that accumulation of more greenhouse gases affect the climate to a larger extent. This work deals with monitoring air pollution in an Industrial area in Chennai which has a thermal power plant and many industries. Though there are road network around this thermal power plant, the predominant source of pollution is from the chimneys of the thermal power plant. Hence AERMOD, a point source model has been used for modelling the pollutants [12], [13],[14], [15]. Researchers have used deep learning to monitor air quality data [16]. Sensors and microcontrollers have been used to find the concentration of pollutants [17,18]. This paper gives a scheme in which IOT can be used along with sensors for continuous monitoring of air quality in Industries which could be an economical means of establishing an integral air quality monitoring system.

2. Methodology:

2.1 Study area characteristics:

Ennore which has a thermal power plant established in 1970 is along the coastal region and is bounded by Bay of Bengal and Kortallaiyar River. Approximate 1000MW power is generated from this power station. It has 3 chimneys each having a height of 80 m and diameter of 4.6 m. with80 m height and 4.6 m diameter. The coal for this power plant is shipped directly from the harbour. The geographical location of this area is 13˚ 12’5” N and 80˚18’42” E. Unplanned establishment of industries have resulted in pollution issues in this area. The concentration of air pollutants have gone beyond the permissible limits in this area. There are no proper air quality monitoring stations in this area which could report the level of pollution on a regular basis. Hence this study was undertaken to assess the air quality and the concentration of the pollutants. Meteorological parameters are important in this study as wind velocity, wind direction, temperature and humidity play a major role in the dispersion of the pollutants [19-23]

2.2 Scheme of work:

This study was carried out in 10 monitoring stations surrounding the thermal power plant randomly so that the distance between the stations was approximately 2 kms. Particulate matter (PM 10 and PM2.5) was monitored using a sensor based smart air quality monitor (Airveda) which is commercially available. For measurement of SO2 thermo scientific analyser (Model 43i) was used. The range of the analyser was 0 to 100 ppm using pulse fluorescence technology. The meteorological data was collected from the daily report that is available in the world weather online database. The monitoring was carried out for 6 months (June to December 2019) for 8 hours (8 am to 4pm) on all days continuously. Monthly average pollution was reported for each monitoring station. Monitored data was compared with the modelled data using AERMOD software and the accuracy of the model was determined by R² value. The details that were used in the software are given in Table 1.
The Gaussian plume equation is used for the effective vertical displacement of the plume, stack height and the plume dispersion in and around the atmosphere as per the wind (downwind and crosswind directions) and meteorological conditions of the vicinity.

The vertical and lateral dispersion thus relies on the atmospheric stability which is a function of the Gaussian curve. The equation below defines the concentration at different heights and lengths from the stack tip:

\[
C(x, y, z) = \frac{Q}{2\pi \sigma_x \sigma_y} \left[ e^{\frac{-(z-h)^2}{2\sigma_z^2}} + e^{\frac{-(z-h)^2}{2\sigma_z^2}} \right] \left[ e^{\frac{-(y)^2}{2\sigma_y^2}} \right] \]

Where, \(C\) : concentration of the dust emitted, \(Q\) : emission rate \(\sigma\) : diffusion values along the axes defined experimentally, \(Y\) : horizontal distance from plume axis, \(Z\) : height from the ground level, \(H\) : emission height

### Table 1: Input Data of the pot source in AERMOD software

| ID  | Base Elevation (m) | Height (m) | Diameter (m) | Exit velocity (m/s) | Exit Temperature (k) | Release type | Emission Rate (g/s) | X1 (m)  | Y1 (m)  |
|-----|-------------------|------------|--------------|---------------------|----------------------|--------------|---------------------|--------|--------|
| ETPS 1 | 12                | 80         | 4.61         | 7.44                | 410                  | VERTICAL    | 21.924              | 42540  | 1459507 |
| ETPS 2 | 12                | 80         | 4.61         | 8.66                | 418                  | VERTICAL    | 25.569              | 425345 | 1459544 |
| ETPS 3 | 12                | 80         | 4.61         | 8.61                | 420                  | VERTICAL    | 21.789              | 425309 | 1459547 |

The results in this work are mainly focussed on finding the vulnerable areas that will be badly affected due to high concentration of pollutants. The study area concerned is given in a satellite image as shown in figure-1. Meteorological information is one of the main parameter needed in any air quality study. The data was collected from online source and the wind rose diagram is plotted as given in figure-2.

The maximum wind speed recorded was 15 kmph in NNE direction and 12 kmph along the S direction. The wind speed plays a major role in diluting the pollutants. The monitored data in all the stations are given in figure-4 to 6. It shows that in all stations invariable of the location the pollutant concentration ranges from 132 to 156 μg/m³. Similarly the concentration of RPM ranged from 35 to 55 μg/m³. Sulphur dioxide concentrations ranged from 39 to 55 μg/m³.

AERMOD software was used for modelling the air quality. The inputs required where are the coordinates of the source, height & diameter of the chimney and emission inventory data. The modelled pollutant in the study area is given in figure-6 to 8.
Figure-1 Satellite image of the study area

Figure-2 Wind rose diagram

Figure-3 Observed TSPM concentrations

Figure-4 Observed RPM concentrations

Figure-5 Observed SO$_2$ concentrations

Figure-6 Modelled TSPM concentrations
The colour coding of the images show the severity of the pollution. The red colour areas depict that the pollution level is maximum and it may cause health hazards to people in the area. Apart from observing and modelling, a correlation between the two variables have been plotted in order to find the reliability of the modelled data. It has been observed that the R² value for RPM and SO₂ is 0.85 and 0.97 which shows that the observed and modelled data correlates well. With reference to TSPM the R² value is less compared to the other two pollutants. But still it is closer to 0.75 which has a fairly good correlation between the two sets of data.

4. Integration of IOT for Air Quality Monitoring
The proposed scheme consists of sensors DHT-11 to acquire the basic data like temperature and humidity and there are sensors like SPS30 for acquiring data on particulate matter PM₂.₅, MQ-7 for detecting carbon monoxide and MSR -MA-5-1196 for detecting SO₂. These sensors will be connected to an Arduino board which facilitates the conversion of analog to digital. The Arduino board is
connected to a Raspberry Pi 3400 low cost single board computer which is connected to a server to store the data. The proposed IOT data acquisition system is given by the block diagram as in figure-12. This scheme will enable industries to have a continuous monitoring system for the air quality and thereby ensure that the pollutant concentrations are within permissible limits.

Air quality prediction methods that consider spatial and temporal correlations are also deployed. Each type of sensor is configured to detect specific types of pollutants and pass on the data to the system. System converts the analogue data received into digital and processes it to raise alerts whenever thresholds are exceeded. This ensures initiation of remediation processes and the summary on dashboard for these alerts enables us to work on the areas to weaken the perimeter of risky pollutants. This continuous monitoring will help industries improve its efforts to manage vulnerabilities and achieve real-time, continuous monitoring for the adherence of the regulatory requirements.

**Figure-12** Scheme for a sensors based system for Air Quality Monitoring

5. Conclusion
The conclusions based on this works are as follows:

- The area near the point source seems to be highly polluted as the wind velocity is not sufficient enough to disperse the pollutants.
- AERMOD software can be used to model the concentration of pollution as it correlates well with the observed data and also the vulnerable areas can be easily identified by the output of the graphs from the software.
- Measures to reduce the pollutant concentration can be taken as the precise location of vulnerable areas is identified.
- Air quality prediction methods deployed via data acquired through IoT system provide continuous monitoring and indicate for actions when the value exceed thresholds.

**References:**
[1]. Arunraj N S, Maiti J 2009 Development of environmental consequence index (ECI) using fuzzy composite programming. *J Hazard. Mater. 162*(1) 29–43
[2]. Kang S MA2002 Sensitivity analysis of the Korean composite environmental index. *Eco. Econ.* 43 159-174.
[3]. Cormier S M, Suter G W 2008 A Framework for Fully Integrating Environmental Assessment. *Environ Manage.* 42(4):543-556.

[4]. Gunasekera MY, Edwards D W 2003 Estimating the environmental impact of catastrophic chemical releases to the atmosphere: An index method for ranking alternative chemical process routes. *Process Saf. Environ Prot.* 81(6):463-474.

[5]. Sinclair A J, Diduck A P 2005 Public involvement in Canadian environmental assessment: enduring challenges and future directions. *Environ Impact Assess.* 53-74.

[6]. Dockery D, Pope C, Xu X, Spengler J, Ware J, Fay M, Ferris B, Speizer F 1993 An association between air pollution and mortality in six US cities. *N Engl J Med.* 329:1753–1759.

[7]. Harrison R, Yin J 2000 Particular matter in the atmosphere: which particle properties are important for its effect on health. *Sci Total Environ.* 249:85–105.

[8]. Harrison RM, Jones AM, Lawrence RG 2004 Major component composition of PM10 and PM2.5 from roadside and urban background sites. *Atmos Environ.* 38:4531–4538.

[9]. Hoek G, Schwartz J, Groot B, Eilers P 1997 Effects of ambient particulate matter and ozone on daily mortality in Rotterdam. *The Netherlands Arch Environ Health.* 52:455–459.

[10]. Sammet J, Dominic F, Curriero F, Coursac I, Zegar S 2000 Fine particulate air pollution and mortality in 20 US cities. 1987–1994. *N Engl J Med.* 343:1742–1747.

[11]. Chow JC, Engelbrecht JP, Watson JG, Wilson WE, Frank NN, Zhu T 2002 Designing monitoring networks to represent outdoor human exposure. *Chemosphere.* 49:9961–9978.

[12]. Querol X, Alastuey A, Rodriguez S, Planas F, Mantilla E, Ruiz C (2001) Monitoring of PM10 and PM2.5 around primary particulate anthropogenic emission sources. *Atmos Environ.* 35:845–849.

[13]. EPA (2004) User’s guide for the AMS/EPA regulatory model – AERMOD. US Environmental Protection Agency, Research Triangle Park, NC.

[14]. EPA (2005) Guideline on air quality models (revised). US Environmental Protection Agency, Research Triangle Park, NC (p. 40 CFR 51).

[15]. Cimorelli AJ, Perry SG, Venkatram A, Weil J, Paine R, Wilson RB, Lee RF, Peters ED, Brode RW 2005 AERMOD: a dispersion model for industrial source applications. Part I: general model formulation and boundary layer characterization. *J Appl Meteorol.* 44:682–693.

[16]. Li X, Peng L, Hu Y, Shao J, Chi T 2016 Deep learning architecture for air quality predictions. *Environ Sci Pollut Res.* 23(22):22408–22417.

[17]. Pokric,B., Kreo, S., Drajic,D., Pokric,M., Jokic, I., Stojanovic, M.J.:2014ekoNET—environmental monitoring using low-cost sensors for detecting gases, particulate matter, and meteorological parameters. In: 8th Eighth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, pp. 421–426. IMIS, IEEE.

[18]. Marquez-Viloria D, Botero-Valencia JS, Villegas-Ceballos, J 2017A low cost georeferenced air-pollution measurement system used as early warning tool. In: XXI Symposium on Signal Processing, Images and Artificial Vision (STSIVA), pp. 1–6. IEEE.

[19]. Kesarkar AP, Dalvi M, Kagnalkar A, Ojha A 2007 Coupling of the Weather Research and Forecasting Model with AERMOD for pollutant dispersion modeling. A case study for PM10 dispersion over Pune, India. *Atmos Environ.* 41:1976–1988.

[20]. Selvakumar Madhavan,Geetha S2012 Influence of Meteorological Parameters on Air Pollutant Concentration for Coimbatore City International Journal of Environ Res Develop, 2(1)21–34.

[21]. Espinosa AFJ, Rodriguez MT, Alvarez FF2004 Source characterization of fine urban particles by multivariate analysis of trace metal speciation. *Atmos Environ.* 38:873–886.

[22]. Karar K, Gupta AK, Kumar A, KantiBiswas A, Devotta S 2005 Statistical interpretation of week day/week end differences of ambient gaseous pollutant, vehicular traffic and meteorological parameter in urban region of Kolkata. *J Environ SciEng.* 47:164–175.

[23]. Singh SP, Prasad R 2005 Analytical study of some observed micrometeorological data. *J Air Pollut Controll* 44:44–49.