

**DISPERSION MODELING OF AIR POLLUTANT
EMISSIONS OF LAKVIJAYA POWER PLANT,
SRI LANKA**

Dissanayaka Mohottalalage Chinthaka Jayanath Dissanayaka

198487T

Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree
Master of Science in Environmental Engineering and Management

Department of Civil Engineering
Faculty of Engineering

University of Moratuwa
Sri Lanka

November 2023

DECLARATION

I declare that the work reported in this thesis is my own under the supervision of Mr. H.D.S. Premasiri, Director of Environmental Studies & Services Division, National Building Research Organization, and Prof. J.M.A. Manatunge, who coordinated the course and all the academic and non-academic staff Department of Civil Engineering, University of Moratuwa except where indicated in reference to the partial fulfillment of my degree of Master of Science of Environmental Engineering and Management.

This thesis has not been submitted for a degree or a diploma from the University of Moratuwa or 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 acknowledgment is made.

I hereby grant the University of Moratuwa the non-exclusive right to reproduce and distribute my thesis in whole or part in any medium. I retain the right to use this content in whole or part in future works.

.....

D.M.C.J Dissanayaka
Signature of the Candidate

Date:.....

The above candidate has carried out research for the Master of Science in Environmental Engineering and Management under my supervision.

Certified by;

Name of the Co Supervisor: Mr. H.D.S. Premasiri
Director of Environmental Studies & Services Division
National Building Research Organization

Signature of the Co Supervisor Date:.....

Certified by;

Name of the Supervisor: Prof. J.M.A. Manatunge
Department of Civil Engineering
University of Moratuwa

Signature of the Supervisor Date:.....

ACKNOWLEDGEMENT

I take this opportunity to offer my gratefulness to my supervisor Mr H.D.S. Premasiri, Director of Environmental Studies & Services Division, National Building Research Organization, for offering me the opportunity to carry out this study and always encouraging me, providing the necessary guidance and—friendly assistance to successfully complete this thesis.

I would like to express my sincere to Prof. J.M.A. Manatunge, who coordinated the course, and all the academic and non-academic staff of the Department of Civil Engineering, University of Moratuwa, for organizing and conducting the Master of Science of Environmental Engineering and Management and encouraging me in various ways to carry out the work successfully.

In addition, I express my sincere gratitude to the management of the Ceylon Electricity Board for granting me the approval to conduct research by referring to documents, test reports, manuals, etc., in 900MW Lakvijaya Coal Power Plant.

ABSTRACT

Air quality models play an important role in providing information for verifying permitting conditions and for exposure assessment purposes. Measured field air quality data was compared with model predictions to show that AERMOD air dispersion model is capable to identified located the maximum air concentration in the study area, provided representative or conservative air concentration estimates, and demonstrated bias and scatter not significantly different than that reported for other compounds.

In general, AERMOD was a useful screening tool for modeling dispersion of major criteria pollutants SO₂, NO₂ and, Particulate Matter (PM) are generated from coal power plant.

This assessment was carried out to investigate the ambient air quality at the surrounding environment when considering the three criteria pollutants such as SO₂, NO₂ and PM emitted from the 900 MW coal power plant situated at Norochcholai. The Air Dispersion modelling software, AERMOD was used for the assessment to find the ground-level concentration of three criteria pollutants. The assessment period is two years, 2020 & 2021, average level of stack emission measurement data during the study period were used as source input data and metrological data obtained by Department of Metrology, Puttalam in same years and terrain data downloaded by webgis were used for the dispersion analysis. The concentration of Pollutants at three locations, which were selected to measure the in-situ ambient air quality, were compared with the measure data.

The air dispersion modeling study shows that the concentration of selected criteria pollutants in surrounding environment is well below The National Environmental (Ambient Air Quality) Regulations, 1994, published under Gazette Extraordinary No. 850/4 of December 1994. The measured data at particular locations was also well below the standard levels.

The calculated AQI values for maximum predicted ground-level concentrations of Particulate Matter for each monsoon and selected locations are in good condition for year 2020 and 2021. However, AQI values for the measured data at selected locations are always greater than the predicted values of ADM since prediction values indicate only the emission by the power plant but measured levels include air emission by other local sources such as open burning of waste and garbage, vehicular emission, domestic emissions and small industries in the area etc.

The pollution control devices such as ESPs, FGDs and Low NO_x burner technologies of the coal power plants play a major role in protecting the ambient air quality levels in the surrounding environment. The functioning of the pollution control devices in optimum conditions at all-time is more important to maintain the standard ambient air quality. Monitoring of ambient air quality in the surrounding environment is a mandatory requirement to identify the changes, if any.

TABLE OF CONTENTS

Declaration.....	i
Acknowledgment.....	ii
Abstract.....	iii
Table of Content.....	iv
List of Figures.....	v
List of Tables.....	vi
List of Abbreviations.....	viii
List of Appendices.....	ix
1. Introduction.....	01
1.1. Background.....	01
...1.1.1. Overview of Lakvijaya Power Plant.....	01
...1.1.2. Air Pollution control technique of Lakvijaya Power Plant	02
...1.1.3. Air quality management.....	05
1.2. Objectives of the Study.....	05
2. Literature Review.....	06
..2.1. Usage of Coal for the power generation.....	06
...2.1.1. Classification of the Coal.....	06
...2.1.2. Pulverized Coal used in a Subcritical Boiler.....	09
..2.2. Coal combustion in Lakvijaya Power Plant.....	10
..2.3. Emission from Coal Power Plant.....	11
..2.4. Air Dispersion Modelling.....	18
2.5. Estimation of Air Quality Index (AQI).....	25
3. Material and Methods.....	29
..3.1. Air Dispersion Modelling (ADM).....	29
....3.1.1. Details description of the Modelling.....	37
3.2. Validation of the model.....	43
3.3. Estimation of Air Quality Index (AQI).....	44
4. Results and Discussion.....	46
4.1. Meteorological Condition.....	46
4.2. Predicted Maximum ground-level concentrations.....	48
4.3. Validation of the Air Dispersion Model.....	52
4.4. Estimation of the AQI.....	72
5. Conclusion and Recommendation.....	74
6. References.....	76

LIST OF FIGURES

Figure 1.1	Location of the Lakvijaya Coal-Fired Thermal Power Plant in Kalpitiya Peninsula	01
Figure 1.2	a) Existing Electro Static Precipitator (ESP) b) Explanation of theory of Electrical Charging inside the ESP	03
Figure 1.3	Flue Gas Desulfurization (FGD) unit a) Arrangement of FGD b) Gas to Gas Heat Exchanger (GGH) c) Sectional view of FGD	04
Figure 3.1	Map showing the study area covered by 50 x 50 km	30
Figure 3.2	Map of the ITI ambient air quality monitoring points	32
Figure 3.3	Terrain contours obtained from the SRTM3 database	41
Figure 4.1	Scatter Plot of SO ₂ 01 Hr Average- Location 07	56
Figure 4.2	Scatter Plot of SO ₂ 01 Hr Average- Location 08	57
Figure 4.3	Scatter Plot of SO ₂ 01 Hr Average- Location 09	58
Figure 4.4	Scatter Plot of SO ₂ 24 Hr Average- Location 07	60
Figure 4.5	Scatter Plot of SO ₂ 24 Hr Average- Location 08	61
Figure 4.6	Scatter Plot of SO ₂ 24 Hr Average- Location 09	62
Figure 4.7	Scatter Plot of NO _x 01 Hr Average- Location 07	64
Figure 4.8	Scatter Plot of NO _x 01 Hr Average- Location 08	65
Figure 4.9	Scatter Plot of NO _x 01 Hr Average- Location 09	66
Figure 4.10	Scatter Plot of NO _x 24 Hr Average- Location 07	68
Figure 4.11	Scatter Plot of NO _x 24 Hr Average- Location 08	69
Figure 4.12	Scatter Plot of NO _x 24 Hr Average- Location 09	70

LIST OF TABLES

Table 2.1	Classification of coal as ASTM standard based on properties	07
Table 2.2	Properties of coal used in Lakvijaya Power Plant (Based on coal test reports)	10
Table 2.3	AQI index categorization with colour band	26
Table 3.1	Description of the point sources within the study area	29
Table 3.2	Stack emissions data from 2020 and 2021	31
Table 3.3	Description of the locations and GPS coordinates of the selected locations	33
Table 3.4	AAQ monitored data use for the validation years for year 2020 and 2021	34
Table 3.5	ADM studies done seasonally	37
Table 3.6	The National Environmental (Ambient Air Quality) Regulations, 1994, published under Gazette Extraordinary No. 850/4 of December 1994	37
Table 3.7	Method of Source emission data usage and data validation for ADM study	40
Table 3.8	Selected locations and GPS coordinates for comparison of AQI	40
Table 3.9	Stationary source information within the study area	42
Table 3.10	Air quality index (AQI) values for a local monitoring station	45
Table 4.1	Summary of Wind Data Information obtained Department Meteorology	47
Table 4.2	Summary of the wind data information obtained from the onsite measurements	47
Table 4.3	Summary of the predicted maximum concentration by the ADM study	49
Table 4.4	Comparison of AAQ values obtained from field measurement and predicted by the ADM	53
Table 4.5	Model Predicted ground-level concentration and Observed (Measured) data for the selected locations ($\mu\text{g}/\text{m}^3$)	55
Table 4.6	Calculation of FAC2 and Normalized Mean Bias for 01 Hr Average SO_2 Concentration – Location 07	56
Table 4.7	Calculation of FAC2 and Normalized Mean Bias for 01 Hr Average SO_2 Concentration – Location 08	57
Table 4.8	Calculation of FAC2 and Normalized Mean Bias for 01 Hr Average SO_2 Concentration – Location 09	58

Table 4.9	Calculation of FAC2 and Normalized Mean Bias for 24 Hr Average SO ₂ Concentration – Location 07	60
Table 4.10	Calculation of FAC2 and Normalized Mean Bias for 24 Hr Average SO ₂ Concentration – Location 08	61
Table 4.11	Calculation of FAC2 and Normalized Mean Bias for 24 Hr Average SO ₂ Concentration – Location 09	62
Table 4.12	Calculation of FAC2 and Normalized Mean Bias for 01 Hr Average NO _x Concentration – Location 07	64
Table 4.13	Calculation of FAC2 and Normalized Mean Bias for 01 Hr Average NO _x Concentration – Location 08	65
Table 4.14	Calculation of FAC2 and Normalized Mean Bias for 01 Hr Average NO _x Concentration – Location 09	66
Table 4.15	Calculation of FAC2 and Normalized Mean Bias for 24 Hr Average NO _x Concentration – Location 07	68
Table 4.16	Calculation of FAC2 and Normalized Mean Bias for 24 Hr Average NO _x Concentration – Location 08	69
Table 4.17	Calculation of FAC2 and Normalized Mean Bias for 24 Hr Average NO _x Concentration – Location 09	70
Table 4.18	Maximum monitored PM concentrations and Monitored and Observed PM concentrations for selected locations/($\mu\text{g}/\text{m}^3$)	72
Table 4.19	AQI values for the Particulate Matter (PM) for Maximum Ground- level concentration and selected locations/($\mu\text{g}/\text{m}^3$)	73

LIST OF ABBREVIATIONS

Abbreviation	Description
AAQ	Ambient Air Quality
ADM	Air Dispersion Model
AERMOD	Software used for the air dispersion modeling study
AQI	Air Quality Index
ASTM	American Society for Testing and Materials
CBL	Connective Boundary Layer
CO	Carbon Monoxide
EPL	Environmental Protection License
ESP	Electro Static Precipitator
FAC2	fraction of predictions within a factor of two
FF	Fabric Filter
FGD	Flue Gas Desulphurization
ISC	Industrial Source Complex
ITI	Industrial Technology Institute
LVPP	Lakviayya Power Plant
MB	Mean Bias
MGE	Mean Gross Error
MPL	Maximum Permissible Level
NE	North East
NMB	Normalized Mean Bias
NMGE	Normalized Mean Gross Error
NO _x	Nitrogen oxides
PM	Particulate Matter
OFA	Over Fire Air
SPM	Suspended Particulate Matter
PBL	Planetary Boundary Layer
PEA-NWP	Provincial Environment Authority – North Western Province
SBL	Stable Boundary Layer
SO ₂	Sulphur Dioxide
SRTM	Shuttle Radar Topography Mission
SW	South West
USEPA	United State Environmental Protection Agency
VOC	Volatile Organic Compound

LIST OF APPENDICES

Appendix	Description	Page
Appendix 1	Wind Information on Departement of Meteorology site at Puttalam	80
Appendix 2	Wind Information on AAQ mesured location	88
Appendix 3	Graphical représentation of the ground level Concentrations SO ₂ , NO _x , & PM	94
Appendix 4	Calculations of Air Quality Index (AQI) for Monitored data & Predicted	166