ASSESMENT OF COST OF EXTERNALITIES FOR CEB THERMAL GENERATION OPTIONS

Piumie Upeksha Karunaratne

118677D

Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

May 2016

ASSESMENT OF COST OF EXTERNALITIES FOR CEB THERMAL GENERATION OPTIONS

Singankutti Achchige Piumie Upeksha Karunaratne

118677D

Dissertation submitted in partial fulfilment of the requirement for the Degree Master of Science

Department of Electrical Engineering

University of Moratuwa
Sri Lanka

May 2016

DECLERATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date:

S.A.P.U. Karunaratne

The above candidate has carried out research for the Masters Dissertation under my supervision.

Signature of the supervisor: Date:

Dr.W.D.A.S. Rodrigo

ACKNOWLEDGEMENT

A work of this nature would have never been succeeded without the support, guidance, assistance and encouragement of numerous other individuals. They include my teachers, batch mates, colleagues, superiors and subordinates in the work place, and family members. I take this opportunity to express my sincere gratitude to all of them.

First and foremost I express my heartfelt gratitude to my dissertation supervisor Dr. W.D.A.S.Rodrigo for giving me the first glimpse on my research topic and guidance given amidst his busy work schedule. His continuous supervision and advices on the research, pave me the way for successful completion of the scope of work. All the staff members at the Department of Electrical Enginnering had been highly supportive in achieving this endeavour and I thank all of them.

At Ceylon Electricity Board, I express my sincere gratitude to all the peers, superiors and subordinate for the support given. My special thank goes to all the Chief Engineers and Electrical Engineers of the Generation Planning Unit and Generation Development Studies Unit of Ceylon Electricity Board who were kind enough to share their knowledge in generation planning sector and supported me in every way.

Furthure, my special thank goes to my fellow Electrical Enginners and other supporting staff at in LakVijaya Coal Power Plant,Norechcholei and Department of Meteorology, Colombo for sharing their information and resources regarding the coal power plant and its meteorological facts for my research.

During the period of this research, I had been relived from the family commitments and therefore I was able to make this endeavour a success. My heartfelt gratitude goes to my parents, husband, son and all the other loving relatives.

ABSTRACT

Costs of externality are effects that are typically not taken into account in finalizing the market price of goods or materials. Environmental impacts and social damage costs are the main externalities needed to be considered.There is a growing requirement for policy analysts to take account of the environment in their decision making and to undertartake the specified cost benefit analysis. Therefore it is a vital fact to monetary value the social and environmental damage that can be occurred due to an infrastructure and to use it as a variable cost.

In the case of power generation, electricity production causes environmental damages of which the associated costs are not borne by the producers or consumers of that electricity. Hence, true generation costs should include both the private costs incurred to provide power such as capital cost, O&M cost and labour and the external costs of damage to the environment.

In Sri Lanka, due to the absence of reliable health and environmental impact studies, an estimated value of 0.13 US Cents/kWh was added as the social damage cost for the scenario studies of coal in Long Term Generation Expansion Plan, (2012 -2032) by the Generation Planning unit of Ceylon Electricity Board.

Thus, in this research, a realistic monetary value for the social damage cost is assessed for coal power generation studies in Sri Lanka based on the environmental and social impacts associates with it. The Impact path way method is discussed and used for the monetary valuation. The respective pollution levels are obtained by means of Gaussian plume air dispersion model. Then with certain assumptions and limitations, value of 0.08 US Cents/kWh is derived as the external cost or the social damage cost for coal power generation studies .Finally, conclusions are drawn based on results and sensitivity analyses.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABRVIATIONS

AAQ	Ambient Air Quality
ADB	Asian Development Bank
CEB	Ceylon Electricity Board
CO2	Carbon Dioxide
COI	Cost of Illness
DRF	Dose Response Function
DS	Divisional Secretariat
E	East
EIPS	Environment Issues in Power Sector
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization
GDP	Gross Domestic Product
HCA	Human Capital Approach
HEI	Health Effect Institute
ITI	Industrial Technology Institute
JVC	Joint Venture Company
LTGEP	Long Term Generation Expansion Plan
N	North
NE	North East
NOx	Oxides of nitrogen
NW	North West
PM	Particulate Matter
PPM	Past Per Million
RAD	Restricted Activity Day
RHA	Respiratory Hospital Admissions
S	South
SE	South East
SOx	Sulfuric Dioxides
SW	South West

TPCL	Trincomalee Power Company Limited
VSL	Value of Statistical Life
W	West
WLD	Work Loss Days
WTA	Willingness to Accept
WTP	Willingness to Pay

LIST OF APPENDICES

Chapter 1

INTRODUCTION

1.1 BACKGROUND

As per the European Commission, costs of externalities are defined as cost and benefits which arise when the social or economic activities of one group of people have an impact on another, and when the first group fail to fully account for their impacts. For some time, it has been well established that electricity generation especially from fossil fuels, creates impacts on third parties other than the producer of the electricity and the consumer of the electricity which are referred to as externalities. Simply, those are the costs that are classically not taken into account in establishing the market price of goods and services. Environmental impacts and social damage costs are the main externalities which are needed to be considered.

In power sector, electricity production causes a lot of environmental damages which are mostly negative, having a damaging impact on the parties concerned. Air pollutants, greenhouse gases, quality of water affected by electricity production, land use values affected by power plant sittings and waste disposal including solid, liquid, and nuclear wastes are some of the environmental damages due to power generation. [1]Some negative impacts due to power generation are increased incidents of cancer following exposure to radiation, loss of fish resulting from acidification of impacts, increased incidents of asthma and respiratory system diseases...etc. .

Electricity generation from various sources has different environmental and social ramifications, particularly when considered along the entire fuel cycle from fuel extraction to power generation and finally waste disposal. Such costs on society and the environment are inflicted by various stages of electricity generation are not reflected in the traditional costing of electricity. These impacts comprise ‘externalities’ in the electricity sector. Conventional energy sources such as coal, diesel, and furnace oil approach with significant costs to one’s health and welfare.

Typically associated costs of these environmental and social impacts are not bore by the generation producers or consumers of that electricity.

When externalities are involved, there is a deviation between private costs such as capital, O&M, labour...etc and social costs such as health cost of air pollution are borne by society. Thus it is apparent that 'full costs' of electricity costs accounting for externalities could be well guided to get better decisions on fuel mix, location and scale as well as power generation and mining technologies. Also full cost of both internal and external costs accounting permits the quantification of potential benefits associated with energy technologies such as renewable energy technologies that have low environmental impacts and with energy-efficient technologies.

Sustainable energy development can be occurred by integrating of such external costs as inputs into policy-making scenarios. Monetization of the external costs of electricity generation is potentially edifying for policy purposes. Furth more, the full social cost of electricity by different sources can be used to plan future capacity with preference being given to the source with the lowest addition of both internal and external costs when major electricity sources remain in public or quasi-public ownership. When electricity is owned by private sector, this full cost can be used by regulators to direct new investments leaving the private owners to respond accordingly. Moreover, the integration of externality can be used to estimate environmental taxes and modify the national accounts by altering some traditional economical parameters with measures that accounts for the depreciation of natural resources as well. Also, general recognition of such external costs is essential in order to steer pollution control policies in a desired direction.

In Sri Lanka, the external costs of power generation have not been evaluated in the generation planning studies yet. Thus, it is a vital factor to include true generation costs with both the private costs and the external costs of the socio environment damages caused by the respective power generation techniques for the generation planning and development studies. [2]That will enhance the entire economy and the sustainable development of the country.

1.2 SCOPE OF WORK

Fossil fuels remain as the dominant source of electricity since the early 1970s. Coal remains as the solitary most important energy source for electricity generation due its cheaper electricity cost. However, both local and global air pollutants such as CO2, SOx and NOx are emitted by burning of fossil fuels. [2]

Considering Sri Lankan scenario, LakVijaya power plant at Norechcholei, Puttalam is the only coal power generation plant operating up to now. It was commissioned in March, 2011.Trincomalee coal power plant at Sampoor, Trincomalee is under feasibility stage. Sites locations of others candidate coal power plants are not being yet finalized by Generation Planning Unit of CEB.

Burning of coal release SOx, NOx and PM to the atmosphere which are the main air pollutants of coal power plants. Due to that, numerous health impacts can be occurred such as respiratory diseases including Asthma and Bronchitis Cough. Those impacts reduce the social welfare and affect the total productivity of the country. Therefore, it is a vital requirement of assessing a social damage cost that can be used as a variable cost in the generation planning studies. Often, lack of information on social welfare loss due to air pollution hampers efforts to reduce air pollution.

In Sri Lanka, given the absence of reliable health and environmental impact studies, an estimated value is mentioned as the Social Damage Cost for the scenario studies of coal in LTGEP, (2012 -2032) by the Generation Planning unit of CEB. That is mainly based on the report of World Bank Six Cities Study, 2010.

Therefore, in this research study, a methodological review on estimation of health cost of local air pollutants from coal power generation in Sri Lanka is undertaken. Simply, the cost of externalities for coal power generation in Sri Lanka will be assessed. Appropriate methodology is discussed for pollution level calculations and monetary valuation based on the available literature and data. Then, with certain assumptions and limitations, a realistic value for the external cost due to coal power generation is obtained.

LITERATURE REVIEW

2.1 COST OF EXTERNALATIES

Cost of externality is effects that are typically not taken into account in establishing the market price of goods or services. The main objective of analysis of cost of externalities is to provide policy makers with a combination of information on a broad variety of effects, to allow better decision making.

When considering the sector of power generation, electricity production causes environmental damages of which the associated costs are not bore by the producers or the consumers of that electricity. Conventional energy sources such as coal, diesel, and furnace oil come with significant costs to one's health and welfare too. Therefore, true generation costs should include both the internal and the external costs where the cost of damage to the environment and cost of health impacts are also embedded.[3]

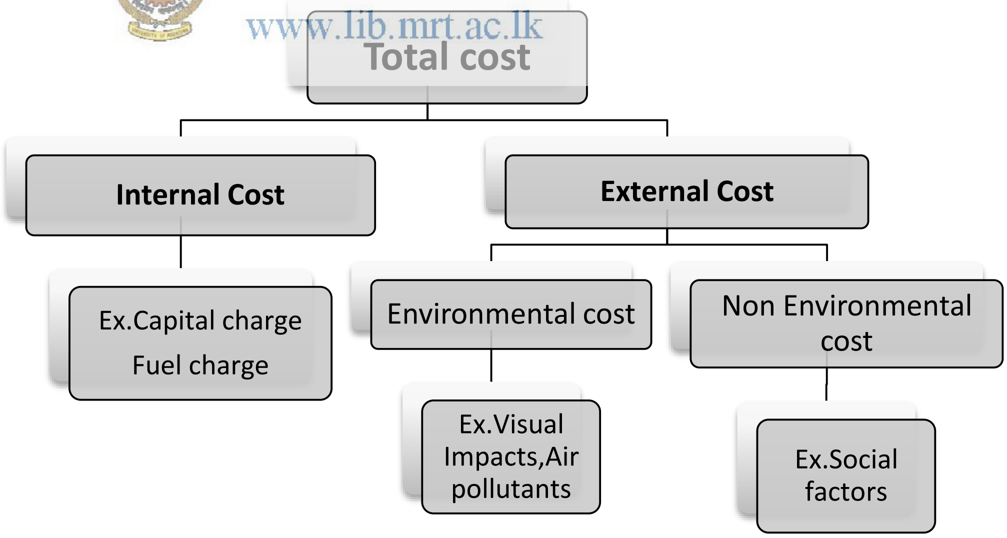


Figure 2.1: Hierarchy of cost components involved in power generation

2.1.1 Classification of Externalities in Power Generation

- Air pollutants including SOx, NOx, particulates, and heavy metals with impacts on human health, flora and fauna, building materials, and on other social assets like recreation and visibility
- Greenhouse gases including carbon dioxide, methane, and chlorofluorocarbons suspected of contributing to global climate change and thus to potential impacts on agriculture and human health
- Water use and water quality affected by electricity production, principally through thermal pollution or hydroelectric projects that affect aquatic populations
- Land use values affected by power plant sittings and by waste disposal including solid, liquid, and nuclear wastes

In order to assess the external impacts and associated costs resulting from the power generation, impact pathway approach is used.

2.2 IMPACT PATH WAY APPROACH

Impact pathway method is simply a typical 'top-down' approach which is highly aggregated, being carried out at a regional or national level. The total quantities of pollutants emitted or present and the total damage that they cause can be estimated by means of the method.

This scheme is summarised in Figure 2.2. [1]

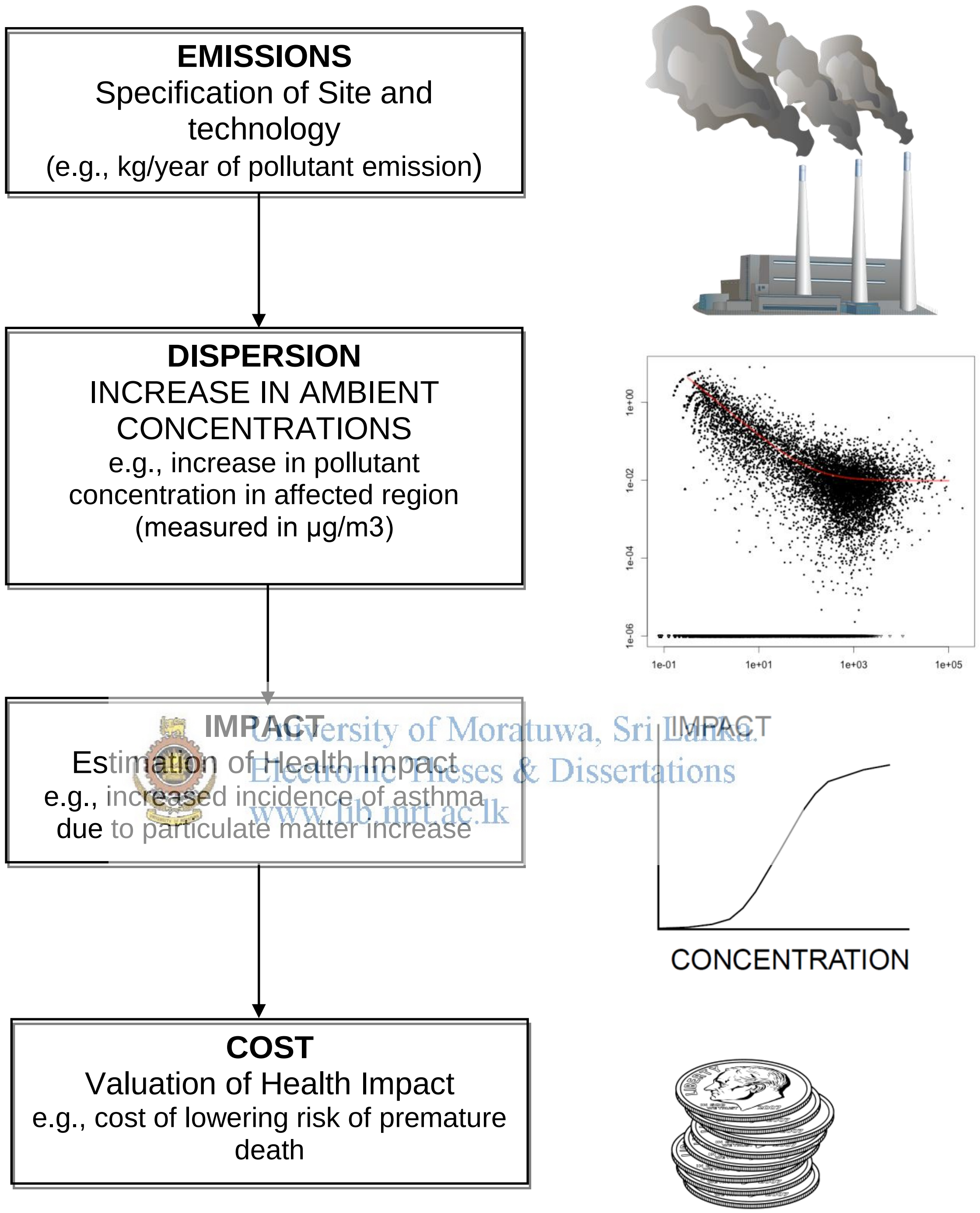


Figure 2.2: An illustration of the main steps of the impact pathways methodology

2.2.1. Estimation of Emissions

The foremost thing is to identify the source or the emission is characterization of the relevant technology and environmental burdens. Data such as fuel type, the quality of fuel, combustion characteristics, source of the composition of the fuel, number of operation hours, no. of tons of particulates per kWh emitted and level of pollution control at the plant should be collected to quantify emissions from the plant under consideration. Then, the emission rate of the various pollutants whose impact is being considered can be calculated. The other relevant information required for estimating the emissions at the source are plant capacity, plant load factor, location of the power generation plant...etc. [1, 2]

2.2.2. Dispersion

The next step of the impact path way methodology is to quantify the ambient pollution concentrations at the receptor level. Those pollutants cause the changes in the pollution level of the atmosphere. The pollution level of the receptor site can be quantified by means of dispersion model which is frequently a computational method. It enables calculating the ambient concentration increase of the relevant pollutants, at a location within the pre specified limited area of the emission source. Also, it gives a mathematical simulation of air pollutant dispersion and envisages downwind concentrations. In the research, the source of the emission of pollutants is power plant. Factors that determine dispersion are physical nature of effluents, chemical nature of effluents, meteorology and the location of the stack. [2, 3]

Depending on the requirement of the meteorological data and computer resources, there are various dispersion model types available in the literature.

History of air pollution dispersion modeling is fairly widespread and dates back to the 1930s and earlier. Bosanquet and Pearson derived one of the early air pollutant plume dispersion equations. [17] In that, Gaussian distribution was not assumed and the effect of ground reflection of the pollutant plume was not included.

An air pollutant plume dispersion equation was derived by Sir Graham Sutton in 1947[18] which the assumption of Gaussian distribution for the vertical and crosswind dispersion of the plume with the effects of ground reflection was included. Under the incentive provided by the initiation of strict environmental control regulations, there was an enormous use of air pollutant plume dispersion calculations between the late 1960s up to present. During that period of time, many computer programs for calculating the dispersion of air pollutant emissions were developed and those are known as "air dispersion models". The basis for most of those models was the complete equation for Gaussian Dispersion Modelling of continuous, buoyant air pollution plumes.

Apart from that, a non steady state puff dispersion model is also used to simulate the effects of time and space varying meteorological conditions on pollution transport, transformation, and removal. It can be mainly applied for long-range transport of pollutants and for complex terrain conditions. Offshore and Coastal Dispersion Model is a Gaussian model which is improved to determine the impact of offshore emissions from point, area or line sources on the air quality of coastal regions. Overwater plume transport & dispersion and changes that occur as the plume crosses the shoreline can be modeled by this model.

In the research, case study areas for pollution level calculation are within 20 km and 100km distances with less complex terrain conditions. Therefore, by considering the above facts, Gaussian Plume Dispersion Model is used for the pollution level calculations due to its simple nature and the appropriate geographical conditions. [12]

2.2.2.1 Gaussian Plume Dispersion Model

Gaussian plume air dispersion model is a widely used dispersion model due to its simple nature with simplistic assumptions and capability of providing reasonable results. The key factors are to obtain accurate results are usage of accurate data and necessary judgment. Reliable results can be produced by means of simple excel based Gaussian-plume models. Also, ambient concentration variations within a zone with medium-complex atmosphere, steep less geological conditions and consistent meteorology can be simulated by the models. In order to simulate deposition and chemistry, a vigilant selection of Gaussian-plume model is required.

The Gaussian plume dispersion model that portrays variation of the concentration of contaminants in the local areal can be shown as follows. [3]

$$C = \frac{Q}{2\,\pi u \sigma_z\,\sigma_y} . exp \frac{-y^2}{2{\sigma_y}^2} . exp \frac{-h^2}{2{\sigma_z}^2}$$

where:

C= atmospheric concentration (µg/m3);

Q = the emission rate (g/s);

u = wind speed (m/s);

y = distance from the plume (m);

h = stack height (m);

σy = crosswind standard deviation / Lateral Dispersion

σz = vertical standard deviation. / Vertical Dispersion

Double Gaussian distribution plumes are used for dispersion in y and z directions which is three dimensional. Instantaneous puff of emissions can be modeled by the Gaussian distribution. It is applied to model probabilities where steady state concentration at a point downstream can be predicted by means of formulae.

Some of the assumptions made when using Gaussian Dispersion model to calculate pollution levels from an emission source are listed below. [2, 3, 11]

- Terrain should be flat and meteorological conditions should be constant.
- Travelling of the plume with the wind should be in a straight line at a constant speed.
- Wind shear of the vertical direction is ignored.
- Gas of the stack is transported downstream.
- Atmospheric stability governs the dispersion in vertical directions.
- By molecular and eddy diffusion governs the dispersion in horizontal plane.
- X-axis is aligned to wind direction.
- Z-axis is aligned vertically upward direction.[vol 2][dispern handout]
- Y-axis is aligned to transverse to the wind direction.
- Concentrations about y-axis and z axis are symmetrical.
- Stack is left by effluents with sufficient momentum and buoyancy.[13]

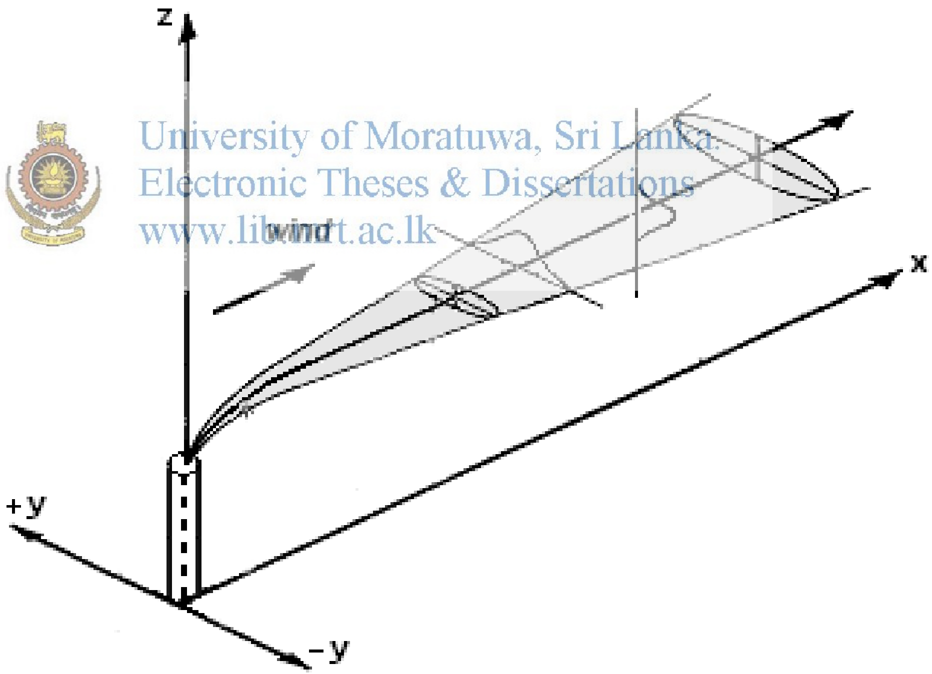


Figure 2.3: Coordinate system showing Gaussian distributions

Source: Dispersion model for point source emission, SemaAwasthi, Mukesh Khare and Prashant Gargava

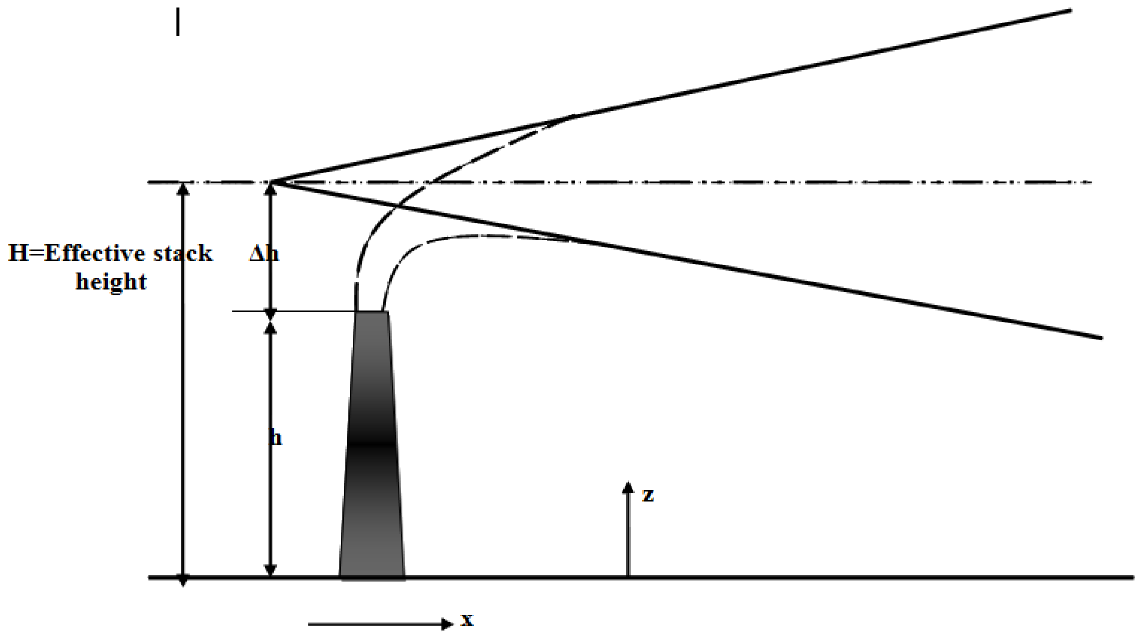


Figure 2.4: A dispersion model with vertical source

Source: Dispersion model for point sourceemission, SemaAwasthi, Mukesh Khare and Prashant Gargava

Atmospheric stability conditions and downwind position x govern the horizontal and vertical dispersion coefficients which are σ_z and σ_y.Correlation of σ_z and σ_y to atmospheric stability and x are established by means of many experimental measurements and charts. Pasquill-Gifford Curves are one of those charts created by Pasquill, F. (1961) to determine σ_z and σ_y as per the respective atmospheric stability condition. The Pasquill stability classes can be tabulated as below. [9, 10,11, 12]

Table 2.1: Pasquill stability classes

Stability class	Definition	Stability class	Definition
A	very unstable	D	neutral
B	unstable	E	Slightly stable
C	Slightly unstable	F	stable

Source: Pasquill, F. (1961). The estimation of the dispersion of windborne material, The Meteorological Magazine, vol 90

Table 2.2: Meteorological conditions that define Pasquill stability classes

Surface wind speed		Daytime incoming solar radiation			Night time cloud cover	
m/s	mi/h	strong	moderate	Slight	> 50%	< 50%
< 2	< 5	A	A-B	B	E	F
2-3	5-7	A-B	B	C	E	F
3-5	7-11	B	B-C	C	D	E
5-6	11-13	C	C-D	D	D	D
> 6	> 13	C	D	D	D	D

Source: Pasquill, F. (1961). The estimation of the dispersion of windborne material, The Meteorological Magazine, vol 90

In Pasquill Gifford curves, concentrations correspond to sample times of around 10 minutes but it is represented 1 hour averages by regulatory models.

Following figures illustrates the graphical representation of σ_z and σ_y for Pasquill stability classes. [9, 10,13]

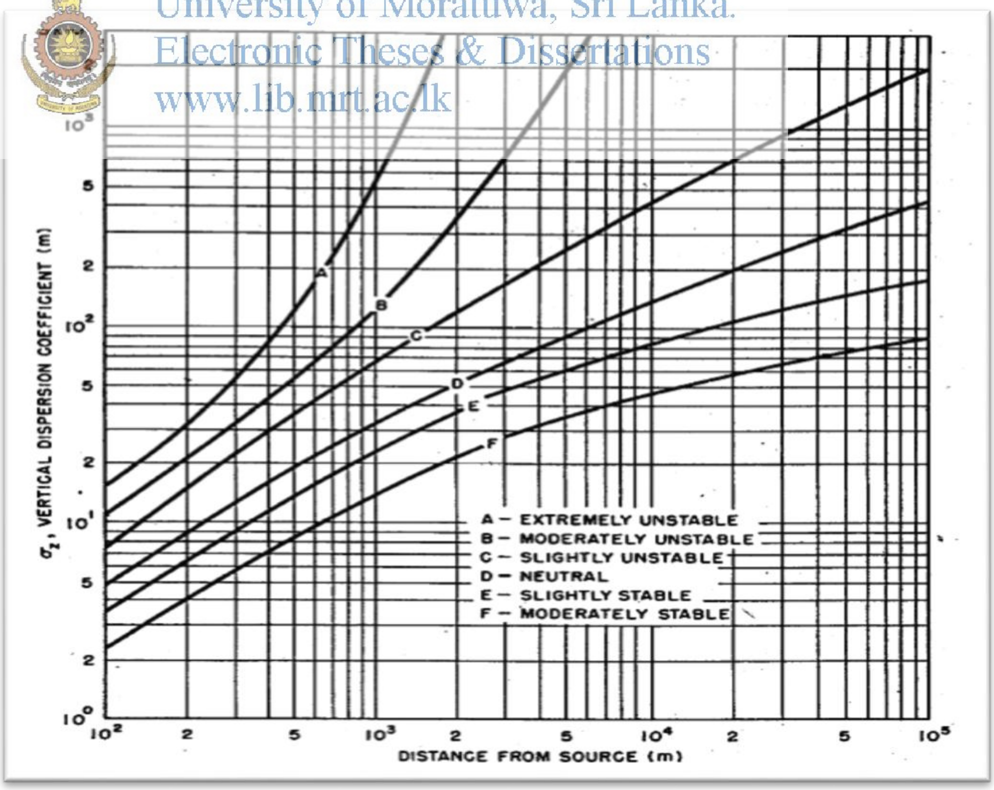


Figure 2.5: Vertical diffusion σ_z Vs downwind distance from source for each class

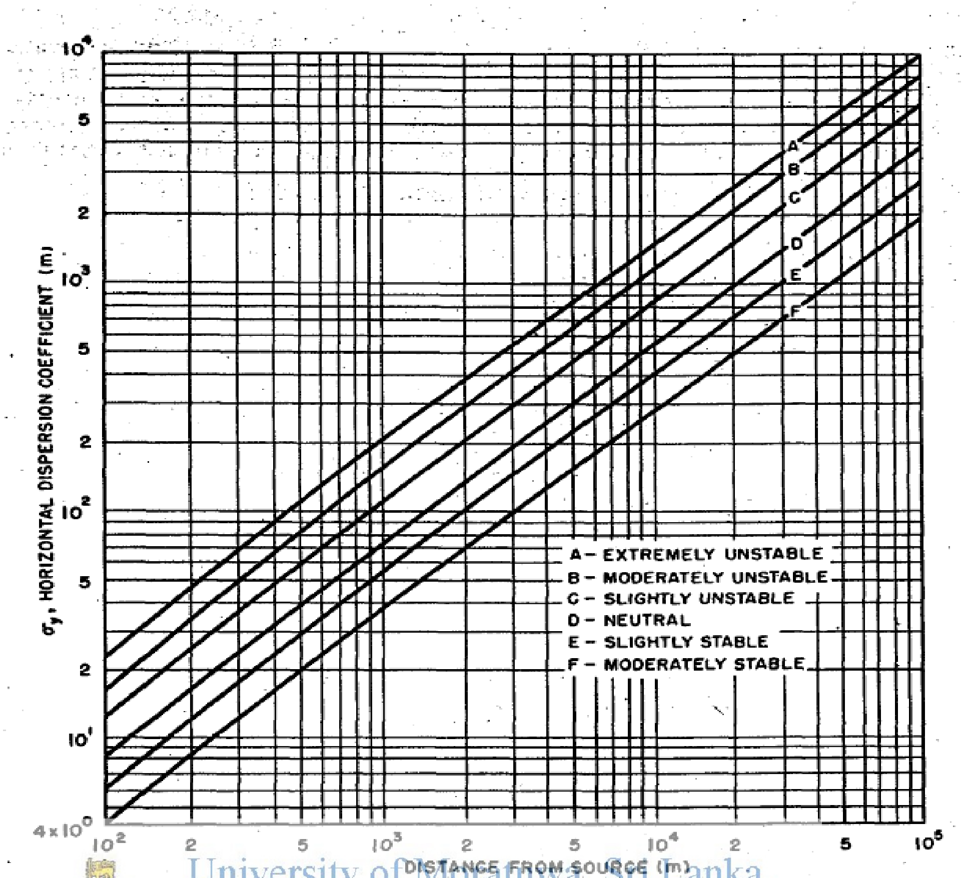


Figure 2.6: Lateral diffusion σ_y Vs downwind distance from source for each class

Source: Pasquill, F. (1961). The estimation of the dispersion of windborne material, The Meteorological Magazine, vol 90

Rural values are represented by solid curves and urban values are represented by dashed lines. The lowest several hundred meters of the atmosphere are represented by the estimated concentrations. Normally σ_z is less than σ_y, specially for more than 1km distances. The concentrations should be within a factor of 2 or 3 of actual values for neutral to moderately unstable atmospheric conditions. [9,10]

2.2.3. Impact

Impact is the characterisation of the population or receptor that is exposed to incremental pollution concentrations. The incremental increases in health impacts are estimated by means of the ambient concentrations of pollutants which can be determined through dispersion modelling. The relationship between air pollution and health impacts is quantified by Dose-response functions (DRFs). Following table shows the cause–specific mortality and morbidity endpoints associated with some of the most extrusive air pollutants.[2]

Table 2.3: Health impacts associated with air pollutants

Outcome	**Disease**	**Pollutant**
Mortality	Respiratory disease Cardiovascular disease COPD Cerebrovascular event Ischemic heart disease Respiratory cancer	Particulate matter (TSP, PM10, PM2.5) NO2 SO2 CO O3 (formed from SOx and VOC)
Respiratory Hospital Admissions (RHA)	Respiratory disease Asthma COPD Cardiovascular disease Cerebrovascular event Congestive heart failure Acute and Chronic bronchitis Cough in children Lower respiratory symptoms	Particulate matter (TSP, PM10, PM2.5) NO2 SO2 CO O3 (formed from SOx and VOC)
Restricted Activity Days (RAD)		PM

Sources: European Commission, 2005; Health Effects Institute (HEI), 2010.
COPD = Chronic-obstructive pulmonary disease, VOC = volatile organic compounds.

2.2.3.1 Dose Response Function

Dose response function is the vital ingredient in the impact pathway methodology. It is also an important parameter as it imposes certain requirements on the dispersion models and economic valuation. The DFRs can be represented as below.

$$Y = f_{impact}(X)$$

Changes in Y in a receptor are caused by a pollution level of X which is the dose actually absorbed by the receptor. In order to consider the validity of a dose response function, it is required to to carry out a great deal of detailed research.

Relatively high doses have often been used to obtain observable response in a sample of reasonable size. That causes much complexity in using results from a great deal of experimental work. Normally such doses are far in excess of the levels of concern in the exposure situations to be evaluated. Therefore, it is necessary to extrapolate from the observed data towards the low doses. [1, 3]

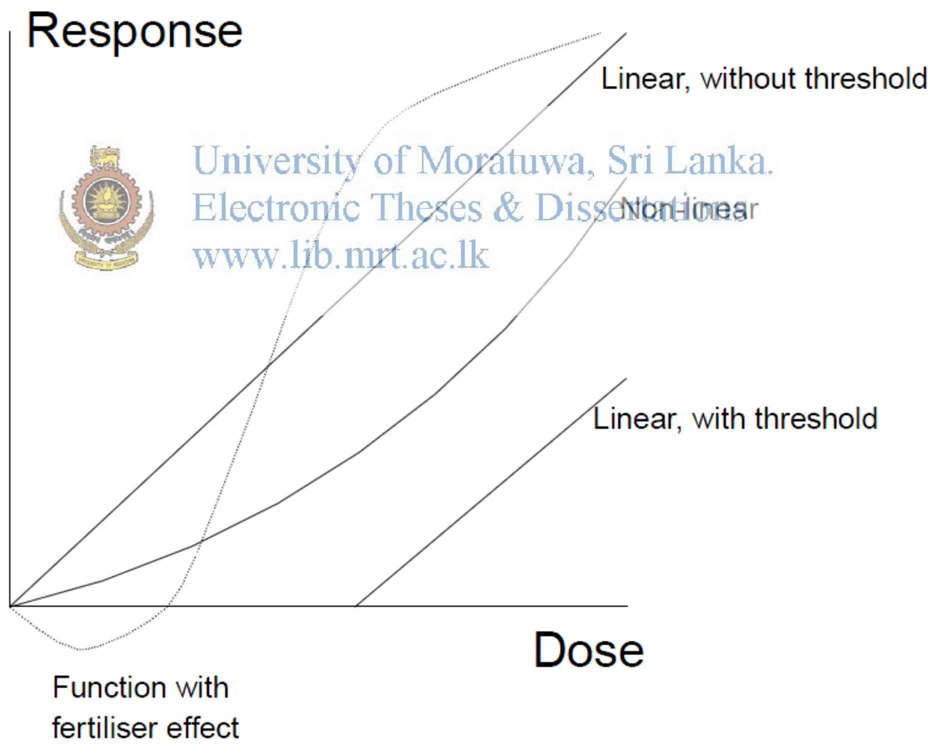


Figure 2.7: Possible forms for dose-response functions

Sources: Externe Externalities of Energy Vol. 1: Summary Compiled by ETSU-UK East Tennessee State University, 1995

The linear model of a straight line from the origin through the experimental data points is the simplest option. Second option is a straight line to some threshold without any effect below that. When an organism has a natural repair mechanism with ability to counteract damage up to a certain limit, thresholds can be occurred. But it is essential to identify the accurate threshold limit as the analysis can be restricted to geographical areas where concentrations are above the threshold.

The possibility of “fertiliser effect” can be occurred at lower doses. For example, in the DFRs for the impact of NOx and SOx on crops, the low doses can increase harvest. It is occurred due to the fact that some pollutants provide elements required by an organism which is depend on the local conditions and overall balance of nutrients. Some dose response functions comprise S-shaped curves due to the saturation of damage at very high doses. Such scenario occurs for the DFRs of Ozone damage to crops. [1, 3]

The studies on DFRs are often conducted in the United States and other developed countries, due to the high cost and demand on computational analyses. Thus it is a common practice to transfer DFRs from developed countries to developing countries due to the difficulties faced in undertaking novel studies.

Even though the available DRF results from developed countries are transferred to developing countries, some misleading results can also be caused. One of them is marking of pollution levels in different ways in developed and developing country contexts. That can cause extrapolated results invalid especially in cases where nonlinear response patterns exist. Also the differences in lifestyle, health status, social and economic conditions between developed and developing countries be likely to change the susceptibilities of citizens to air pollution. Therefore, it is more vital to use DFRs of similar class of countries to obtain more realistic results. It is also diminish errors in transferring of DRF from the original site to the policy site where health cost of air pollution is quickly assessed.

Now in the Asian literature, some studies on DFRs have been carried out and Health Effects Institute Reports (2004 and 2010) where a affluence of Asian studies has been quantitatively brief for the short-term exposure effects of air, is a good example for that. [2]

HEI summary estimates for mortality health impacts are tabulated as below. It is based on per 10µg/m3 increase in ambient pollutant concentration.

Table 2.4: HEI summary of estimates of Mortality Outcomes

Pollutant / Mortality causes	**Percent Change (Point estimate)**	**Percent Change (95% CI)**
PM10		
All causes, all ages	0.27	0.12 to 0.42
All causes, >= 65	0.45	0.29 to 0.61
Respiratory, all ages	0.86	0.34 to 1.39
Respiratory, >= 65	1.09	0.55 to 1.63
Cardiovascular, all ages	0.36	0.09 to 0.62
Cardiovascular, >= 65	0.53	0.53 to 0.75
NO2		
All causes, all ages	0.98	0.54 to 1.42
Respiratory, all ages	1.74	0.85 to 2.63
Cardiovascular, all ages	1.08	0.59 to 1.56
SO2		
All causes, all ages	0.68	0.40 to 0.95
Respiratory, all ages	1.00	0.60 to 1.40
Cardiovascular, all ages	0.95	0.30 to 1.60
COPD, all ages	1.72	0.10 to 3.36

Source: HEI (2010).

HEI summary estimates for mortality health impacts are tabulated as below. It is based on per 10µg/m3 increase in ambient pollutant concentration.

When considering morbidity outcomes, actual quantitative summarizations are not reported excluding respiratory hospital admissions (RHA).Following table illustrates the HEI summary estimates for morbidity outcomes. [2]

Table 2.5: HEI summary of estimates of Morbidity Outcomes

Pollutant /Health end point	Percent Change (simple average)	Percent Change (range of estimates)
PM10		
RHA (All Respiratory Causes) RHA (Asthma Incidents) RHA (COPD) CVHA (All CVD) CVHA (Angina / Ischemic) Loss of work days	1.3 1.2 1.5 0.7 0.7 31.5 days/1000 adults/year	0.2 to 2.2 0.5 to 1.6 1.1 to 1.9 0.6 to 0.8 - 29 to 39 days/1000 adults/year
NO2		
RHA (All Respiratory Causes) CVHA (Angina / Ischemic)	0.92 0.8	0.17 to 1.68 0.0 to 1.2
SO2		
RHA RHA (Asthma Incidents)	0.51 1.4	-0.17 to 1.190.60 to 1.40 1.2 to 1.7

Source: Various individual studies reported in the HEI (2010).

CVHA refers cardiovascular hospital admissions and CVD refers cardiovascular disease.

Thus, as per the applicability and reliability considerations, it is recommended to use HEI summary estimates to obtain the average estimates for mortality and morbidity endpoints for rapid project assessments in Asian countries. [2]

2.2.4. Economic Valuation

The next step of the Impact path way approach is the monetary valuation of the health impact caused by reasonable increased pollution concentration. Depend on the type of health outcome, different kinds of valuation method can be applied for monetary valuation.

Valuation is based on following two approaches base on individual preference.

- Willingness to pay (WTP) for environmental improvement
- Willingness to accept (WTA) the environmental damage [1]

2.2.4.1 Valuation of Mortality

In this valuation method, small reduction in one's risks of dying due to incremental levels of pollution exposure is estimated. Here the willingness to pay (WTP) approach is used and has a limited extent. The value of life itself is not directly measured, but the value of reducing the probabilities of premature death is obtained. Thus, the sum of the amounts that affected individuals are willing to pay to lower small risk of premature death is same as the obtained value by the method.

The monetary value of avoiding premature mortality can be estimated using

- Human Capital Approach (HCA)
  - Productivity based approach
  - It is assumed social worth is a function of market productivity

  Limitations
  - Affected by discrimination in wage setting & labor market imperfection
  - A lower bound estimate can be obtained

- Value of Statistical Life (VSL)
  - Better associated with economic theories
  - Can be derived from either states preference data or labor market data
  - Better approach

2.2.4.2 Valuation of Morbidity

It is more challenging to valuate morbidity as there are many health endpoints associated with it. The WTP approach can also be used here but it is consisted of several cost components, which are associated with the welfare effects of illnesses.

- Cost of medical care related with the treatment of an illness. This includes direct expenditures such as doctor's consultation fee, cost of medication, cost of hospital admission etc...

- Cost of income losses due to work loss day (WLD) and restricted activity day (RAD). The opportunity cost of productivity reduction due to duration of illness which is an indirect expenditure can be reflected by this. The cost can be determined through the current market driven wage rate.
- Cost of prevention actions to reduce exposure to pollution. This mainly depends on the defensive actions to avoid damages and the choices of defensive behaviours.
- Cost of disutility due to restrictions imposed during the period of illness. This contains distress, discomfort, pain, anxiety etc... which are non-market in nature and can only be deduced by means of a WTP survey [1,2]

The cumulative effect of cost of medical care and cost of income losses due to WLD/RAD which are medical expenditures and income losses, is known as the cost-of-illness (COI).Due to the vast differences in costs of medical care of various countries depending on their socioeconomic conditions, it is necessary to carry out a primary COI study to determine a proper valuation for morbidity outcomes. Therefore the last two cost components can be omitted as those are psychic and behavioural substances. [2]

Chapter 3

RESEARCH METHODOLOGY

3.1 PROCEDURE

In this research, a realistic monetary value for the social damage cost or the external cost for coal power generation studies will be assessed based on the environmental and social impacts associates with it.

Initially, coal power generation is selected as the generation technology. Here 900 MW LakVijaya coal power plant, Norechcholei, Puttalam is considered as the case study. Then the relevant air pollution data and meteorological data are obtained. With the collected data and by means of the software application of Google earth, the pollution levels of LakVijaya coal power plant will be calculated. The other candidate coal power plants will also be discussed and their respective pollution levels will be obtained and analysed in the same manner. The results of the pollution levels will further be analysed with the values of the ITI, Colombo.

Based on the obtained pollution data and the relevant socio economic data which are obtained from various sources, the economic valuation of the external cost or the social damage cost will be calculated. Then the outcome will be analysed and concluded based on a sensitivity analysis.

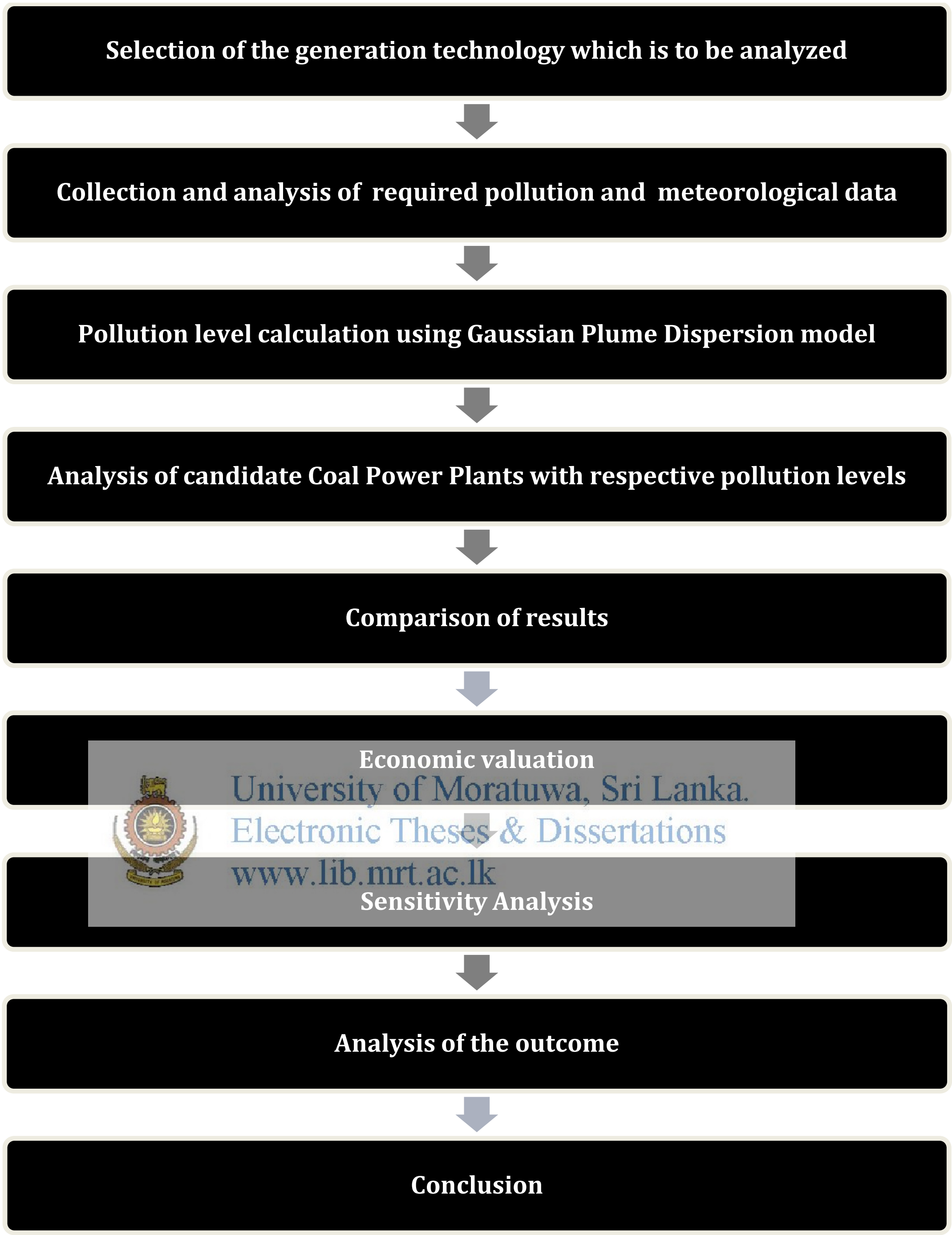


Figure 3.1: Summary of the research procedure

3.2 DATA REQUIREMENT

The relevant meteorological data of coal power plant sites are obtained from the Department of Meteorology and the plant data are obtained from LakVijaya coal power plant. The social and economic data for economic valuation are obtained from the Ministry of Health and Department of Census and Statics. Details of the candidate coal power plants are obtained from the Generation Planning Unit and Generation Development Unit of CEB.

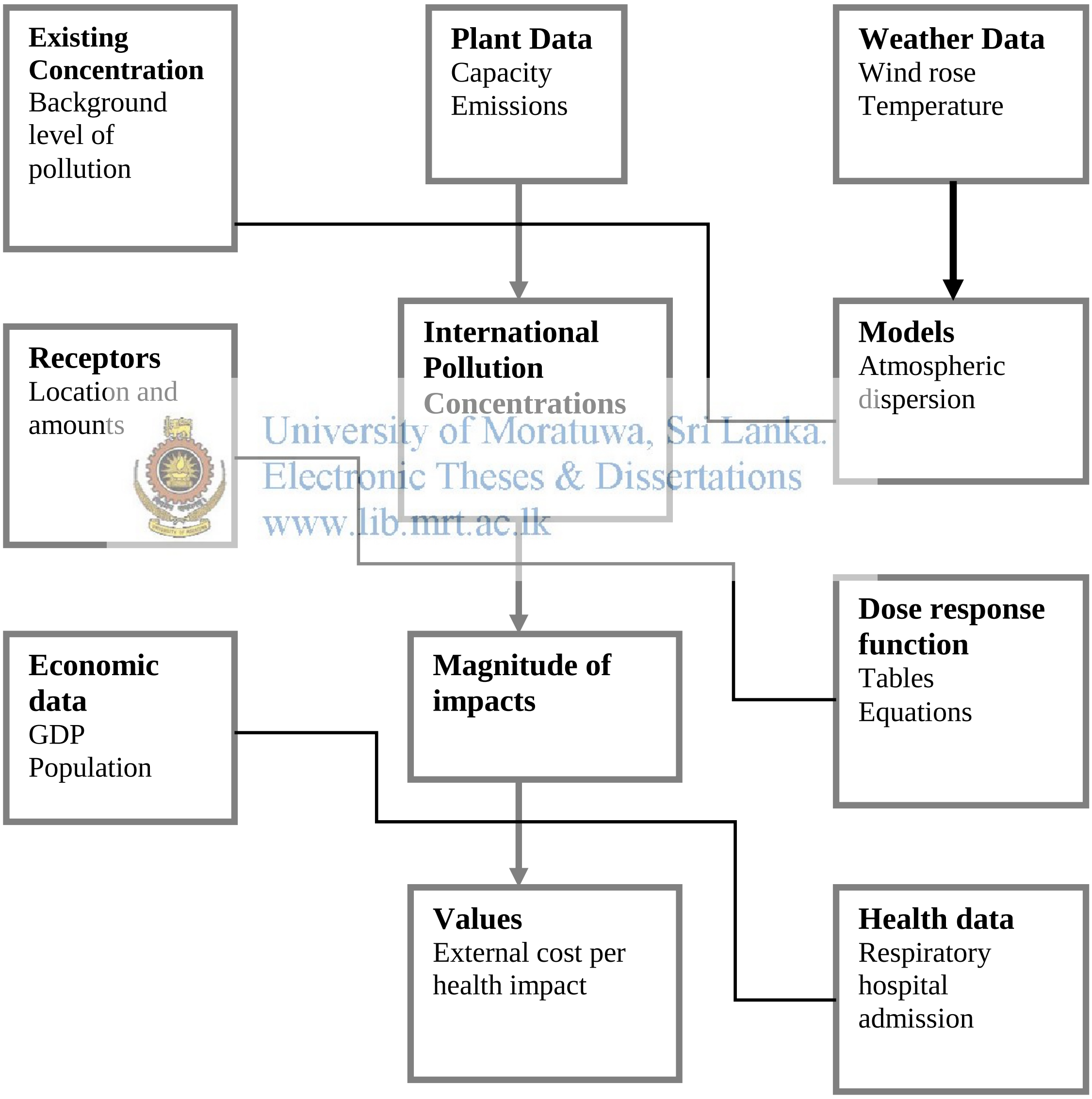


Figure 3.2: Overview of data requirement for the research procedure

Source: Externe Externalities of Energy Vol. 1: Summary Compiled by ETSU-UK East Tennessee State University, 1995

3.3 PLANT DATA

3.3.1 LakVijaya Coal Power Plant

The plant is located at Norochcholai, Puttalam, on the southern end of the Kalpitiya Peninsula. It was commissioned on 22 March 2011 with one unit and now consists of three 300MW Units with overall capacity of 900MW.This is the first coal power plant constructed in Sri Lanka. Bituminous coal is used as the design fuel of the boiler which is subcritical natural circulation drum, with primary intermediate reheating, balanced draft and corner tangential firing. [16]

Table 3.1: Boiler main Technical Specification

Item	Parameter	Unit
Coal mass flow	100.2	t/h
Gas temperature at AH outlet (with/without AH leakage)	123 / 128	°C
Gas flow at AH outlet	1222	t/h
ESP inlet gas flow	~1.5 *106	m3/h
ESP inlet dust concentration	≤15	g/Nm3

Source: 2 × 300MW Coal Power Project Puttalam II, Sri Lanka-Emissions Performance Test Procedure, Harbin Power System Engineering & Research Institute Co., Ltd

Table 3.2: Design quality of fuel

Item	Symbol	unit	Design Coal	Check Coal 1	Check Coal 2	Range
Carbon	Car	%	65.0	60.0	60.5	61.4-68.7
Hydrogen	Har	%	3.8	3.6	3.4	3.4-4.3
Oxygen	Oar	%	6.2	3.0	5.1	6.5-12.1
Nitrogen	Nar	%	1.5	1.7	1.4	1.0-1.6
Sulphur	St.ar	%	0.5	0.7	0.5	0.2-0.7
Ash	At.ar	%	11.0	15.0	10.1	4.5-16.0
Total moisture	War	%	12.0	16.0	19.0	8.0-16.0
Volatile matter	VMar	%	27.0	5.0	24.9	21.9-39.9
Fixed Carbon	Fcar	%	49.5	43.3	45.5	41.3-57.1
High heat value	Qg.ar	MJ/kg Kcal/kg	26.4 6300	25.3 6050	24.7 5900	24.8-28.9 5920-6900
Hartz	HGI		50	42	50	40-59
Grindability index						

Source: 2 × 300MW Coal Power Project Puttalam II, Sri Lanka-missions Performance Test Procedure, Harbin Power System Engineering & Research Institute Co., Ltd

The main air pollutants of the plant are fly ash or dust, Sox and NOx. The fly ash is captured in the electrostatic precipitator and Sox is captured in a seawater flue gas desulfurization (FGD) plan. The general emission concentrations and the release parameters can be tabulated as below. [16]

Table 3.3: General emission concentrations

No	Parameter	unit	value
1	Nox	mg/MJ	≤260
2	SO2	mg/MJ	≤56
3	Dust	mg/MJ	≤15

Source: 2 × 300MW Coal Power Project Puttalam II, Sri Lanka-Emissions Performance Test Procedure, Harbin Power System Engineering & Research Institute Co., Ltd.

Table 3.4: Release parameters

Stack height	**150m**
Type of source	Flue gas from boiler
Flue gas flow	Approximately 1010 to 1200 km³/h
Exit temperature	Approximately 100 ºC to 130ºC

Sources: Emissions Performance Test Procedure, Harbin Power System Engineering & Research Institute Co., Ltd

3.3.2 Candidate Coal Power Plants

There are several candidate plants have been considered for the optimum generation mix for the base case in the Long Term Generation Expansion Plan 2015-2034 by the Generation Planning Unit of CEB. [7]

Table 3.5: List of Candidate Coal Power Plants

Year	Thermal Addition
2020	2 x 250 MW Coal Power Plan - Trincomalee Power Company Ltd
2022	2 x 300 MW new coal power plant – Trincomalee-2,phase I
2024	1 x 300 MW new coal power plant – Southern region
2027	1 x 300 MW new coal power plant – Southern region
2029	1 x 300 MW new coal power plant – Trincomalee-2,phase II
2030	1 x 300 MW new coal power plant – Trincomalee-2,phase II
2032	2 x 300 MW new coal power plant – Southern region
2034	1 x 300 MW new coal power plant – Southern region

Source: LTGEP (2015-2034)

A location for 500MW coal power plant which is a joint venture project of CEB and NTPC Limited, India already selected and for 1200 MW plant is being in the process of finalizing. Some locations for the southern region are also considered but not analysed in detail. [7]

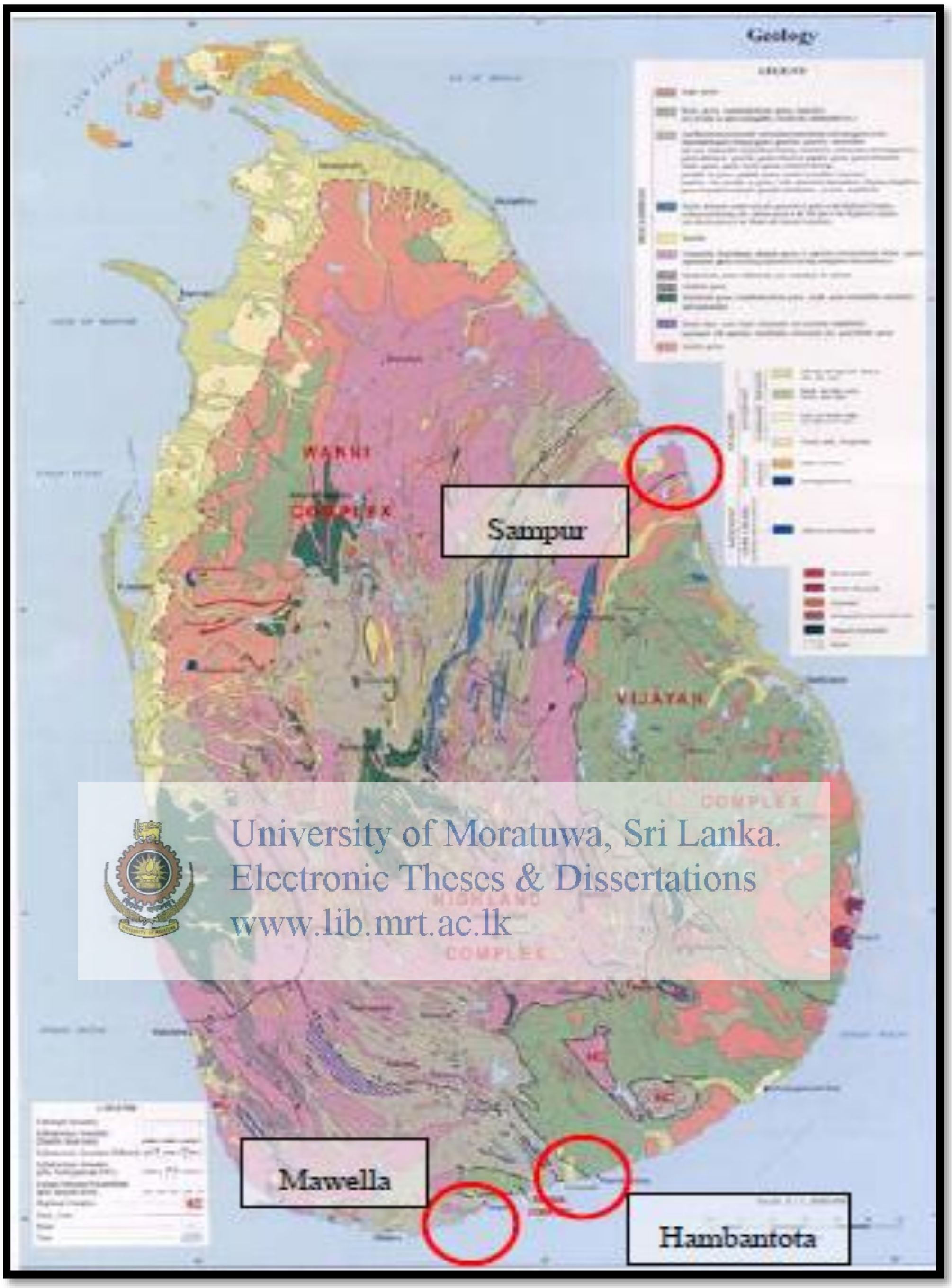


Figure 3.3: Locations of the candidate coal plants

Source: Coal sites by Generation Development Studies Unit, CEB

Some of the advantages and issues regarding each site can be listed as below.

Figure 3.4: Location of the site at Sampoor

- Sampoor (for 1200MW plant)

- Construction cost of port facility can be reduced
- Security of the land due to Industrial Development Plan
- Site is located near the IPP (CEB/NTPC Joint Venture) project site thus the port facility in can be utilized in common

Issue;

- Land acquisition
- Resettlement of inhabitants and compensation for fishermen
- Cooling water intake and outfall routes are too long and far from the seacoast
- Adjustment with IPP development plan

Figure 3.5: Location of the site at Hambantota

- Hambantota
  - Land and port facility are available
  - Not affect to the fishery

Issue;

- Uncertainness of third port development plan
- Lease cost of land
- Guarantee private coal unloading berth
- Compensation for residents on seawater outfall channel route

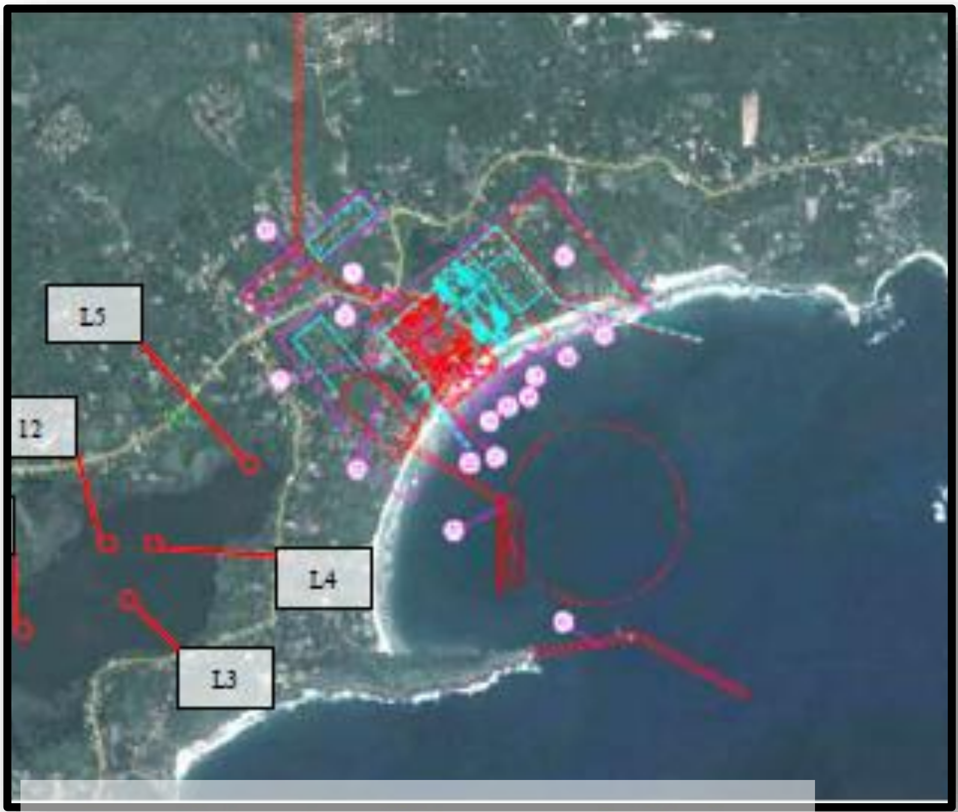


Figure 3.6: Location of the site at Mawella

- Mawella

- Locates in South Region
- Reduction of port facility construction cost

Issues;

- Land acquisition
- Resettlement of residents and Compensation for fishermen

3.3.2.1 Trincomalee Coal Power Plant

The coal power plant is consisted of 2 x 250 MW units which is Implemented by Trincomalee Power Company Limited, a Joint Venture Company of Ceylon CEB and NTPC Limited, India.The project site is located near Sampoor village in Koddiyar Pattu of the Divisional Secretariat (DS) Division of Mutur, in District Trincomalee in Eastern Province of Sri Lanka.

Pulverised coal fired technology will be used for power generation and the coal will be imported by Lanka Coal Company Limited through shipping from countries such as Indonesia, South Africa, Australia etc. For the initial start up of the boiler and part load operations, Lanka Auto Diesel will be used. The daily requirement of coal will be 5149 metric tonnes with average gross calorific value of 5500 Kcal/kg and 100% Plant Load Factor. The maximum ash content of the coal will be 16% and maximum sulphur content will be 1.2%. Lanka Auto Diesel will have minimum gross calorific value of 10,500 kcal/kg and a maximum sulphur content of 0.25%. The stack height will be 135m. [14, 15]

Table 3.6: Pollution data of the plant

Pollutant	Emission Rate (g/s)
Sox	422.21
NOx	169.31
PM	26.96

Source: Emissions Performance Test Procedure, Harbin Power System Engineering & Research Institute Co., Ltd

3.4 METEOROLOGICAL DATA

The required average wind data and the temperature data for calculation of pollution levels of the coal sites tabulated as below. Latest yearly data were obtained for the wind distribution of the sites.

Table 3.7: Monthly Average wind Data & Maximum Wind Speed – Puttalam

June 2014 – May 2015

	June	July	August	September	October	November	December
Average (km/h)	11.9	13	11	9.7	5.5	4.4	5.1
Maximum /Direction (km/h)	28.8 SW	30.4 SW	25.6 SW	23 SW	19 SW	13.6 N	23.4 NE

	January	February	March	April	May
Average (km/h)	6.15	6	5.5	4.2	7.4
Maximum /Direction (km/h)	18 NW	18 NE	15.2 N	11.8 NW	18.2 S

Source: Climate Division, Department of Meteorology, Colombo 07

Table 3.8: Resultant Wind Data in Trincomalee

August 2013 – July 2014

Year	**Januay**		**February**		**March**		**April**		**May**	
	Dir.	Spe.	Dir.	Spe.	Dir.	Spe.	Dir.	Spe.	Dir.	Spe.
2013										
2014	40	4.9	39	4.3	79	4.6	167	4	217	12.8

June		**July**		**August**		**September**		**October**	
Dir.	Spe.	Dir.	Spe.	Dir.	Spe.	Dir.	Spe.	Dir.	Spe.
				238	9.7	240	11	232	7.1
229	11.3	237	12.3						

November		**December**	
Dir.	Spe.	Dir.	Spe.
301	4.4	358	5

Source: Data Division, Department of Meteorology, Colombo 07

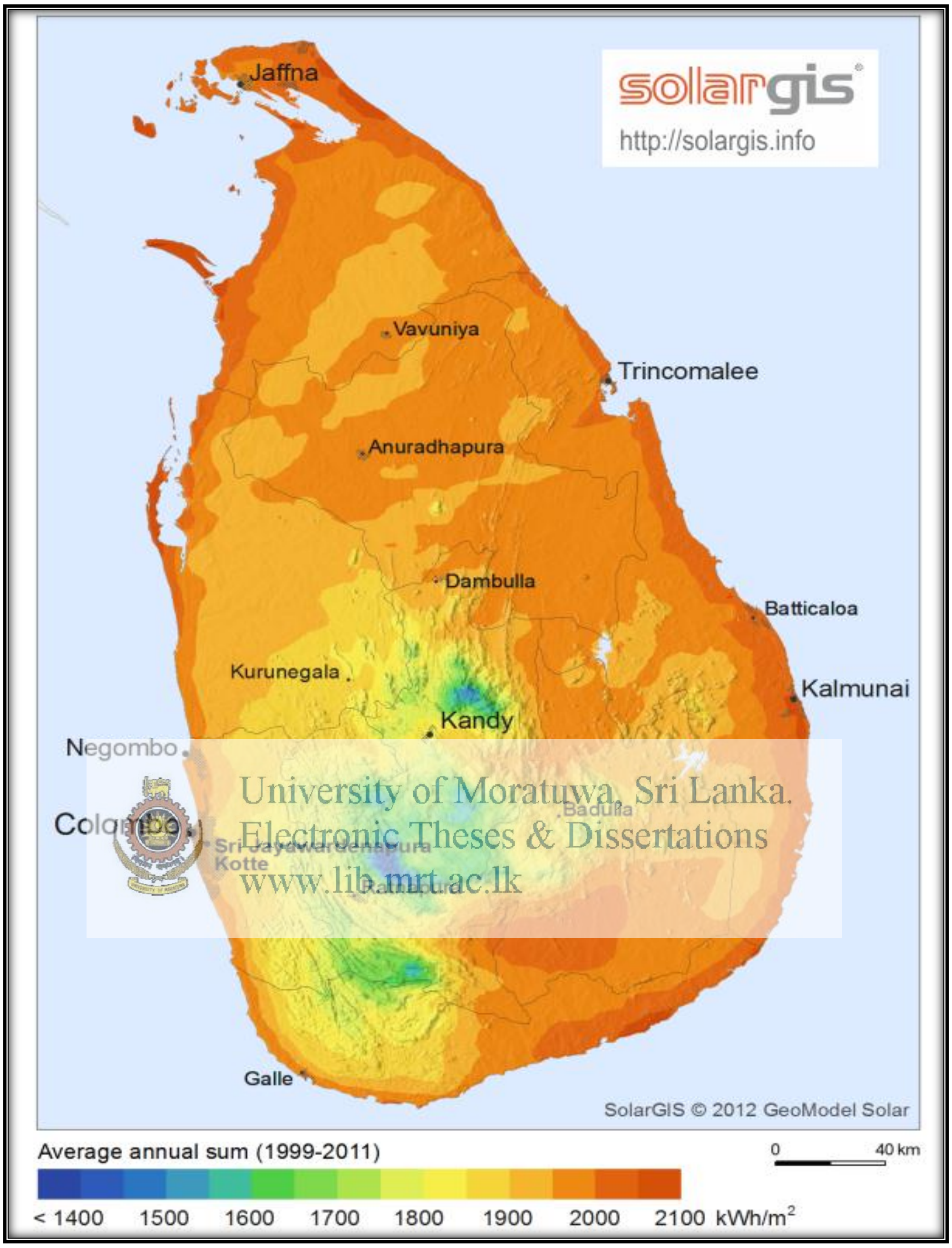


Figure 3.7: Solar irradiation map of Sri Lanka

Source: http://solargis.info

3.5 SOCIAL AND ECONOMIC DATA

There are 9 districts covered for the case study area in the economic valuation section. Thus the relevant social and economic data can be listed as below.

- Population – relevant to 100 km case study are
- Morbidity rate
- Mortality rate
- GDP rates of Sri Lanka and India (In state of Tamil Nadu)

Table 3.9: Population relevant to area of the case study

Districts covered by 100 km case study area	Population
Puttalam	762,396
Gampaha	2,304,833
Kegalle	840,648
Vavuniya	172,115
Mannar	99,570
Kandy	1,375,382
Matale	484,531
Kurunagala	1,618,466
Anuradhapura	860,575

Source: Census of Population and Housing 2012-Final Report, Department of Census & Statics

Table 3.10: Mortality and Morbidity rates relevant to the case study

Deaths due to diseases of the respiratory system, excluding diseases of the upper respiratory track	14 death per 100000 population
Leading causes of hospitalization due to diseases of the respiratory system excluding diseases of the upper respiratory track	2200 per 100000 population

Source: Annual Health Bulletin- 2012 Medical Statistics Unit, Ministry of Health

Table 3.11: GDP levels for the case study

Country	GDP Level
Sri Lanka	67.18 billion USD
India-State of Tamil Nadu	150 billion USD

Sources: World Bank 2013

State Domestic Product and other aggregates, 2004-05 series, Ministry of Statistics and Programme Implementation, India- 27 February 2015

POLLUTION LEVEL CALCULATION

4.1 POLLUTION LEVELS OF LAKVIJAYA COAL POWER PLANT

Step 01:

A 20km area is selected around the plant for the pollution level calculation. It is consisted with 400 square grid cells each with 2km of length.

Figure 4.1: Selected area for the pollution level calculation at LakVijaya plant

The midpoint of each grid cell is considered for pollution level calculation. Corresponding x, y, z coordinates are measured through Google earth as per the figure 4.2.

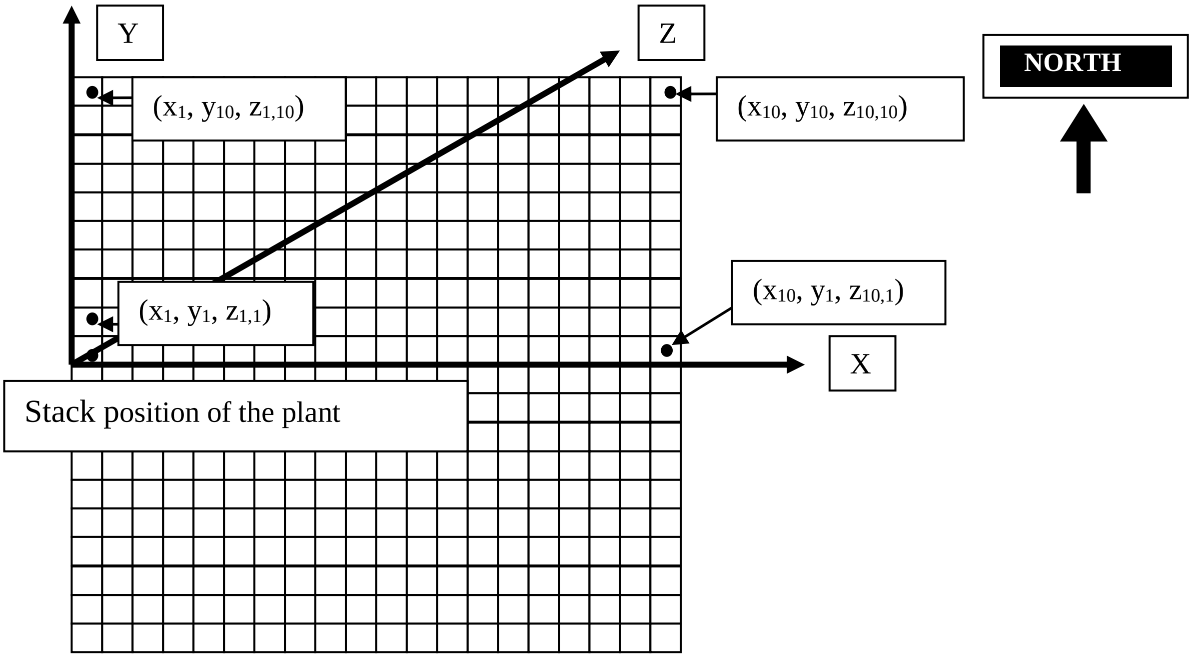


Figure 4.2: Selection of coordinates of each grid cell

Then the (x,y,z) coordinates of all the grid cells are put into separate data matrices in MS Excel. The relevant data matrixes for the Northern direction pollution level calculation of LakVijaya power plant is shown in Appendix 01.A sample data matrix with distances in km is shown in figure 4.3.

0.5,4.5, 7	1.5,4.5, 6	2.5,4.5, 6	3.5,4.5, 2	4.5,4.5, 0	5.5,4.5, 0	6.5,4.5, 0	7.5,4.5, 0	8.5,4.5, 0	9.5,4.5, 6
0.5,3.5, 7	1.5,3.5, 9	2.5,3.5, 0	3.5,3.5, 0	4.5,3.5, 0	5.5,3.5, 0	6.5,3.5, 0	7.5,3.5, 0	8.5,3.5, 2	9.5,3.5, 3
0.5,2.5, 7	1.5,2.5, 9	2.5,2.5, 4	3.5,2.5, 2	4.5,2.5, 0	5.5,2.5, 0	6.5,2.5, 0	7.5,2.5, 0	8.5,2.5, 1	9.5,2.5, 3
0.5,1.5, 4	1.5,1.5, 3	2.5,1.5, 3	3.5,1.5, 0	4.5,1.5, 0	5.5,1.5, 0	6.5,1.5, 0	7.5,1.5, 0	8.5,1.5, 0	9.5,1.5, 0
0.5,0.5, 1	1.5,0.5, 1	2.5,0.5, 0	3.5,0.5, 0	4.5,0.5, 0	5.5,0.5, 0	6.5,0.5, 0	7.5,0.5, 0	8.5,0.5, 0	9.5,0.5, 0
0.5,-0.5,3	1.5,-0.5,2	2.5,-0.5,1	3.5,-0.5,0	4.5,-0.5,0	5.5,-0.5,0	6.5,-0.5,0	7.5,-0.5,0	8.5,-0.5,0	9.5,-0.5,0
0.5,-1.5,6	1.5,-1.5,6	2.5,-1.5,3	3.5,-1.5,0	4.5,-1.5,0	5.5,-1.5,0	6.5,-1.5,0	7.5,-1.5,0	8.5,-1.5,0	9.5,-1.5,0
0.5,-2.5,6	1.5,-2.5,7	2.5,-2.5,5	3.5,-2.5,1	4.5,-2.5,0	5.5,-2.5,0	6.5,-2.5,0	7.5,-2.5,0	8.5,-2.5,0	9.5,-2.5,0
0.5,-3.5,5	1.5,-3.5,7	2.5,-3.5,5	3.5,-3.5,2	4.5,-3.5,0	5.5,-3.5,0	6.5,-3.5,0	7.5,-3.5,0	8.5,-3.5,0	9.5,-3.5,0
0.5,-4.5,3	1.5,-4.5,5	2.5,-4.5,5	3.5,-4.5,10	4.5,-4.5,13	5.5,-4.5,9	6.5,-4.5,6	7.5,-4.5,3	8.5,-4.5,2	9.5,-4.5,1

Figure 4.3: Sample data matrix for area up to 10km with 1x1 km grid cells

Step 02:

The annual average wind distribution of Puttalam district (as shown in table 3.7) is divided in to 4 directions. Then the average wind speed for each direction is calculated to obtain the per directional pollution level.

The relevant Pasquill-Gifford class for each direction is obtained through the corresponding calculated wind data and solar radiation level of the district. (According to the solar irradiation map in figure 3.7)

Table 4.1: Summary of annual wind distribution into four directions -Puttalam

Direction	Average Wind Speed (m/sec)	Stability Class
North	1.38	A
South West	2.83	B
North West	1.62	A
North East	1.54	A

Then the required Lateral Dispersion (σy) & Vertical Dispersion (σz) are obtained for each grid cell by means of Pasquill-Gifford curves shown in figures 2.5 and 2.6.

Table 4.2: σy and σz for each distance x

X	A		B	
	σz	σy	σz	σy
1000	500	200	120	17
1250	800	225	175	175
2000	3000	400	250	180
3000	3000	550	800	400
3750	3000	560	1250	450
4000	3000	700	1400	500
5000	3000	850	2000	650
6000	3000	950	3000	700
6250	3000	1000	3000	800
7000	3000	1100	3000	850
8000	3000	1400	3000	950
8750	3000	1450	3000	1000
9000	3000	1500	3000	1100
10000	3000	1550	3000	1335
11000	3000	1600	3000	1420
11250	3000	1656.25	3000	1343.75
12000	3000	1700	3000	1490
13000	3000	1800	3000	1505
13750	3000	1968.75	3000	1531.25
14000	3000	1980	3000	1590
15000	3000	2000	3000	1675
16250	3000	2281.25	3000	1718.75
17000	3000	2100	3000	1845
18000	3000	2200	3000	1900
18750	3000	2593.75	3000	1906.25
19000	3000	2600	3000	2015
21250	3000	2875	3000	2125
23750	3000	3125	3000	2375
26250	3000	3375	3000	2625
28750	3000	3625	3000	2875
31250	3000	3906.25	3000	3093.75
33750	3000	4218.75	3000	3281.25
36250	3000	4531.25	3000	3468.75
38750	3000	4843.75	3000	3656.25
41250	3000	5125	3000	3875
43750	3000	5375	3000	4125
46250	3000	5625	3000	4375
48750	3000	5875	3000	4625
51250	3000	6093.75	3000	4812.5
53750	3000	6281.25	3000	4937.5
56250	3000	6468.75	3000	5062.5
58750	3000	6656.25	3000	5187.5
61250	3000	6843.75	3000	5343.75
63750	3000	7031.25	3000	5531.25
66250	3000	7218.75	3000	5718.75
68750	3000	7406.25	3000	5906.25
71250	3000	7562.5	3000	6093.75
73750	3000	7687.5	3000	6281.25
76250	3000	7812.5	3000	6468.75
78750	3000	7937.5	3000	6656.25
81250	3000	8125	3000	6781.25
83750	3000	8375	3000	6843.75
86250	3000	8625	3000	6906.25
88750	3000	8875	3000	6968.75
91250	3000	9125	3000	7125
93750	3000	9375	3000	7375
96250	3000	9625	3000	7625
98750	3000	9875	3000	7875

Step 03:

For each direction, pollution level of the whole area is calculated by grid levels by means of MS Excel. The Gaussian Plume dispersion model is used to obtain the respective pollution level of the grid cells. The other parameters needed for the model are

- Stack height (shown in table 3.4)
- General emission concentrations (shown in table 3.3)

Pollution levels due to plant NOx and SOx emissions are calculated. Here PM is not considered as the respective emission level is comparatively lower than SOx and NOx levels.

Step 04:

The output pollution levels are obtained as follows.

- NOx Concentrations

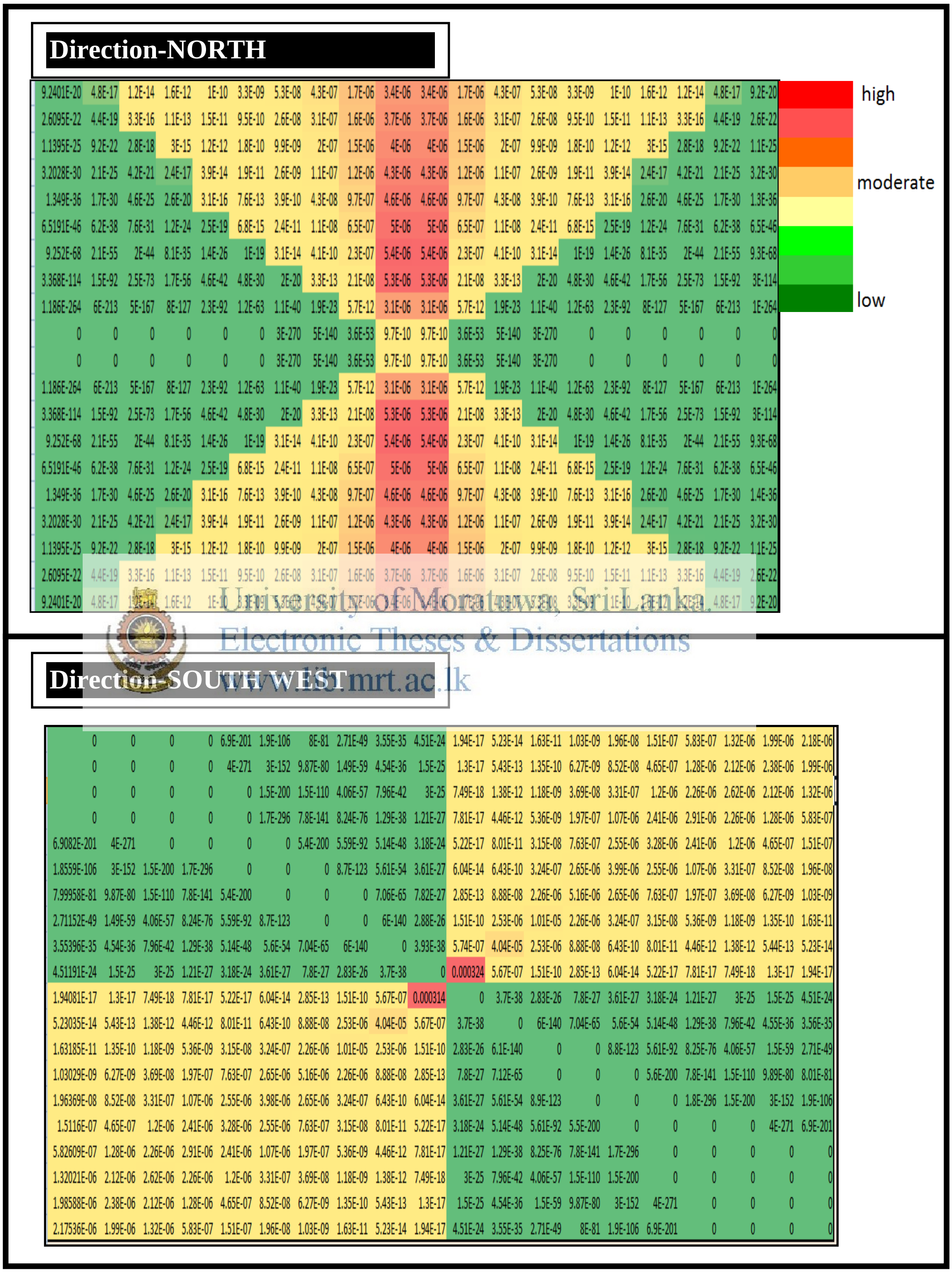


Figure 4.4: NOx Concentrations of North and South West directions

Direction-NORTH WEST

3.1945E-06	3.03E-06	2.31E-06	1.32E-06	5.19E-07	1.26E-07	1.65E-08	9.38E-10	1.79E-11	2.36E-13	1.14E-15	2.15E-19	1E-31	1.54E-42	1.12E-64	2.1E-105	2.4E-189	0	0	0
3.03275E-06	3.48E-06	3.26E-06	2.33E-06	1.16E-06	3.61E-07	5.97E-08	4.24E-09	1.84E-10	3.4E-12	5.82E-15	7.89E-24	4.07E-32	4.74E-49	1.4E-80	2.8E-146	0	0	0	0
2.30532E-06	3.26E-06	3.83E-06	3.51E-06	2.3E-06	9.5E-07	2.11E-07	2.72E-08	1.71E-09	2.04E-11	2.28E-17	1.98E-23	7.95E-36	2.61E-59	6E-109	8.3E-235	0	0	0	0
1.31594E-06	2.33E-06	3.51E-06	4.26E-06	3.79E-06	2.19E-06	7.6E-07	1.46E-07	9.31E-09	2.41E-12	1.76E-16	5.25E-25	1.39E-41	2.29E-77	1.2E-169	0	0	0	0	2.4E-189
5.18794E-07	1.16E-06	2.3E-06	3.79E-06	4.79E-06	4.02E-06	2.1E-06	5.51E-07	9.37E-09	2.86E-11	1.37E-16	2.11E-27	1.59E-51	2.2E-115	0	0	0	8.3E-235	2.8E-146	2.1E-105
1.26494E-07	3.61E-07	9.5E-07	2.19E-06	4.02E-06	5.11E-06	4.24E-06	1.33E-06	8.52E-08	1.4E-10	9.13E-17	2E-31	6.04E-72	0	0	0	1.2E-169	6E-109	1.4E-80	1.12E-64
1.64662E-08	5.97E-08	2.11E-07	7.6E-07	2.1E-06	4.24E-06	6.97E-06	4.65E-06	5.66E-07	1.13E-09	4.56E-17	2.26E-39	8.1E-200	0	0	2.2E-115	2.29E-77	2.62E-59	4.74E-49	1.54E-42
9.3849E-10	4.24E-09	2.72E-08	1.46E-07	5.51E-07	1.33E-06	4.65E-06	9.02E-06	3.95E-06	1.87E-08	1.17E-17	3.05E-91	0	8.1E-200	6.04E-72	1.59E-51	1.39E-41	7.95E-36	4.07E-32	1E-31
1.78572E-11	1.84E-10	1.71E-09	9.31E-09	9.37E-09	8.52E-08	5.66E-07	3.95E-06	1.39E-05	8.42E-07	4.26E-26	0	3.05E-91	2.26E-39	2E-31	2.11E-27	5.25E-25	1.98E-23	7.9E-24	2.15E-19
2.3615E-13	3.4E-12	2.04E-11	2.41E-12	2.86E-11	1.4E-10	1.12E-09	1.87E-08	8.42E-07	0.000221	0	4.25E-26	1.17E-17	4.56E-17	9.13E-17	1.37E-16	1.76E-16	2.28E-17	5.82E-15	1.14E-15
1.14165E-15	5.81E-15	2.28E-17	1.76E-16	1.37E-16	9.13E-17	4.56E-17	1.17E-17	4.25E-26	0	0.00022	8.42E-07	1.87E-08	1.12E-09	1.4E-10	2.86E-11	2.41E-12	2.04E-11	3.41E-12	2.36E-13
2.15262E-19	7.89E-24	1.98E-23	5.25E-25	2.11E-27	2E-31	2.26E-39	3.05E-91	0	4.25E-26	8.42E-07	1.39E-05	3.95E-06	5.66E-07	8.52E-08	9.37E-09	9.31E-09	1.72E-09	1.84E-10	1.79E-11
1.00209E-31	4.07E-32	7.95E-36	1.39E-41	1.59E-51	6.04E-72	8.1E-200	0	3.05E-91	1.17E-17	1.87E-08	3.95E-06	9.02E-06	4.65E-06	1.33E-06	5.51E-07	1.46E-07	2.72E-08	4.24E-09	9.39E-10
1.5372E-42	4.74E-49	2.61E-59	2.29E-77	2.2E-115	0	0	8.1E-200	2.26E-39	4.56E-17	1.12E-09	5.66E-07	4.65E-06	6.97E-06	4.24E-06	2.1E-06	7.6E-07	2.11E-07	5.97E-08	1.65E-08
1.1154E-64	1.4E-80	6E-109	1.2E-169	0	0	0	6.04E-72	2E-31	9.13E-17	1.4E-10	8.52E-08	1.33E-06	4.24E-06	5.11E-06	4.02E-06	2.2E-06	9.51E-07	3.61E-07	1.27E-07
2.1333E-105	2.8E-146	8.3E-235	0	0	0	2.2E-115	1.59E-51	2.11E-27	1.37E-16	2.86E-11	9.37E-09	5.51E-07	2.1E-06	4.02E-06	4.79E-06	3.79E-06	2.3E-06	1.16E-06	5.19E-07
2.3805E-189	0	0	0	0	1.2E-169	2.29E-77	1.39E-41	5.25E-25	1.76E-16	2.41E-12	9.31E-09	1.46E-07	7.6E-07	2.19E-06	3.79E-06	4.26E-06	3.51E-06	2.33E-06	1.32E-06
0	0	0	0	8.3E-235	6E-109	2.61E-59	7.95E-36	1.98E-23	2.28E-17	2.04E-11	1.71E-09	2.72E-08	2.11E-07	9.51E-07	2.3E-06	3.51E-06	3.84E-06	3.26E-06	2.31E-06
0	0	0	0	2.8E-146	1.4E-80	4.74E-49	4.07E-32	7.89E-24	5.81E-15	3.4E-12	1.84E-10	4.24E-09	5.97E-08	3.61E-07	1.16E-06	2.33E-06	3.26E-06	3.49E-06	3.03E-06
0	0	0	2.4E-189	2.1E-105	1.12E-64	1.54E-42	1E-31	2.15E-19	1.14E-15	2.36E-13	1.79E-11	9.39E-10	1.65E-08	1.27E-07	5.19E-07	1.32E-06	2.31E-06	3.03E-06	3.2E-06

Direction-NORTH EAST

0	0	[illegible]	2.5E-189	2.2E-105	1.17E-64	1.61E-42	1.05E-31	2.26E-19	1.2E-15	2.48E-13	1.87E-11	9.85E-10	1.73E-08	1.33E-07	5.44E-07	1.38E-06	2.42E-06	3.19E-06	3.35E-06
0	0	[illegible]	0	2.9E-146	1.47E-80	4.98E-49	4.27E-32	8.28E-24	6.1E-15	3.57E-12	1.93E-10	4.44E-09	6.26E-08	3.78E-07	1.22E-06	2.44E-06	3.42E-06	3.66E-06	3.19E-06
0	0	[illegible]	0	8.7E-235	6.3E-109	2.74E-59	8.34E-36	2.07E-23	2.39E-17	2.14E-11	1.8E-09	2.86E-08	[illegible]	9.97E-07	2.41E-06	3.69E-06	4.03E-06	3.42E-06	2.42E-06
2.4983E-189	0	[illegible]	0	0	1.2E-169	2.4E-77	1.46E-41	5.51E-25	1.84E-16	2.53E-12	9.77E-09	1.53E-07	7.98E-07	2.3E-06	3.98E-06	4.47E-06	3.69E-06	2.44E-06	1.38E-06
2.2389E-105	2.9E-146	8.7E-235	0	0	0	2.4E-115	1.67E-51	2.22E-27	1.43E-16	3E-11	9.84E-09	5.79E-07	2.21E-06	4.22E-06	5.03E-06	3.98E-06	2.41E-06	1.22E-06	5.45E-07
1.1706E-64	1.47E-80	6.3E-109	1.2E-169	0	0	0	6.34E-72	2.1E-31	9.59E-17	1.47E-10	8.94E-08	1.4E-06	4.45E-06	5.36E-06	4.22E-06	2.3E-06	9.98E-07	3.79E-07	1.33E-07
1.61328E-42	4.98E-49	2.74E-59	2.4E-77	2.4E-115	0	0	8.5E-200	2.37E-39	4.78E-17	1.18E-09	5.94E-07	4.88E-06	7.31E-06	4.45E-06	2.21E-06	7.98E-07	2.21E-07	6.26E-08	1.73E-08
1.05168E-31	4.27E-32	8.34E-36	1.46E-41	1.67E-51	6.34E-72	8.5E-200	0	3.2E-91	1.23E-17	1.97E-08	4.14E-06	9.47E-06	4.88E-06	1.4E-06	5.79E-07	1.53E-07	2.86E-08	4.45E-09	9.85E-10
2.25915E-19	8.28E-24	2.07E-23	5.51E-25	2.22E-27	2.1E-31	2.37E-39	3.2E-91	0	4.47E-26	8.84E-07	1.46E-05	4.14E-06	5.94E-07	8.94E-08	9.84E-09	9.77E-09	1.8E-09	1.94E-10	1.88E-11
1.19815E-15	6.1E-15	2.39E-17	1.84E-16	1.43E-16	9.58E-17	4.78E-17	1.23E-17	4.46E-26	0	0.000231	8.84E-07	1.97E-08	1.18E-09	1.47E-10	3E-11	2.53E-12	2.14E-11	3.57E-12	2.48E-13
2.47838E-13	3.57E-12	2.14E-11	2.53E-12	3E-11	1.47E-10	1.18E-09	1.97E-08	8.84E-07	0.000231	0	4.46E-26	1.23E-17	4.78E-17	9.58E-17	1.43E-16	1.84E-16	2.39E-17	6.11E-15	1.2E-15
1.87409E-11	1.93E-10	1.8E-09	9.77E-09	9.84E-09	8.94E-08	5.94E-07	4.14E-06	1.46E-05	8.84E-07	4.46E-26	0	3.2E-91	2.37E-39	2.1E-31	2.22E-27	5.51E-25	2.07E-23	8.29E-24	2.26E-19
9.84936E-10	4.44E-09	2.86E-08	1.53E-07	5.79E-07	1.4E-06	4.88E-06	9.47E-06	4.14E-06	1.97E-08	1.23E-17	3.2E-91	0	8.6E-200	6.34E-72	1.67E-51	1.46E-41	8.34E-36	4.28E-32	1.05E-31
1.72811E-08	6.26E-08	2.21E-07	7.98E-07	2.21E-06	4.45E-06	7.31E-06	4.88E-06	5.94E-07	1.18E-09	4.78E-17	2.37E-39	8.6E-200	0	0	2.4E-115	2.41E-77	2.75E-59	4.98E-49	1.61E-42
1.32754E-07	3.78E-07	9.97E-07	2.3E-06	4.22E-06	5.36E-06	4.45E-06	1.4E-06	8.94E-08	1.47E-10	9.58E-17	2.1E-31	6.34E-72	0	0	0	1.2E-169	6.3E-109	1.47E-80	1.17E-64
5.44469E-07	1.22E-06	2.41E-06	3.98E-06	5.03E-06	4.22E-06	2.21E-06	5.79E-07	9.84E-09	3E-11	1.43E-16	2.22E-27	1.67E-51	2.4E-115	0	0	0	8.7E-235	2.9E-146	2.2E-105
1.38107E-06	2.44E-06	3.69E-06	4.47E-06	3.98E-06	2.3E-06	7.98E-07	1.53E-07	9.77E-09	2.53E-12	1.84E-16	5.51E-25	1.46E-41	2.4E-77	1.2E-169	0	0	0	0	2.5E-189
2.41941E-06	3.42E-06	4.02E-06	3.69E-06	2.41E-06	9.97E-07	2.21E-07	2.86E-08	1.8E-09	2.14E-11	2.39E-17	2.07E-23	8.34E-36	2.74E-59	6.3E-109	8.7E-235	0	0	0	0
3.18285E-06	3.66E-06	3.42E-06	2.44E-06	1.22E-06	3.78E-07	6.26E-08	4.44E-09	1.93E-10	3.57E-12	6.1E-15	8.28E-24	4.27E-32	4.98E-49	1.47E-80	2.9E-146	0	0	0	0
3.35259E-06	3.18E-06	2.42E-06	1.38E-06	5.44E-07	1.33E-07	1.73E-08	9.85E-10	1.87E-11	2.48E-13	1.2E-15	2.26E-19	1.05E-31	1.61E-42	1.17E-64	2.2E-105	2.5E-189	0	0	0

Figure 4.5: NOx Concentrations of North West and North East directions

- SOx Concentrations

Direction-NORTH

1.99017E-20	1.03E-17	2.67E-15	3.44E-13	2.22E-11	7.16E-10	1.15E-08	9.24E-08	3.71E-07	7.42409E-07	7.42397E-07	3.71E-07	9.24E-08	1.15E-08	7.16E-10	2.22E-11	3.45E-13	2.67E-15	1.03E-17	1.99E-20
5.62042E-23	9.55E-20	7.1E-17	2.31E-14	3.29E-12	2.05E-10	5.59E-09	6.68E-08	3.49E-07	7.96672E-07	7.96621E-07	3.49E-07	6.68E-08	5.59E-09	2.05E-10	3.29E-12	2.31E-14	7.11E-17	9.56E-20	5.62E-23
2.45434E-26	1.99E-22	5.93E-19	6.5E-16	2.62E-13	3.89E-11	2.13E-09	4.27E-08	3.15E-07	8.57519E-07	8.5745E-07	3.15E-07	4.27E-08	2.13E-09	3.89E-11	2.62E-13	6.5E-16	5.93E-19	1.99E-22	2.46E-26
6.89826E-31	4.62E-26	8.99E-22	5.09E-18	8.39E-15	4.02E-12	5.61E-10	2.28E-08	2.69E-07	9.25267E-07	9.25178E-07	2.69E-07	2.28E-08	5.61E-10	4.02E-12	8.39E-15	5.09E-18	8.99E-22	4.62E-26	6.9E-31
2.90556E-37	3.72E-31	9.98E-26	5.61E-21	6.62E-17	1.64E-13	8.47E-11	9.2E-09	2.09E-07	9.99103E-07	9.99039E-07	2.09E-07	9.2E-09	8.47E-11	1.64E-13	6.62E-17	5.62E-21	9.98E-26	3.72E-31	2.91E-37
1.4041E-46	1.33E-38	1.64E-31	2.62E-25	5.46E-20	1.47E-15	5.17E-12	2.36E-09	1.4E-07	1.0756E-06	1.07551E-06	1.4E-07	2.36E-09	5.17E-12	1.47E-15	5.46E-20	2.62E-25	1.64E-31	1.33E-38	1.4E-46
1.99275E-68	4.49E-56	4.3E-45	1.74E-35	3E-27	2.19E-20	6.77E-15	8.87E-11	4.93E-08	1.16372E-06	1.16359E-06	4.93E-08	8.87E-11	6.77E-15	2.19E-20	3E-27	1.74E-35	4.3E-45	4.5E-56	1.99E-68
7.2544E-115	3.16E-93	5.44E-74	3.68E-57	9.83E-43	1.03E-30	4.29E-21	7E-14	4.51E-09	1.14444E-06	1.14434E-06	4.51E-09	7E-14	4.29E-21	1.03E-30	9.83E-43	3.68E-57	5.44E-74	3.17E-93	7.3E-115
2.5535E-265	1.2E-213	1.1E-167	1.7E-127	4.89E-93	2.53E-64	2.37E-41	4E-24	1.22E-12	6.76615E-07	6.76604E-07	1.22E-12	4E-24	2.37E-41	2.53E-64	4.89E-93	1.7E-127	1.1E-167	1.2E-213	2.6E-265
0	0	0	0	0	0	5.5E-271	1.1E-140	7.74E-54	2.08314E-10	2.08314E-10	7.74E-54	1.1E-140	5.5E-271	0	0	0	0	0	0
0	0	0	0	0	0	5.5E-271	1.1E-140	7.74E-54	2.07943E-10	2.07943E-10	7.74E-54	1.1E-140	5.5E-271	0	0	0	0	0	0
2.5535E-265	1.2E-213	1.1E-167	1.7E-127	4.89E-93	2.53E-64	2.37E-41	4E-24	1.22E-12	6.76549E-07	6.76549E-07	1.22E-12	4E-24	2.37E-41	2.53E-64	4.89E-93	1.7E-127	1.1E-167	1.2E-213	2.6E-265
7.2544E-115	3.16E-93	5.44E-74	3.68E-57	9.83E-43	1.03E-30	4.29E-21	7E-14	4.51E-09	1.14429E-06	1.14429E-06	4.51E-09	7E-14	4.29E-21	1.03E-30	9.83E-43	3.68E-57	5.44E-74	3.17E-93	7.3E-115
1.99275E-68	4.49E-56	4.3E-45	1.74E-35	3E-27	2.19E-20	6.77E-15	8.87E-11	4.93E-08	1.16353E-06	1.16355E-06	4.93E-08	8.87E-11	6.77E-15	2.19E-20	3E-27	1.74E-35	4.3E-45	4.5E-56	1.99E-68
1.4041E-46	1.33E-38	1.64E-31	2.62E-25	5.46E-20	1.47E-15	5.17E-12	2.36E-09	1.4E-07	1.07544E-06	1.07544E-06	1.4E-07	2.36E-09	5.17E-12	1.47E-15	5.46E-20	2.63E-25	1.64E-31	1.33E-38	1.4E-46
2.90556E-37	3.72E-31	9.98E-26	5.61E-21	6.62E-17	1.64E-13	8.47E-11	9.2E-09	2.09E-07	9.9899E-07	9.9899E-07	2.09E-07	9.2E-09	8.47E-11	1.64E-13	6.62E-17	5.62E-21	9.99E-26	3.72E-31	2.91E-37
6.89826E-31	4.62E-26	8.99E-22	5.09E-18	8.39E-15	4.02E-12	5.61E-10	2.28E-08	2.69E-07	9.25147E-07	9.25147E-07	2.69E-07	2.28E-08	5.61E-10	4.02E-12	8.39E-15	5.09E-18	8.99E-22	4.62E-26	6.9E-31
2.45434E-26	1.99E-22	5.93E-19	6.5E-16	2.62E-13	3.89E-11	2.13E-09	4.27E-08	3.15E-07	8.57407E-07	8.57407E-07	3.15E-07	4.27E-08	2.13E-09	3.89E-11	2.62E-13	6.5E-16	5.93E-19	1.99E-22	2.46E-26
5.62042E-23	9.55E-20	7.1E-17	2.31E-14	3.29E-12	2.05E-10	5.59E-09	6.68E-08	3.49E-07	7.96556E-07	7.96556E-07	3.49E-07	6.68E-08	5.59E-09	2.05E-10	3.29E-12	2.31E-14	7.1E-17	9.55E-20	5.62E-23
1.99017E-20	1.03E-17	2.67E-15	3.44E-13	2.22E-11	7.16E-10	1.15E-08	9.24E-08	3.71E-07	7.42324E-07	7.42324E-07	3.71E-07	9.24E-08	1.15E-08	7.16E-10	2.22E-11	3.45E-13	2.67E-15	1.03E-17	1.99E-20

Direction-SOUTH WEST

0	[illegible]	[illegible]	0	1.5E-201	4E-107	1.72E-81	5.84E-50	7.66E-36	9.71906E-25	4.18061E-18	1.13E-14	3.51E-12	2.22E-10	4.23E-09	3.26E-08	1.26E-07	2.85E-07	4.28E-07	4.69E-07
0	0	0	0	8.6E-272	6.5E-153	2.13E-80	3.22E-60	9.79E-37	3.22288E-26	2.80666E-18	1.17E-13	2.91E-11	1.35E-09	1.83E-08	1E-07	2.76E-07	4.57E-07	5.12E-07	4.28E-07
0	0	0	0	0	3.2E-201	3.2E-111	8.74E-58	1.71E-42	6.46353E-26	1.6129E-18	2.97E-13	2.53E-10	7.94E-09	7.14E-08	2.59E-07	4.87E-07	5.64E-07	4.57E-07	2.85E-07
0	0	0	0	0	3.6E-297	1.7E-141	1.78E-76	2.78E-39	2.60168E-28	1.68199E-17	9.6E-13	1.15E-09	4.24E-08	2.3E-07	5.19E-07	6.28E-07	4.87E-07	2.76E-07	1.26E-07
1.4879E-201	8.6E-272	0	0	0	0	1.2E-200	1.21E-92	1.11E-48	6.84139E-25	1.12461E-17	1.73E-11	6.79E-09	1.64E-07	5.48E-07	7.07E-07	5.19E-07	2.6E-07	1E-07	3.26E-08
3.9972E-107	6.5E-153	3.2E-201	3.6E-297	0	0	0	1.9E-123	1.21E-54	7.77427E-28	1.30094E-14	1.39E-10	6.97E-08	5.71E-07	8.58E-07	5.49E-07	2.3E-07	7.14E-08	1.84E-08	4.23E-09
1.72299E-81	2.13E-80	3.2E-111	1.7E-141	1.2E-200	0	0	0	1.52E-65	1.6833E-27	6.13609E-14	1.91E-08	4.86E-07	1.11E-06	5.71E-07	1.64E-07	4.24E-08	7.95E-09	1.35E-09	2.22E-10
5.84021E-50	3.22E-60	8.74E-58	1.78E-76	1.21E-92	1.9E-123	0	0	1.3E-140	6.20643E-27	3.24729E-11	5.45E-07	2.18E-06	4.86E-07	6.97E-08	6.79E-09	1.15E-09	2.53E-10	2.91E-11	3.52E-12
7.65468E-36	9.79E-37	1.71E-42	2.78E-39	1.11E-48	1.21E-54	1.52E-65	1.3E-140	0	8.46126E-39	1.23546E-07	8.71E-06	5.45E-07	1.91E-08	1.39E-10	1.73E-11	9.6E-13	2.97E-13	1.17E-13	1.13E-14
9.71795E-25	3.22E-26	6.46E-26	2.6E-28	6.84E-25	7.77E-28	1.68E-27	6.09E-27	7.96E-39	0	6.97472E-05	1.22E-07	3.25E-11	6.13E-14	1.3E-14	1.12E-17	1.68E-17	1.61E-18	2.81E-18	4.18E-18
4.1802E-18	2.81E-18	1.61E-18	1.68E-17	1.12E-17	1.3E-14	6.13E-14	3.25E-11	1.22E-07	6.76224E-05	0	7.96E-39	6.09E-27	1.68E-27	7.77E-28	6.84E-25	2.6E-28	6.47E-26	3.22E-26	9.72E-25
1.12654E-14	1.17E-13	2.97E-13	9.6E-13	1.73E-11	1.39E-10	1.91E-08	5.45E-07	8.71E-06	1.22096E-07	7.95856E-39	0	1.3E-140	1.52E-65	1.21E-54	1.11E-48	2.78E-39	1.72E-42	9.79E-37	7.66E-36
3.51475E-12	2.91E-11	2.53E-10	1.15E-09	6.79E-09	6.97E-08	4.86E-07	2.18E-06	5.45E-07	3.24503E-11	6.09153E-27	1.3E-140	0	0	1.9E-123	1.21E-92	1.78E-76	8.75E-58	3.22E-60	5.85E-50
2.21909E-10	1.35E-09	7.94E-09	4.24E-08	1.64E-07	5.71E-07	1.11E-06	4.86E-07	1.91E-08	6.1347E-14	1.67988E-27	1.53E-65	0	0	0	1.2E-200	1.7E-141	3.2E-111	2.13E-80	1.72E-81
4.22948E-09	1.83E-08	7.14E-08	2.3E-07	5.48E-07	8.58E-07	5.71E-07	6.97E-08	1.39E-10	1.30075E-14	7.76908E-28	1.21E-54	1.9E-123	0	0	0	3.9E-297	3.2E-201	6.5E-153	4E-107
3.25576E-08	1E-07	2.59E-07	5.19E-07	7.07E-07	5.48E-07	1.64E-07	6.79E-09	1.73E-11	1.12456E-17	6.83963E-25	1.11E-48	1.21E-92	1.2E-200	0	0	0	0	8.7E-272	1.5E-201
1.25485E-07	2.76E-07	4.87E-07	6.27E-07	5.19E-07	2.3E-07	4.24E-08	1.15E-09	9.6E-13	1.68193E-17	2.60135E-28	2.78E-39	1.78E-76	1.7E-141	3.7E-297	0	0	0	0	0
2.84354E-07	4.56E-07	5.64E-07	4.87E-07	2.59E-07	7.14E-08	7.94E-09	2.53E-10	2.97E-13	1.61282E-18	6.46269E-26	1.71E-42	8.75E-58	3.2E-111	3.2E-201	0	0	0	0	0
4.27727E-07	5.12E-07	4.56E-07	2.76E-07	1E-07	1.83E-08	1.35E-09	2.91E-11	1.17E-13	2.80643E-18	3.22242E-26	9.79E-37	3.22E-60	2.13E-80	6.5E-153	8.6E-272	0	0	0	0
4.68539E-07	4.28E-07	2.84E-07	1.25E-07	3.26E-08	4.23E-09	2.22E-10	3.51E-12	1.13E-14	4.1802E-18	9.71795E-25	7.65E-36	5.84E-50	1.72E-81	4E-107	1.5E-201	0	0	0	0

Figure 4.6: SOx Concentrations of North and SouthWest directions

Direction-NORTH WEST

6.88045E-07	6.53E-07	4.97E-07	2.83E-07	1.12E-07	2.72E-08	3.55E-09	2.02E-10	3.85E-12	5.0869E-14	2.45918E-16	4.64E-20	2.16E-32	3.31E-43	2.4E-65	4.6E-106	5.1E-190	0	0	0
6.53208E-07	7.51E-07	7.02E-07	5.01E-07	2.5E-07	7.77E-08	1.29E-08	9.12E-10	3.97E-11	7.33107E-13	1.25255E-15	1.7E-24	8.77E-33	1.02E-49	3.01E-81	6E-147	0	0	0	0
4.96529E-07	7.02E-07	8.26E-07	7.57E-07	4.95E-07	2.05E-07	4.53E-08	5.86E-09	3.69E-10	4.39618E-12	4.90889E-18	4.26E-24	1.71E-36	5.63E-60	1.3E-109	1.8E-235	0	0	0	0
2.83434E-07	5.01E-07	7.57E-07	9.17E-07	8.17E-07	4.73E-07	1.64E-07	3.14E-08	2E-09	5.19892E-13	3.78118E-17	1.13E-25	3E-42	4.93E-78	2.5E-170	0	0	0	0	5.1E-190
1.1174E-07	2.5E-07	4.95E-07	8.17E-07	1.03E-06	8.65E-07	4.53E-07	1.19E-07	2.02E-09	6.15456E-12	2.94197E-17	4.55E-28	3.43E-52	4.8E-116	0	0	0	1.8E-235	6E-147	4.6E-106
2.72449E-08	7.77E-08	2.05E-07	4.73E-07	8.65E-07	1.1E-06	9.14E-07	2.87E-07	1.83E-08	3.0177E-11	1.96706E-17	4.32E-32	1.3E-72	0	0	0	2.5E-170	1.3E-109	3.01E-81	2.4E-65
3.54657E-09	1.29E-08	4.53E-08	1.64E-07	4.53E-07	9.14E-07	1.5E-06	1E-06	1.22E-07	2.42316E-10	9.81778E-18	4.86E-40	1.8E-200	0	0	4.8E-116	4.94E-78	5.63E-60	1.02E-49	3.31E-43
2.02136E-10	9.12E-10	5.86E-09	3.14E-08	1.19E-07	2.87E-07	1E-06	1.94E-06	8.5E-07	4.03788E-09	2.51917E-18	6.56E-92	0	1.8E-200	1.3E-72	3.43E-52	3E-42	1.71E-36	8.78E-33	2.16E-32
3.84616E-12	3.97E-11	3.69E-10	2E-09	2.02E-09	1.83E-08	1.22E-07	8.5E-07	3E-06	1.81401E-07	9.17289E-27	0	6.56E-92	4.86E-40	4.32E-32	4.55E-28	1.13E-25	4.26E-24	1.7E-24	4.64E-20
5.08632E-14	7.33E-13	4.4E-12	5.2E-13	6.15E-12	3.02E-11	2.42E-10	4.04E-09	1.81E-07	4.75032E-05	0	9.15E-27	2.52E-18	9.82E-18	1.97E-17	2.94E-17	3.78E-17	4.91E-18	1.25E-15	2.46E-16
2.45894E-16	1.25E-15	4.91E-18	3.78E-17	2.94E-17	1.97E-17	9.82E-18	2.52E-18	9.15E-27	0	4.74186E-05	1.81E-07	4.04E-09	2.42E-10	3.02E-11	6.15E-12	5.2E-13	4.4E-12	7.33E-13	5.09E-14
4.63641E-20	1.7E-24	4.26E-24	1.13E-25	4.55E-28	4.32E-32	4.86E-40	6.56E-92	0	9.14587E-27	1.81384E-07	3E-06	8.5E-07	1.22E-07	1.83E-08	2.02E-09	2E-09	3.69E-10	3.97E-11	3.85E-12
2.15834E-32	8.77E-33	1.71E-36	3E-42	3.43E-52	1.3E-72	1.8E-200	0	6.56E-92	2.51905E-18	4.03736E-09	8.5E-07	1.94E-06	1E-06	2.87E-07	1.19E-07	3.15E-08	5.86E-09	9.13E-10	2.02E-10
3.31089E-43	1.02E-49	5.63E-60	4.93E-78	4.8E-116	0	0	1.8E-200	4.86E-40	9.81729E-18	2.42281E-10	1.22E-07	1E-06	1.5E-06	9.14E-07	4.53E-07	1.64E-07	4.54E-08	1.29E-08	3.55E-09
2.4024E-65	3.01E-81	1.3E-109	2.5E-170	0	0	0	1.3E-72	4.32E-32	1.96693E-17	3.01726E-11	1.83E-08	2.88E-07	9.14E-07	1.1E-06	8.65E-07	4.73E-07	2.05E-07	7.77E-08	2.73E-08
4.5948E-106	6E-147	1.8E-235	0	0	0	4.8E-116	3.43E-52	4.55E-28	2.94182E-17	6.15385E-12	2.02E-09	1.19E-07	4.53E-07	8.65E-07	1.03E-06	8.17E-07	4.95E-07	2.5E-07	1.12E-07
5.1272E-190	0	0	0	0	2.5E-170	4.93E-78	3E-42	1.13E-25	3.78106E-17	5.19824E-13	2E-09	3.15E-08	1.64E-07	4.73E-07	8.17E-07	9.18E-07	7.57E-07	5.01E-07	2.84E-07
0	0	0	0	1.8E-235	1.3E-109	5.63E-60	1.71E-36	4.26E-24	4.90865E-18	4.39561E-12	3.69E-10	5.86E-09	4.54E-08	2.05E-07	4.95E-07	7.57E-07	8.26E-07	7.02E-07	4.97E-07
0	0	0	0	6E-147	3.01E-81	1.02E-49	8.77E-33	1.7E-24	1.25244E-15	7.33001E-13	3.97E-11	9.12E-10	1.29E-08	7.77E-08	2.5E-07	5.01E-07	7.02E-07	7.51E-07	6.54E-07
0	0	0	5.1E-190	4.6E-106	2.4E-65	3.31E-43	2.16E-32	4.64E-20	2.45894E-16	5.08632E-14	3.85E-12	2.02E-10	3.55E-09	2.72E-08	1.12E-07	2.83E-07	4.97E-07	6.53E-07	6.88E-07

Direction-NORTH EAST

0	0	0	5.4E-190	4.8E-106	2.52E-65	3.47E-43	2.27E-32	4.87E-20	2.58093E-16	5.33856E-14	4.04E-12	2.12E-10	3.72E-09	2.86E-08	1.17E-07	2.98E-07	5.21E-07	6.86E-07	7.23E-07
0	0	0	0	6.3E-147	3.16E-81	1.07E-49	9.2E-33	1.78E-24	1.31462E-15	7.6934E-13	4.17E-11	9.57E-10	1.35E-08	8.15E-08	2.62E-07	5.26E-07	7.37E-07	7.88E-07	6.86E-07
0	0	0	0	1.9E-235	1.3E-109	5.91E-60	1.8E-36	4.47E-24	5.15235E-18	4.61338E-12	3.88E-10	6.15E-09	4.76E-08	2.15E-07	5.19E-07	7.94E-07	8.67E-07	7.37E-07	5.21E-07
5.381E-190	0	0	0	0	2.6E-170	5.18E-78	3.15E-42	1.19E-25	3.9687E-17	5.45569E-13	2.1E-09	3.3E-08	1.72E-07	4.96E-07	8.58E-07	9.63E-07	7.95E-07	5.26E-07	2.98E-07
4.8222E-106	6.3E-147	1.9E-235	0	0	0	5.1E-116	3.6E-52	4.78E-28	3.08776E-17	6.45873E-12	2.12E-09	1.25E-07	4.75E-07	9.08E-07	1.08E-06	8.58E-07	5.2E-07	2.62E-07	1.17E-07
2.5213E-65	3.16E-81	1.3E-109	2.6E-170	0	0	0	1.37E-72	4.53E-32	2.06458E-17	3.16679E-11	1.93E-08	3.02E-07	9.59E-07	1.16E-06	9.08E-07	4.96E-07	2.15E-07	8.15E-08	2.86E-08
3.47475E-43	1.07E-49	5.91E-60	5.18E-78	5.1E-116	0	0	3.2E-201	5.1E-40	1.03048E-17	2.5428E-10	1.28E-07	1.05E-06	1.58E-06	9.59E-07	4.75E-07	1.72E-07	4.76E-08	1.35E-08	3.72E-09
2.26516E-32	9.2E-33	1.8E-36	3.15E-42	3.6E-52	1.37E-72	3.2E-201	0	1.2E-92	2.64406E-18	4.23738E-09	8.92E-07	2.04E-06	1.05E-06	3.02E-07	1.25E-07	3.3E-08	6.15E-09	9.58E-10	2.12E-10
4.86587E-20	1.78E-24	4.47E-24	1.19E-25	4.78E-28	4.53E-32	5.1E-40	1.2E-92	0	1.67146E-27	1.90376E-07	3.15E-06	8.92E-07	1.28E-07	1.93E-08	2.12E-09	2.1E-09	3.88E-10	4.17E-11	4.04E-12
2.58064E-16	1.31E-15	5.15E-18	3.97E-17	3.09E-17	2.06E-17	1.03E-17	2.64E-18	1.67E-27	0	8.6656E-06	1.9E-07	4.24E-09	2.54E-10	3.17E-11	6.46E-12	5.46E-13	4.62E-12	7.7E-13	5.34E-14
5.33804E-14	7.69E-13	4.61E-12	5.46E-13	6.46E-12	3.17E-11	2.54E-10	4.24E-09	1.9E-07	8.66517E-06	0	1.67E-27	2.64E-18	1.03E-17	2.06E-17	3.09E-17	3.97E-17	5.15E-18	1.32E-15	2.58E-16
4.03651E-12	4.17E-11	3.88E-10	2.1E-09	2.12E-09	1.93E-08	1.28E-07	8.92E-07	3.15E-06	1.9036E-07	1.67129E-27	0	1.2E-92	5.1E-40	4.53E-32	4.78E-28	1.19E-25	4.47E-24	1.79E-24	4.87E-20
2.1214E-10	9.57E-10	6.15E-09	3.3E-08	1.25E-07	3.02E-07	1.05E-06	2.04E-06	8.92E-07	4.23717E-09	2.64371E-18	1.2E-92	0	3.2E-201	1.37E-72	3.6E-52	3.15E-42	1.8E-36	9.21E-33	2.27E-32
3.72209E-09	1.35E-08	4.76E-08	1.72E-07	4.75E-07	9.59E-07	1.58E-06	1.05E-06	1.28E-07	2.54267E-10	1.03033E-17	5.1E-40	3.2E-201	0	0	5.1E-116	5.18E-78	5.91E-60	1.07E-49	3.48E-43
2.85933E-08	8.15E-08	2.15E-07	4.96E-07	9.08E-07	1.16E-06	9.59E-07	3.02E-07	1.93E-08	3.16658E-11	2.06428E-17	4.53E-32	1.37E-72	0	0	0	2.6E-170	1.3E-109	3.16E-81	2.52E-65
1.1727E-07	2.62E-07	5.19E-07	8.57E-07	1.08E-06	9.08E-07	4.75E-07	1.25E-07	2.12E-09	6.45841E-12	3.08741E-17	4.78E-28	3.6E-52	5.1E-116	0	0	0	1.9E-235	6.3E-147	4.8E-106
2.97461E-07	5.26E-07	7.94E-07	9.63E-07	8.57E-07	4.96E-07	1.72E-07	3.3E-08	2.1E-09	5.45551E-13	3.96819E-17	1.19E-25	3.15E-42	5.18E-78	2.6E-170	0	0	0	0	5.4E-190
5.21103E-07	7.37E-07	8.67E-07	7.94E-07	5.19E-07	2.15E-07	4.76E-08	6.15E-09	3.88E-10	4.61315E-12	5.15158E-18	4.47E-24	1.8E-36	5.91E-60	1.3E-109	1.9E-235	0	0	0	0
6.85536E-07	7.88E-07	7.37E-07	5.26E-07	2.62E-07	8.15E-08	1.35E-08	9.57E-10	4.17E-11	7.69277E-13	1.31443E-15	1.78E-24	9.2E-33	1.07E-49	3.16E-81	6.3E-147	0	0	0	0
7.22097E-07	6.86E-07	5.21E-07	2.97E-07	1.17E-07	2.86E-08	3.72E-09	2.12E-10	4.04E-12	5.33804E-14	2.58064E-16	4.87E-20	2.27E-32	3.47E-43	2.52E-65	4.8E-106	5.4E-190	0	0	0

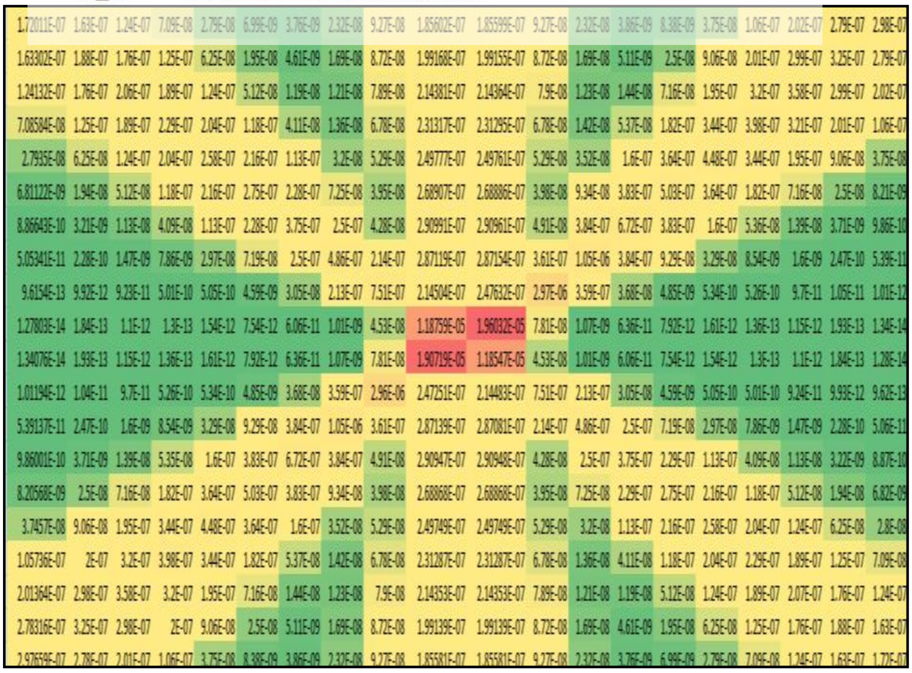
Figure 4.7: SOx Concentrations of North West and North East directions

- Resultant Monthly Average Concentrations

NOx CONCERNTRATION

7.98624E-07	7.58E-07	5.76E-07	3.29E-07	1.3E-07	3.25E-08	1.75E-08	1.08E-07	4.3E-07	8.62E-07	8.62E-07	4.3E-07	1.08E-07	1.79E-08	3.89E-08	1.74E-07	4.91E-07	9.36E-07	1.29E-06	1.38E-06
7.58188E-07	8.71E-07	8.15E-07	5.81E-07	2.9E-07	9.04E-08	2.14E-08	7.85E-08	4.05E-07	9.25E-07	9.25E-07	4.05E-07	7.86E-08	2.37E-08	1.16E-07	4.21E-07	9.31E-07	1.39E-06	1.51E-06	1.29E-06
5.76329E-07	8.15E-07	9.58E-07	8.78E-07	5.74E-07	2.38E-07	5.51E-08	5.64E-08	3.67E-07	9.95E-07	9.95E-07	3.67E-07	5.7E-08	6.69E-08	3.32E-07	9.04E-07	1.49E-06	1.66E-06	1.39E-06	9.36E-07
3.28985E-07	5.81E-07	8.78E-07	1.06E-06	9.48E-07	5.48E-07	1.91E-07	6.3E-08	3.15E-07	1.07E-06	1.07E-06	3.15E-07	6.61E-08	2.49E-07	8.43E-07	1.6E-06	1.85E-06	1.49E-06	9.31E-07	4.91E-07
1.29698E-07	2.9E-07	5.74E-07	9.48E-07	1.2E-06	1E-06	5.25E-07	1.49E-07	2.45E-07	1.16E-06	1.16E-06	2.46E-07	1.63E-07	7.42E-07	1.69E-06	2.08E-06	1.6E-06	9.04E-07	4.21E-07	1.74E-07
3.16235E-08	9.01E-08	2.38E-07	5.48E-07	1E-06	1.28E-06	1.06E-06	3.36E-07	1.83E-07	1.25E-06	1.25E-06	1.85E-07	4.34E-07	1.78E-06	2.34E-06	1.69E-06	8.43E-07	3.32E-07	1.16E-07	3.81E-08
4.11656E-09	1.49E-08	5.26E-08	1.9E-07	5.25E-07	1.06E-06	1.74E-06	1.16E-06	1.99E-07	1.35E-06	1.35E-06	2.28E-07	1.78E-06	3.12E-06	1.78E-06	7.42E-07	2.49E-07	6.45E-08	1.72E-08	4.58E-09
2.34622E-10	1.06E-09	6.8E-09	3.65E-08	1.38E-07	3.34E-07	1.16E-06	2.25E-06	9.92E-07	1.33E-06	1.33E-06	1.67E-06	4.89E-06	1.78E-06	4.31E-07	1.53E-07	3.97E-08	7.44E-09	1.15E-09	2.5E-10
4.46429E-12	4.61E-11	4.29E-10	2.33E-09	2.34E-09	2.13E-08	1.42E-07	9.87E-07	3.48E-06	9.96E-07	1.15E-06	1.38E-05	1.67E-06	1.71E-07	2.25E-08	2.48E-09	2.44E-09	4.5E-10	4.85E-11	4.7E-12
5.93371E-14	8.52E-13	5.1E-12	6.03E-13	7.14E-12	3.5E-11	2.81E-10	4.69E-09	2.11E-07	5.51E-05	0.000139	3.63E-07	4.96E-09	2.95E-10	3.68E-11	7.5E-12	6.33E-13	5.36E-12	8.95E-13	6.23E-14
6.22497E-14	8.94E-13	5.35E-12	6.33E-13	7.5E-12	3.68E-11	2.95E-10	4.96E-09	3.63E-07	0.000136	5.5E-05	2.11E-07	4.69E-09	2.81E-10	3.5E-11	7.14E-12	6.04E-13	5.1E-12	8.53E-13	5.94E-14
4.69831E-12	4.85E-11	4.5E-10	2.44E-09	2.48E-09	2.25E-08	1.71E-07	1.67E-06	1.38E-05	1.15E-06	9.96E-07	3.48E-06	9.87E-07	1.42E-07	2.13E-08	2.34E-09	2.33E-09	4.29E-10	4.61E-11	4.47E-12
2.50314E-10	1.14E-09	7.43E-09	3.96E-08	1.53E-07	4.31E-07	1.78E-06	4.89E-06	1.67E-06	1.33E-06	1.33E-06	9.92E-07	2.26E-06	1.16E-06	3.34E-07	1.38E-07	3.65E-08	6.81E-09	1.06E-09	2.35E-10
4.57786E-09	1.72E-08	6.45E-08	2.49E-07	7.42E-07	1.78E-06	3.12E-06	1.78E-06	2.28E-07	1.35E-06	1.35E-06	1.99E-07	1.16E-06	1.74E-06	1.06E-06	5.25E-07	1.9E-07	5.27E-08	1.49E-08	4.12E-09
3.80978E-08	1.16E-07	3.32E-07	8.43E-07	1.69E-06	2.34E-06	1.78E-06	4.34E-07	1.85E-07	1.25E-06	1.25E-06	1.83E-07	3.36E-07	1.06E-06	1.28E-06	1E-06	5.49E-07	2.38E-07	9.02E-08	3.16E-08
1.73907E-07	4.21E-07	9.04E-07	1.6E-06	2.08E-06	1.69E-06	7.42E-07	1.63E-07	2.46E-07	1.16E-06	1.16E-06	2.45E-07	1.49E-07	5.26E-07	1E-06	1.2E-06	9.49E-07	5.75E-07	2.9E-07	1.3E-07
4.90919E-07	9.31E-07	1.49E-06	1.85E-06	1.6E-06	8.43E-07	2.49E-07	6.61E-08	3.15E-07	1.07E-06	1.07E-06	3.15E-07	6.3E-08	1.91E-07	5.49E-07	9.49E-07	1.07E-06	8.79E-07	5.82E-07	3.29E-07
9.34905E-07	1.39E-06	1.66E-06	1.49E-06	9.04E-07	3.32E-07	6.69E-08	5.7E-08	3.67E-07	9.95E-07	9.95E-07	3.67E-07	5.64E-08	5.51E-08	2.38E-07	5.74E-07	8.79E-07	9.59E-07	8.15E-07	5.77E-07
1.29218E-06	1.51E-06	1.39E-06	9.31E-07	4.21E-07	1.16E-07	2.37E-08	7.86E-08	4.05E-07	9.25E-07	9.25E-07	4.05E-07	7.85E-08	2.14E-08	9.04E-08	2.9E-07	5.81E-07	8.15E-07	8.72E-07	7.59E-07
1.38199E-06	1.29E-06	9.35E-07	4.91E-07	1.74E-07	3.89E-08	1.79E-08	1.08E-07	4.3E-07	8.62E-07	8.62E-07	4.3E-07	1.08E-07	1.75E-08	3.25E-08	1.3E-07	3.29E-07	5.76E-07	7.58E-07	7.99E-07

SOx CONCERNTRATION



1.72011E-07	1.63E-07	1.24E-07	7.09E-08	2.79E-08	6.99E-09	3.76E-09	2.32E-08	9.27E-08	1.85602E-07	1.85599E-07	9.27E-08	2.32E-08	3.86E-09	8.38E-09	3.75E-08	1.06E-07	2.02E-07	2.79E-07	2.98E-07
1.63302E-07	1.88E-07	1.76E-07	1.25E-07	6.25E-08	1.95E-08	4.61E-09	1.69E-08	8.72E-08	1.99168E-07	1.99155E-07	8.72E-08	1.69E-08	5.11E-09	2.5E-08	9.06E-08	2.01E-07	2.99E-07	3.25E-07	2.79E-07
1.24132E-07	1.76E-07	2.06E-07	1.89E-07	1.24E-07	5.12E-08	1.19E-08	1.21E-08	7.89E-08	2.14381E-07	2.14364E-07	7.9E-08	1.23E-08	1.44E-08	7.16E-08	1.95E-07	3.2E-07	3.58E-07	2.99E-07	2.02E-07
7.08584E-08	1.25E-07	1.89E-07	2.29E-07	2.04E-07	1.18E-07	4.11E-08	1.36E-08	6.78E-08	2.31317E-07	2.31295E-07	6.78E-08	1.42E-08	5.37E-08	1.82E-07	3.44E-07	3.98E-07	3.21E-07	2.01E-07	1.06E-07
2.7935E-08	6.25E-08	1.24E-07	2.04E-07	2.58E-07	2.16E-07	1.13E-07	3.2E-08	5.29E-08	2.49777E-07	2.49761E-07	5.29E-08	3.52E-08	1.6E-07	3.64E-07	4.48E-07	3.44E-07	1.95E-07	9.06E-08	3.75E-08
6.81122E-09	1.94E-08	5.12E-08	1.18E-07	2.16E-07	2.75E-07	2.28E-07	7.25E-08	3.95E-08	2.68907E-07	2.68886E-07	3.98E-08	9.34E-08	3.83E-07	5.03E-07	3.64E-07	1.82E-07	7.16E-08	2.5E-08	8.21E-09
8.86643E-10	3.21E-09	1.13E-08	4.09E-08	1.13E-07	2.28E-07	3.75E-07	2.5E-07	4.28E-08	2.90991E-07	2.90961E-07	4.91E-08	3.84E-07	6.72E-07	3.83E-07	1.6E-07	5.36E-08	1.39E-08	3.71E-09	9.86E-10
5.05341E-11	2.28E-10	1.47E-09	7.86E-09	2.97E-08	7.19E-08	2.5E-07	4.86E-07	2.14E-07	2.87119E-07	2.87154E-07	3.61E-07	1.05E-06	3.84E-07	9.29E-08	3.29E-08	8.54E-09	1.6E-09	2.47E-10	5.39E-11
9.6154E-13	9.92E-12	9.23E-11	5.01E-10	5.05E-10	4.59E-09	3.05E-08	2.13E-07	7.51E-07	2.14504E-07	2.47632E-07	2.97E-06	3.59E-07	3.68E-08	4.85E-09	5.34E-10	5.26E-10	9.7E-11	1.05E-11	1.01E-12
1.27803E-14	1.84E-13	1.1E-12	1.3E-13	1.54E-12	7.54E-12	6.06E-11	1.01E-09	4.53E-08	1.18759E-05	1.96032E-05	7.81E-08	1.07E-09	6.36E-11	7.92E-12	1.61E-12	1.36E-13	1.15E-12	1.93E-13	1.34E-14
1.34076E-14	1.93E-13	1.15E-12	1.36E-13	1.61E-12	7.92E-12	6.36E-11	1.07E-09	7.81E-08	1.90719E-05	1.18547E-05	4.53E-08	1.01E-09	6.06E-11	7.54E-12	1.54E-12	1.3E-13	1.1E-12	1.84E-13	1.28E-14
1.01194E-12	1.04E-11	9.7E-11	5.26E-10	5.34E-10	4.85E-09	3.68E-08	3.59E-07	2.96E-06	2.47251E-07	2.14483E-07	7.51E-07	2.13E-07	3.05E-08	4.59E-09	5.05E-10	5.01E-10	9.24E-11	9.93E-12	9.62E-13
5.39137E-11	2.47E-10	1.6E-09	8.54E-09	3.29E-08	9.29E-08	3.84E-07	1.05E-06	3.61E-07	2.87139E-07	2.87081E-07	2.14E-07	4.86E-07	2.5E-07	7.19E-08	2.97E-08	7.86E-09	1.47E-09	2.28E-10	5.06E-11
9.86001E-10	3.71E-09	1.39E-08	5.35E-08	1.6E-07	3.83E-07	6.72E-07	3.84E-07	4.91E-08	2.90947E-07	2.90948E-07	4.28E-08	2.5E-07	3.75E-07	2.29E-07	1.13E-07	4.09E-08	1.13E-08	3.22E-09	8.87E-10
8.20568E-09	2.5E-08	7.16E-08	1.82E-07	3.64E-07	5.03E-07	3.83E-07	9.34E-08	3.98E-08	2.68868E-07	2.68868E-07	3.95E-08	7.25E-08	2.29E-07	2.75E-07	2.16E-07	1.18E-07	5.12E-08	1.94E-08	6.82E-09
3.7457E-08	9.06E-08	1.95E-07	3.44E-07	4.48E-07	3.64E-07	1.6E-07	3.52E-08	5.29E-08	2.49749E-07	2.49749E-07	5.29E-08	3.2E-08	1.13E-07	2.16E-07	2.58E-07	2.04E-07	1.24E-07	6.25E-08	2.8E-08
1.05736E-07	2E-07	3.2E-07	3.98E-07	3.44E-07	1.82E-07	5.37E-08	1.42E-08	6.78E-08	2.31287E-07	2.31287E-07	6.78E-08	1.36E-08	4.11E-08	1.18E-07	2.04E-07	2.29E-07	1.89E-07	1.25E-07	7.09E-08
2.01364E-07	2.98E-07	3.58E-07	3.2E-07	1.95E-07	7.16E-08	1.44E-08	1.23E-08	7.9E-08	2.14353E-07	2.14353E-07	7.89E-08	1.21E-08	1.19E-08	5.12E-08	1.24E-07	1.89E-07	2.07E-07	1.76E-07	1.24E-07
2.78316E-07	3.25E-07	2.98E-07	2E-07	9.06E-08	2.5E-08	5.11E-09	1.69E-08	8.72E-08	1.99139E-07	1.99139E-07	8.72E-08	1.69E-08	4.61E-09	1.95E-08	6.25E-08	1.25E-07	1.76E-07	1.88E-07	1.63E-07
2.97659E-07	2.78E-07	2.01E-07	1.06E-07	3.75E-08	8.38E-09	3.86E-09	2.32E-08	9.27E-08	1.85581E-07	1.85581E-07	9.27E-08	2.32E-08	3.76E-09	6.99E-09	2.79E-08	7.09E-08	1.24E-07	1.63E-07	1.72E-07

Figure 4.8: Monthly average NOx and SOx Concentrations

4.2 POLLUTION LEVELS OF TRINCOMALEE COAL POWER PLANT

The same steps of the previously described method are followed to obtain the pollution levels of Trincomalee Coal Power Plant as well. A 20km area is selected around the plant to calculate pollution levels and 400 grid cells each with the same size are chosen for the calculation.

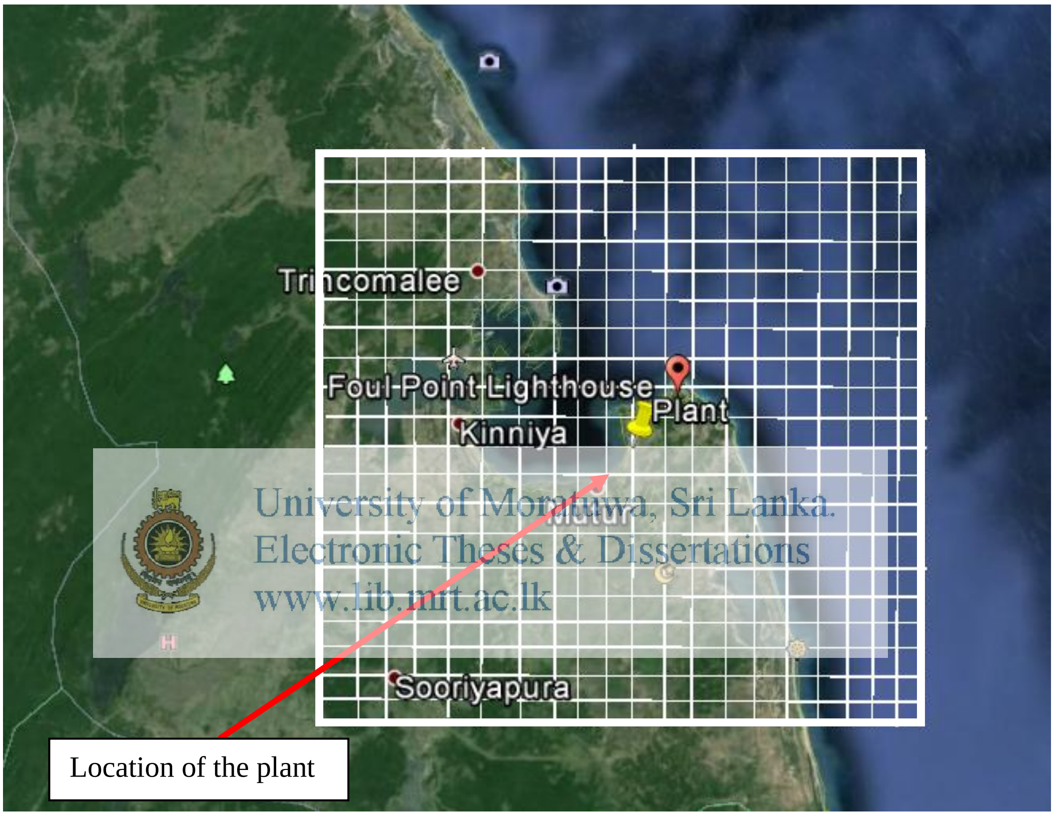


Figure 4.9: Selected area for the pollution level calculation at Trincomalee Coal plant

The annual wind distribution is sub divided into 4 directions and the pollution level of the case study area is obtained for each direction. The corresponding stability class for each is derived from wind data, temperature data and Pasquill Gifford curves. Then, the relevant lateral dispersion and vertical dispersion coefficients are obtained through Pasquill Gifford curves same as in the previous case study.

Table 4.3: Summary of annual wind distribution into four directions -Trincomalee

Direction	Average Wind Speed (m/sec)	Stability Class
South	2.33	B
South West	2.9	B
North West	1.28	A
North East	1.96	A

The pollution levels of NOx and SOx concentrations are obtained using MS Excel with the aid of other required parameters shown in below.

- Stack height -135 m
- General emission concentrations (shown in table 3.6)

In this case also, pollution levels of PM are not calculated due to its comparatively lower level of emission. The data matrixes for x, y, z and other data are used in the same way done for LakVijaya coal power plant. A specimen computation of pollution levels in Trincomalee coal power plant when wind flows in Southern direction is shown in Appendix 02.

The output pollution levels are obtained as follows.

- NOx Concentrations

Direction-SOUTH

2.2E-25	1.5E-21	4.1E-18	4E-15	1.5E-12	2.1E-10	1.1E-08	2E-07	1.5E-06	3.9105E-06	3.9E-06	1.5E-06	2E-07	1.1E-08	2.1E-10	1.5E-12	4E-15	4.1E-18	1.5E-21	2.2E-25
4.5E-29	1.8E-24	2.1E-20	8E-17	9.2E-14	3.3E-11	3.6E-09	1.2E-07	1.3E-06	4.1707E-06	4.2E-06	1.3E-06	1.2E-07	3.6E-09	3.3E-11	9.2E-14	8E-17	2.1E-20	1.8E-24	4.5E-29
6.1E-34	2.3E-28	2E-23	4.4E-19	2.3E-15	2.9E-12	8.6E-10	6.2E-08	1.1E-06	4.4522E-06	4.5E-06	1.1E-06	6.2E-08	8.6E-10	2.9E-12	2.3E-15	4.4E-19	2.1E-23	2.3E-28	6.1E-34
1.5E-40	1.2E-33	1.6E-27	3.7E-22	1.5E-17	1E-13	1.2E-10	2.4E-08	8.1E-07	4.7488E-06	4.7E-06	8.1E-07	2.4E-08	1.2E-10	1E-13	1.5E-17	3.7E-22	1.6E-27	1.2E-33	1.5E-40
6.9E-50	4.1E-41	2.6E-33	1.7E-26	1.2E-20	9E-16	7.1E-12	6E-09	5.3E-07	5.0427E-06	5E-06	5.3E-07	6E-09	7.1E-12	9E-16	1.2E-20	1.7E-26	2.6E-33	4.1E-41	6.9E-50
1.3E-70	1.1E-57	3.4E-46	3.8E-36	1.6E-27	2.4E-20	1.3E-14	2.6E-10	2E-07	5.3597E-06	5.4E-06	2E-07	2.6E-10	1.3E-14	2.4E-20	1.6E-27	3.8E-36	3.4E-46	1.1E-57	1.3E-70
3E-114	1.5E-92	2.5E-73	1.7E-56	4.5E-42	4.7E-30	2E-20	3.2E-13	2.1E-08	5.2485E-06	5.2E-06	2.1E-08	3.2E-13	2E-20	4.7E-30	4.5E-42	1.7E-56	2.5E-73	1.5E-92	3E-114
6E-191	6E-154	5E-121	2.8E-92	1.3E-67	4.8E-47	1.3E-30	2.9E-18	4.9E-10	6.2911E-06	6.3E-06	4.9E-10	2.9E-18	1.3E-30	4.8E-47	1.3E-67	2.8E-92	5E-121	6E-154	6E-191
0	0	0	4E-234	5E-169	1E-114	2.6E-71	9.7E-39	5E-17	3.6269E-06	3.6E-06	5E-17	9.7E-39	2.6E-71	1E-114	5E-169	4E-234	0	0	0
0	0	0	0	0	0	0	6E-216	3.4E-80	2.5069E-12	2.5E-12	3.4E-80	6E-216	0	0	0	0	0	0	0
0	0	0	0	0	0	0	6E-216	3.4E-80	2.4381E-12	2.4E-12	3.4E-80	6E-216	0	0	0	0	0	0	0
0	0	0	4E-234	5E-169	1E-114	2.6E-71	9.7E-39	5E-17	3.6224E-06	3.6E-06	5E-17	9.7E-39	2.6E-71	1E-114	5E-169	4E-234	0	0	0
6E-191	6E-154	5E-121	2.8E-92	1.3E-67	4.8E-47	1.3E-30	2.9E-18	4.9E-10	6.2894E-06	6.3E-06	4.9E-10	2.9E-18	1.3E-30	4.8E-47	1.3E-67	2.8E-92	5E-121	6E-154	6E-191
3E-114	1.5E-92	2.5E-73	1.7E-56	4.5E-42	4.7E-30	2E-20	3.2E-13	2.1E-08	5.2477E-06	5.2E-06	2.1E-08	3.2E-13	2E-20	4.7E-30	4.5E-42	1.7E-56	2.5E-73	1.5E-92	3E-114
1.3E-70	1.1E-57	3.4E-46	3.8E-36	1.6E-27	2.4E-20	1.3E-14	2.6E-10	2E-07	5.359E-06	5.4E-06	2E-07	2.6E-10	1.3E-14	2.4E-20	1.6E-27	3.8E-36	3.4E-46	1.1E-57	1.3E-70
6.9E-50	4.1E-41	2.6E-33	1.7E-26	1.2E-20	9E-16	7.1E-12	6E-09	5.3E-07	5.0422E-06	5E-06	5.3E-07	6E-09	7.2E-12	9E-16	1.2E-20	1.7E-26	2.6E-33	4.1E-41	6.9E-50
1.5E-40	1.2E-33	1.6E-27	3.7E-22	1.5E-17	1E-13	1.2E-10	2.4E-08	8.1E-07	4.7483E-06	4.7E-06	8.1E-07	2.4E-08	1.2E-10	1E-13	1.5E-17	3.7E-22	1.6E-27	1.2E-33	1.5E-40
6.1E-34	2.3E-28	2E-23	4.4E-19	2.3E-15	2.9E-12	8.6E-10	6.2E-08	1.1E-06	4.4517E-06	4.5E-06	1.1E-06	6.2E-08	8.6E-10	2.9E-12	2.3E-15	4.4E-19	2E-23	2.3E-28	6.1E-34
4.5E-29	1.8E-24	2.1E-20	8E-17	9.2E-14	3.3E-11	3.6E-09	1.2E-07	1.3E-06	4.1702E-06	4.2E-06	1.3E-06	1.2E-07	3.6E-09	3.3E-11	9.2E-14	8E-17	2.1E-20	1.8E-24	4.5E-29
2.2E-25	1.5E-21	4.1E-18	4E-15	1.5E-12	2.1E-10	1.1E-08	2E-07	1.5E-06	3.9101E-06	3.9E-06	1.5E-06	2E-07	1.1E-08	2.1E-10	1.5E-12	4E-15	4.1E-18	1.5E-21	2.2E-25

Direction-SOUTH WEST

0	0	0	0	5E-201	1E-106	5.7E-81	1.9E-49	2.5E-35	3.1924E-24	1.4E-17	3.7E-14	1.2E-11	7.3E-10	1.4E-08	1.1E-07	4.1E-07	9.3E-07	1.4E-06	1.5E-06
0	0	0	0	3E-271	2E-152	7E-80	1.1E-59	3.2E-36	1.0586E-25	9.2E-18	3.8E-13	9.5E-11	4.4E-09	6E-08	3.3E-07	9.1E-07	1.5E-06	1.7E-06	1.4E-06
0	0	0	0	0	1E-200	1E-110	2.9E-57	5.6E-42	2.123E-25	5.3E-18	9.8E-13	8.3E-10	2.6E-08	2.3E-07	8.5E-07	1.6E-06	1.9E-06	1.5E-06	9.3E-07
0	0	0	0	0	1E-296	6E-141	5.8E-76	9.1E-39	8.5456E-28	5.5E-17	3.2E-12	3.8E-09	1.4E-07	7.6E-07	1.7E-06	2.1E-06	1.6E-06	9.1E-07	4.1E-07
5E-201	3E-271	0	0	0	0	4E-200	4E-92	3.6E-48	2.2478E-24	3.7E-17	5.7E-11	2.2E-08	5.4E-07	1.8E-06	2.3E-06	1.7E-06	8.5E-07	3.3E-07	1.1E-07
1E-106	2E-152	1E-200	1E-296	0	0	0	6E-123	4E-54	2.5556E-27	4.3E-14	4.5E-10	2.3E-07	1.9E-06	2.8E-06	1.8E-06	7.6E-07	2.3E-07	6E-08	1.4E-08
5.7E-81	7E-80	1E-110	6E-141	4E-200	0	0	0	5.2E-65	5.545E-27	2E-13	6.3E-08	1.6E-06	3.6E-06	1.9E-06	5.4E-07	1.4E-07	2.6E-08	4.4E-09	7.3E-10
1.9E-49	1.1E-59	2.9E-57	5.8E-76	4E-92	6E-123	0	0	5E-140	2.105E-26	1.1E-10	1.8E-06	7.1E-06	1.6E-06	2.3E-07	2.2E-08	3.8E-09	8.3E-10	9.5E-11	1.2E-11
2.5E-35	3.2E-36	5.6E-42	9.1E-39	3.6E-48	4E-54	5.2E-65	5E-140	0	3.2031E-38	4.2E-07	2.9E-05	1.8E-06	6.3E-08	4.5E-10	5.7E-11	3.2E-12	9.8E-13	3.8E-13	3.7E-14
3.2E-24	1.1E-25	2.1E-25	8.5E-28	2.2E-24	2.6E-27	5.5E-27	2.1E-26	3E-38	0	0.00026	4.1E-07	1.1E-10	2E-13	4.3E-14	3.7E-17	5.5E-17	5.3E-18	9.2E-18	1.4E-17
1.4E-17	9.2E-18	5.3E-18	5.5E-17	3.7E-17	4.3E-14	2E-13	1.1E-10	4.1E-07	0.0002576	0	3E-38	2.1E-26	5.5E-27	2.6E-27	2.2E-24	8.5E-28	2.1E-25	1.1E-25	3.2E-24
3.7E-14	3.8E-13	9.8E-13	3.2E-12	5.7E-11	4.5E-10	6.3E-08	1.8E-06	2.9E-05	4.149E-07	3E-38	0	5E-140	5.2E-65	4E-54	3.6E-48	9.1E-39	5.6E-42	3.2E-36	2.5E-35
1.2E-11	9.5E-11	8.3E-10	3.8E-09	2.2E-08	2.3E-07	1.6E-06	7.1E-06	1.8E-06	1.0692E-10	2.1E-26	5E-140	0	0	6E-123	4E-92	5.8E-76	2.9E-57	1.1E-59	1.9E-49
7.3E-10	4.4E-09	2.6E-08	1.4E-07	5.4E-07	1.9E-06	3.6E-06	1.6E-06	6.3E-08	2.0168E-13	5.5E-27	5.2E-65	0	0	0	4E-200	6E-141	1E-110	7E-80	5.7E-81
1.4E-08	6E-08	2.3E-07	7.6E-07	1.8E-06	2.8E-06	1.9E-06	2.3E-07	4.5E-10	4.2738E-14	2.6E-27	4E-54	7E-123	0	0	0	1E-296	1E-200	2E-152	1E-106
1.1E-07	3.3E-07	8.5E-07	1.7E-06	2.3E-06	1.8E-06	5.4E-07	2.2E-08	5.7E-11	3.6938E-17	2.2E-24	3.6E-48	4E-92	4E-200	0	0	0	0	3E-271	5E-201
4.1E-07	9.1E-07	1.6E-06	2.1E-06	1.7E-06	7.6E-07	1.4E-07	3.8E-09	3.2E-12	5.5246E-17	8.5E-28	9.1E-39	5.8E-76	6E-141	1E-296	0	0	0	0	0
9.3E-07	1.5E-06	1.9E-06	1.6E-06	8.5E-07	2.3E-07	2.6E-08	8.3E-10	9.8E-13	5.2976E-18	2.1E-25	5.6E-42	2.9E-57	1E-110	1E-200	0	0	0	0	0
1.4E-06	1.7E-06	1.5E-06	9.1E-07	3.3E-07	6E-08	4.4E-09	9.5E-11	3.8E-13	9.2182E-18	1.1E-25	3.2E-36	1.1E-59	7E-80	2E-152	3E-271	0	0	0	0
1.5E-06	1.4E-06	9.3E-07	4.1E-07	1.1E-07	1.4E-08	7.3E-10	1.2E-11	3.7E-14	1.3731E-17	3.2E-24	2.5E-35	1.9E-49	5.7E-81	1E-106	5E-201	0	0	0	0

Figure 4.10: NOx Concentrations of South and South West directions

Direction-NORTH WEST

1.9E-06	1.8E-06	1.4E-06	7.9E-07	3.1E-07	7.6E-08	9.8E-09	5.6E-10	1.1E-11	1.4124E-13	6.8E-16	1.3E-19	6E-32	9.2E-43	6.7E-65	1E-105	1E-189	0	0	0
1.8E-06	2.1E-06	1.9E-06	1.4E-06	6.9E-07	2.2E-07	3.6E-08	2.5E-09	1.1E-10	2.0356E-12	3.5E-15	4.7E-24	2.4E-32	2.8E-49	8.4E-81	2E-146	0	0	0	0
1.4E-06	1.9E-06	2.3E-06	2.1E-06	1.4E-06	5.7E-07	1.3E-07	1.6E-08	1E-09	1.2206E-11	1.4E-17	1.2E-23	4.8E-36	1.6E-59	4E-109	5E-235	0	0	0	0
7.9E-07	1.4E-06	2.1E-06	2.5E-06	2.3E-06	1.3E-06	4.5E-07	8.7E-08	5.6E-09	1.4435E-12	1E-16	3.1E-25	8.3E-42	1.4E-77	7E-170	0	0	0	0	1E-189
3.1E-07	6.9E-07	1.4E-06	2.3E-06	2.9E-06	2.4E-06	1.3E-06	3.3E-07	5.6E-09	1.7089E-11	8.2E-17	1.3E-27	9.5E-52	1E-115	0	0	0	5E-235	2E-146	1E-105
7.6E-08	2.2E-07	5.7E-07	1.3E-06	2.4E-06	3.1E-06	2.5E-06	8E-07	5.1E-08	8.379E-11	5.5E-17	1.2E-31	3.6E-72	0	0	0	7E-170	4E-109	8.4E-81	6.7E-65
9.8E-09	3.6E-08	1.3E-07	4.5E-07	1.3E-06	2.5E-06	4.2E-06	2.8E-06	3.4E-07	6.7281E-10	2.7E-17	1.3E-39	5E-200	0	0	1E-115	1.4E-77	1.6E-59	2.8E-49	9.2E-43
5.6E-10	2.5E-09	1.6E-08	8.7E-08	3.3E-07	8E-07	2.8E-06	5.4E-06	2.4E-06	1.1212E-08	7E-18	1.8E-91	0	5E-200	3.6E-72	9.5E-52	8.3E-42	4.8E-36	2.4E-32	6E-32
1.1E-11	1.1E-10	1E-09	5.6E-09	5.6E-09	5.1E-08	3.4E-07	2.4E-06	8.3E-06	5.0368E-07	2.6E-26	0	1.8E-91	1.3E-39	1.2E-31	1.3E-27	3.1E-25	1.2E-23	4.7E-24	1.3E-19
1.4E-13	2E-12	1.2E-11	1.4E-12	1.7E-11	8.4E-11	6.7E-10	1.1E-08	5E-07	0.00013298	0	2.6E-26	7E-18	2.7E-17	5.5E-17	8.2E-17	1.1E-16	1.4E-17	3.5E-15	6.8E-16
6.8E-16	3.5E-15	1.4E-17	1E-16	8.2E-17	5.5E-17	2.7E-17	7E-18	2.6E-26	0	0.00013	5E-07	1.1E-08	6.7E-10	8.4E-11	1.7E-11	1.4E-12	1.2E-11	2E-12	1.4E-13
1.3E-19	4.7E-24	1.2E-23	3.1E-25	1.3E-27	1.2E-31	1.3E-39	1.8E-91	0	2.5607E-26	5E-07	8.3E-06	2.4E-06	3.4E-07	5.1E-08	5.6E-09	5.6E-09	1E-09	1.1E-10	1.1E-11
6E-32	2.4E-32	4.8E-36	8.3E-42	9.5E-52	3.6E-72	5E-200	0	1.8E-91	6.9945E-18	1.1E-08	2.4E-06	5.4E-06	2.8E-06	8E-07	3.3E-07	8.7E-08	1.6E-08	2.5E-09	5.6E-10
9.2E-43	2.8E-49	1.6E-59	1.4E-77	1E-115	0	0	5E-200	1.3E-39	2.7259E-17	6.7E-10	3.4E-07	2.8E-06	4.2E-06	2.5E-06	1.3E-06	4.5E-07	1.3E-07	3.6E-08	9.9E-09
6.7E-65	8.4E-81	4E-109	7E-170	0	0	0	3.6E-72	1.2E-31	5.4615E-17	8.4E-11	5.1E-08	8E-07	2.5E-06	3.1E-06	2.4E-06	1.3E-06	5.7E-07	2.2E-07	7.6E-08
1E-105	2E-146	5E-235	0	0	0	1E-115	9.5E-52	1.3E-27	8.1684E-17	1.7E-11	5.6E-09	3.3E-07	1.3E-06	2.4E-06	2.9E-06	2.3E-06	1.4E-06	6.9E-07	3.1E-07
1E-189	0	0	0	0	7E-170	1.4E-77	8.3E-42	3.1E-25	1.0499E-16	1.4E-12	5.6E-09	8.7E-08	4.5E-07	1.3E-06	2.3E-06	2.5E-06	2.1E-06	1.4E-06	7.9E-07
0	0	0	0	5E-235	4E-109	1.6E-59	4.8E-36	1.2E-23	1.363E-17	1.2E-11	1E-09	1.6E-08	1.3E-07	5.7E-07	1.4E-06	2.1E-06	2.3E-06	2E-06	1.4E-06
0	0	0	0	2E-146	8.4E-81	2.8E-49	2.4E-32	4.7E-24	3.4776E-15	2E-12	1.1E-10	2.5E-09	3.6E-08	2.2E-07	6.9E-07	1.4E-06	1.9E-06	2.1E-06	1.8E-06

Direction-NORTH EAST

0	0	0	2E-189	2E-105	1E-64	1.4E-42	9.2E-32	2E-19	[illegible]	2.2E-13	1.6E-11	8.6E-10	1.5E-08	1.2E-07	4.8E-07	1.2E-06	2.1E-06	2.8E-06	2.9E-06
0	0	[illegible]	[illegible]	3E-146	1.3E-80	4.3E-49	3.7E-32	7.2E-24	5.3328E-15	3.1E-12	1.7E-10	3.9E-09	5.5E-08	3.3E-07	1.1E-06	2.1E-06	3E-06	3.2E-06	2.8E-06
0	0	[illegible]	[illegible]	8E-235	5E-109	2.4E-59	7.3E-36	1.8E-23	[illegible]	1.9E-11	1.6E-09	2.5E-08	1.9E-07	8.7E-07	2.1E-06	3.2E-06	3.5E-06	3E-06	2.1E-06
2E-189	0	[illegible]	[illegible]	0	1E-169	2.1E-77	1.3E-41	4.8E-25	1.6099E-16	2.2E-12	8.5E-09	1.3E-07	7E-07	2E-06	3.5E-06	3.9E-06	3.2E-06	2.1E-06	1.2E-06
2E-105	3E-146	8E-235	0	0	0	2E-115	1.5E-51	1.9E-27	1.2526E-16	2.6E-11	8.6E-09	5.1E-07	1.9E-06	3.7E-06	4.4E-06	3.5E-06	2.1E-06	1.1E-06	4.8E-07
1E-64	1.3E-80	5E-109	1E-169	0	0	0	5.5E-72	1.8E-31	8.3751E-17	1.3E-10	7.8E-08	1.2E-06	3.9E-06	4.7E-06	3.7E-06	2E-06	8.7E-07	3.3E-07	1.2E-07
1.4E-42	4.3E-49	2.4E-59	2.1E-77	2E-115	0	0	1E-200	2.1E-39	4.1802E-17	1E-09	5.2E-07	4.3E-06	6.4E-06	3.9E-06	1.9E-06	7E-07	1.9E-07	5.5E-08	1.5E-08
9.2E-32	3.7E-32	7.3E-36	1.3E-41	1.5E-51	5.5E-72	1E-200	0	4.9E-92	1.0726E-17	1.7E-08	3.6E-06	8.3E-06	4.3E-06	1.2E-06	5.1E-07	1.3E-07	2.5E-08	3.9E-09	8.6E-10
2E-19	7.2E-24	1.8E-23	4.8E-25	1.9E-27	1.8E-31	2.1E-39	4.9E-92	0	6.7804E-27	7.7E-07	1.3E-05	3.6E-06	5.2E-07	7.8E-08	8.6E-09	8.5E-09	1.6E-09	1.7E-10	1.6E-11
1E-15	5.3E-15	2.1E-17	1.6E-16	1.3E-16	8.4E-17	4.2E-17	1.1E-17	6.8E-27	0	3.5E-05	7.7E-07	1.7E-08	1E-09	1.3E-10	2.6E-11	2.2E-12	1.9E-11	3.1E-12	2.2E-13
2.2E-13	3.1E-12	1.9E-11	2.2E-12	2.6E-11	1.3E-10	1E-09	1.7E-08	7.7E-07	3.5151E-05	0	6.8E-27	1.1E-17	4.2E-17	8.4E-17	1.3E-16	1.6E-16	2.1E-17	5.3E-15	1E-15
1.6E-11	1.7E-10	1.6E-09	8.5E-09	8.6E-09	7.8E-08	5.2E-07	3.6E-06	1.3E-05	7.7222E-07	6.8E-27	0	4.9E-92	2.1E-39	1.8E-31	1.9E-27	4.8E-25	1.8E-23	7.2E-24	2E-19
8.6E-10	3.9E-09	2.5E-08	1.3E-07	5.1E-07	1.2E-06	4.3E-06	8.3E-06	3.6E-06	1.7189E-08	1.1E-17	4.9E-92	0	1E-200	5.5E-72	1.5E-51	1.3E-41	7.3E-36	3.7E-32	9.2E-32
1.5E-08	5.5E-08	1.9E-07	7E-07	1.9E-06	3.9E-06	6.4E-06	4.3E-06	5.2E-07	1.0315E-09	4.2E-17	2.1E-39	1E-200	0	0	2E-115	2.1E-77	2.4E-59	4.4E-49	1.4E-42
1.2E-07	3.3E-07	8.7E-07	2E-06	3.7E-06	4.7E-06	3.9E-06	1.2E-06	7.8E-08	1.2846E-10	8.4E-17	1.8E-31	5.5E-72	0	0	0	1E-169	5E-109	1.3E-80	1E-64
4.8E-07	1.1E-06	2.1E-06	3.5E-06	4.4E-06	3.7E-06	1.9E-06	5.1E-07	8.6E-09	2.6199E-11	1.3E-16	1.9E-27	1.5E-51	2E-115	0	0	0	8E-235	3E-146	2E-105
1.2E-06	2.1E-06	3.2E-06	3.9E-06	3.5E-06	2E-06	7E-07	1.3E-07	8.5E-09	2.2131E-12	1.6E-16	4.8E-25	1.3E-41	2.1E-77	1E-169	0	0	0	0	2E-189
2.1E-06	3E-06	3.5E-06	3.2E-06	2.1E-06	8.7E-07	1.9E-07	2.5E-08	1.6E-09	1.8714E-11	2.1E-17	1.8E-23	7.3E-36	2.4E-59	5E-109	8E-235	0	0	0	0
2.8E-06	3.2E-06	3E-06	2.1E-06	1.1E-06	3.3E-07	5.5E-08	3.9E-09	1.7E-10	3.1207E-12	5.3E-15	7.2E-24	3.7E-32	4.3E-49	1.3E-80	3E-146	0	0	0	0
2.9E-06	2.8E-06	2.1E-06	1.2E-06	4.8E-07	1.2E-07	1.5E-08	8.6E-10	1.6E-11	2.1654E-13	1E-15	2E-19	9.2E-32	1.4E-42	1E-64	2E-105	2E-189	0	0	0

Figure 4.11: NOx Concentrations of North West and North East directions

- SOx Concentrations

Direction- SOUTH

3.7E-25	2.6E-21	6.9E-18	6.8E-15	2.5E-12	3.4E-10	1.8E-08	3.4E-07	2.4E-06	6.6E-06	6.6E-06	2.4E-06	3.4E-07	1.8E-08	3.4E-10	2.5E-12	6.8E-15	6.9E-18	2.6E-21	3.7E-25
7.6E-29	3E-24	3.6E-20	1.3E-16	1.5E-13	5.5E-11	6.1E-09	2.1E-07	2.2E-06	7E-06	7E-06	2.2E-06	2.1E-07	6.1E-09	5.5E-11	1.5E-13	1.3E-16	3.6E-20	3E-24	7.6E-29
1E-33	3.8E-28	3.4E-23	7.4E-19	3.8E-15	4.8E-12	1.4E-09	1E-07	1.8E-06	7.5E-06	7.5E-06	1.8E-06	1E-07	1.4E-09	4.8E-12	3.8E-15	7.4E-19	3.4E-23	3.8E-28	1E-33
2.4E-40	2E-33	2.7E-27	6.2E-22	2.5E-17	1.7E-13	2E-10	4E-08	1.4E-06	8E-06	8E-06	1.4E-06	4E-08	2E-10	1.7E-13	2.5E-17	6.2E-22	2.7E-27	2E-33	2.4E-40
1.2E-49	6.9E-41	4.3E-33	2.9E-26	2E-20	1.5E-15	1.2E-11	1E-08	9E-07	8.4E-06	8.4E-06	9E-07	1E-08	1.2E-11	1.5E-15	2E-20	2.9E-26	4.3E-33	6.9E-41	1.2E-49
2.2E-70	1.9E-57	5.7E-46	6.4E-36	2.6E-27	3.9E-20	2.2E-14	4.4E-10	3.3E-07	9E-06	9E-06	3.3E-07	4.4E-10	2.2E-14	3.9E-20	2.6E-27	6.4E-36	5.7E-46	1.9E-57	2.2E-70
6E-114	2.4E-92	4.2E-73	2.8E-56	7.6E-42	7.9E-30	3.3E-20	5.4E-13	3.5E-08	8.8E-06	8.8E-06	3.5E-08	5.4E-13	3.3E-20	7.9E-30	7.6E-42	2.8E-56	4.2E-73	2.4E-92	6E-114
1E-190	1E-153	8E-121	4.8E-92	2.2E-67	8.1E-47	2.3E-30	4.9E-18	8.1E-10	1.1E-05	1.1E-05	8.1E-10	4.9E-18	2.3E-30	8.1E-47	2.2E-67	4.8E-92	8E-121	1E-153	1E-190
0	0	0	6E-234	8E-169	2E-114	4.4E-71	1.6E-38	8.4E-17	6.1E-06	6.1E-06	8.4E-17	1.6E-38	4.4E-71	2E-114	8E-169	6E-234	0	0	0
0	0	0	0	0	0	0	1E-215	5.7E-80	4.2E-12	4.2E-12	5.7E-80	1E-215	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1E-215	5.7E-80	4.1E-12	4.1E-12	5.7E-80	1E-215	0	0	0	0	0	0	0
0	0	0	6E-234	8E-169	2E-114	4.4E-71	1.6E-38	8.4E-17	6.1E-06	6.1E-06	8.4E-17	1.6E-38	4.4E-71	2E-114	8E-169	6E-234	0	0	0
1E-190	1E-153	8E-121	4.8E-92	2.2E-67	8.1E-47	2.3E-30	4.9E-18	8.1E-10	1.1E-05	1.1E-05	8.1E-10	4.9E-18	2.3E-30	8.1E-47	2.2E-67	4.8E-92	8E-121	1E-153	1E-190
6E-114	2.4E-92	4.2E-73	2.8E-56	7.6E-42	7.9E-30	3.3E-20	5.4E-13	3.5E-08	8.8E-06	8.8E-06	3.5E-08	5.4E-13	3.3E-20	7.9E-30	7.6E-42	2.8E-56	4.2E-73	2.4E-92	6E-114
2.2E-70	1.9E-57	5.7E-46	6.4E-36	2.6E-27	3.9E-20	2.2E-14	4.4E-10	3.3E-07	9E-06	9E-06	3.3E-07	4.4E-10	2.2E-14	3.9E-20	2.6E-27	6.4E-36	5.7E-46	1.9E-57	2.2E-70
1.2E-49	6.9E-41	4.3E-33	2.9E-26	2E-20	1.5E-15	1.2E-11	1E-08	9E-07	8.4E-06	8.4E-06	9E-07	1E-08	1.2E-11	1.5E-15	2E-20	2.9E-26	4.3E-33	6.9E-41	1.2E-49
2.4E-40	2E-33	2.7E-27	6.2E-22	2.5E-17	1.7E-13	2E-10	4E-08	1.4E-06	8E-06	8E-06	1.4E-06	4E-08	2E-10	1.7E-13	2.5E-17	6.2E-22	2.7E-27	2E-33	2.4E-40
1E-33	3.8E-28	3.4E-23	7.4E-19	3.8E-15	4.8E-12	1.4E-09	1E-07	1.8E-06	7.5E-06	7.5E-06	1.8E-06	1E-07	1.4E-09	4.8E-12	3.8E-15	7.4E-19	3.4E-23	3.8E-28	1E-33
7.6E-29	3E-24	3.6E-20	1.3E-16	1.5E-13	5.5E-11	6.1E-09	2.1E-07	2.2E-06	7E-06	7E-06	2.2E-06	2.1E-07	6.1E-09	5.5E-11	1.5E-13	1.3E-16	3.6E-20	3E-24	7.6E-29
3.7E-25	2.6E-21	6.9E-18	6.8E-15	2.5E-12	3.4E-10	1.8E-08	3.4E-07	2.4E-06	6.6E-06	6.6E-06	2.4E-06	3.4E-07	1.8E-08	3.4E-10	2.5E-12	6.8E-15	6.9E-18	2.6E-21	3.7E-25

Direction-SOUTH WEST

0	0	0	0	8E-201	2E-106	9.5E-81	3.2E-49	4.2E-35	5.3E-24	2.3E-17	6.2E-14	1.9E-11	1.2E-09	2.3E-08	1.8E-07	6.9E-07	1.6E-06	2.4E-06	2.6E-06
0	0	0	0	5E-271	4E-152	1.2E-79	1.8E-59	5.4E-36	1.8E-25	1.5E-17	6.4E-13	1.6E-10	7.4E-09	1E-07	5.5E-07	1.5E-06	2.5E-06	2.8E-06	2.4E-06
0	0	0	0	0	2E-200	2E-110	4.8E-57	9.4E-42	3.6E-25	8.9E-18	1.6E-12	1.4E-09	4.4E-08	3.9E-07	1.4E-06	2.7E-06	3.1E-06	2.5E-06	1.6E-06
0	0	0	0	0	2E-296	9E-141	9.8E-76	1.5E-38	1.4E-27	9.3E-17	5.3E-12	6.4E-09	2.3E-07	1.3E-06	2.9E-06	3.5E-06	2.7E-06	1.5E-06	6.9E-07
8E-201	5E-271	0	0	0	0	7E-200	6.7E-92	6.1E-48	3.8E-24	6.2E-17	9.5E-11	3.7E-08	9E-07	3E-06	3.9E-06	2.9E-06	1.4E-06	5.5E-07	1.8E-07
2E-106	4E-152	2E-200	2E-296	0	0	0	1E-122	6.7E-54	4.3E-27	7.2E-14	7.6E-10	3.8E-07	3.1E-06	4.7E-06	3E-06	1.3E-06	3.9E-07	1E-07	2.3E-08
9.5E-81	1.2E-79	2E-110	9E-141	7E-200	0	0	0	8.7E-65	9.3E-27	3.4E-13	1.1E-07	2.7E-06	6.1E-06	3.1E-06	9E-07	2.3E-07	4.4E-08	7.4E-09	1.2E-09
3.2E-49	1.8E-59	4.8E-57	9.8E-76	6.7E-92	1E-122	0	0	8E-140	3.5E-26	1.8E-10	3E-06	1.2E-05	2.7E-06	3.8E-07	3.7E-08	6.4E-09	1.4E-09	1.6E-10	1.9E-11
4.2E-35	5.4E-36	9.4E-42	1.5E-38	6.1E-48	6.7E-54	8.6E-65	8E-140	0	5.4E-38	7E-07	4.8E-05	3E-06	1.1E-07	7.6E-10	9.5E-11	5.3E-12	1.6E-12	6.4E-13	6.2E-14
5.3E-24	1.8E-25	3.6E-25	1.4E-27	3.8E-24	4.3E-27	9.3E-27	3.5E-26	5.1E-38	0	0.00044	7E-07	1.8E-10	3.4E-13	7.2E-14	6.2E-17	9.3E-17	8.9E-18	1.5E-17	2.3E-17
2.3E-17	1.5E-17	8.9E-18	9.3E-17	6.2E-17	7.2E-14	3.4E-13	1.8E-10	7E-07	0.00043	0	5.1E-38	3.5E-26	9.3E-27	4.3E-27	3.8E-24	1.4E-27	3.6E-25	1.8E-25	5.4E-24
6.2E-14	6.4E-13	1.6E-12	5.3E-12	9.5E-11	7.6E-10	1.1E-07	3E-06	4.8E-05	7E-07	5.1E-38	0	8E-140	8.6E-65	6.7E-54	6.1E-48	1.5E-38	9.4E-42	5.4E-36	4.2E-35
1.9E-11	1.6E-10	1.4E-09	6.4E-09	3.7E-08	3.8E-07	2.7E-06	1.2E-05	3E-06	1.8E-10	3.5E-26	8E-140	0	0	1E-122	6.7E-92	9.8E-76	4.8E-57	1.8E-59	3.2E-49
1.2E-09	7.4E-09	4.4E-08	2.3E-07	9E-07	3.1E-06	6.1E-06	2.7E-06	1.1E-07	3.4E-13	9.3E-27	8.7E-65	0	0	0	7E-200	9E-141	2E-110	1.2E-79	9.5E-81
2.3E-08	1E-07	3.9E-07	1.3E-06	3E-06	4.7E-06	3.1E-06	3.8E-07	7.6E-10	7.2E-14	4.3E-27	6.7E-54	1E-122	0	0	0	2E-296	2E-200	4E-152	2E-106
1.8E-07	5.5E-07	1.4E-06	2.9E-06	3.9E-06	3E-06	9E-07	3.7E-08	9.5E-11	6.2E-17	3.8E-24	6.1E-48	6.7E-92	7E-200	0	0	0	0	5E-271	8E-201
6.9E-07	1.5E-06	2.7E-06	3.5E-06	2.9E-06	1.3E-06	2.3E-07	6.4E-09	5.3E-12	9.3E-17	1.4E-27	1.5E-38	9.8E-76	9E-141	2E-296	0	0	0	0	0
1.6E-06	2.5E-06	3.1E-06	2.7E-06	1.4E-06	3.9E-07	4.4E-08	1.4E-09	1.6E-12	8.9E-18	3.6E-25	9.4E-42	4.8E-57	2E-110	2E-200	0	0	0	0	0
2.4E-06	2.8E-06	2.5E-06	1.5E-06	5.5E-07	1E-07	7.4E-09	1.6E-10	6.4E-13	1.5E-17	1.8E-25	5.4E-36	1.8E-59	1.2E-79	4E-152	5E-271	0	0	0	0
2.6E-06	2.4E-06	1.6E-06	6.9E-07	1.8E-07	2.3E-08	1.2E-09	1.9E-11	6.2E-14	2.3E-17	5.3E-24	4.2E-35	3.2E-49	9.5E-81	2E-106	8E-201	0	0	0	0

Figure 4.12: SOx Concentrations of South and South West directions

Direction-NORTH WEST

3.2E-06	3.04E-06	2.31E-06	1.32E-06	5.2E-07	1.27E-07	1.65E-08	9.4E-10	1.79E-11	2.37E-13	1.14E-15	2.16E-19	1E-31	1.54E-42	1.12E-64	2.1E-105	2.4E-189	0	0	0
3.04E-06	3.49E-06	3.27E-06	2.33E-06	1.16E-06	3.61E-07	5.98E-08	4.24E-09	1.85E-10	3.41E-12	5.83E-15	7.91E-24	4.08E-32	4.75E-49	1.4E-80	2.8E-146	0	0	0	0
2.31E-06	3.27E-06	3.84E-06	3.52E-06	2.3E-06	9.52E-07	2.11E-07	2.73E-08	1.72E-09	2.04E-11	2.28E-17	1.98E-23	7.96E-36	2.62E-59	6E-109	8.3E-235	0	0	0	0
1.32E-06	2.33E-06	3.52E-06	4.27E-06	3.8E-06	2.2E-06	7.61E-07	1.46E-07	9.32E-09	2.42E-12	1.76E-16	5.26E-25	1.39E-41	2.3E-77	1.2E-169	0	0	0	0	2.4E-189
5.2E-07	1.16E-06	2.3E-06	3.8E-06	4.8E-06	4.02E-06	2.11E-06	5.52E-07	9.39E-09	2.86E-11	1.37E-16	2.12E-27	1.6E-51	2.3E-115	0	0	0	8.4E-235	2.8E-146	2.1E-105
1.27E-07	3.61E-07	9.52E-07	2.2E-06	4.02E-06	5.12E-06	4.25E-06	1.34E-06	8.53E-08	1.4E-10	9.15E-17	2.01E-31	6.05E-72	0	0	0	1.2E-169	6E-109	1.4E-80	1.12E-64
1.65E-08	5.98E-08	2.11E-07	7.61E-07	2.11E-06	4.25E-06	6.98E-06	4.66E-06	5.67E-07	1.13E-09	4.57E-17	2.26E-39	8.2E-200	0	0	2.3E-115	2.3E-77	2.62E-59	4.75E-49	1.54E-42
9.4E-10	4.24E-09	2.73E-08	1.46E-07	5.52E-07	1.34E-06	4.66E-06	9.04E-06	3.96E-06	1.88E-08	1.17E-17	3.08E-91	0	8.2E-200	6.05E-72	1.6E-51	1.4E-41	7.96E-36	4.08E-32	1E-31
1.79E-11	1.85E-10	1.72E-09	9.32E-09	9.39E-09	8.53E-08	5.67E-07	3.96E-06	1.4E-05	8.44E-07	4.3E-26	0	3.08E-91	2.26E-39	2.01E-31	2.12E-27	5.26E-25	1.98E-23	7.91E-24	2.16E-19
2.37E-13	3.41E-12	2.04E-11	2.42E-12	2.86E-11	1.4E-10	1.13E-09	1.88E-08	8.44E-07	0.000223	0	4.29E-26	1.17E-17	4.57E-17	9.15E-17	1.37E-16	1.76E-16	2.28E-17	5.83E-15	1.14E-15
1.14E-15	5.83E-15	2.28E-17	1.76E-16	1.37E-16	9.15E-17	4.57E-17	1.17E-17	4.29E-26	0	0.000222	8.44E-07	1.88E-08	1.13E-09	1.4E-10	2.86E-11	2.42E-12	2.05E-11	3.41E-12	2.37E-13
2.16E-19	7.91E-24	1.98E-23	5.26E-25	2.12E-27	2.01E-31	2.26E-39	3.08E-91	0	4.29E-26	8.44E-07	1.4E-05	3.96E-06	5.67E-07	8.53E-08	9.39E-09	9.32E-09	1.72E-09	1.85E-10	1.79E-11
1E-31	4.08E-32	7.96E-36	1.39E-41	1.6E-51	6.05E-72	8.2E-200	0	3.08E-91	1.17E-17	1.88E-08	3.96E-06	9.04E-06	4.66E-06	1.34E-06	5.52E-07	1.46E-07	2.73E-08	4.25E-09	9.41E-10
1.54E-42	4.75E-49	2.62E-59	2.3E-77	2.3E-115	0	0	8.2E-200	2.26E-39	4.57E-17	1.13E-09	5.67E-07	4.66E-06	6.98E-06	4.25E-06	2.11E-06	7.62E-07	2.11E-07	5.98E-08	1.65E-08
1.12E-64	1.4E-80	6E-109	1.2E-169	0	0	0	6.05E-72	2.01E-31	9.15E-17	1.4E-10	8.53E-08	1.34E-06	4.25E-06	5.12E-06	4.03E-06	2.2E-06	9.53E-07	3.61E-07	1.27E-07
2.1E-105	2.8E-146	8.3E-235	0	0	0	2.3E-115	1.6E-51	2.12E-27	1.37E-16	2.86E-11	9.39E-09	5.52E-07	2.11E-06	4.03E-06	4.8E-06	3.8E-06	2.3E-06	1.16E-06	5.2E-07
2.4E-189	0	0	0	0	1.2E-169	2.3E-77	1.39E-41	5.26E-25	1.76E-16	2.42E-12	9.32E-09	1.46E-07	7.62E-07	2.2E-06	3.8E-06	4.27E-06	3.52E-06	2.33E-06	1.32E-06
0	0	0	0	8.3E-235	6E-109	2.62E-59	7.96E-36	1.98E-23	2.28E-17	2.04E-11	1.72E-09	2.73E-08	2.11E-07	9.52E-07	2.3E-06	3.52E-06	3.84E-06	3.27E-06	2.31E-06
0	0	0	0	2.8E-146	1.4E-80	4.75E-49	4.08E-32	7.91E-24	5.83E-15	3.41E-12	1.85E-10	4.24E-09	5.98E-08	3.61E-07	1.16E-06	2.33E-06	3.27E-06	3.49E-06	3.04E-06
0	0	0	2.4E-189	2.1E-105	1.12E-64	1.54E-42	1E-31	2.16E-19	1.14E-15	2.37E-13	1.79E-11	9.4E-10	1.65E-08	1.27E-07	5.2E-07	1.32E-06	2.31E-06	3.04E-06	3.2E-06

Direction-NORTH EAST

0	0	0	3.7E-189	3.3E-105	1.71E-64	2.36E-42	1.54E-31	3.31E-19	1.75E-15	3.63E-13	2.74E-11	1.44E-09	2.53E-08	1.94E-07	7.97E-07	2.02E-06	3.54E-06	4.66E-06	4.91E-06
0	0	0	0	4.3E-146	2.15E-80	7.29E-49	6.25E-32	1.21E-23	8.93E-15	5.23E-12	2.83E-10	6.51E-09	9.17E-08	5.54E-07	1.78E-06	3.57E-06	5.01E-06	5.36E-06	4.66E-06
0	0	0	0	1.3E-234	9.1E-109	4.02E-59	1.22E-35	3.03E-23	3.5E-17	3.14E-11	2.63E-09	4.18E-08	3.23E-07	1.46E-06	3.53E-06	5.4E-06	5.89E-06	5.01E-06	3.54E-06
3.7E-189	0	0	0	0	1.8E-169	3.52E-77	2.14E-41	8.06E-25	2.7E-16	3.71E-12	1.43E-08	2.24E-07	1.17E-06	3.37E-06	5.83E-06	6.55E-06	5.4E-06	3.57E-06	2.02E-06
3.3E-105	4.3E-146	1.3E-234	0	0	0	3.5E-115	2.45E-51	3.25E-27	2.1E-16	4.39E-11	1.44E-08	8.47E-07	3.23E-06	6.17E-06	7.36E-06	5.83E-06	3.53E-06	1.78E-06	7.97E-07
1.71E-64	2.15E-80	9.1E-109	1.8E-169	0	0	0	9.28E-72	3.08E-31	1.4E-16	2.15E-10	1.31E-07	2.05E-06	6.52E-06	7.85E-06	6.17E-06	3.37E-06	1.46E-06	5.54E-07	1.94E-07
2.36E-42	7.29E-49	4.02E-59	3.52E-77	3.5E-115	0	0	2.2E-200	3.47E-39	7E-17	1.73E-09	8.7E-07	7.14E-06	1.07E-05	6.52E-06	3.23E-06	1.17E-06	3.23E-07	9.17E-08	2.53E-08
1.54E-31	6.25E-32	1.22E-35	2.14E-41	2.45E-51	9.28E-72	2.2E-200	0	8.15E-92	1.8E-17	2.88E-08	6.06E-06	1.39E-05	7.14E-06	2.05E-06	8.47E-07	2.24E-07	4.18E-08	6.51E-09	1.44E-09
3.31E-19	1.21E-23	3.03E-23	8.06E-25	3.25E-27	3.08E-31	3.47E-39	8.15E-92	0	1.14E-26	1.29E-06	2.14E-05	6.06E-06	8.7E-07	1.31E-07	1.44E-08	1.43E-08	2.63E-09	2.83E-10	2.74E-11
1.75E-15	8.93E-15	3.5E-17	2.7E-16	2.1E-16	1.4E-16	7E-17	1.8E-17	1.14E-26	0	5.89E-05	1.29E-06	2.88E-08	1.73E-09	2.15E-10	4.39E-11	3.71E-12	3.14E-11	5.23E-12	3.63E-13
3.63E-13	5.23E-12	3.13E-11	3.71E-12	4.39E-11	2.15E-10	1.73E-09	2.88E-08	1.29E-06	5.89E-05	0	1.14E-26	1.8E-17	7E-17	1.4E-16	2.1E-16	2.7E-16	3.5E-17	8.94E-15	1.75E-15
2.74E-11	2.83E-10	2.63E-09	1.43E-08	1.44E-08	1.31E-07	8.7E-07	6.06E-06	2.14E-05	1.29E-06	1.14E-26	0	8.15E-92	3.47E-39	3.08E-31	3.25E-27	8.06E-25	3.04E-23	1.21E-23	3.31E-19
1.44E-09	6.51E-09	4.18E-08	2.24E-07	8.47E-07	2.05E-06	7.14E-06	1.39E-05	6.06E-06	2.88E-08	1.8E-17	8.15E-92	0	2.2E-200	9.28E-72	2.45E-51	2.14E-41	1.22E-35	6.26E-32	1.54E-31
2.53E-08	9.17E-08	3.23E-07	1.17E-06	3.23E-06	6.52E-06	1.07E-05	7.14E-06	8.7E-07	1.73E-09	7E-17	3.47E-39	2.2E-200	0	0	3.5E-115	3.52E-77	4.02E-59	7.29E-49	2.36E-42
1.94E-07	5.54E-07	1.46E-06	3.37E-06	6.17E-06	7.85E-06	6.52E-06	2.05E-06	1.31E-07	2.15E-10	1.4E-16	3.08E-31	9.28E-72	0	0	0	1.8E-169	9.2E-109	2.15E-80	1.71E-64
7.97E-07	1.78E-06	3.53E-06	5.83E-06	7.36E-06	6.17E-06	3.23E-06	8.47E-07	1.44E-08	4.39E-11	2.1E-16	3.25E-27	2.45E-51	3.5E-115	0	0	0	1.3E-234	4.3E-146	3.3E-105
2.02E-06	3.57E-06	5.4E-06	6.54E-06	5.83E-06	3.37E-06	1.17E-06	2.24E-07	1.43E-08	3.71E-12	2.7E-16	8.06E-25	2.14E-41	3.52E-77	1.8E-169	0	0	0	0	3.7E-189
3.54E-06	5.01E-06	5.89E-06	5.4E-06	3.53E-06	1.46E-06	3.23E-07	4.18E-08	2.63E-09	3.13E-11	3.5E-17	3.03E-23	1.22E-35	4.02E-59	9.2E-109	1.3E-234	0	0	0	0
4.66E-06	5.35E-06	5.01E-06	3.57E-06	1.78E-06	5.54E-07	9.17E-08	6.51E-09	2.83E-10	5.23E-12	8.93E-15	1.21E-23	6.26E-32	7.29E-49	2.15E-80	4.3E-146	0	0	0	0
4.91E-06	4.66E-06	3.54E-06	2.02E-06	7.97E-07	1.94E-07	2.53E-08	1.44E-09	2.74E-11	3.63E-13	1.75E-15	3.31E-19	1.54E-31	2.36E-42	1.71E-64	3.3E-105	3.7E-189	0	0	0

Figure 4.13: SOx Concentrations of North West and North East directions

- Resultant Monthyl Average Concentrations

NOx CONCERNTRATION

4.78E-07	4.53E-07	3.45E-07	1.97E-07	7.76E-08	1.9E-08	5.11E-09	5.1E-08	3.65E-07	9.77616E-07	9.78E-07	3.65E-07	5.11E-08	6.61E-09	3.25E-08	1.46E-07	4.05E-07	7.62E-07	1.05E-06	1.12E-06
4.53E-07	5.21E-07	4.87E-07	3.48E-07	1.73E-07	5.39E-08	9.82E-09	3.13E-08	3.22E-07	1.04268E-06	1.04E-06	3.22E-07	3.17E-08	1.57E-08	9.77E-08	3.48E-07	7.6E-07	1.12E-06	1.22E-06	1.05E-06
3.45E-07	4.87E-07	5.73E-07	5.25E-07	3.44E-07	1.42E-07	3.17E-08	1.95E-08	2.68E-07	1.11306E-06	1.11E-06	2.68E-07	2.19E-08	5.5E-08	2.76E-07	7.4E-07	1.21E-06	1.34E-06	1.12E-06	7.62E-07
1.97E-07	3.48E-07	5.25E-07	6.37E-07	5.67E-07	3.28E-07	1.14E-07	2.78E-08	2.04E-07	1.1872E-06	1.19E-06	2.05E-07	4.04E-08	2.09E-07	6.92E-07	1.3E-06	1.49E-06	1.21E-06	7.6E-07	4.05E-07
7.76E-08	1.73E-07	3.44E-07	5.67E-07	7.16E-07	6.01E-07	3.14E-07	8.39E-08	1.35E-07	1.26068E-06	1.26E-06	1.36E-07	1.33E-07	6.17E-07	1.37E-06	1.68E-06	1.3E-06	7.4E-07	3.48E-07	1.46E-07
1.89E-08	5.39E-08	1.42E-07	3.28E-07	6.01E-07	7.64E-07	6.34E-07	2E-07	6.19E-08	1.33996E-06	1.34E-06	6.88E-08	3.63E-07	1.44E-06	1.88E-06	1.37E-06	6.92E-07	2.77E-07	9.77E-08	3.25E-08
2.46E-09	8.92E-09	3.15E-08	1.14E-07	3.14E-07	6.34E-07	1.04E-06	6.95E-07	8.98E-08	1.31229E-06	1.31E-06	1.51E-07	1.47E-06	2.51E-06	1.44E-06	6.17E-07	2.09E-07	5.48E-08	1.48E-08	3.96E-09
1.4E-10	6.33E-10	4.07E-09	2.18E-08	8.24E-08	2E-07	6.95E-07	1.35E-06	5.9E-07	1.57557E-06	1.58E-06	1.35E-06	3.85E-06	1.47E-06	3.63E-07	1.32E-07	3.44E-08	6.45E-09	9.95E-10	2.18E-10
2.67E-12	2.76E-11	2.56E-10	1.39E-09	1.4E-09	1.27E-08	8.47E-08	5.9E-07	2.08E-06	1.03264E-06	1.2E-06	1.04E-05	1.35E-06	1.46E-07	1.96E-08	2.16E-09	2.13E-09	3.93E-10	4.24E-11	4.11E-12
3.56E-14	5.1E-13	3.05E-12	3.61E-13	4.27E-12	2.09E-11	1.68E-10	2.8E-09	1.26E-07	3.32442E-05	7.5E-05	2.97E-07	4.32E-09	2.58E-10	3.21E-11	6.55E-12	5.53E-13	4.68E-12	7.81E-13	5.43E-14
5.43E-14	7.81E-13	4.68E-12	5.53E-13	6.55E-12	3.21E-11	2.58E-10	4.32E-09	2.97E-07	7.31879E-05	3.32E-05	1.26E-07	2.8E-09	1.68E-10	2.09E-11	4.27E-12	3.61E-13	3.05E-12	5.1E-13	3.56E-14
4.1E-12	4.23E-11	3.93E-10	2.13E-09	2.16E-09	1.96E-08	1.46E-07	1.35E-06	1.04E-05	1.20238E-06	1.03E-06	2.08E-06	5.9E-07	8.47E-08	1.27E-08	1.4E-09	1.39E-09	2.56E-10	2.76E-11	2.67E-12
2.18E-10	9.95E-10	6.45E-09	3.44E-08	1.32E-07	3.63E-07	1.47E-06	3.85E-06	1.35E-06	1.57668E-06	1.58E-06	5.9E-07	1.35E-06	6.95E-07	2E-07	8.24E-08	2.18E-08	4.07E-09	6.34E-10	1.4E-10
3.96E-09	1.48E-08	5.48E-08	2.09E-07	6.17E-07	1.44E-06	2.51E-06	1.47E-06	1.51E-07	1.31219E-06	1.31E-06	8.98E-08	6.95E-07	1.04E-06	6.34E-07	3.14E-07	1.14E-07	3.15E-08	8.93E-09	2.46E-09
3.25E-08	9.77E-08	2.76E-07	6.92E-07	1.37E-06	1.88E-06	1.44E-06	3.63E-07	6.88E-08	1.33979E-06	1.34E-06	6.19E-08	2E-07	6.34E-07	7.64E-07	6.01E-07	3.28E-07	1.42E-07	5.39E-08	1.89E-08
1.46E-07	3.48E-07	7.4E-07	1.3E-06	1.68E-06	1.37E-06	6.17E-07	1.33E-07	1.36E-07	1.26055E-06	1.26E-06	1.35E-07	8.39E-08	3.14E-07	6.01E-07	7.17E-07	5.67E-07	3.44E-07	1.74E-07	7.76E-08
4.05E-07	7.6E-07	1.21E-06	1.49E-06	1.3E-06	6.92E-07	2.09E-07	4.04E-08	2.05E-07	1.18707E-06	1.19E-06	2.04E-07	2.78E-08	1.14E-07	3.28E-07	5.67E-07	6.37E-07	5.25E-07	3.48E-07	1.97E-07
7.62E-07	1.12E-06	1.34E-06	1.21E-06	7.4E-07	2.76E-07	5.5E-08	2.19E-08	2.68E-07	1.11294E-06	1.11E-06	2.68E-07	1.95E-08	3.17E-08	1.42E-07	3.44E-07	5.25E-07	5.73E-07	4.88E-07	3.45E-07
1.05E-06	1.22E-06	1.12E-06	7.6E-07	3.48E-07	9.77E-08	1.57E-08	3.17E-08	3.22E-07	1.04254E-06	1.04E-06	3.22E-07	3.13E-08	9.83E-09	5.39E-08	1.73E-07	3.48E-07	4.87E-07	5.21E-07	4.54E-07
1.12E-06	1.05E-06	7.62E-07	4.05E-07	1.46E-07	3.25E-08	6.61E-09	5.11E-08	3.65E-07	9.77516E-07	9.78E-07	3.65E-07	5.1E-08	5.11E-09	1.9E-08	7.76E-08	1.97E-07	3.45E-07	4.54E-07	4.78E-07

SOx CONCERNTRATION

8E-07	7.6E-07	5.77E-07	3.3E-07	1.3E-07	3.18E-08	8.56E-09	8.55E-08	6.11E-07	1.64E-06	1.64E-06	6.11E-07	8.56E-08	1.11E-08	5.45E-08	2.44E-07	6.78E-07	1.28E-06	1.75E-06	1.87E-06
7.6E-07	8.73E-07	8.16E-07	5.82E-07	2.91E-07	9.03E-08	1.65E-08	5.25E-08	5.39E-07	1.75E-06	1.75E-06	5.39E-07	5.31E-08	2.63E-08	1.64E-07	5.83E-07	1.27E-06	1.88E-06	2.04E-06	1.75E-06
5.77E-07	8.16E-07	9.6E-07	8.8E-07	5.75E-07	2.38E-07	5.31E-08	3.27E-08	4.49E-07	1.86E-06	1.86E-06	4.49E-07	3.67E-08	9.21E-08	4.63E-07	1.24E-06	2.02E-06	2.25E-06	1.88E-06	1.28E-06
3.3E-07	5.82E-07	8.8E-07	1.07E-06	9.5E-07	5.49E-07	1.9E-07	4.65E-08	3.42E-07	1.99E-06	1.99E-06	3.44E-07	6.76E-08	3.5E-07	1.16E-06	2.17E-06	2.5E-06	2.02E-06	1.27E-06	6.78E-07
1.3E-07	2.91E-07	5.75E-07	9.5E-07	1.2E-06	1.01E-06	5.26E-07	1.41E-07	2.26E-07	2.11E-06	2.11E-06	2.27E-07	2.24E-07	1.03E-06	2.3E-06	2.81E-06	2.17E-06	1.24E-06	5.83E-07	2.44E-07
3.17E-08	9.03E-08	2.38E-07	5.49E-07	1.01E-06	1.28E-06	1.06E-06	3.34E-07	1.04E-07	2.24E-06	2.24E-06	1.15E-07	6.09E-07	2.42E-06	3.14E-06	2.3E-06	1.16E-06	4.63E-07	1.64E-07	5.44E-08
4.12E-09	1.49E-08	5.27E-08	1.9E-07	5.26E-07	1.06E-06	1.75E-06	1.16E-06	1.5E-07	2.2E-06	2.2E-06	2.52E-07	2.45E-06	4.2E-06	2.42E-06	1.03E-06	3.5E-07	9.18E-08	2.48E-08	6.63E-09
2.35E-10	1.06E-09	6.81E-09	3.66E-08	1.38E-07	3.34E-07	1.16E-06	2.26E-06	9.89E-07	2.64E-06	2.64E-06	2.27E-06	6.46E-06	2.45E-06	6.08E-07	2.21E-07	5.77E-08	1.08E-08	1.67E-09	3.65E-10
4.47E-12	4.62E-11	4.29E-10	2.33E-09	2.35E-09	2.13E-08	1.42E-07	9.89E-07	3.49E-06	1.73E-06	2.02E-06	1.74E-05	2.27E-06	2.44E-07	3.29E-08	3.62E-09	3.58E-09	6.59E-10	7.1E-11	6.88E-12
5.96E-14	8.55E-13	5.11E-12	6.05E-13	7.16E-12	3.51E-11	2.82E-10	4.69E-09	2.11E-07	5.57E-05	0.000126	4.97E-07	7.24E-09	4.32E-10	5.38E-11	1.1E-11	9.27E-13	7.84E-12	1.31E-12	9.1E-14
9.1E-14	1.31E-12	7.84E-12	9.27E-13	1.1E-11	5.38E-11	4.32E-10	7.24E-09	4.97E-07	0.000123	5.56E-05	2.11E-07	4.69E-09	2.82E-10	3.51E-11	7.16E-12	6.05E-13	5.11E-12	8.55E-13	5.96E-14
6.87E-12	7.09E-11	6.59E-10	3.58E-09	3.62E-09	3.29E-08	2.44E-07	2.27E-06	1.74E-05	2.01E-06	1.73E-06	3.49E-06	9.89E-07	1.42E-07	2.13E-08	2.35E-09	2.33E-09	4.3E-10	4.62E-11	4.48E-12
3.65E-10	1.67E-09	1.08E-08	5.77E-08	2.21E-07	6.08E-07	2.45E-06	6.46E-06	2.27E-06	2.64E-06	2.64E-06	9.89E-07	2.26E-06	1.16E-06	3.34E-07	1.38E-07	3.66E-08	6.82E-09	1.06E-09	2.35E-10
6.63E-09	2.48E-08	9.18E-08	3.5E-07	1.03E-06	2.42E-06	4.2E-06	2.45E-06	2.52E-07	2.2E-06	2.2E-06	1.5E-07	1.16E-06	1.75E-06	1.06E-06	5.26E-07	1.9E-07	5.28E-08	1.5E-08	4.13E-09
5.44E-08	1.64E-07	4.63E-07	1.16E-06	2.3E-06	3.14E-06	2.42E-06	6.09E-07	1.15E-07	2.24E-06	2.24E-06	1.04E-07	3.34E-07	1.06E-06	1.28E-06	1.01E-06	5.5E-07	2.38E-07	9.04E-08	3.17E-08
2.44E-07	5.83E-07	1.24E-06	2.17E-06	2.81E-06	2.3E-06	1.03E-06	2.24E-07	2.27E-07	2.11E-06	2.11E-06	2.26E-07	1.41E-07	5.26E-07	1.01E-06	1.2E-06	9.5E-07	5.76E-07	2.91E-07	1.3E-07
6.78E-07	1.27E-06	2.02E-06	2.5E-06	2.17E-06	1.16E-06	3.5E-07	6.76E-08	3.44E-07	1.99E-06	1.99E-06	3.42E-07	4.65E-08	1.9E-07	5.5E-07	9.5E-07	1.07E-06	8.8E-07	5.83E-07	3.3E-07
1.28E-06	1.88E-06	2.25E-06	2.02E-06	1.24E-06	4.63E-07	9.21E-08	3.67E-08	4.49E-07	1.86E-06	1.86E-06	4.49E-07	3.27E-08	5.31E-08	2.38E-07	5.76E-07	8.8E-07	9.6E-07	8.17E-07	5.78E-07
1.75E-06	2.04E-06	1.88E-06	1.27E-06	5.83E-07	1.64E-07	2.63E-08	5.31E-08	5.39E-07	1.75E-06	1.75E-06	5.39E-07	5.25E-08	1.65E-08	9.03E-08	2.91E-07	5.82E-07	8.17E-07	8.73E-07	7.6E-07
1.87E-06	1.75E-06	1.28E-06	6.78E-07	2.44E-07	5.45E-08	1.11E-08	8.56E-08	6.11E-07	1.64E-06	1.64E-06	6.11E-07	8.55E-08	8.56E-09	3.18E-08	1.3E-07	3.3E-07	5.78E-07	7.6E-07	8E-07

Figure 4.14: Monthly average NOx and Sox Concentrations

4.3 SUMMARY OF POLLUTION LEVELS

The summary of the NOx and SOx concentrations and the maximum pollution levels can be tabulated as below.

Table 4.4: Summary of the pollution levels of two plants

	LakVijaya Coal Power Plant	Trincomalee Coal Power Plant
Maximum NOx Level	139 μg/m³	75 μg/m³
Maximum SOx Level	19.6 μg/m³	126 μg/m³
Location of the Maximum Level	around 1-1.5 km away from the plant of the stack	about1-1.5 km away from the plant of the stack

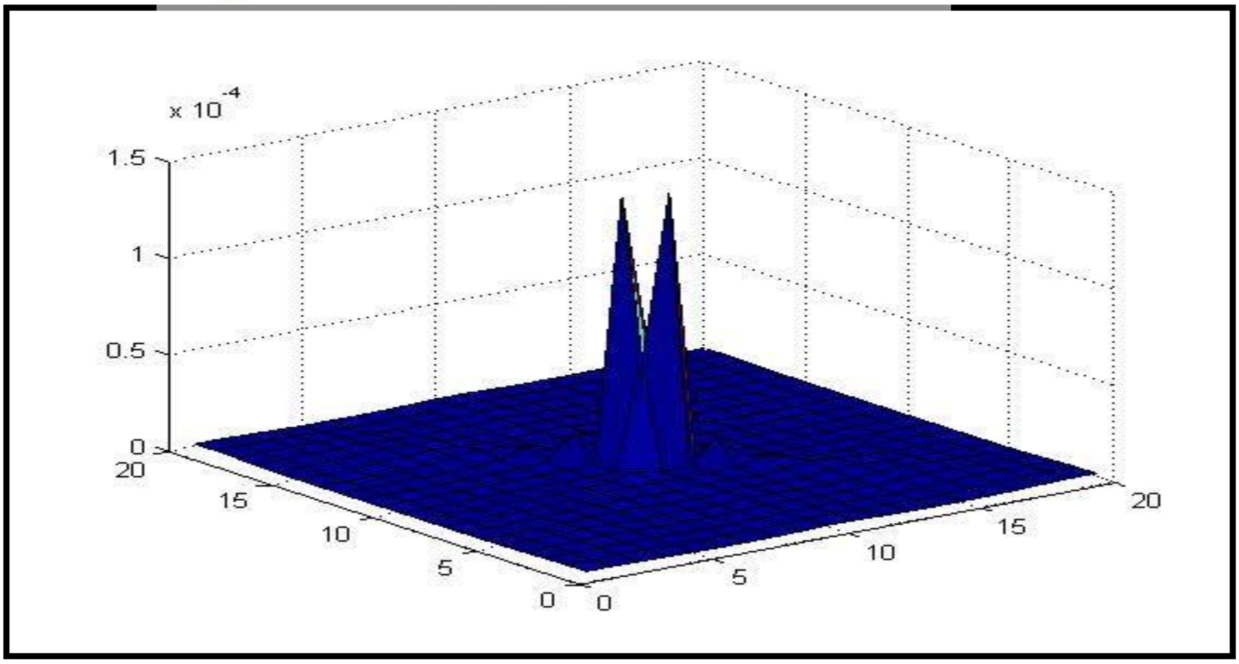


Figure 4.15: Graphical representation of pollution concentrations

4.4 ANALYSIS OF POLLUTION LEVELS

Pollution levels of the proposed site of Trincomalee coal power plant was measured by the Environmental Technology Section of Industrial Technology Institute (ITI), Colombo 07 for the Environmental Impact Assessment Report which was prepared by MANTEC Consultants (PVT) Ltd., New Delhi.

In this study also, the area for this air dispersion modeling was taken as the area covered by 20 km from the boundary of the proposed coal power plant site at Sampoor. The air dispersion modeling was carried out for SO2, NOx and PM under two scenarios and five cases. The forecasted ambient concentrations of SO2 and NOx were averaged for 1-hr, 8-hr and 24-hr while PM was averaged for 24-hr and annual. Further the predicted maximum emission concentrations were compared with their corresponding Ambient Air Quality (AAQ) standard. (Given in Appendix 06)

Table 4.5: Summary of the results predicted by the air dispersion modelling study

Air Quality Parameter	**Predicted Maximum SO2 Concentration [µg/m3]**			**Predicted Maximum NOX Concentration [µg/m3]**		
Averaging Period	1hr	hr 8	hr 24	1hr	hr 8	hr 24
AAQ Standard	200	120	80	250	150	100
Maximum Concentration	117.54	43.30	21.36	137.0	50.45	24.88

Source: Report on Air Dispersion Modelling Study for Proposed 500mw Coal Power Plant at Sampoor by ITI, Colombo 07

The corresponding values of the research are averaged to monthly as the relevant wind data are only available in monthly wise.

Table 4.6: Comparison of research values and ITI values

Pollutant	SOx	NOx
Maximum Concentration (per month)	126 µg/m³	75 µg/m³
Maximum Concentration (per day)	4.2 µg/m³	2.5 µg/m³
Values of ITI	21.36	24.88
AAQ Standard	80	100

The research values are significantly lower than the values obtained by ITI and both are not exceeding the AAQ limits. The reasons for the deviations can be listed as below.

- Values obtained by ITI were calculated using the software program "Industrial Source Complex AMS/EPA Regulatory Model" (ISC-AERMOD View) software 'Version 8.5.1' which was developed by Lakes Environmental, USA. The detailed description of the features of the model is given in Appendix 05. Values of the research were obtained using Gaussian plume dispersion model in MS Excel using data matrixes. The specimen workbooks prepared to obtain SOx and NOx levels in LakVijaya power plant and Trincomalee power plant is shown in Appendix 01and 02.

- The predicted concentrations of the pollutants were averaged in to 1hour, 8 hour and 24 hour periods by the study of ITI. The values of the research are obtained to monthly average periods as the wind data of the meteorological department are only available in monthly levels.

- Meteorological data were obtained by purchasing MM5 meteorological preprocessed data (AERMET Ready) from the Lakes Environment Software by sending the satellite image of the study area obtained from 'Google Earth'. Then the required upper air data and hourly surface data were purchased from the Lakes Environment Software to use as inputs to the ISC-AERMOD View software. In the research, the relevant monthly surface meteorological data are obtained only from the Department of Meteorology, Colombo 07.Thus the accuracy of meteorological input data of the ITI study may be higher compared to the research data.

- Terrain values for receptor grids were imported from the Lakes Environmental official website for the study of ITI while the corresponding values for study of the research were obtained using Google Earth.

The main negative aspect of the software ISC-AERMOD method is the significant high cost for meteorological data purchasing. For Sampoor coal power plant study, about 200000 LKR were paid for data acquiring by the ITI. Therefore, by further implementing the research method, preliminary air quality studies can be done simply and cost-effectively.

ECONOMIC VALUATION

5.1 PROCEDURE

The economic valuation procedure can be sub devided in to four main steps.

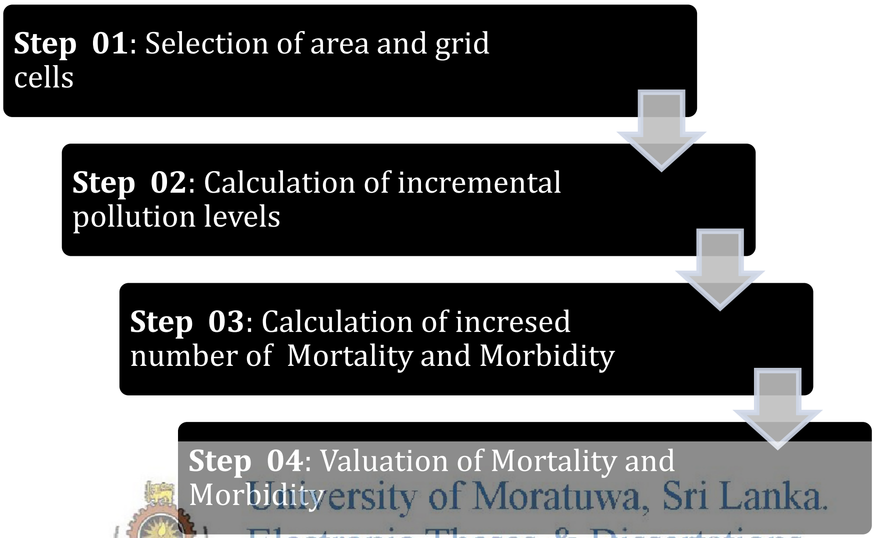


Figure 5.1: Main steps of economic valuation procedure

The procedure follows the steps of the case study which was done for selected sites for a super critical coal power plant proposed by the government of India which would be located in Cheyyur in Kancheepuram district in of Tamil Nadu. It is illustrated in Appendix 07.

5.2 STEP 01: SELECTION OF AREA AND GRID CELLS

LakVijaya power plant is selected as the case study for the economic valuation of the external cost or the social damage cost (as per the LTGEP 2013-2032). A 100km area consisting with 400 rectangular grid cells from the plant is considered and each cell is 5km long and 10 km wide.

Figure 5.2: Selected area for the case study of economic valuation

The pollution level of the area is obtained by grid cell wise according to the same method described in the chapter 04.The direction wise NOx and SOx distributions are shown in Appendix 03.

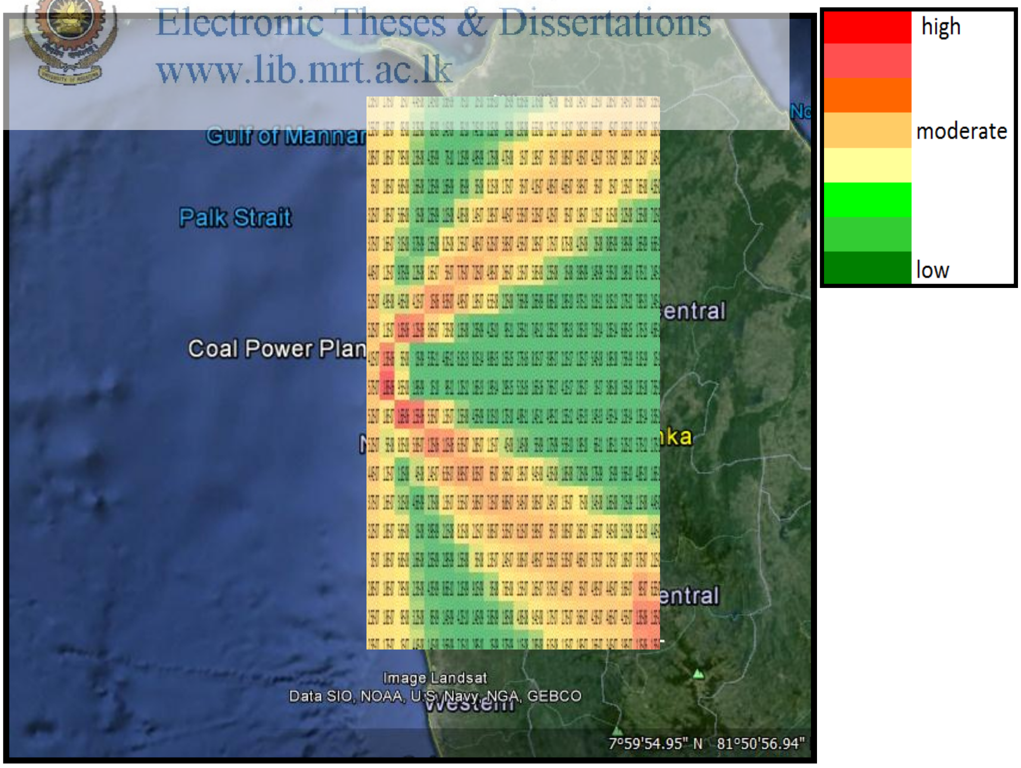


Figure 5.3: Pollution concentrations of NOx and SOx in the case study area

5.3 STEP 02: CALCULATION OF INCREMENTAL POLLUTION LEVELS

There are nine districts which covered by the case study area. The relevant most recent population of each districts are given in table 3.9.The number of affected population in each district is obtained by assuming that the area covering in each district is proportional to the pretentious population.

Table 5.1: The number of affected population in each district

Districts covered by the case study area	Approximate percentage covered area	Relevant Population for the case study
Puttalam	100%	762396
Kurunagala	100%	1618466
Gampaha	50%	1152417
Kegalle	50%	420324
Anuradhapura	60%	516345
Vavuniya	60%	103269
Mannar	50%	49785
Kandy	25%	343846
Matale	25%	121133

Then the relevant incremental pollution level of NOx and SOx are obtained using the monthly average pollution concentration matrix. The pollution levels are converted into per 10 μg/m³ values in order to refer the DRF of HEI estimates.

The pollution levels gained from the research model are assumed as the incremental pollution levels by setting the initial levels 0.Then the monthly values are converted in to annual values as the mortality and morbidity levels are stated in per annum numbers.

Table 5.2: The incremental pollution level in each district

Districts covered by the case study area	Relevant Population for the case study	NOx Increment per 10 µg/m³	SOx Increment per 10 µg/m³
Puttalam	762,396	2.1480	0.4620
Gampaha	1618466	0.3048	0.0656
Kegalle	1152416.5	0.5532	0.1117
Vavuniya	420324	0.4740	0.1022
Mannar	516345	0.0355	0.0077
Kandy	103269	1.5600	0.3372
Matale	49785	0.0523	0.0113
Kurunagala	343846	1.0632	0.2292
Anuradhapura	121133	0.9216	0.1980

5.4 STEP 03: CALCULATION OF INCRESED NUMBER OF MORTALITY AND MORBIDITY

The increased number of mortality and morbidity are obtained for each district by means of the DRF of HEI estimates, 2010 (shown in table 2.4 and table 2.5) and annual mortality and morbidity rates of Sri Lanka. (Shown in table 3.10)

Table 5.3: Summary of the incremental mortality and morbidity levels

Pollutant	**Percent change per 10 µg/m³**	
	Mortality	Morbidity
NOx	3.8	0.92
SOx	4.35	0.51

According to the incremental pollution levels obtained in table 5.2, the relevant increments of mortality and morbidity levels for each district can be calculated. Then, the total number of mortality and morbidity increments due to the plant emissions can be obtained. As per the DRF summary, the percentage of mortality and morbidity increments can be tabulated.

Table 5.4: Percentage increment of mortality and morbidity levels

Districts	NOx Increment per 10 µg/m³	SOx Increment per 10 µg/m³	Percent change in mortality as per DRF		Percent change in morbidity as per DRF	
			For NOx	For SOx	For NOx	For SOx
Puttalam	2.1480	0.4620	8.1624	2.0097	1.9762	0.2356
Gampaha	0.3048	0.0656	1.1582	0.2855	0.2804	0.0334
Kegalle	0.5532	0.1117	2.1022	0.4860	0.5089	0.0570
Vavunia	0.4740	0.1022	1.8012	0.4447	0.4361	0.0521
Mannar	0.0355	0.0077	0.1350	0.0335	0.0327	0.0040
Kandy	1.5600	0.3372	5.9280	1.4668	1.4352	0.1720
Matale	0.0523	0.0113	0.1988	0.0491	0.0481	0.0056
Kurunagala	1.0632	0.2292	4.0401	0.9970	0.9781	0.1169
Anuradhapura	0.9216	0.1980	3.5020	0.8613	0.8479	0.1010

The increased mortality and morbidity numbers can be obtained by means of the population data of each district, mortality and morbidity statistics of Sri Lanka and the percentage increments. Hence, the total mortality increments and morbidity increments due to the air pollutants emitted by the plant can be calculated.

Table 5.5: Increased numbers of the mortality rates

Districts	Total Morbidity as statistics	Increased morbidity per year due to increment%	
		For NOx	For SOx
Puttalam	16773	331	40
Gampaha	25353	71	8
Kegalle	9247	47	5
Vavunia	2272	10	1
Mannar	1095	1	1
Kandy	7565	109	13
Matale	2665	1	0
Kurunagala	35606	348	42
Anuradhapura	11360	96	11

Table 5.6: Increased numbers of the morbidity rates

Districts	Total Mortality as statistics	Increased mortality per year due to increment%	
		For NOx	For SOx
Puttalam	107	9	2
Gampaha	161	2	0
Kegalle	59	1	0
Vavunia	14	0	0
Mannar	7	0	0
Kandy	48	3	1
Matale	17	0	0
Kurunagala	227	9	2
Anuradhapura	72	3	1

Table 5.7: Summary of the increment of impacts due to air pollutant of the plant

Total mortality of the case study area	712	**Total morbidity of the case study area**	111936
Mortality Increment due to Coal power plant	33	Morbidity Increment due to Coal power plant	1135
Percentage Increment	**4.6%**	Percentage Increment	**1.1%**

5.5 STEP 04: VALUATION OF MORTALITY AND MORBIDITY

The valuation of mortality and morbidity is the final step of the external cost valuation procedure. There are no comprehensive studies done to estimate Value of Statistical Life (VSL) and Cost of Illness (COI) related to the pollutants associated with the power sector in Sri Lanka. Therefore, it is recommended by the World Bank to use VSL and COI values of other countries based on the respective GDP ratios of the two countries. Hence the corresponding values of India-state of Tamil Nadu (as illustrated in Appendix 07) are used for the study.

Table 5.8: GDP levels of India-Tamil Nadu and Sri Lanka

	India-State of Tamil Nadu	**Sri Lanka**
Gross Domestic Product	150 billion USD	67.18 billion USD
GDP ratio (Sri Lanka / India)	0.45	

Sources: World Bank 2013

State Domestic Product and other aggregates, 2004-05 series, Ministry of Statistics and Programme Implementation, India, 27 February 2015

Based on the above GDP ratio and the VSL and COI of Tamil Nadu, the corresponding valuation basis for Sri Lanka can be obtained.

Table 5.9: GDP levels

For Sri Lanka		
VSL	149400 USD	per incidence/per person
COI	909.9 USD	per incidence/per person

Then the valuation of the mortality and morbidity levels for the case study can be calculated.

Table 5.10: Valuation estimates for the case study

Item	Increased Incidence	Valuation basis	Valuation Estimates
Mortality	33	149400	4930200 USD
Morbidity	1135	910	1123726.5 USD
Total			6053926.5 USD

The total cost estimate is converted into standard US Cents per kWh, in order to compare with the social damage cost of the LTGEP 2012-2032.

Table 5.11: Social damage cost for coal power generation

For year	5995214.256	US $
For8760 h	5995214.256	US $
For h	684.385	US $/h
For 900 MW	684.385	US $/h
For 1kWh	0.00076	US $/kWh
	0.08	US Cents/kWh

Chapter 6

RESULTS

6.1 COMPARISON

The social damage cost used for the coal power studies in LTGEP 2013-2032 is slightly higher than the value obtained by the research.[7]

Table 6.1: Social damage cost comparison

Social Damage Cost used for the coal power plants in LTGEP 2013-2032	**Social Damage Cost obtained by the research**
0.13 US Cents/kWh	**0.08 US Cents/kWh**

0.13 US Cents/kWh is a directly captured value from World Bank Six Cities Study (Santiago, Krakow, Mumbai, Shanghai, Manila and Bangkok). [8] Also, in Environmental Impact Assessment Report for Trincomalee coal power plant project (2x250 MW)- January, 2015 by Mantec Consultants (Pvt.) Ltd., New Delhi, no monetary valuation is done and only mitigation actions were described.

Table 6.2: Social Damage Cost Estimates of some other studies

Study	**Country**	**Fuel**	**External Cost Range (US cents/kWh)**
Schuman and Cavanagh (1982)	US	Coal	0.06- 44.07
Van Horen (1996)	South Africa	Coal	0.90-5.01
Resources for the Future (1994-98)	US	Oil	0.04-0.32
Resources for the Future (1994-98)	US	Gas	0.01-0.03
Friedrich and Kallenbach (1991)	Germany	Coal	0.36-0.86
Resources for the Future (1994-98)	US	Coal	0.11-0.48
Regional Economic Research Inc.(1994)	US	Oil	0.03-5.81
European Commission (1999)	US	Gas	0.003-0.48
European Commission (1999)	Sweden	Coal	0.84-16.93

Source: Valuation of Health Impacts of Air Pollution from Power Plants in Asia: A Practical Guide by Herath Gunatilake, Karthik Ganesan, and Eleanor Bacani

Thus, it can be concluded that the value obtained by the research is s realistic to some extent.

Chapter 7

SENSITIVITY ANALYSIS

The In this chapter, the analysis is extended to examine the variation of the output by considering uncertainty in the estimation of physical impacts and their valuation.

The key sensitivity parameters of the external cost for coal power generation can be listed as below.

- GDP ratio
- Dose Response Function
- Mortality Rate
- Morbidity Rate
- Value of Statistical Life
- Cost of Illness
- Pollution Concentration

Calculations of sensitivity analysis are done to examine how much the total external costs change in response to a change in a given sensitivity parameter value. The detailed sensitivity analysis calculations are shown in Appendix 04.

Table 7.1: Summary of the sensitivity analysis

Parameter	Increment% of the External Cost	
	10% Increment	50% Increment
GDP ratio of India/Sri Lanka	10.00	50.00
Dose Response Function Mortality	8.84	44.20
Dose Response Function Morbidity	1.15	5.79
Mortality Rate	8.84	44.20
Morbidity Rate	1.15	5.79
Value of Statistical Life	8.84	44.20
Cost of Illness	1.15	5.79
Pollution Concentration	10.00	50.00

Chapter 8

RESEARCH LIMITATIONS

As discussed in the previous chapters, the result of the research is built with several important assumptions and limitations which are listed below.

- Applying of HEI estimates for the quantification of mortality and morbidity outcomes
    - Due to the socioeconomic difference of the South Asian countries (Republic of Korea, Republic of China ,Hong Kong, Japan, Thailand, India ,Singapore and Malaysia) where HEI estimates were obtained, the actual responses to the air pollutants can be different

- VSL and COI values are obtained by means of the GDP ratio of India-State Tamil Nadu and Sri Lanka based on the respective values of a study of India
    - Variation of the GDP ratio can cause the variation of the Social Damage Cost in significant mannar
    - When the GDP ratio is varying into 5 times of its initial value, external cost will be varied to 0.08 US Cents/kWh to 0.38 US Cents/kWh (As per the table 8.1)
    - 0.13 US Cents/kWh lies in between 1.5 times and 2 times of the GDP ratio
    - Thus,the both the reaserch value and the value of LTGEP can be to be considered as realistic

- Usage of district base mortality and morbidity rates for the valuation due to the unavailability of the city wise data
    - The actual number of affected people in each district can be different

Table 8.1: Variation of the social damage cost for diferent GDP ratios

	India	**Sri Lanka**									
		GDP ratio									
		Initial value	**x 1**	**x 1.5**	**x 2**	**x 2.5**	**x 3**	**x 3.5**	**x 4**	**x 4.5**	**x 5**
VSL (USD)	332000	**0.45**	149400	224100	298800	373500	448200	522900	597600	672300	747000
COI (USD)	2022		909.9	1364.85	1819.8	2274.75	2729.7	3184.65	3639.6	4094.55	4549.5
Social Damage Cost (USD)			5962936.5	8944404.75	11925873	14907341.25	17888809.5	20870277.75	23851746	26833214.25	29814682.5
Social Damage Cost (US Cents/kWh)			0.075	0.113	0.151	0.189	0.226	0.264	0.302	0.34	0.378
			0.08	**0.11**	**0.15**	**0.19**	**0.23**	**0.26**	**0.3**	**0.34**	**0.38**

Chapter 9

CONCLUSION

Valuation of cost of externality is an important issue in modern society. Especially when considering the power sector, it is a vital fact to monetary value the social and environmental damages that could be occurred due to each power generation technique in order to make proper policy decisions. It is further aid to gain optimum, green power generation mix with sustainable development as well.

In order to full fill this requirement, an estimated value of 0.13 US Cents/kWh was added as the social damage cost for coal power generation in LTGEP, (2012 -2032) for the first time by the Generation Planning unit of CEB.

Thus in the research ,value of 0.08 US Cents/kWh is obtained through pollution level calculation by means of Gaussian plume dispersion model and monetary valuation of health impacts by making certain assumptions and limitations.

According to the sensitivity analysis, GDP ratio and the pollution concentrations are the most susceptible parameters for the external cost output. If the GDP ratio is changed from initial value up to 5 times, the external cost value will change from 0.08 US Cents/kWh to 0.38 US Cents/kWh. The external cost values for thermal generation options of various other countries have similar range of values. This reveals that both the research value and the value of LTGEP are realistic for some extent. Mortality rate and Dose Response Function of Mortality are also having significant effect to the output of external cost next to the previously mentioned parameters. However, Mortality rates and Morbidity rates are only available in district wise and latest health and economic statistics are also unavailable. So the actual number of affected people can be different. In the same time, wind profile owns a significant effect to the output of the pollution level calculation that can affect the final results. Though the available meteorological data may not much precise, it has to be rely on the obtained data.

Therefore, in order to improve the results, a national wise rigorous valuation method should be implemented for loss of human life and cost of illness valuations due to air pollutants by means ofappropriate local research studies. Also, available regulatory measures of pollution control must be strengthen while rigorous monitoring programs should be implemented. By achieving these targets, more pragmatic value for the external cost can be attained.

For further research, pollution levels and health cost due to PM can also be obtained as it is not included in this study due to its lower emission level compared to SOx and NOx levels. Also, this method can be applied for other thermal generation options such as Diesel engines and Gas turbines.

Finally, if the model discussed in the research will be further enhanced with the aid of above mentioned particulars and much more accurate and realistic data, it can be recommended for Generation Planning unit of CEB to implement the valuation method for pre-feasibility studies of selecting optimum coal power plant mix out of several proposed plant selections and sites. Further, the method can be proposed for other thermal generation options if the research model will be extended to other thermal generation techniques.

REFERENCES

[1] European Commission, Directorate-General XII, Science, Research and Development, "EXTERNE, EXTERNALATIES OF ENERGY", Vol.1: SUMMARY, EUR 16520 EN, 1995

[2] Herath Gunatilake, Karthik Ganesan, and Eleanor Bacani, "Valuation of Health Impacts of Air Pollution from Power Plants in Asia: A Practical Guide", ADB South Asia working paper series, NO. 30, October 2014

[3] ETSU and Metroeconomica ," EXTERNALITIES OF ENERGY-EXTERNE PROJECT", Volume 2, METHODOLOGY, Method for Estimation of Physical Impacts and Monetary Valuation for Priority Impact Pathways, Bridport ,UK, Part 1: Impact Assessment, Part 2: Economic Valuation

[4] International Energy Agency, "Power Generation from Coal, Measuring and Reporting Efficiency Performance and CO2 Emissions", 2010

[5] Tarjanne Risto, Kivistö Aija, "COMPARISON OF ELECTRICITY GENERATION COSTS", LAPPEENRANTA UNIVERSITY OF TECHNOLOGY, 2008

[6] Energy Information Administration, "Electricity Generation and Environmental Externalities: Case Studies", Office of Coal, Nuclear, Electric and Alternate Fuels Coal and Electric Analysis Branch, U.S ,September 1995

[7] Ceylon Electricity Board, "Long Term Generation Expansion Plan- 2013-2032", August 2013

[8] Economic Consulting Associates, Resource Management Associates, Environmental Resources Management, "Sri Lanka: Environmental Issues in the Power Sector", November 2009

[9] Pasquill, F. "The estimation of the dispersion of windborne material" The Meteorological Magazine, volume 90, 1961

[10] SemaAwasthi, Mukesh Khare and Prashant Gargava, “General plume dispersion model for point sourceemission”

[11] Phil Dacunto and Mike Hendricks, “A Better Way to Illustrate Atmospheric Dispersion in the Classroom” Department of Geography and Environmental Engineering,United States Military Academy, West Point, NY

[12] Briggs, G.A., "Some recent analyses of plume rise observation", Proc. Second Internat', Clean Air Congress, Academic Press, New York, 1971

[13] Turner, “Workbook of Atmospheric Dispersion Estimates”, 1969

[14] Mantec Consultants (Pvt.) Ltd., “Environmental Impact Assessment Report for Trincomalee Thermal Power Project (2x250 MW) Trincomalee, Sri Lanka “, Volume-II: Annexures, New Delhi, India, January 2015

[15] Mantec Consultants (Pvt.) Ltd., “Environmental Impact Assessment Report for Trincomalee Thermal Power Project (2x250 MW) Trincomalee, Sri Lanka “, New Delhi, India , January 2015

[16] Harbin Power System Engineering & Research Institute Co., Ltd, “2 × 300MW Coal Power Project Puttalam II, Sri Lanka -Emissions Performance Test Procedure”, July 2014

[17] Bosanquet, C.H. and Pearson, J.L., "The spread of smoke and gases from chimneys", 1936

[18] Sutton, O.G., "The problem of diffusion in the lower atmosphere", QJRMS, 73:257, 1947 and "The theoretical distribution of airborne pollution from factory chimneys", QJRMS, 73:426, 1947

[19] “Solar GIS," [Online]. Available: http://solargis.info

APPENDIX 01: Pollution level of the 20km area around LakVijaya coal power plant, Norechcholei, Puttalam: Specimen Computation

Direction-North

Required Parameters

Q (g/s)	234 (NOx)
	50.4 (SOx)

H (m)	150

U (m/s)	1.375

Where , Q = Emission rate

H = Stack height

U = Wind speed

The Gaussian plume equation

$$C = \frac{Q}{2\,\pi u \sigma_z\, \sigma_y} . exp \frac{-y^2}{2{\sigma_y}^2} . exp \frac{-(\,H-z)^2}{2{\sigma_z}^2}$$

Where,

(*x, y, z*) = coordinates of the midpoint of a grid cell

σ_y and σ_y = Lateral and Vertical Dispersion coefficient

C = Pollution Concentration

Data Matrices of NOx Concentration

X (m)	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000
	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000
	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000
	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000
	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000
	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000
	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000
	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000
	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000
	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000
	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000
	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000
	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000
	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000

y (m)	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000

z(m)	0	0	0	0	0	0	0	0	4	7	6	1	0	0	2	13	26	56	60	51
	0	0	0	0	0	0	0	0	3	9	5	1	0	0	1	10	21	46	52	59
	0	0	0	0	0	0	0	0	1	8	3	0	0	0	0	7	23	43	46	55
	0	0	0	0	0	0	0	0	2	8	2	0	0	0	0	9	29	34	38	48
	0	0	0	0	0	0	0	0	2	7	3	0	0	0	0	16	20	22	27	36
	0	0	0	0	0	0	0	0	1	9	4	0	0	0	5	8	10	12	15	22
	0	0	0	0	0	0	0	0	1	10	3	0	0	1	3	4	6	18	21	14
	0	0	0	0	0	0	0	0	0	8	3	0	0	1	2	2	8	27	41	33
	0	0	0	0	0	0	0	0	0	6	5	1	0	0	0	5	12	32	52	53
	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	6	13	27	47	50
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	14	27	40	41
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	14	35	52	58
	0	0	0	0	0	0	0	0	0	0	0	1	4	4	4	11	15	34	61	69
	0	0	0	0	0	0	0	0	0	0	1	5	7	8	9	12	16	38	57	61
	0	0	0	0	0	0	0	0	0	0	0	4	8	8	11	16	37	42	42	44
	0	0	0	0	0	0	0	0	0	0	0	4	8	10	11	19	24	29	44	71
	0	0	0	0	0	0	0	0	0	0	0	3	6	7	11	15	20	30	41	64
	0	0	0	0	0	0	0	0	0	0	0	1	3	6	9	13	17	28	36	48
	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7	12	15	20	26	32
	0	0	0	0	0	0	0	0	0	0	0	0	2	4	5	9	13	19	27	34

σy (m)	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125
	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125
	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400

σz (m)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Data Matrices of NOx Concentration – 20 km area-Northern Direction

9E-20	5E-17	1E-14	2E-12	1E-10	3E-09	5E-08	4E-07	2E-06	3E-06	3E-06	2E-06	4E-07	5E-08	3E-09	1E-10	2E-12	1E-14	5E-17	9E-20
3E-22	4E-19	3E-16	1E-13	2E-11	1E-09	3E-08	3E-07	2E-06	4E-06	4E-06	2E-06	3E-07	3E-08	1E-09	2E-11	1E-13	3E-16	4E-19	3E-22
1E-25	9E-22	3E-18	3E-15	1E-12	2E-10	1E-08	2E-07	1E-06	4E-06	4E-06	1E-06	2E-07	1E-08	2E-10	1E-12	3E-15	3E-18	9E-22	1E-25
3E-30	2E-25	4E-21	2E-17	4E-14	2E-11	3E-09	1E-07	1E-06	4E-06	4E-06	1E-06	1E-07	3E-09	2E-11	4E-14	2E-17	4E-21	2E-25	3E-30
1E-36	2E-30	5E-25	3E-20	3E-16	8E-13	4E-10	4E-08	1E-06	5E-06	5E-06	1E-06	4E-08	4E-10	8E-13	3E-16	3E-20	5E-25	2E-30	1E-36
7E-46	6E-38	8E-31	1E-24	3E-19	7E-15	2E-11	1E-08	6E-07	5E-06	5E-06	6E-07	1E-08	2E-11	7E-15	3E-19	1E-24	8E-31	6E-38	7E-46
9E-68	2E-55	2E-44	8E-35	1E-26	1E-19	3E-14	4E-10	2E-07	5E-06	5E-06	2E-07	4E-10	3E-14	1E-19	1E-26	8E-35	2E-44	2E-55	9E-68
3E-114	1E-92	3E-73	2E-56	5E-42	5E-30	2E-20	3E-13	2E-08	5E-06	5E-06	2E-08	3E-13	2E-20	5E-30	5E-42	2E-56	3E-73	1E-92	3E-114
1E-264	6E-213	5E-167	8E-127	2E-92	1E-63	1E-40	2E-23	6E-12	3E-06	3E-06	6E-12	2E-23	1E-40	1E-63	2E-92	8E-127	5E-167	6E-213	1E-264
0	0	0	0	0	0	3E-270	5E-140	4E-53	1E-09	1E-09	4E-53	5E-140	3E-270	0	0	0	0	0	0
0	0	0	0	0	0	3E-270	5E-140	4E-53	1E-09	1E-09	4E-53	5E-140	3E-270	0	0	0	0	0	0
1E-264	6E-213	5E-167	8E-127	2E-92	1E-63	1E-40	2E-23	6E-12	3E-06	3E-06	6E-12	2E-23	1E-40	1E-63	2E-92	8E-127	5E-167	6E-213	1E-264
3E-114	1E-92	3E-73	2E-56	5E-42	5E-30	2E-20	3E-13	2E-08	5E-06	5E-06	2E-08	3E-13	2E-20	5E-30	5E-42	2E-56	3E-73	1E-92	3E-114
9E-68	2E-55	2E-44	8E-35	1E-26	1E-19	3E-14	4E-10	2E-07	5E-06	5E-06	2E-07	4E-10	3E-14	1E-19	1E-26	8E-35	2E-44	2E-55	9E-68
7E-46	6E-38	8E-31	1E-24	3E-19	7E-15	2E-11	1E-08	6E-07	5E-06	5E-06	6E-07	1E-08	2E-11	7E-15	3E-19	1E-24	8E-31	6E-38	7E-46
1E-36	2E-30	5E-25	3E-20	3E-16	8E-13	4E-10	4E-08	1E-06	5E-06	5E-06	1E-06	4E-08	4E-10	8E-13	3E-16	3E-20	5E-25	2E-30	1E-36
3E-30	2E-25	4E-21	2E-17	4E-14	2E-11	3E-09	1E-07	1E-06	4E-06	4E-06	1E-06	1E-07	3E-09	2E-11	4E-14	2E-17	4E-21	2E-25	3E-30
1E-25	9E-22	3E-18	3E-15	1E-12	2E-10	1E-08	2E-07	1E-06	4E-06	4E-06	1E-06	2E-07	1E-08	2E-10	1E-12	3E-15	3E-18	9E-22	1E-25
3E-22	4E-19	3E-16	1E-13	2E-11	1E-09	3E-08	3E-07	2E-06	4E-06	4E-06	2E-06	3E-07	3E-08	1E-09	2E-11	1E-13	3E-16	4E-19	3E-22

high

low

Data Matrices of SOx Concentration

X (m)	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000
	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000
	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000
	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000
	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000
	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000
	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000
	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000
	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000
	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000
	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000
	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000
	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000
	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000

y (m)	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000
	19000	17000	15000	13000	11000	9000	7000	5000	3000	1000	-1000	-3000	-5000	-7000	-9000	-11000	-13000	-15000	-17000	-19000

z(m)	0	0	0	0	0	0	0	0	4	7	6	1	0	0	2	13	26	56	60	51
	0	0	0	0	0	0	0	0	3	9	5	1	0	0	1	10	21	46	52	59
	0	0	0	0	0	0	0	0	1	8	3	0	0	0	0	7	23	43	46	55
	0	0	0	0	0	0	0	0	2	8	2	0	0	0	0	9	29	34	38	48
	0	0	0	0	0	0	0	0	2	7	3	0	0	0	0	16	20	22	27	36
	0	0	0	0	0	0	0	0	1	9	4	0	0	0	5	8	10	12	15	22
	0	0	0	0	0	0	0	0	1	10	3	0	0	1	3	4	6	18	21	14
	0	0	0	0	0	0	0	0	0	8	3	0	0	1	2	2	8	27	41	33
	0	0	0	0	0	0	0	0	0	6	5	1	0	0	0	5	12	32	52	53
	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	6	13	27	47	50
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	14	27	40	41
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	14	35	52	58
	0	0	0	0	0	0	0	0	0	0	0	1	4	4	4	11	15	34	61	69
	0	0	0	0	0	0	0	0	0	0	1	5	7	8	9	12	16	38	57	61
	0	0	0	0	0	0	0	0	0	0	0	4	8	8	11	16	37	42	42	44
	0	0	0	0	0	0	0	0	0	0	0	4	8	10	11	19	24	29	44	71
	0	0	0	0	0	0	0	0	0	0	0	3	6	7	11	15	20	30	41	64
	0	0	0	0	0	0	0	0	0	0	0	1	3	6	9	13	17	28	36	48
	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7	12	15	20	26	32
	0	0	0	0	0	0	0	0	0	0	0	0	2	4	5	9	13	19	27	34

σy (m)	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125
	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	1125	2400	2400	1125
	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	2200	2200	1400
	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	2000	2000	1600
	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1600	1600	2000
	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	1400	1400	2200
	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	1125	1125	2400

σz (m)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Data Matrices of SOx Concentration– 20 km area-Northern Direction

2E-20	1E-17	3E-15	3E-13	2E-11	7E-10	1E-08	9E-08	4E-07	7E-07	0	4E-07	9E-08	1E-08	7E-10	2E-11	3E-13	3E-15	1E-17	2E-20
5.6E-23	1E-19	7E-17	2E-14	3E-12	2E-10	6E-09	7E-08	3E-07	8E-07	0	3E-07	7E-08	6E-09	2E-10	3E-12	2E-14	7E-17	1E-19	6E-23
2.5E-26	2E-22	6E-19	7E-16	3E-13	4E-11	2E-09	4E-08	3E-07	9E-07	0	3E-07	4E-08	2E-09	4E-11	3E-13	7E-16	6E-19	2E-22	2E-26
6.9E-31	5E-26	9E-22	5E-18	8E-15	4E-12	6E-10	2E-08	3E-07	9E-07	0	3E-07	2E-08	6E-10	4E-12	8E-15	5E-18	9E-22	5E-26	7E-31
2.9E-37	4E-31	1E-25	6E-21	7E-17	2E-13	8E-11	9E-09	2E-07	1E-06	0	2E-07	9E-09	8E-11	2E-13	7E-17	6E-21	1E-25	4E-31	3E-37
1.4E-46	1E-38	2E-31	3E-25	5E-20	1E-15	5E-12	2E-09	1E-07	1E-06	0	1E-07	2E-09	5E-12	1E-15	5E-20	3E-25	2E-31	1E-38	1E-46
2E-68	4E-56	4E-45	2E-35	3E-27	2E-20	7E-15	9E-11	5E-08	1E-06	0	5E-08	9E-11	7E-15	2E-20	3E-27	2E-35	4E-45	4E-56	2E-68
7E-115	3E-93	5E-74	4E-57	1E-42	1E-30	4E-21	7E-14	5E-09	1E-06	0	5E-09	7E-14	4E-21	1E-30	1E-42	4E-57	5E-74	3E-93	7E-115
3E-265	1E-213	1E-167	2E-127	5E-93	3E-64	2E-41	4E-24	1E-12	7E-07	0	1E-12	4E-24	2E-41	3E-64	5E-93	2E-127	1E-167	1.2362E-213	3E-265
0	0	0	0	0	0	6E-271	1E-140	8E-54	2E-10	0	8E-54	1E-140	6E-271	0	0	0	0	0	0
0	0	0	0	0	0	6E-271	1E-140	8E-54	2E-10	0	8E-54	1E-140	6E-271	0	0	0	0	0	0
3E-265	1E-213	1E-167	2E-127	5E-93	3E-64	2E-41	4E-24	1E-12	7E-07	0	1E-12	4E-24	2E-41	3E-64	5E-93	2E-127	1E-167	1.2362E-213	3E-265
7E-115	3E-93	5E-74	4E-57	1E-42	1E-30	4E-21	7E-14	5E-09	1E-06	0	5E-09	7E-14	4E-21	1E-30	1E-42	4E-57	5E-74	3E-93	7E-115
2E-68	4E-56	4E-45	2E-35	3E-27	2E-20	7E-15	9E-11	5E-08	1E-06	0	5E-08	9E-11	7E-15	2E-20	3E-27	2E-35	4E-45	4E-56	2E-68
1.4E-46	1E-38	2E-31	3E-25	5E-20	1E-15	5E-12	2E-09	1E-07	1E-06	0	1E-07	2E-09	5E-12	1E-15	5E-20	3E-25	2E-31	1E-38	1E-46
2.9E-37	4E-31	1E-25	6E-21	7E-17	2E-13	8E-11	9E-09	2E-07	1E-06	0	2E-07	9E-09	8E-11	2E-13	7E-17	6E-21	1E-25	4E-31	3E-37
6.9E-31	5E-26	9E-22	5E-18	8E-15	4E-12	6E-10	2E-08	3E-07	9E-07	0	3E-07	2E-08	6E-10	4E-12	8E-15	5E-18	9E-22	5E-26	7E-31
2.5E-26	2E-22	6E-19	7E-16	3E-13	4E-11	2E-09	4E-08	3E-07	9E-07	0	3E-07	4E-08	2E-09	4E-11	3E-13	7E-16	6E-19	2E-22	2E-26
5.6E-23	1E-19	7E-17	2E-14	3E-12	2E-10	6E-09	7E-08	3E-07	8E-07	0	3E-07	7E-08	6E-09	2E-10	3E-12	2E-14	7E-17	1E-19	6E-23
2E-20	1E-17	3E-15	3E-13	2E-11	7E-10	1E-08	9E-08	4E-07	7E-07	0	4E-07	9E-08	1E-08	7E-10	2E-11	3E-13	3E-15	1E-17	2E-20

high

low

APPENDIX 02: Pollution level of the 20km area around Trincomalee Coal Power Plant, Sampoor, Trincomalee: Specimen Computation

Direction-South

Required Parameters

Q (g/s)	169.31 **(NOx)**
	283.63 **(SOx)**

H (m)	135

U (m/s)	2.333

Where , Q = Emission rate

H = Stack height

U = Wind speed

The Gaussian plume equation

$$C = \frac{Q}{2\,\pi u \sigma_z \,\sigma_y} . \, exp\frac{-y^2}{2{\sigma_y}^2} . \, exp\frac{-(\,H-z)^2}{2{\sigma_z}^2}$$

Where,

(*x, y, z*) = coordinates of the midpoint of a grid cell

σ_y and σ_y = Lateral and Vertical Dispersion coefficient

C = Pollution Concentration

Data Matrices of NOx Concentration

X (m)	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000
	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000
	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000
	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000
	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000
	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000
	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000
	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000
	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000
	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000
	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000
	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000
	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000
	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000

y (m)	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-19000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000

Z (m)	0	0	0	0	0	0	0	0	4	7	6	1	0	0	2	13	26	56	60	51
	0	0	0	0	0	0	0	0	3	9	5	1	0	0	1	10	21	46	52	59
	0	0	0	0	0	0	0	0	1	8	3	0	0	0	0	7	23	43	46	55
	0	0	0	0	0	0	0	0	2	8	2	0	0	0	0	9	29	34	38	48
	0	0	0	0	0	0	0	0	2	7	3	0	0	0	0	16	20	22	27	36
	0	0	0	0	0	0	0	0	1	9	4	0	0	0	5	8	10	12	15	22
	0	0	0	0	0	0	0	0	1	10	3	0	0	1	3	4	6	18	21	14
	0	0	0	0	0	0	0	0	0	8	3	0	0	1	2	2	8	27	41	33
	0	0	0	0	0	0	0	0	0	6	5	1	0	0	0	5	12	32	52	53
	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	6	13	27	47	50
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	14	27	40	41
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	14	35	52	58
	0	0	0	0	0	0	0	0	0	0	0	1	4	4	4	11	15	34	61	69
	0	0	0	0	0	0	0	0	0	0	1	5	7	8	9	12	16	38	57	61
	0	0	0	0	0	0	0	0	0	0	0	4	8	8	11	16	37	42	42	44
	0	0	0	0	0	0	0	0	0	0	0	4	8	10	11	19	24	29	44	71
	0	0	0	0	0	0	0	0	0	0	0	3	6	7	11	15	20	30	41	64
	0	0	0	0	0	0	0	0	0	0	0	1	3	6	9	13	17	28	36	48
	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7	12	15	20	26	32
	0	0	0	0	0	0	0	0	0	0	0	0	2	4	5	9	13	19	27	34

σy (m)	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015
	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845
	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675
	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505
	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335
	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335
	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505
	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675
	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845
	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015
σz (m)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Data Matrices of NOx Concentration– 20 km area-Sothern Direction

2E-25	2E-21	4E-18	4E-15	1E-12	2E-10	1E-08	2E-07	1E-06	4E-06	4E-06	1E-06	2E-07	1E-08	2E-10	1E-12	4.04978E-15	4.09826E-18	0	0
5E-29	2E-24	2E-20	8E-17	9E-14	3E-11	4E-09	1E-07	1E-06	4E-06	4E-06	1E-06	1E-07	4E-09	3E-11	9E-14	8.00456E-17	2.14361E-20	0	0
6E-34	2E-28	2E-23	4E-19	2E-15	3E-12	9E-10	6E-08	1E-06	4E-06	4E-06	1E-06	6E-08	9E-10	3E-12	2E-15	4.4254E-19	2.05028E-23	0	0
1E-40	1E-33	2E-27	4E-22	1E-17	1E-13	1E-10	2E-08	8E-07	5E-06	5E-06	8E-07	2E-08	1E-10	1E-13	1E-17	3.72045E-22	1.59191E-27	0	0
7E-50	4E-41	3E-33	2E-26	1E-20	9E-16	7E-12	6E-09	5E-07	5E-06	5E-06	5E-07	6E-09	7E-12	9E-16	1E-20	1.7121E-26	2.57319E-33	0	0
1E-70	1E-57	3E-46	4E-36	2E-27	2E-20	1E-14	3E-10	2E-07	5E-06	5E-06	2E-07	3E-10	1E-14	2E-20	2E-27	3.79998E-36	3.38847E-46	0	0
3E-114	1E-92	2E-73	2E-56	5E-42	5E-30	2E-20	3E-13	2E-08	5E-06	5E-06	2E-08	3E-13	2E-20	5E-30	5E-42	1.68905E-56	2.49415E-73	0	0
6E-191	6E-154	5E-121	3E-92	1E-67	5E-47	1E-30	3E-18	5E-10	6E-06	6E-06	5E-10	3E-18	1E-30	5E-47	1E-67	2.84306E-92	4.7031E-121	0	0
0	0	0	4E-234	5E-169	1E-114	3E-71	1E-38	5E-17	4E-06	4E-06	5E-17	1E-38	3E-71	1E-114	5E-169	3.5929E-234	0	0	0
0	0	0	0	0	0	0	6E-216	3E-80	3E-12	3E-12	3E-80	6E-216	0	0	0	0	0	0	0
0	0	0	0	0	0	0	6E-216	3E-80	2E-12	2E-12	3E-80	6E-216	0	0	0	0	0	0	0
0	0	0	4E-234	5E-169	1E-114	3E-71	1E-38	5E-17	4E-06	4E-06	5E-17	1E-38	3E-71	1E-114	5E-169	3.5943E-234	0	0	0
6E-191	6E-154	5E-121	3E-92	1E-67	5E-47	1E-30	3E-18	5E-10	6E-06	6E-06	5E-10	3E-18	1E-30	5E-47	1E-67	2.84368E-92	4.7039E-121	0	0
3E-114	1E-92	2E-73	2E-56	5E-42	5E-30	2E-20	3E-13	2E-08	5E-06	5E-06	2E-08	3E-13	2E-20	5E-30	5E-42	1.68928E-56	2.49474E-73	0	0
1E-70	1E-57	3E-46	4E-36	2E-27	2E-20	1E-14	3E-10	2E-07	5E-06	5E-06	2E-07	3E-10	1E-14	2E-20	2E-27	3.80125E-36	3.38969E-46	0	0
7E-50	4E-41	3E-33	2E-26	1E-20	9E-16	7E-12	6E-09	5E-07	5E-06	5E-06	5E-07	6E-09	7E-12	9E-16	1E-20	1.71219E-26	2.57341E-33	0	0
1E-40	1E-33	2E-27	4E-22	1E-17	1E-13	1E-10	2E-08	8E-07	5E-06	5E-06	8E-07	2E-08	1E-10	1E-13	1E-17	3.72004E-22	1.59183E-27	0	0
6E-34	2E-28	2E-23	4E-19	2E-15	3E-12	9E-10	6E-08	1E-06	4E-06	4E-06	1E-06	6E-08	9E-10	3E-12	2E-15	4.42506E-19	2.04994E-23	0	0
5E-29	2E-24	2E-20	8E-17	9E-14	3E-11	4E-09	1E-07	1E-06	4E-06	4E-06	1E-06	1E-07	4E-09	3E-11	9E-14	8.00394E-17	2.14298E-20	0	0
2E-25	2E-21	4E-18	4E-15	1E-12	2E-10	1E-08	2E-07	1E-06	4E-06	4E-06	1E-06	2E-07	1E-08	2E-10	1E-12	4.04911E-15	4.09662E-18	0	0

high low

Data Matrices of SOx Concentration

X (m)	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000
	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000	-17000
	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000	-15000
	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000	-13000
	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000	-11000
	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000	-9000
	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000	-7000
	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000	-5000
	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000	-3000
	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000
	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000
	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000
	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000	17000
	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000	19000

y (m)	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000
	-19000	-17000	-15000	-13000	-11000	-9000	-7000	-5000	-3000	-1000	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000

z(m)	0	0	0	0	0	0	0	0	4	7	6	1	0	0	2	13	26	56	60	51
	0	0	0	0	0	0	0	0	3	9	5	1	0	0	1	10	21	46	52	59
	0	0	0	0	0	0	0	0	1	8	3	0	0	0	0	7	23	43	46	55
	0	0	0	0	0	0	0	0	2	8	2	0	0	0	0	9	29	34	38	48
	0	0	0	0	0	0	0	0	2	7	3	0	0	0	0	16	20	22	27	36
	0	0	0	0	0	0	0	0	1	9	4	0	0	0	5	8	10	12	15	22
	0	0	0	0	0	0	0	0	1	10	3	0	0	1	3	4	6	18	21	14
	0	0	0	0	0	0	0	0	0	8	3	0	0	1	2	2	8	27	41	33
	0	0	0	0	0	0	0	0	0	6	5	1	0	0	0	5	12	32	52	53
	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	6	13	27	47	50
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	14	27	40	41
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	14	35	52	58
	0	0	0	0	0	0	0	0	0	0	0	1	4	4	4	11	15	34	61	69
	0	0	0	0	0	0	0	0	0	0	1	5	7	8	9	12	16	38	57	61
	0	0	0	0	0	0	0	0	0	0	0	4	8	8	11	16	37	42	42	44
	0	0	0	0	0	0	0	0	0	0	0	4	8	10	11	19	24	29	44	71
	0	0	0	0	0	0	0	0	0	0	0	3	6	7	11	15	20	30	41	64
	0	0	0	0	0	0	0	0	0	0	0	1	3	6	9	13	17	28	36	48
	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7	12	15	20	26	32
	0	0	0	0	0	0	0	0	0	0	0	0	2	4	5	9	13	19	27	34

σy (m)	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015
	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845
	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675
	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505
	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335
	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650	650
	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335
	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505
	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675	1675
	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845
	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015

σ_z (m)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Data Matrices of SOx Concentration– 20 km area-Sothern Direction

4E-25	3E-21	7E-18	7E-15	3E-12	3E-10	2E-08	3E-07	2E-06	7E-06	7E-06	2E-06	3E-07	2E-08	3E-10	3E-12	7E-15	7E-18	3E-21	4E-25
8E-29	3E-24	4E-20	1E-16	2E-13	6E-11	6E-09	2E-07	2E-06	7E-06	7E-06	2E-06	2E-07	6E-09	6E-11	2E-13	1E-16	4E-20	3E-24	8E-29
1E-33	4E-28	3E-23	7E-19	4E-15	5E-12	1E-09	1E-07	2E-06	7E-06	7E-06	2E-06	1E-07	1E-09	5E-12	4E-15	7E-19	3E-23	4E-28	1E-33
2E-40	2E-33	3E-27	6E-22	2E-17	2E-13	2E-10	4E-08	1E-06	8E-06	8E-06	1E-06	4E-08	2E-10	2E-13	2E-17	6E-22	3E-27	2E-33	2E-40
1E-49	7E-41	4E-33	3E-26	2E-20	2E-15	1E-11	1E-08	9E-07	8E-06	8E-06	9E-07	1E-08	1E-11	2E-15	2E-20	3E-26	4E-33	7E-41	1E-49
2E-70	2E-57	6E-46	6E-36	3E-27	4E-20	2E-14	4E-10	3E-07	9E-06	9E-06	3E-07	4E-10	2E-14	4E-20	3E-27	6E-36	6E-46	2E-57	2E-70
6E-114	2E-92	4E-73	3E-56	8E-42	8E-30	3E-20	5E-13	3E-08	9E-06	9E-06	3E-08	5E-13	3E-20	8E-30	8E-42	3E-56	4E-73	2E-92	6E-114
1E-190	1E-153	8E-121	5E-92	2E-67	8E-47	2E-30	5E-18	8E-10	1E-05	1E-05	8E-10	5E-18	2E-30	8E-47	2E-67	5E-92	8E-121	1E-153	1E-190
0	0	0	6E-234	8E-169	2E-114	4E-71	2E-38	8E-17	6E-06	6E-06	8E-17	2E-38	4E-71	2E-114	8E-169	6E-234	0	0	0
0	0	0	0	0	0	0	1E-215	6E-80	4E-12	4E-12	6E-80	1E-215	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1E-215	6E-80	4E-12	4E-12	6E-80	1E-215	0	0	0	0	0	0	0
0	0	0	6E-234	8E-169	2E-114	4E-71	2E-38	8E-17	6E-06	6E-06	8E-17	2E-38	4E-71	2E-114	8E-169	6E-234	0	0	0
1E-190	1E-153	8E-121	5E-92	2E-67	8E-47	2E-30	5E-18	8E-10	1E-05	1E-05	8E-10	5E-18	2E-30	8E-47	2E-67	5E-92	8E-121	1E-153	1E-190
6E-114	2E-92	4E-73	3E-56	8E-42	8E-30	3E-20	5E-13	3E-08	9E-06	9E-06	3E-08	5E-13	3E-20	8E-30	8E-42	3E-56	4E-73	2E-92	6E-114
2E-70	2E-57	6E-46	6E-36	3E-27	4E-20	2E-14	4E-10	3E-07	9E-06	9E-06	3E-07	4E-10	2E-14	4E-20	3E-27	6E-36	6E-46	2E-57	2E-70
1E-49	7E-41	4E-33	3E-26	2E-20	2E-15	1E-11	1E-08	9E-07	8E-06	8E-06	9E-07	1E-08	1E-11	2E-15	2E-20	3E-26	4E-33	7E-41	1E-49
2E-40	2E-33	3E-27	6E-22	2E-17	2E-13	2E-10	4E-08	1E-06	8E-06	8E-06	1E-06	4E-08	2E-10	2E-13	2E-17	6E-22	3E-27	2E-33	2E-40
1E-33	4E-28	3E-23	7E-19	4E-15	5E-12	1E-09	1E-07	2E-06	7E-06	7E-06	2E-06	1E-07	1E-09	5E-12	4E-15	7E-19	3E-23	4E-28	1E-33
8E-29	3E-24	4E-20	1E-16	2E-13	6E-11	6E-09	2E-07	2E-06	7E-06	7E-06	2E-06	2E-07	6E-09	6E-11	2E-13	1E-16	4E-20	3E-24	8E-29
4E-25	3E-21	7E-18	7E-15	3E-12	3E-10	2E-08	3E-07	2E-06	7E-06	7E-06	2E-06	3E-07	2E-08	3E-10	3E-12	7E-15	7E-18	3E-21	4E-25

high low

APPENDIX 03: Pollution level of the 100km area around LakVijaya coal power plant, Norechcholei, Puttalam: For Economic Valuation

NOx Emissions - Northern Direction

9.2E-07	7E-07	4E-07	2E-07	6E-08	1E-08	3E-09	4E-10	4E-11	4E-12	2E-13	1E-14	4E-16	1E-17	2E-19	3E-21	4E-23	4E-25	2E-27	1E-29
1E-06	7E-07	4E-07	1E-07	3E-08	6E-09	7E-10	6E-11	4E-12	2E-13	6E-15	1E-16	2E-18	2E-20	2E-22	9E-25	4E-27	1E-29	2E-32	3E-35
1.1E-06	7E-07	3E-07	9E-08	2E-08	2E-09	2E-10	1E-11	3E-13	8E-15	1E-16	1E-18	9E-21	4E-23	1E-25	2E-28	3E-31	2E-34	1E-37	5E-41
1.2E-06	7E-07	3E-07	6E-08	9E-09	7E-10	4E-11	1E-12	2E-14	3E-16	2E-18	9E-21	2E-23	4E-26	4E-29	3E-32	1E-35	2E-39	3E-43	3E-47
1.3E-06	7E-07	2E-07	4E-08	4E-09	2E-10	7E-12	1E-13	1E-15	6E-18	2E-20	3E-23	3E-26	2E-29	5E-33	9E-37	9E-41	5E-45	1E-49	2E-54
1.5E-06	6E-07	1E-07	1E-08	4E-10	6E-12	4E-14	1E-16	2E-19	1E-22	3E-26	3E-30	1E-34	3E-39	3E-44	1E-49	2E-55	2E-61	6E-68	9E-75
1.8E-06	5E-07	3E-08	7E-10	4E-12	5E-15	2E-18	2E-22	7E-27	5E-32	1E-37	6E-44	1E-50	4E-58	5E-66	1E-74	1E-83	3E-93	2E-103	3E-114
2.1E-06	2E-07	2E-09	1E-12	1E-16	8E-22	5E-28	3E-35	2E-43	1E-52	6E-63	3E-74	1E-86	6E-100	2E-114	9E-130	3E-146	1E-163	3E-182	1E-201
2.1E-06	4E-09	1E-14	1E-22	1E-33	4E-47	2E-63	2E-82	4E-104	1E-128	1E-155	1E-185	4E-218	2E-253	2E-291	0	0	0	0	0
1.4E-07	1E-22	1E-52	1E-97	7E-158	5E-233	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.4E-07	1E-22	1E-52	1E-97	7E-158	5E-233	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.1E-06	4E-09	1E-14	1E-22	1E-33	4E-47	2E-63	2E-82	4E-104	1E-128	1E-155	1E-185	4E-218	2E-253	2E-291	0	0	0	0	0
2.1E-06	2E-07	2E-09	1E-12	1E-16	8E-22	5E-28	3E-35	2E-43	1E-52	6E-63	3E-74	1E-86	6E-100	2E-114	9E-130	3E-146	1E-163	3E-182	1E-201
1.8E-06	5E-07	3E-08	7E-10	4E-12	5E-15	2E-18	2E-22	7E-27	5E-32	1E-37	6E-44	1E-50	4E-58	5E-66	1E-74	1E-83	3E-93	2E-103	3E-114
1.5E-06	6E-07	1E-07	1E-08	4E-10	6E-12	4E-14	1E-16	2E-19	1E-22	3E-26	3E-30	1E-34	3E-39	3E-44	1E-49	2E-55	2E-61	6E-68	9E-75
1.3E-06	7E-07	2E-07	4E-08	4E-09	2E-10	7E-12	1E-13	1E-15	6E-18	2E-20	3E-23	3E-26	2E-29	5E-33	9E-37	9E-41	5E-45	1E-49	2E-54
1.2E-06	7E-07	3E-07	6E-08	9E-09	7E-10	4E-11	1E-12	2E-14	3E-16	2E-18	9E-21	2E-23	4E-26	4E-29	3E-32	1E-35	2E-39	3E-43	3E-47
1.1E-06	7E-07	3E-07	9E-08	2E-08	2E-09	2E-10	1E-11	3E-13	8E-15	1E-16	1E-18	9E-21	4E-23	1E-25	2E-28	3E-31	2E-34	1E-37	5E-41
1E-06	7E-07	4E-07	1E-07	3E-08	6E-09	7E-10	6E-11	4E-12	2E-13	6E-15	1E-16	2E-18	2E-20	2E-22	9E-25	4E-27	1E-29	2E-32	3E-35
9.2E-07	7E-07	4E-07	2E-07	6E-08	1E-08	3E-09	4E-10	4E-11	4E-12	2E-13	1E-14	4E-16	1E-17	2E-19	3E-21	4E-23	4E-25	2E-27	1E-29

NOx Emissions – North Eastern Direction

4.8E-20	8E-18	6E-16	2E-14	4E-13	6E-12	6E-11	4E-10	2E-09	8E-09	2E-08	6E-08	1E-07	2E-07	4E-07	6E-07	7E-07	8E-07	9E-07	8E-07
2.4E-19	7E-17	7E-15	3E-13	5E-12	6E-11	5E-10	3E-09	1E-08	4E-08	1E-07	2E-07	4E-07	6E-07	7E-07	9E-07	1E-06	9E-07	8E-07	7E-07
1.1E-18	6E-16	7E-14	3E-12	6E-11	7E-10	4E-09	2E-08	6E-08	2E-07	3E-07	5E-07	8E-07	9E-07	1E-06	1E-06	9E-07	7E-07	6E-07	4E-07
2.3E-18	3E-15	7E-13	3E-11	6E-10	6E-09	3E-08	1E-07	3E-07	5E-07	8E-07	1E-06	1E-06	1E-06	1E-06	8E-07	5E-07	4E-07	2E-07	1E-07
9.1E-18	2E-14	6E-12	3E-10	6E-09	4E-08	2E-07	4E-07	8E-07	1E-06	1E-06	1E-06	1E-06	8E-07	5E-07	3E-07	2E-07	1E-07	5E-08	3E-08
2.3E-16	5E-13	1E-10	4E-09	5E-08	3E-07	7E-07	1E-06	1E-06	1E-06	1E-06	8E-07	5E-07	3E-07	1E-07	7E-08	3E-08	1E-08	6E-09	3E-09
9.3E-15	3E-11	4E-09	8E-08	5E-07	1E-06	2E-06	2E-06	1E-06	7E-07	4E-07	2E-07	9E-08	4E-08	1E-08	6E-09	2E-09	8E-10	3E-10	1E-10
3.3E-13	2E-09	2E-07	1E-06	2E-06	2E-06	1E-06	6E-07	2E-07	8E-08	3E-08	1E-08	3E-09	1E-09	4E-10	1E-10	4E-11	1E-11	3E-12	1E-12
5.1E-10	4E-07	3E-06	3E-06	1E-06	3E-07	5E-08	9E-09	2E-09	4E-10	1E-10	3E-11	1E-11	3E-12	9E-13	3E-13	9E-14	3E-14	7E-15	2E-15
1.1E-06	4E-06	2E-07	4E-09	2E-10	2E-11	2E-12	3E-13	4E-14	6E-15	1E-15	3E-16	2E-16	8E-17	5E-17	2E-17	8E-18	3E-18	1E-18	4E-19
6.3E-65	4E-172	2E-60	3E-33	2E-25	6E-27	8E-26	5E-25	2E-24	2E-24	1E-24	6E-25	3E-25	4E-25	9E-25	2E-24	3E-24	3E-24	2E-24	1E-24
1.9E-22	2E-96	0	0	6E-258	7E-104	3E-64	1E-60	2E-52	6E-47	5E-43	8E-41	1E-39	9E-39	5E-38	7E-37	2E-35	3E-34	3E-33	1E-32
5.3E-21	3E-33	4E-82	0	0	0	0	7E-218	1E-123	5E-110	3E-90	4E-77	5E-68	2E-62	4E-59	2E-56	4E-54	2E-51	1E-48	4E-46
7.6E-21	2E-31	1E-50	4E-77	3E-185	0	0	0	0	0	1E-203	2E-175	3E-139	9E-116	2E-99	2E-89	5E-83	7E-78	2E-73	7E-69
4.3E-21	2E-28	1E-40	8E-61	3E-96	1E-141	0	0	0	0	0	0	2E-304	2E-256	2E-199	1E-162	2E-137	1E-121	2E-111	4E-103
4.2E-22	5E-28	3E-36	1E-48	8E-69	2E-101	1E-157	7E-227	0	0	0	0	0	0	0	0	6E-271	5E-218	9E-182	5E-159
1.3E-22	4E-28	6E-35	4E-44	1E-56	3E-75	2E-105	3E-153	1E-234	0	0	0	0	0	0	0	0	0	0	1E-281
2.3E-22	3E-27	1E-33	1E-41	1E-51	1E-64	4E-82	2E-108	3E-150	3E-216	0	0	0	0	0	0	0	0	0	0
2.4E-22	3E-26	1E-31	2E-38	2E-47	1E-58	4E-72	1E-89	5E-113	7E-148	2E-203	2E-290	0	0	0	0	0	0	0	0
7E-23	3E-26	2E-30	9E-36	6E-43	3E-52	3E-64	7E-79	2E-96	3E-119	4E-149	7E-194	6E-265	0	0	0	0	0	0	0

NOx Emissions – South Western Direction

1.8E-28	1E-24	6E-22	2E-19	2E-17	2E-15	9E-14	2E-12	4E-11	4E-10	2E-09	1E-08	3E-08	8E-08	2E-07	3E-07	4E-07	5E-07	6E-07	6E-07
2E-28	9E-24	4E-20	2E-17	2E-15	9E-14	2E-12	4E-11	5E-10	4E-09	2E-08	6E-08	1E-07	3E-07	4E-07	6E-07	6E-07	6E-07	5E-07	4E-07
5.4E-28	4E-23	4E-19	4E-16	1E-13	5E-12	8E-11	9E-10	6E-09	3E-08	1E-07	2E-07	4E-07	6E-07	7E-07	7E-07	6E-07	4E-07	3E-07	2E-07
2.7E-26	2E-21	8E-18	8E-15	2E-12	1E-10	2E-09	2E-08	7E-08	2E-07	4E-07	6E-07	8E-07	7E-07	6E-07	4E-07	3E-07	1E-07	8E-08	4E-08
1.2E-24	2E-19	1E-15	6E-13	6E-11	2E-09	3E-08	1E-07	4E-07	7E-07	9E-07	8E-07	7E-07	4E-07	2E-07	1E-07	5E-08	2E-08	8E-09	3E-09
7.6E-24	1E-17	2E-13	7E-11	4E-09	5E-08	3E-07	7E-07	1E-06	1E-06	7E-07	4E-07	2E-07	7E-08	3E-08	8E-09	3E-09	8E-10	2E-10	7E-11
3.8E-22	2E-15	2E-11	6E-09	1E-07	7E-07	1E-06	1E-06	7E-07	3E-07	1E-07	4E-08	1E-08	3E-09	7E-10	1E-10	2E-11	5E-12	1E-12	3E-13
5.4E-18	6E-12	1E-08	4E-07	2E-06	1E-06	7E-07	2E-07	4E-08	7E-09	1E-09	2E-10	3E-11	8E-12	2E-12	3E-13	4E-14	5E-15	5E-16	8E-17
1.4E-14	7E-08	2E-06	2E-06	3E-07	3E-08	2E-09	2E-10	2E-11	1E-12	1E-13	9E-15	8E-16	1E-16	3E-17	8E-18	3E-18	4E-19	4E-20	3E-21
3.9E-07	2E-06	4E-09	7E-11	2E-13	1E-15	1E-17	4E-19	5E-20	1E-20	2E-21	3E-22	3E-23	3E-24	4E-25	1E-25	7E-26	5E-26	4E-26	8E-27
6E-104	3E-281	3E-72	6E-49	4E-47	6E-38	8E-39	2E-39	5E-40	2E-39	3E-38	3E-37	2E-36	2E-36	7E-37	2E-37	1E-37	1E-37	5E-37	2E-36
5.8E-32	2E-115	0	0	0	3E-159	1E-128	4E-89	8E-83	4E-78	2E-74	1E-69	3E-64	4E-60	8E-57	4E-55	2E-54	5E-54	1E-53	2E-52
6E-29	2E-63	3E-125	0	0	0	0	0	2E-253	3E-164	2E-145	2E-131	1E-120	3E-109	6E-98	3E-89	2E-82	2E-78	3E-76	2E-74
3.7E-32	4E-48	5E-74	1E-155	2E-286	0	0	0	0	0	0	2E-263	2E-226	2E-199	5E-179	1E-158	2E-139	1E-124	3E-113	4E-106
1.5E-33	2E-47	4E-67	1E-96	3E-143	2E-291	0	0	0	0	0	0	0	0	0	4E-282	3E-249	2E-217	2E-188	2E-166
1.5E-32	5E-44	3E-61	7E-85	1E-116	7E-164	2E-236	0	0	0	0	0	0	0	0	0	0	0	0	5E-286
2E-32	5E-41	8E-54	6E-72	2E-98	3E-134	5E-181	2E-249	0	0	0	0	0	0	0	0	0	0	0	0
1E-33	6E-41	5E-50	1E-62	2E-81	1E-107	2E-145	2E-195	5E-260	0	0	0	0	0	0	0	0	0	0	0
2.4E-34	2E-41	2E-49	1E-59	4E-72	1E-89	3E-115	7E-151	8E-202	1E-268	0	0	0	0	0	0	0	0	0	0
1.1E-33	3E-40	2E-48	5E-58	6E-69	3E-82	9E-99	8E-122	2E-155	7E-202	6E-268	0	0	0	0	0	0	0	0	0

high low

NOx Emissions – North Western Direction

1.4E-22	5E-26	4E-30	2E-35	1E-42	6E-52	6E-64	1E-78	4E-96	7E-119	7E-149	1E-193	1E-264	0	0	0	0	0	0	0
4.6E-22	5E-26	3E-31	3E-38	3E-47	2E-58	7E-72	2E-89	9E-113	1E-147	4E-203	3E-290	0	0	0	0	0	0	0	0
4.5E-22	6E-27	2E-33	2E-41	2E-51	2E-64	7E-82	4E-108	7E-150	5E-216	0	0	0	0	0	0	0	0	0	0
2.5E-22	8E-28	1E-34	7E-44	3E-56	5E-75	5E-105	6E-153	2E-234	0	0	0	0	0	0	0	0	0	0	9E-281
8.1E-22	1E-27	6E-36	2E-48	2E-68	4E-101	3E-157	1E-226	0	0	0	0	0	0	0	0	1E-270	1E-217	6E-181	4E-158
8.2E-21	3E-28	2E-40	2E-60	6E-96	2E-141	0	0	0	0	0	0	4E-304	3E-256	3E-199	2E-162	4E-137	3E-121	1E-110	3E-102
1.5E-20	4E-31	2E-50	7E-77	5E-185	0	0	0	0	0	2E-203	4E-175	6E-139	2E-115	3E-99	4E-89	9E-83	1E-77	1E-72	5E-68
1E-20	6E-33	7E-82	0	0	0	0	1E-217	2E-123	9E-110	6E-90	7E-77	1E-67	3E-62	7E-59	4E-56	8E-54	4E-51	1E-47	3E-45
3.7E-22	4E-96	0	0	1E-257	1E-103	6E-64	3E-60	4E-52	1E-46	4E-42	2E-40	2E-39	2E-38	1E-37	1E-36	4E-35	6E-34	2E-32	8E-32
1.2E-64	7E-172	3E-60	5E-33	3E-25	1E-26	2E-25	1E-24	4E-24	4E-24	2E-24	1E-24	6E-25	8E-25	2E-24	3E-24	6E-24	6E-24	1E-23	1E-23
2.1E-06	7E-06	4E-07	8E-09	4E-10	4E-11	5E-12	6E-13	8E-14	1E-14	2E-15	6E-16	3E-16	2E-16	9E-17	4E-17	2E-17	6E-18	9E-18	3E-18
9.9E-10	7E-07	6E-06	6E-06	2E-06	5E-07	1E-07	2E-08	3E-09	7E-10	2E-10	6E-11	2E-11	6E-12	2E-12	6E-13	2E-13	5E-14	5E-14	1E-14
6.4E-13	4E-09	3E-07	2E-06	5E-06	4E-06	3E-06	1E-06	4E-07	2E-07	6E-08	2E-08	7E-09	2E-09	8E-10	2E-10	7E-11	2E-11	2E-11	7E-12
1.8E-14	6E-11	8E-09	2E-07	1E-06	3E-06	4E-06	3E-06	2E-06	1E-06	8E-07	4E-07	2E-07	7E-08	3E-08	1E-08	4E-09	1E-09	2E-09	6E-10
4.5E-16	9E-13	2E-10	8E-09	1E-07	5E-07	1E-06	2E-06	3E-06	3E-06	2E-06	2E-06	9E-07	5E-07	3E-07	1E-07	6E-08	3E-08	4E-08	2E-08
1.8E-17	4E-14	1E-11	7E-10	1E-08	8E-08	3E-07	8E-07	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	1E-06	6E-07	4E-07	2E-07	4E-07	2E-07
4.5E-18	6E-15	1E-12	7E-11	1E-09	1E-08	6E-08	2E-07	5E-07	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	1E-06	1E-06	7E-07	1E-06	8E-07
2.2E-18	1E-15	1E-13	6E-12	1E-10	1E-09	8E-09	4E-08	1E-07	3E-07	6E-07	1E-06	1E-06	2E-06	2E-06	2E-06	2E-06	1E-06	4E-06	3E-06
4.7E-19	1E-16	1E-14	6E-13	1E-11	1E-10	1E-09	6E-09	2E-08	7E-08	2E-07	4E-07	7E-07	1E-06	1E-06	2E-06	2E-06	2E-06	5E-06	5E-06
9.3E-20	2E-17	1E-15	4E-14	9E-13	1E-11	1E-10	8E-10	4E-09	1E-08	4E-08	1E-07	2E-07	5E-07	8E-07	1E-06	1E-06	2E-06	5E-06	5E-06

high low

NOx Emissions – Resultant Monthly Average Concentration

2.3E-07	2E-07	1E-07	4E-08	1E-08	4E-09	7E-10	2E-10	5E-10	2E-09	6E-09	2E-08	4E-08	8E-08	1E-07	2E-07	3E-07	3E-07	4E-07	3E-07
2.5E-07	2E-07	9E-08	3E-08	8E-09	1E-09	3E-10	7E-10	3E-09	1E-08	3E-08	7E-08	1E-07	2E-07	3E-07	4E-07	4E-07	4E-07	3E-07	3E-07
2.8E-07	2E-07	8E-08	2E-08	4E-09	7E-10	1E-09	5E-09	2E-08	5E-08	1E-07	2E-07	3E-07	4E-07	4E-07	4E-07	4E-07	3E-07	2E-07	1E-07
3E-07	2E-07	7E-08	2E-08	2E-09	2E-09	8E-09	3E-08	8E-08	2E-07	3E-07	4E-07	5E-07	5E-07	4E-07	3E-07	2E-07	1E-07	8E-08	4E-08
3.2E-07	2E-07	6E-08	1E-08	2E-09	1E-08	5E-08	1E-07	3E-07	4E-07	5E-07	5E-07	4E-07	3E-07	2E-07	1E-07	6E-08	3E-08	2E-08	7E-09
3.7E-07	2E-07	3E-08	4E-09	1E-08	8E-08	3E-07	5E-07	6E-07	6E-07	5E-07	3E-07	2E-07	9E-08	4E-08	2E-08	9E-09	4E-09	2E-09	7E-10
4.4E-07	1E-07	1E-08	2E-08	2E-07	5E-07	8E-07	7E-07	5E-07	3E-07	1E-07	6E-08	3E-08	1E-08	4E-09	1E-09	5E-10	2E-10	7E-11	2E-11
5.2E-07	5E-08	5E-08	4E-07	1E-06	9E-07	5E-07	2E-07	7E-08	2E-08	8E-09	3E-09	9E-10	3E-10	1E-10	3E-11	9E-12	3E-12	8E-13	2E-13
5.2E-07	1E-07	1E-06	1E-06	4E-07	7E-08	1E-08	2E-09	4E-10	9E-11	2E-11	7E-12	3E-12	8E-13	2E-13	7E-14	2E-14	7E-15	2E-15	5E-16
4.1E-07	1E-06	5E-08	1E-09	5E-11	5E-12	6E-13	8E-14	1E-14	1E-15	3E-16	8E-17	4E-17	2E-17	1E-17	5E-18	2E-18	8E-19	3E-19	1E-19
5.7E-07	2E-06	1E-07	2E-09	1E-10	9E-12	1E-12	2E-13	2E-14	3E-15	5E-16	2E-16	8E-17	4E-17	2E-17	1E-17	4E-18	1E-18	2E-18	7E-19
5.2E-07	2E-07	2E-06	1E-06	5E-07	1E-07	2E-08	4E-09	8E-10	2E-10	5E-11	1E-11	5E-12	2E-12	4E-13	1E-13	5E-14	1E-14	1E-14	3E-15
5.2E-07	5E-08	8E-08	6E-07	1E-06	1E-06	6E-07	3E-07	1E-07	4E-08	1E-08	5E-09	2E-09	6E-10	2E-10	6E-11	2E-11	5E-12	6E-12	2E-12
4.4E-07	1E-07	1E-08	4E-08	2E-07	6E-07	9E-07	8E-07	6E-07	4E-07	2E-07	9E-08	4E-08	2E-08	7E-09	3E-09	1E-09	4E-10	5E-10	2E-10
3.7E-07	2E-07	3E-08	5E-09	3E-08	1E-07	4E-07	6E-07	7E-07	7E-07	5E-07	4E-07	2E-07	1E-07	7E-08	3E-08	2E-08	7E-09	1E-08	4E-09
3.2E-07	2E-07	6E-08	1E-08	4E-09	2E-08	8E-08	2E-07	4E-07	5E-07	6E-07	6E-07	5E-07	4E-07	3E-07	2E-07	9E-08	5E-08	9E-08	4E-08
3E-07	2E-07	7E-08	2E-08	2E-09	3E-09	1E-08	5E-08	1E-07	2E-07	4E-07	5E-07	5E-07	5E-07	5E-07	4E-07	3E-07	2E-07	4E-07	2E-07
2.8E-07	2E-07	8E-08	2E-08	4E-09	9E-10	2E-09	9E-09	3E-08	8E-08	2E-07	3E-07	4E-07	5E-07	5E-07	5E-07	4E-07	4E-07	9E-07	7E-07
2.5E-07	2E-07	9E-08	3E-08	8E-09	1E-09	4E-10	1E-09	6E-09	2E-08	5E-08	9E-08	2E-07	3E-07	4E-07	4E-07	5E-07	4E-07	1E-06	1E-06
2.3E-07	2E-07	1E-07	4E-08	1E-08	4E-09	7E-10	3E-10	1E-09	4E-09	1E-08	3E-08	6E-08	1E-07	2E-07	3E-07	3E-07	4E-07	1E-06	1E-06

high low

SOx Emissions - Northern Direction

2E-07	1E-07	9E-08	4E-08	1E-08	3E-09	6E-10	8E-11	9E-12	8E-13	5E-14	2E-15	8E-17	2E-18	5E-20	7E-22	9E-24	8E-26	5E-28	3E-30
2E-07	2E-07	8E-08	3E-08	7E-09	1E-09	2E-10	1E-11	9E-13	4E-14	1E-15	3E-17	4E-19	5E-21	4E-23	2E-25	8E-28	2E-30	4E-33	6E-36
2E-07	2E-07	7E-08	2E-08	4E-09	5E-10	4E-11	2E-12	7E-14	2E-15	3E-17	3E-19	2E-21	8E-24	2E-26	5E-29	6E-32	5E-35	3E-38	1E-41
3E-07	2E-07	6E-08	1E-08	2E-09	2E-10	8E-12	3E-13	5E-15	6E-17	4E-19	2E-21	5E-24	9E-27	9E-30	6E-33	2E-36	5E-40	7E-44	6E-48
3E-07	2E-07	5E-08	9E-09	8E-10	5E-11	1E-12	3E-14	3E-16	1E-18	4E-21	7E-24	7E-27	4E-30	1E-33	2E-37	2E-41	1E-45	3E-50	5E-55
3E-07	1E-07	3E-08	2E-09	8E-11	1E-12	9E-15	3E-17	4E-20	2E-23	6E-27	7E-31	3E-35	7E-40	7E-45	3E-50	5E-56	4E-62	1E-68	2E-75
4E-07	1E-07	7E-09	1E-10	8E-13	1E-15	5E-19	5E-23	1E-27	1E-32	2E-38	1E-44	2E-51	9E-59	1E-66	3E-75	3E-84	6E-94	4E-104	6E-115
4E-07	4E-08	4E-10	3E-13	2E-17	2E-22	1E-28	7E-36	4E-44	2E-53	1E-63	6E-75	3E-87	1E-100	5E-115	2E-130	7E-147	2E-164	7E-183	2E-202
4E-07	9E-10	3E-15	2E-23	3E-34	9E-48	4E-64	4E-83	9E-105	3E-129	2E-156	3E-186	9E-219	4E-254	4E-292	0	0	0	0	0
3E-08	3E-23	3E-53	2E-98	2E-158	1E-233	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3E-08	3E-23	3E-53	2E-98	2E-158	1E-233	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4E-07	9E-10	3E-15	2E-23	3E-34	9E-48	4E-64	4E-83	9E-105	3E-129	2E-156	3E-186	9E-219	4E-254	4E-292	0	0	0	0	0
4E-07	4E-08	4E-10	3E-13	2E-17	2E-22	1E-28	7E-36	4E-44	2E-53	1E-63	6E-75	3E-87	1E-100	5E-115	2E-130	7E-147	2E-164	7E-183	2E-202
4E-07	1E-07	7E-09	1E-10	8E-13	1E-15	5E-19	5E-23	1E-27	1E-32	2E-38	1E-44	2E-51	9E-59	1E-66	3E-75	3E-84	6E-94	4E-104	6E-115
3E-07	1E-07	3E-08	2E-09	8E-11	1E-12	9E-15	3E-17	4E-20	2E-23	6E-27	7E-31	3E-35	7E-40	7E-45	3E-50	5E-56	4E-62	1E-68	2E-75
3E-07	2E-07	5E-08	9E-09	8E-10	5E-11	1E-12	3E-14	3E-16	1E-18	4E-21	7E-24	7E-27	4E-30	1E-33	2E-37	2E-41	1E-45	3E-50	5E-55
3E-07	2E-07	6E-08	1E-08	2E-09	2E-10	8E-12	3E-13	5E-15	6E-17	4E-19	2E-21	5E-24	9E-27	9E-30	6E-33	2E-36	5E-40	7E-44	6E-48
2E-07	2E-07	7E-08	2E-08	4E-09	5E-10	4E-11	2E-12	7E-14	2E-15	3E-17	3E-19	2E-21	8E-24	2E-26	5E-29	6E-32	5E-35	3E-38	1E-41
2E-07	2E-07	8E-08	3E-08	7E-09	1E-09	2E-10	1E-11	9E-13	4E-14	1E-15	3E-17	4E-19	5E-21	4E-23	2E-25	8E-28	2E-30	4E-33	6E-36
2E-07	1E-07	9E-08	4E-08	1E-08	3E-09	6E-10	8E-11	9E-12	8E-13	5E-14	2E-15	8E-17	2E-18	5E-20	7E-22	8E-24	8E-26	5E-28	3E-30

SOx Emissions – North Eastern Direction

1E-20	2E-18	1E-16	4E-15	9E-14	1E-12	1E-11	9E-11	4E-10	2E-09	5E-09	1E-08	3E-08	5E-08	8E-08	1E-07	2E-07	2E-07	2E-07	2E-07
5E-20	2E-17	2E-15	6E-14	1E-12	1E-11	1E-10	6E-10	3E-09	8E-09	2E-08	4E-08	8E-08	1E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07
2E-19	1E-16	1E-14	7E-13	1E-11	1E-10	9E-10	4E-09	1E-08	3E-08	7E-08	1E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	1E-07	9E-08
5E-19	7E-16	2E-13	7E-12	1E-10	1E-09	6E-09	2E-08	6E-08	1E-07	2E-07	2E-07	2E-07	2E-07	2E-07	2E-07	1E-07	8E-08	5E-08	3E-08
2E-18	4E-15	1E-12	7E-11	1E-09	9E-09	4E-08	9E-08	2E-07	2E-07	3E-07	3E-07	2E-07	2E-07	1E-07	7E-08	4E-08	2E-08	1E-08	5E-09
5E-17	1E-13	2E-11	9E-10	1E-08	6E-08	2E-07	3E-07	3E-07	3E-07	2E-07	2E-07	1E-07	6E-08	3E-08	2E-08	7E-09	3E-09	1E-09	6E-10
2E-15	7E-12	9E-10	2E-08	1E-07	3E-07	4E-07	4E-07	3E-07	2E-07	9E-08	4E-08	2E-08	8E-09	3E-09	1E-09	4E-10	2E-10	6E-11	2E-11
7E-14	5E-10	4E-08	3E-07	5E-07	5E-07	3E-07	1E-07	5E-08	2E-08	6E-09	2E-09	7E-10	2E-10	8E-11	3E-11	8E-12	2E-12	7E-13	2E-13
1E-10	8E-08	7E-07	7E-07	2E-07	6E-08	1E-08	2E-09	4E-10	8E-11	2E-11	6E-12	2E-12	7E-13	2E-13	6E-14	2E-14	6E-15	2E-15	4E-16
2E-07	8E-07	4E-08	8E-10	5E-11	4E-12	5E-13	7E-14	8E-15	1E-15	2E-16	7E-17	3E-17	2E-17	1E-17	5E-18	2E-18	6E-19	3E-19	9E-20
1E-65	8E-173	3E-61	6E-34	4E-26	1E-27	2E-26	1E-25	4E-25	5E-25	2E-25	1E-25	7E-26	9E-26	2E-25	4E-25	7E-25	7E-25	4E-25	3E-25
4E-23	4E-97	0	0	1E-258	2E-104	7E-65	3E-61	4E-53	1E-47	1E-43	2E-41	2E-40	2E-39	1E-38	2E-37	4E-36	6E-35	7E-34	2E-33
1E-21	6E-34	8E-83	0	0	0	0	2E-218	3E-124	1E-110	7E-91	8E-78	1E-68	4E-63	8E-60	4E-57	9E-55	4E-52	3E-49	8E-47
2E-21	4E-32	2E-51	8E-78	6E-186	0	0	0	0	0	2E-204	5E-176	6E-140	2E-116	4E-100	5E-90	1E-83	2E-78	3E-74	2E-69
9E-22	4E-29	2E-41	2E-61	7E-97	2E-142	0	0	0	0	0	0	5E-305	4E-257	4E-200	2E-163	4E-138	3E-122	4E-112	9E-104
9E-23	1E-28	7E-37	3E-49	2E-69	4E-102	3E-158	1E-227	0	0	0	0	0	0	0	0	1E-271	1E-218	2E-182	1E-159
3E-23	9E-29	1E-35	8E-45	3E-57	6E-76	5E-106	6E-154	2E-235	0	0	0	0	0	0	0	0	0	0	3E-282
5E-23	7E-28	3E-34	2E-42	3E-52	2E-65	8E-83	5E-109	7E-151	6E-217	0	0	0	0	0	0	0	0	0	0
5E-23	6E-27	3E-32	4E-39	3E-48	2E-59	8E-73	2E-90	1E-113	1E-148	5E-204	3E-291	0	0	0	0	0	0	0	0
2E-23	6E-27	4E-31	2E-36	1E-43	7E-53	6E-65	1E-79	4E-97	7E-120	8E-150	1E-194	1E-265	0	0	0	0	0	0	0

high low

SOx Emissions – South Western Direction

4E-29	2E-25	1E-22	4E-20	5E-18	4E-16	2E-14	5E-13	8E-12	8E-11	5E-10	2E-09	7E-09	2E-08	4E-08	6E-08	9E-08	1E-07	1E-07	1E-07
4E-29	2E-24	9E-21	4E-18	4E-16	2E-14	5E-13	9E-12	1E-10	8E-10	4E-09	1E-08	3E-08	6E-08	9E-08	1E-07	1E-07	1E-07	1E-07	9E-08
1E-28	8E-24	8E-20	9E-17	2E-14	1E-12	2E-11	2E-10	1E-09	6E-09	2E-08	5E-08	9E-08	1E-07	1E-07	1E-07	1E-07	9E-08	6E-08	4E-08
6E-27	3E-22	2E-18	2E-15	4E-13	2E-11	4E-10	3E-09	1E-08	4E-08	9E-08	1E-07	2E-07	2E-07	1E-07	9E-08	6E-08	3E-08	2E-08	8E-09
3E-25	5E-20	2E-16	1E-13	1E-11	4E-10	6E-09	3E-08	8E-08	1E-07	2E-07	2E-07	1E-07	9E-08	5E-08	2E-08	1E-08	4E-09	2E-09	7E-10
2E-24	3E-18	4E-14	2E-11	8E-10	1E-08	6E-08	2E-07	2E-07	2E-07	1E-07	8E-08	4E-08	2E-08	5E-09	2E-09	5E-10	2E-10	5E-11	1E-11
8E-23	4E-16	5E-12	1E-09	3E-08	1E-07	3E-07	3E-07	2E-07	7E-08	2E-08	8E-09	2E-09	7E-10	1E-10	3E-11	5E-12	1E-12	2E-13	5E-14
1E-18	1E-12	2E-09	9E-08	3E-07	3E-07	1E-07	4E-08	8E-09	1E-09	2E-10	4E-11	7E-12	2E-12	4E-13	7E-14	8E-15	1E-15	1E-16	2E-17
3E-15	1E-08	4E-07	4E-07	7E-08	6E-09	4E-10	4E-11	4E-12	3E-13	2E-14	2E-15	2E-16	3E-17	6E-18	2E-18	6E-19	9E-20	8E-21	7E-22
8E-08	3E-07	8E-10	1E-11	5E-14	3E-16	2E-18	9E-20	1E-20	2E-21	5E-22	7E-23	6E-24	6E-25	8E-26	2E-26	2E-26	1E-26	8E-27	2E-27
1E-104	7E-282	6E-73	1E-49	8E-48	1E-38	2E-39	4E-40	1E-40	3E-40	6E-39	6E-38	4E-37	5E-37	1E-37	5E-38	2E-38	3E-38	1E-37	3E-37
1E-32	5E-116	0	0	0	7E-160	3E-129	1E-89	2E-83	9E-79	4E-75	3E-70	6E-65	9E-61	2E-57	9E-56	3E-55	1E-54	3E-54	4E-53
1E-29	4E-64	6E-126	0	0	0	0	0	4E-254	7E-165	5E-146	5E-132	2E-121	6E-110	1E-98	6E-90	4E-83	5E-79	7E-77	5E-75
8E-33	9E-49	1E-74	2E-156	4E-287	0	0	0	0	0	0	4E-264	5E-227	5E-200	1E-179	3E-159	5E-140	2E-125	6E-114	8E-107
3E-34	3E-48	1E-67	2E-97	7E-144	4E-292	0	0	0	0	0	0	0	0	0	9E-283	7E-250	4E-218	4E-189	4E-167
3E-33	1E-44	7E-62	1E-85	2E-117	2E-164	5E-237	0	0	0	0	0	0	0	0	0	0	0	0	1E-286
4E-33	1E-41	2E-54	1E-72	4E-99	7E-135	1E-181	3E-250	0	0	0	0	0	0	0	0	0	0	0	0
2E-34	1E-41	1E-50	2E-63	5E-82	3E-108	5E-146	4E-196	1E-260	0	0	0	0	0	0	0	0	0	0	0
5E-35	5E-42	4E-50	3E-60	9E-73	2E-90	6E-116	1E-151	2E-202	3E-269	0	0	0	0	0	0	0	0	0	0
2E-34	7E-41	4E-49	1E-58	1E-69	6E-83	2E-99	2E-122	4E-156	1E-202	1E-268	0	0	0	0	0	0	0	0	0

high low

SOx Emissions – North Western Direction

3E-23	1E-26	9E-31	4E-36	2E-43	1E-52	1E-64	3E-79	8E-97	1E-119	2E-149	3E-194	3E-265	0	0	0	0	0	0	0
1E-22	1E-26	5E-32	7E-39	7E-48	5E-59	2E-72	4E-90	2E-113	3E-148	9E-204	7E-291	0	0	0	0	0	0	0	0
1E-22	1E-27	5E-34	4E-42	5E-52	4E-65	1E-82	1E-108	1E-150	1E-216	0	0	0	0	0	0	0	0	0	0
5E-23	2E-28	2E-35	2E-44	6E-57	1E-75	1E-105	1E-153	4E-235	0	0	0	0	0	0	0	0	0	0	2E-281
2E-22	2E-28	1E-36	5E-49	3E-69	8E-102	6E-158	3E-227	0	0	0	0	0	0	0	0	3E-271	2E-218	1E-181	8E-159
2E-21	7E-29	5E-41	3E-61	1E-96	4E-142	0	0	0	0	0	0	1E-304	7E-257	7E-200	4E-163	9E-138	6E-122	3E-111	6E-103
3E-21	9E-32	5E-51	2E-77	1E-185	0	0	0	0	0	5E-204	1E-175	1E-139	4E-116	7E-100	9E-90	2E-83	3E-78	2E-73	1E-68
2E-21	1E-33	2E-82	0	0	0	0	3E-218	5E-124	2E-110	1E-90	1E-77	2E-68	7E-63	2E-59	8E-57	2E-54	8E-52	2E-48	6E-46
8E-23	9E-97	0	0	3E-258	3E-104	1E-64	6E-61	8E-53	3E-47	2E-43	4E-41	4E-40	4E-39	2E-38	3E-37	8E-36	1E-34	5E-33	2E-32
3E-65	2E-172	7E-61	1E-33	7E-26	3E-27	3E-26	2E-25	8E-25	9E-25	4E-25	2E-25	1E-25	2E-25	4E-25	8E-25	1E-24	1E-24	3E-24	2E-24
5E-07	2E-06	8E-08	2E-09	9E-11	8E-12	1E-12	1E-13	2E-14	2E-15	4E-16	1E-16	7E-17	3E-17	2E-17	9E-18	3E-18	1E-18	2E-18	6E-19
2E-10	2E-07	1E-06	1E-06	5E-07	1E-07	2E-08	4E-09	7E-10	2E-10	4E-11	1E-11	4E-12	1E-12	4E-13	1E-13	4E-14	1E-14	1E-14	3E-15
1E-13	9E-10	7E-08	5E-07	1E-06	9E-07	5E-07	2E-07	9E-08	3E-08	1E-08	4E-09	1E-09	5E-10	2E-10	5E-11	2E-11	4E-12	5E-12	1E-12
4E-15	1E-11	2E-09	3E-08	2E-07	5E-07	8E-07	7E-07	5E-07	3E-07	2E-07	8E-08	4E-08	2E-08	6E-09	2E-09	9E-10	3E-10	4E-10	1E-10
1E-16	2E-13	4E-11	2E-09	2E-08	1E-07	3E-07	5E-07	6E-07	6E-07	5E-07	3E-07	2E-07	1E-07	6E-08	3E-08	1E-08	6E-09	9E-09	4E-09
4E-18	8E-15	2E-12	1E-10	2E-09	2E-08	7E-08	2E-07	3E-07	5E-07	5E-07	5E-07	4E-07	3E-07	2E-07	1E-07	8E-08	4E-08	8E-08	4E-08
1E-18	1E-15	3E-13	1E-11	3E-10	2E-09	1E-08	4E-08	1E-07	2E-07	3E-07	4E-07	5E-07	5E-07	4E-07	3E-07	2E-07	2E-07	3E-07	2E-07
5E-19	3E-16	3E-14	1E-12	3E-11	3E-10	2E-09	8E-09	3E-08	7E-08	1E-07	2E-07	3E-07	4E-07	4E-07	4E-07	4E-07	3E-07	8E-07	6E-07
1E-19	3E-17	3E-15	1E-13	2E-12	3E-11	2E-10	1E-09	5E-09	2E-08	4E-08	8E-08	2E-07	2E-07	3E-07	4E-07	4E-07	4E-07	1E-06	1E-06
2E-20	4E-18	2E-16	8E-15	2E-13	3E-12	2E-11	2E-10	9E-10	3E-09	1E-08	2E-08	5E-08	1E-07	2E-07	2E-07	3E-07	3E-07	1E-06	1E-06

high low

SOx Emissions – Resultant Monthly Average Concentration

5E-08	4E-08	2E-08	9E-09	3E-09	8E-10	2E-10	4E-11	1E-10	4E-10	1E-09	4E-09	9E-09	2E-08	3E-08	5E-08	6E-08	7E-08	8E-08	8E-08
5E-08	4E-08	2E-08	7E-09	2E-09	3E-10	7E-11	2E-10	7E-10	2E-09	6E-09	1E-08	3E-08	4E-08	6E-08	8E-08	9E-08	8E-08	7E-08	6E-08
6E-08	4E-08	2E-08	5E-09	9E-10	2E-10	2E-10	1E-09	4E-09	1E-08	2E-08	4E-08	6E-08	8E-08	9E-08	9E-08	8E-08	6E-08	5E-08	3E-08
6E-08	4E-08	1E-08	3E-09	5E-10	3E-10	2E-09	6E-09	2E-08	4E-08	6E-08	9E-08	1E-07	1E-07	8E-08	6E-08	4E-08	3E-08	2E-08	9E-09
7E-08	4E-08	1E-08	2E-09	5E-10	2E-09	1E-08	3E-08	6E-08	1E-07	1E-07	1E-07	9E-08	6E-08	4E-08	2E-08	1E-08	7E-09	3E-09	2E-09
8E-08	3E-08	7E-09	8E-10	3E-09	2E-08	5E-08	1E-07	1E-07	1E-07	1E-07	6E-08	4E-08	2E-08	9E-09	4E-09	2E-09	8E-10	4E-10	1E-10
9E-08	3E-08	2E-09	5E-09	3E-08	1E-07	2E-07	2E-07	1E-07	6E-08	3E-08	1E-08	5E-09	2E-09	8E-10	3E-10	1E-10	4E-11	1E-11	5E-12
1E-07	1E-08	1E-08	9E-08	2E-07	2E-07	1E-07	4E-08	1E-08	5E-09	2E-09	6E-10	2E-10	6E-11	2E-11	7E-12	2E-12	6E-13	2E-13	5E-14
1E-07	2E-08	3E-07	3E-07	8E-08	2E-08	3E-09	5E-10	9E-11	2E-11	5E-12	2E-12	5E-13	2E-13	5E-14	2E-14	5E-15	1E-15	4E-16	1E-16
9E-08	3E-07	1E-08	2E-10	1E-11	1E-12	1E-13	2E-14	2E-15	3E-16	6E-17	2E-17	8E-18	4E-18	3E-18	1E-18	4E-19	2E-19	7E-20	2E-20
1E-07	4E-07	2E-08	4E-10	2E-11	2E-12	3E-13	3E-14	4E-15	6E-16	1E-16	3E-17	2E-17	9E-18	5E-18	2E-18	8E-19	3E-19	5E-19	2E-19
1E-07	4E-08	3E-07	3E-07	1E-07	3E-08	5E-09	1E-09	2E-10	4E-11	1E-11	3E-12	1E-12	3E-13	1E-13	3E-14	1E-14	3E-15	3E-15	7E-16
1E-07	1E-08	2E-08	1E-07	2E-07	2E-07	1E-07	6E-08	2E-08	9E-09	3E-09	1E-09	4E-10	1E-10	4E-11	1E-11	4E-12	1E-12	1E-12	4E-13
9E-08	3E-08	2E-09	9E-09	5E-08	1E-07	2E-07	2E-07	1E-07	8E-08	4E-08	2E-08	9E-09	4E-09	2E-09	6E-10	2E-10	8E-11	1E-10	3E-11
8E-08	3E-08	7E-09	1E-09	6E-09	3E-08	8E-08	1E-07	2E-07	1E-07	1E-07	8E-08	5E-08	3E-08	1E-08	7E-09	3E-09	2E-09	2E-09	1E-09
7E-08	4E-08	1E-08	2E-09	8E-10	5E-09	2E-08	4E-08	8E-08	1E-07	1E-07	1E-07	1E-07	8E-08	6E-08	3E-08	2E-08	1E-08	2E-08	9E-09
6E-08	4E-08	1E-08	3E-09	5E-10	6E-10	3E-09	1E-08	3E-08	5E-08	8E-08	1E-07	1E-07	1E-07	1E-07	8E-08	6E-08	4E-08	8E-08	5E-08
6E-08	4E-08	2E-08	5E-09	9E-10	2E-10	4E-10	2E-09	6E-09	2E-08	3E-08	6E-08	8E-08	1E-07	1E-07	1E-07	9E-08	8E-08	2E-07	1E-07
5E-08	4E-08	2E-08	7E-09	2E-09	3E-10	9E-11	3E-10	1E-09	4E-09	1E-08	2E-08	4E-08	6E-08	8E-08	9E-08	1E-07	1E-07	3E-07	3E-07
5E-08	4E-08	2E-08	9E-09	3E-09	8E-10	2E-10	6E-11	2E-10	8E-10	2E-09	6E-09	1E-08	2E-08	4E-08	6E-08	7E-08	8E-08	2E-07	3E-07

APPENDIX 04: Calculations of Sensitivity Analysis

Key Parameters

GDP ratio

Dose Response Function Mortality/Morbidity (DRF Mt/DRF Mb)

Mortality Rate (Mt)

Morbidity Rate (Mb)

Value of Statistical Life (VSL)

Cost of Illness (COI)

Pollution Concentration (PC)

OUT PUT - COST OF EXTERNALATY

Mt X Population X VSL [{PC Nox X DFR(Mt-Nox)} + { PC Sox X DFR(Mt-Sox) }] +
Mb X Population X COI [{PC Nox X DFR(Mb-Nox)} +{ PC Sox X DFR(Mb-Sox) }]

Case 01 : Puttalam District		Base Case		10% Increment of DRF (Mt)		20% Increment of DRF (Mt)		30% Increment of DRF (Mt)		50% Increment of DRF (Mt)	
		NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx
Incremental Pollution Concerntration	PC	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148
Dose Response Function Mortality DFR	DRF (Mt)	3.80%	4.35%	4.18%	4.79%	4.56%	5.22%	4.94%	5.66%	5.70%	6.53%
Dose Response Function Morbidity DFR	DRF (Mb)	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%
Mortality Rate	Mt	0.00014		0.00014		0.00014		0.00014		0.00014	
Morbidity Rate	Mb	0.022		0.022		0.022		0.022		0.022	
Value of Statistical Life	VSL	149,400	USD	149,400	USD	149,400	USD	149,400	USD	149,400	USD
Cost of Illness	COI	910	USD	910	USD	910	USD	910	USD	910	USD
Affected Population	Population	762,396		762,396		762,396		762,396		762,396	
Out put	USD	2002020.3		2179014		2356009		2533002.6		2886990.75	
Change% of the output				**8.840773**		**17.6815**		**26.52232**		**44.2038671**	

Case 01 : Puttalam District		Base Case		10% Increment of DRF (Mb)		20% Increment of DRF (Mb)		30% Increment of DRF (Mb)		50% Increment of DRF (Mb)	
		NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx
Incremental Pollution Concerntration	**PC**	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148
Dose Response Function Mortality DFR	**DRF (Mt)**	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%
Dose Response Function Morbidity DFR	**DRF (Mb)**	0.92%	0.51%	1.01%	0.56%	1.10%	0.61%	1.20%	0.66%	1.38%	0.77%
Mortality Rate	**Mt**	0.00014		0.00014		0.00014		0.00014		0.00014	
Morbidity Rate	**Mb**	0.022		0.022		0.022		0.022		0.022	
Value of Statistical Life	**VSL**	149,400	USD	149,400	USD	149,400	USD	149,400	USD	149,400	USD
Cost of Illness	**COI**	910	USD	910	USD	910	USD	910	USD	910	USD
Affected Population	**Population**	762,396		762,396		762,396		762,396		762,396	
Out put	**USD**	2002020.3		2025228		2048436		2071644.2		2118060.1	
Change% of the output				**1.159227**		**2.31845**		**3.4776798**		**5.79613294**	

Case 01 : Puttalam District		Base Case		10% Increment of Mortality Rate		20% Increment of Mortality Rate		30% Increment of Mortality Rate		50% Increment of Mortality Rate	
		NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx
Incremental Pollution Concerntration	**PC**	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148
Dose Response Function Mortality DFR	**DRF (Mt)**	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%
Dose Response Function Morbidity DFR	**DRF (Mb)**	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%
Mortality Rate	**Mt**	0.00014		0.000154		0.00017		0.000182		0.00021	
Morbidity Rate	**Mb**	0.022		0.022		0.022		0.022		0.022	
Value of Statistical Life	**VSL**	149,400	USD	149,400	USD	149,400	USD	149,400	USD	149,400	USD
Cost of Illness	**COI**	910	USD	910	USD	910	USD	910	USD	910	USD
Affected Population	**Population**	762,396		762,396		762,396		762,396		762,396	
Out put	**USD**	2002020.3		2179014		2356009		2533002.6		2886990.75	
Change% of the output				**8.840773**		**17.6815**		**26.52232**		**44.2038671**	

Case 01 : Puttalam District		Base Case		10% Increment of Morbidity Rate		20% Increment of Morbidity Rate		30% Increment of Morbidity Rate		50% Increment of Morbidity Rate	
		NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx
Incremental Pollution Concerntration	**PC**	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148
Dose Response Function Mortality DFR	**DRF (Mt)**	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%
Dose Response Function Morbidity DFR	**DRF (Mb)**	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%
Mortality Rate	**Mt**	0.00014		0.00014		0.00014		0.00014		0.00014	
Morbidity Rate	**Mb**	0.022		0.0242		0.0264		0.0286		0.033	
Value of Statistical Life	**VSL**	149,400	USD	149,400	USD	149,400	USD	149,400	USD	149,400	USD
Cost of Illness	**COI**	910	USD	910	USD	910	USD	910	USD	910	USD
Affected Population	**Population**	762,396		762,396		762,396		762,396		762,396	
Out put	**USD**	2002020.3		2025228		2048436		2071644.2		2118060.1	
Change% of the output				**1.159227**		**2.31845**		**3.4776798**		**5.79613294**	

Case 01 : Puttalam District		Base Case		10% Increment of VSL		20% Increment of VSL		30% Increment of VSL		50% Increment of VSL	
		NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx
Incremental Pollution Concerntration	PC	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148
Dose Response Function Mortality DFR	DRF (Mt)	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%
Dose Response Function Morbidity DFR	DRF (Mb)	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%
Mortality Rate	Mt	0.00014		0.00014		0.00014		0.00014		0.00014	
Morbidity Rate	Mb	0.022		0.022		0.022		0.022		0.022	
Value of Statistical Life	VSL	149,400	USD	164,340	USD	179,280	USD	194,220	USD	224,100	USD
Cost of Illness	COI	910	USD	910	USD	910	USD	910	USD	910	USD
Affected Population	Population	762,396		762,396		762,396		762,396		762,396	
Out put	USD	2002020.3		2179014		2356009		2533002.6		2886990.75	
Change% of the output				**8.840773**		**17.6815**		**26.52232**		**44.2038671**	

Case 01 : Puttalam District		Base Case		10% Increment of COI		20% Increment of COI		30% Increment of COI		50% Increment of COI	
		NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx
Incremental Pollution Concerntration	PC	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148
Dose Response Function Mortality DFR	DRF (Mt)	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%
Dose Response Function Morbidity DFR	DRF (Mb)	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%
Mortality Rate	Mt	0.00014		0.00014		0.00014		0.00014		0.00014	
Morbidity Rate	Mb	0.022		0.022		0.022		0.022		0.022	
Value of Statistical Life	VSL	149,400	USD	149,400	USD	149,400	USD	149,400	USD	149,400	USD
Cost of Illness	COI	910	USD	1,001	USD	1,092	USD	1,183	USD	1,365	USD
Affected Population	Population	762,396		762,396		762,396		762,396		762,396	
Out put	USD	2002020.3		2025228		2048436		2071644.2		2118060.1	
Change% of the output				1.159227		2.31845		3.4776798		5.79613294	

Case 01 : Puttalam District		Base Case		10% Increment of Pollution Concentration		20% Increment of Pollution Concentration		30% Increment of Pollution Concentration		50% Increment of Pollution Concentration	
		NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx
Incremental Pollution Concenrtration	**PC**	0.462	2.148	0.5082	2.3628	0.5544	2.5776	0.6006	2.7924	0.693	3.222
Dose Response Function Mortality DFR	**DRF (Mt)**	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%
Dose Response Function Morbidity DFR	**DRF (Mb)**	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%
Mortality Rate	**Mt**	0.00014		0.00014		0.00014		0.00014		0.00014	
Morbidity Rate	**Mb**	0.022		0.022		0.022		0.022		0.022	
Value of Statistical Life	**VSL**	149,400	USD	149,400	USD	149,400	USD	149,400	USD	149,400	USD
Cost of Illness	**COI**	910	USD	910	USD	910	USD	910	USD	910	USD
Affected Population	**Population**	762,396		762,396		762,396		762,396		762,396	
Out put	**USD**	2002020.3		2202222		2402424		2602626.4		3003030.51	
Change% of the output				**10**		**20**		**30**		**50**	

Case 01 : Puttalam District		Base Case		10% Increment of GDP ratio of India/Sri Lanka		20% Increment of GDP ratio of India/Sri Lanka		30% Increment of GDP ratio of India/Sri Lanka		50% Increment of GDP ratio of India/Sri Lanka	
		NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx	NOx	SOx
Incremental Pollution Concerntration	PC	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148	0.462	2.148
Dose Response Function Mortality DFR	DRF (Mt)	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%	3.80%	4.35%
Dose Response Function Morbidity DFR	DRF (Mb)	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%	0.92%	0.51%
Mortality Rate	Mt	0.00014		0.00014		0.00014		0.00014		0.00014	
Morbidity Rate	Mb	0.022		0.022		0.022		0.022		0.022	
Value of Statistical Life	VSL	149,400	USD	164,340	USD	179,280	USD	194,220	USD	224,100	USD
Cost of Illness	COI	910	USD	1,001	USD	1,092	USD	1,183	USD	1,365	USD
Affected Population	Population	762,396		762,396		762,396		762,396		762,396	
Out put	USD	2002020.3		2202222		2402424		2602626.4		3003030.51	
Change% of the output				10		20		30		50	

APPENDIX 05: Description of 'ISC-AERMOD View'

Source: *REPORT ON AIR DISPERSION MODELLING STUDY FOR PROPOSED 500 MW COAL POWER PLANT AT SAMPOOR*, Report No: CS 1415036, Prepared by Environmental Technology Section, Industrial Technology Institute, 2014.11.27

Model Description

'AERMOD View' is a complete and powerful air dispersion modeling Package .It incorporates the following popular U.S. EPA air dispersion models into one integrated interface.

1. AERMOD
2. ISCST3
3. ISC-PRIME

These US EPA air dispersion models are widely used to assess pollution concentration and deposition from a wide variety of sources.

- The AMS/EPA **R**egulatory **Mod**el (AERMOD) is the next generation air dispersion model based on planetary boundary layer theory

- The **I**ndustrial **S**ource **C**omplex - **S**hort **T**erm regulatory air dispersion model (ISCST3) is a Gaussian plume model and is widely used to assess pollution concentration and/or deposition flux on receptors from a wide variety of sources

- The **I**ndustrial **S**ource **C**omplex - **P**lume **Ri**se **M**odel **E**nhancements (ISCPRIME) dispersion model is similar to the ISCST3 model, but contains enhanced building downwash analysis.

Technical specifications of each are given below in Table 1, 2 and 3 respectively. AERMOD utilizes a similar input and output structure to ISCST3 and shares many of the same features, as well as offering additional features. AERMOD fully incorporates the PRIME building downwash algorithms, advanced depositional parameters, local terrain effects, and advanced meteorological turbulence calculations.

Table 1: Technical Specifications - AERMOD

Parameter	Description
Model Name	AERMOD
Developed By	AERMIC - (American Meteorological Society (AMS) and United States Environmental Protection Agency (US EPA)
Model Type	Steady-state Gaussian plume air dispersion model
Range	Up to 50km from the source
Atmospheric Stability Model	Planetary boundary layer theory, turbulence scaling concepts
Wind Field	Homogeneous
Release Types	Buoyant or neutrally buoyant plumes
Emission Types	Constant or time-varying, planned or fugitive
Atmospheric Chemistry	NOX to NO2 and SO2 decay
Source Types	Point, area, volume, open pit, line*, flare*
Meteorology	Hourly surface and upper air data (processed by AERMET)
Terrain	Flat or elevated (terrain processed by AERMAP)
Receptors	Several types of grids (Cartesian, polar) and discrete receptors
Other Options	Building downwash (modelled by BPIP-PRIME)
Regulatory Status	Preferred US EPA regulatory model for near-field applications

Table 2: Technical Specifications - ISCST3

Parameter	Description
Model Name	ISCST3 - Industrial Source Complex Short Term model (US EPA)
Developed By	United States Environmental Protection Agency (US EPA)
Model Type	Steady-state Gaussian plume air dispersion model
Time Step	1 hour
Range	Up to 50km from the source
Terrain	Flat and elevated
Building Downwash	Modelled by BPIP
Source Types	Point, area, volume, open pit, line*, flare*
Input Meteorology	Hourly surface data and mixing height data (through PCRAMMET)
Atmospheric Stability Model	Pasquill-Gifford Stability Classes
Wind Field	Homogeneous
Release Types	Buoyant or neutrally buoyant plumes
Emission Types	Constant or time-varying, planned or fugitive
Atmospheric Chemistry	NOX to NO2 and SO2 decay
Regulatory Status	Former US EPA regulatory model for near-field applications

Table 3: Technical Specifications - ISC-PRIME

Parameter	Description
Model Name	ISC-PRIME model
Developed By	United States Environmental Protection Agency (US EPA)
Model Type	Steady-state Gaussian plume air dispersion model
Time Step	1 hour
Range	Up to 50km from the source
Terrain	Flat and elevated
Building Downwash	Modeled by BPIP-PRIME
Source Types	Point, area, volume, open pit, line*, flare*
Input Meteorology	Hourly surface data and mixing height data (through RAMMET)
Atmospheric Stability Model	Pasquill-Gifford Stability Classes
Wind Field	Homogeneous
Release Types	Buoyant or neutrally buoyant plumes
Emission Types	Constant or time-varying, planned or fugitive
Atmospheric Chemistry	NOX à NO2 and SO2 decay
Regulatory Status	Former US EPA regulatory model for near-field applications

APPENDIX 06: The National Environmental (Ambient Air Quality) Regulations

ශ්‍රී ලංකා ප්‍රජාතාන්ත්‍රික සමාජවාදී ජනරජයේ ගැසට් පත්‍රය

අති විශෙෂ

The Gazette of the Democratic Socialist Republic of Sri Lanka

EXTRAORDINARY

අංක 1562/22 - 2008 අගෝස්තු 15 වැනි සිකුරාදා - 2008.08.15

No. 1562/22 - FRIDAY, AUGUST 15, 2008

(Published by Authority)

PART I : SECTION (I) — GENERAL

Government Notifications

L.D.B. 4/81.

THE NATIONAL ENVIRONMENTAL ACT, No. 47 OF 1980

REGULATIONS made by Minister of Environment and Natural Resources under Section 32 of the National Environmental Act, No. 47 of 1980.

PATALI CHAMPIKA RANAWAKA,
Minister of Environment and Natural Resources.

Colombo,
13th August, 2008.

Regulations

The National Environmental (Ambient Air Quality) Regulations, 1994, published in *Gazette Extraordinary*, No. 850/4 of December, 1994 are hereby amended by the subsitution for the Schedule to that regulation of the following :-

"SCHEDULE

Pollutant	*Averaging Time**	*Maximum Permissible Level*		*+ Method of measurement*
		μgm^{-3}	*ppm*	
1. Particulate Matter - Aerodynamic diameter is less than 10 μm in size (PM_{10})	Annual	50	—	Hi-volume sampling and Gravimtric or Beta Attenuation
	24 hrs.	100	—	
2. Particulate Matter - Aerodynamic diameter is less than 2.5 μm in size ($PM_{2.5}$)	Annual	25	—	Hi-volume sampling and Gravimtric or Beta Attenuation
	24 hrs.	50	—	

1A

SCHEDULE *(Contd.,)*

Pollutant	*Averaging Time**	*Maximum Permissible Level*		*+ Method of measurement*
		μgm^{-3}	*ppm*	
3. Nitrogen Dioxide (NO_2)	24 hrs.	100	0.05	Colorimetric using saltzman Method or equivalent Gas phase chemiluminescence
	8 hrs.	150	0.08	
	1hr.	250	0.13	
4. Sulphur Dixoxide (SO_2)	24 hrs.	80	0.03	Pararosaniliene Method or equivalent Pulse Flourescent
	8 hrs.	120	0.05	
	1hrs.	200	0.08	
5. Ozone (O_3)	1 hr.	200	0.10	Chemiluminescence Method or equivalent Ultraviolet photometric
6. Carbon Monoxide (CO)	8 hrs.	10,000	9.00	Non-Dispersive Infrared Spectroscopy"
	1 hr.	30,000	26.00	
	Any time	58,000	50.00	

* Minimum number of observatons required to determine the average over the specified period —

03 hour average - 03 consecutive hourly average
08 hour average - 08 hourly average
24 hour average - 18 hourly average
Yearly average - 09 monthly average with at least 02 monthly average each quarter.

+ By using Chemicals or Automatic Analysers.

08-1106

PRINTED AT THE DEPARTMENT OF GOVERNMENT PRINTING, SRI LANKA.

APPENDIX 07: Summary of case study: 800 MW Coal power plant in Cheyyur in Kancheepuram, Tamil Nadu, India

Regulations

A. Technology and Pollutant Load

Only one 800 MW unit of a proposed 4000 MW plant has been considered. The assumed characteristics of the thermal power plant and fuel specification are outlined in Tables 5 and 6, respectively. The efficiencies assumed are in line with the highest standards of the industry and are representative of the future of thermal energy generation. The fuel with a calorific value of 4000 kcal/kg, from an indigenous source would have typical characteristics as indicated in Table 6.

Table 5: Pollution Load from 800 MW Coal Power Plant.

Assumptions	
Capacity	800 MW
Plant Load Factor	85%
Specific fuel consumption	0.53 kg/kWh
Fuel consumption rate	8664 Tons/day
Conversion Efficiency	90.0%
Cycle Efficiency	45.0%
Overall Efficiency	40.5%
Heat rate	2123.5 kcal/kWh
Unabated Pollution Load (tons/day)	
SO_2 production	139
NO_2 production	171
CO_2 production	10,801
PM_{10} production	358

CO_2= carbon dioxide; kcal=kilocalorie; kg= kilogram; kWh=kilowatt hour; MW= megawatt; NO_2= nitrogen dioxide; PM10= Particulate matter up to 10 micrometers in size; SO_2= sulfur dioxide;

The assumptions about calorific value, ash, and sulfur content are typical of Indian sub-bituminous coals. Imported coal would be more desirable, but a significantly more expensive option. The resulting emissions from the proposed unit are calculated based on simple stoichiometric ratios for the combustion products. Table 5 outlines the unabated pollution load at the plant site, the highest of which is CO2 production at 10,801 tons a day. The net emissions given a standard abatement process and technology are calculated based on efficiency assumptions of the abatement devices. Table 7 provides the pollution load after standard abatement.

Table 6: Fuel Specification

Coal composition	Percent (%)
C	34.0
S	0.8
N	0.6
Ash	35.0

C=carbon, N=nitrogen, S=sulfur

Table 7: Pollution Load at Plant Site

Emission	% Control	Emissions after control (tons/day)
SO_2	95.0	6.9
NO_2	85.0	25.6
PM_{10}	99.0	3.6

B. Dispersion Modelling

The figures corresponding to the emissions in Table 7 are used as inputs to the dispersion model. The parameters required to model the dispersion of pollutant are derived from the power plant at Mundra (Table 8). The locally relevant parameters such as wind speed and direction are approximated using the data available for a nearby station (i.e., Cuddalore is located 50 kms. away from Cheyyur). To simplify assumptions associated with the calculations, moderately unstable conditions were assumed in assigning the stability parameter.

Table 8: Dispersion Parameters

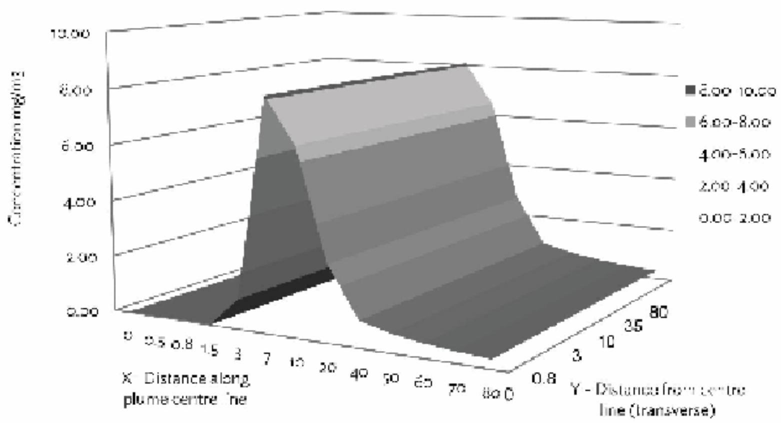
Table 8: Dispersion Parameters

	Value
Stack height (m)	275
Stack diameter (m)	6
Gas exit velocity (m/s)	5
Gas exit temperature (C)	200
Ambient Temperature(C)	30
Wind Velocity (m/s)	1

NO2= nitrogen dioxide, PM10= Particulate matter up to 10 micrometers in size, SO2= sulfur dioxide.

A Gaussian plume model was evaluated using the parameters established in Table 8. The above and ground level concentration profile over a 100km radius was established (See Appendix 4 for a detailed information of the dispersion parameters). Figure 4 shows the variation of PM10 concentration.

Figure 4: Concentration Surface Profile of Pollutants Downstream of Source



Source: *Authors estimates.*

Note: Output from the Gaussian-Plume model for PM_{10} dispersion.

Since the concentration profile (at the ground level) is a continuous variable rather than discrete one, the increased pollutant load was evaluated in specific urban clusters around the power plant. A list of all major towns and cities within a 100 km radius was initially considered and only the significant population centers were retained for this exercise (Table 9). The estimated marginal increases in pollutant concentration (mg/m3) for SO2, NO2, and PM10 are computed using the pollution load data and parameter values discussed above for the coal power plant project.

Table 9: Pollutant Concentration at Discrete Population Cluster Locations

City	Population	Distance from Cheyyur (kms)	SO_2 Increase per 10 ug/m^3	NO_2 Increase per 10 ug/m^3	PM_{10} Increase per 10 ug/m^3
Chennai	6,540,462	85	0.57	2.10	0.29
Pondicherry	505,959	51	1.12	4.16	0.58
Kancheepuram	188,733	64	0.86	3.19	0.45
Cuddalore	158,634	75	0.69	2.55	0.36
Thiruvannamalai	130,567	100	0.44	1.62	0.23
Arakonam	78,686	89	0.57	2.10	0.29
Thindivanam	67,737	40	1.55	5.72	0.80
Chengalpattu	62,852	39	1.55	5.72	0.80
Arani	60,815	85	0.57	2.10	0.29
Thiruvallur	45,732	89	0.57	2.10	0.29
Melvisharam	36,757	100	0.44	1.62	0.23
Sriperumbudur	16,156	69	0.86	3.19	0.45
Ananthapuram	6,138	73	0.69	2.55	0.36
Vandavasi	29,620	52	1.12	4.16	0.58

C. Quantification of Health Impacts

After estimating the incremental increase in pollutant concentration, the next step entails quantifying the physical health impacts. We use the mean estimates of DRFs reported for both mortality and morbidity outcomes presented in HEI Summary Estimates. Here we apply the direct transfer of average values in these tables.

Mortality Impacts

Baseline deaths associated with acute mortality are first computed based on national health figures. After applying the estimated increase in pollutant concentration from the dispersion modelling and the mean risk rate reported, we estimate the total increase in mortality incidence at about 94 premature deaths per year (Table 10). It should be noted that the relatively small increase in premature mortality incidence may be attributed, to a large extent, to the high abatement measures being applied at the plant site, removing about 95%, 85%, and 99% of SO2, NO2, and PM10 respectively. In the absence of any abatement, mortality incidence is estimated at 1,243 premature deaths per year.

Table 10: Estimated Increase in Mortality Incidence Associated with Air Pollution, by City

City	Population	Distance from Source (kms)	SO_2	NO_2	PM_{10}	Total by City
Chennai	6,540,462	85	10	56	3	70
Pondicherry	505,959	51	2	9	1	11
Kancheepuram	188,733	64	0	2	0	3
Cuddalore	158,634	75	0	2	0	2
Thiruvannamalai	130,567	100	0	1	0	1
Arakonam	78,686	89	0	1	0	1
Thindivanam	67,737	40	0	2	0	2
Chengalpattu	62,852	39	0	1	0	2
Arani	60,815	85	0	1	0	1
Thiruvallur	45,732	89	0	0	0	0
Melvisharam	36,757	100	0	0	0	0
Sriperumbudur	16,156	69	0	0	0	0
Ananthapuram	6,138	73	0	0	0	0
Vandavasi	29,620	52	0	1	0	1
TOTAL	7,928,848	–	14	75	5	94

Morbidity Impacts

Respiratory Hospital Admissions (RHAs) and Work Loss Days (WLDs) are two of the most common representations of morbidity incidence; hence these are reflected in this exercise. Using the same information for pollutant concentration, we have estimated the cases per person for a given increase in pollutant load (per 10µg/m3). Table 11 reports an increase of approximately 22,862 in RHA (all-cause) and 8,117 lost work days annually because of illnesses linked to pollution from coal-fired power plants such as minor respiratory infections, cough, and asthma. Again, such increase in morbidity incidence is moderated by the high abatement level for SO2, NO2, and PM10 applied at the plant site. Without abatement measures, RHA incidence is estimated at approximately 500,000 cases and WLD at 800,000.

Table 11: Increased Morbidity Incidence by Pollutant type

City	Respiratory Hospital Admissions (all causes)				WLD
	SO_2	NO_2	PM_{10}	TOTAL	PM_{10}
Chennai	1,895	12,636	2,494	17,025	6,044
Pondicherry	290	1,935	382	2,607	926
Kancheepuram	83	555	109	747	265
Cuddalore	56	372	74	502	178
Thiruvannamalai	29	195	39	263	93
Arakonam	23	152	30	205	73
Thindivanam	53	357	70	480	171
Chengalpattu	50	331	65	446	158
Arani	18	117	23	158	56
Thiruvallur	13	88	17	119	42
Melvisharam	8	55	11	74	26
Sriperumbudur	7	47	9	64	23
Ananthapuram	2	14	3	19	7
Vandavasi	17	113	22	153	54
TOTAL	2,545	16,968	3,350	22,862	8,117

D. Economic Valuation

Following previous discussions, health outcomes are monetized in two ways. For the valuation of acute mortality, we apply a benefit transfer of a VSL estimate from Madheswaran (2007). This local study estimates VSL at Rs. 15 million ($331, 858), based on a sample of 1000 workers from Chennai and Mumbai. The cumulative cost for an increase in mortality risks is estimated at $31.08 million (Table 12). Meanwhile morbidity outcomes are monetized using a two-step valuation approach. First, COI is computed for RHA using available cost information from Patankar and Trivedi (2011). This study was the most recent study available in the literature and it was conducted in Mumbai which has very similar social economic setting to the study site. The average daily wage rate from the Ministry of Labor and Employment, Government of India was used to value WLD. Because cost of hospitalization

and medical care from public services is likely to be subsidized, the COI derived from this should only be considered as lower bound. Hence to accurately reflect real cost of hospitalization and medical care, we assume that total RHA cost constitutes about 75% private and 25% public treatment. The estimated COI is then multiplied to the mean scaling factor (2.16) to allow for the estimation of WTP.

As shown in Table 12, the WTP is estimated at $15.12 million. Cumulatively, the social cost of morbidity stands at about $46.21 million.

Table 12: Valuation Estimates for Mortality and Morbidity

Item	Increased incidence	Valuation basis	Valuation estimate	
			Rs.	$
Acute mortality	94	15,000,000	1,403,742,523	31,083,758
Morbidity (WTP)				
RHA	22,862	13,750	679,009,882	15,035,648
WLD	8,117	224	3,933,990	87,112
TOTAL	–	–	2,086,686,395	46,206,519

In Table 13, it can be observed that pollutant load is much lower after emission control. For instance, PM10 emission savings are estimated at 355 tons/day following a high level of abatement. On per kWh (per unit) basis, the total cost imposed by local air pollution is computed to be about $1.05 cents.

The only Indian estimate is this review is close to our estimate and it is within the range of estimates. This shows that our estimate is reasonably accurate. However, it must be noted that the estimated health cost achieved only because of the expenditures incurred in installing abatement measures (FGD and SCR) for the removal of pollutants to an assumed degree. In the absence of abatement measures, the hefty cost of pollution on society is estimated at $12.58 cents per kWh. Put differently, if the industry invests about $0.28 cents per kWh for pollution control spending (removing about 85% to 99% of three major pollutants), this brings down the health cost imposed on society to $1.05 per kWh with a net welfare gain of $11.25 cents per kWh.

Table 13: Pollution Load by Emission Control

Pollutant	Zero Pollution Control (tons/day)	With Pollution Control (tons/day)	Net gain
SO_2	138.62	6.93	131.69
NO_2	170.80	25.62	145.18
PM10	357.94	3.58	354.36
TC/kWh ($)	12.58	1.05	11.53

TC/kWh= total cost per kilowatt hour.